PHASE1REPORT

MINIMUM TECHNICAL STANDARDS FOR ELECTRONIC CONSPICUITY AND ASSOCIATED SURVEILLANCE

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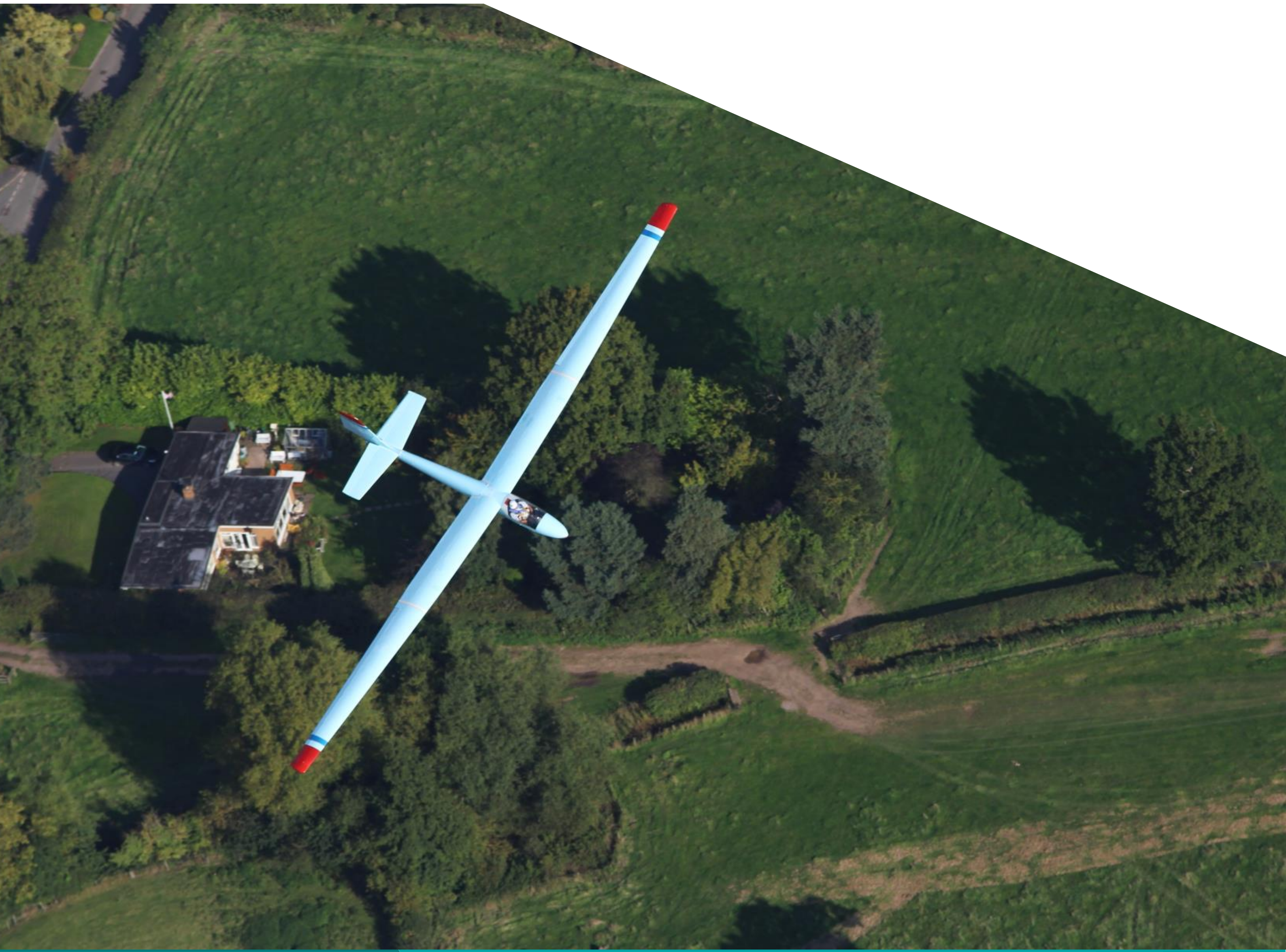

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1 - INTRODUCTION

1.1 - General

This document has been produced by EGIS as part of the project working on behalf of the UK Civil Aviation Authority (CAA) to Develop Minimum Technical Standards for Electronic Conspicuity (EC[1]) and associated Surveillance.

1.2 - Background and objectives

The CAA wish to develop minimum technical standards for EC and associated surveillance in order to:

- Realise the full benefits outlined in the Airspace Modernisation Strategy (AMS) CAP 1711,
- Respond to the request from the Department for Transport (DfT) to develop specifications which take into account future requirements for all aviation and thus take account of a wider set of use cases, and
- Enable innovation in future EC capability.

The objective of the AMS is to deliver quicker, quieter and cleaner journeys, and more capacity for the benefit of those who use and are affected by UK airspace. Importantly, one of the parameters within which this must be achieved is ensuring a shared and integrated airspace that facilitates safe and ready access to airspace for all classes of airspace users, including Commercial Air Transport (CAT), General Aviation (GA), military, and new entrants such as Unmanned Aircraft Systems (UAS) and spacecraft. To achieve the objective while delivering airspace for all airspace users, the AMS outlines the UK's communications, navigation and surveillance infrastructure and air traffic management as specific enablers that will help deliver the expected benefits. Specifically, the enablers identified within the AMS are:

- Review of Flight Information Services (FIS) provision in the UK.
- Airspace classification review.
- Electronic surveillance solutions.

The CAA's requirements listed above are directly relevant to this third point, i.e. the deployment of electronic surveillance solutions to aircraft and at airports to aid integration of traffic. This includes the development of new airspace structures such as transponder mandatory zones, new procedures for air traffic services, and the deployment of EC devices and electronic surveillance information displays. The deployment of electronic surveillance solutions (depending upon solutions selected, may depend upon:

- The widespread introduction of interoperable EC devices.
- The further development of airborne and ground-based equipment.
- The development of national standards for the core requirements the devices and equipment should meet.

The CAA established an Electronic Conspicuity Deployment Programme (ECDP) to manage the elements highlighted above and was tasked by the Department for Transport to develop surveillance specifications that take into account the future requirements for all airspace users including new entrants such as UAS operators and spacecraft. This would serve as an evolution of the current limited use of EC to mitigate the risk of collisions for the wider GA community in controlled airspace to a scenario whereby all aircraft will need to be electronically conspicuous to each other and to air traffic services on the ground to enable the concept of future airspace described in the AMS.

This project is to develop a suitable minimum technical standards for EC and associated surveillance that will evolve the current limited use of EC in support of the objective of the AMS.

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[1] EC refers to Electronic Conspicuity; European Commission is spelt in full.

1.3 - Project scope

The project is has broken down the services required into three phases:

- Phase 1: Assessment of the current environment and existing standards concluding in a high-level recommendation for a future approach.
- Phase 2: Assessment of the recommended approach from Phase 1 with industry stakeholders to define the future environment.
- 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.

This report is **Phase 1** (as described above), and assesses the current and potential future aviation environment within the UK against global regulations, standards and policy and technologies in use to derive and down-select options for deployment of EC.

This report is evidenced-based; all criteria and analysis are based on of evidence provided from previous studies or data sources, primary research activities were not a part of the study. Where evidence is not available and assumptions have to be made, these are explicitly stated.

It captures sufficient information to enable the drivers and constraints to be identified and options compared. This report is not intended to be a comprehensive catalogue of all information.

In developing Phase 1, an approach broadly following three activities has been followed. These are described below:

- **Task 1: Literature review of existing equipage and available avionics standards:** The report has compiled a list from a variety of sources of existing EC devices searching not only the UK market but also international markets. As the final solutions may include systems working on different frequencies or principles, the report considers the interoperability of these systems and the availability of interfaces between the systems. The information about interoperability between air-to-air and air-to-ground systems or components is one aspect considered for suitable solutions, particularly focusing on the interoperability between EC devices and airborne collision avoidance systems.
  The report gathers information about the national and international standards and requirements on surveillance and collision avoidance avionics which could be applicable in a UK context for use by Visual Flight Rules (VFR) traffic within and outside of controlled airspace. The initial review of applicable regulations includes the results of known working groups which are amending existing standards and regulations and also those working on new standards relevant to the scope of the project to understand the near future environment.
- **Task 2: Determine the future use of airspace foreseen in the AMS that will require evolutions in the existing equipage and/or avionics standards:** The existing surveillance infrastructure installed and used in the UK may not be suitable to detect and support provision of separation to all airspace users (particularly in the future airspace), therefore the report highlights gaps that exist between the current surveillance infrastructure and the necessary infrastructure for the AMS.
  It reviews the existing national and international standards for each element related to Air Traffic Service (ATS) / UAS Traffic management (UTM) and systems enabling Beyond Visual Line of Sight (BVLOS) UAS separation/deconfliction will be compared to identify areas where the national regulations, standards and guidance will need to be amended or developed.
  Considering the current surveillance infrastructure, standards for BVLOS UAS identification and detection, the report also considers the inclusion of Traffic Information Service-Broadcast (TIS-B) in the future airspace to prevent collisions between airspace users in different airspace classes.
- **Task 3: Develop future options to evolve existing avionics standards and recommend one of the options with an associated roadmap:** Having identified the gaps, the operational needs and the capabilities and limitations of the existing systems and components, the report identifies options supporting the provision of ATS and FIS services with required separations and deconfliction between

aircraft.

Since there are different options to achieve the desired result, the report considers how the proposed options gather surveillance data in order to provide the required services and achieve deconfliction of the aircraft in the air through airborne collision avoidance systems.

Different options bear different implementation costs and the potential costs are related to the approximate costs for the stakeholders in terms of purchasing and installation of ground equipment and avionics when appropriate, licences, frequency fees, type ratings, certification and redesign costs for each of the proposed options. This are considered in the development of the options

1.4 - Intended readership

The primary intended readership of this report is the UK CAA and DFT.

The report may be distributed to UK aviation stakeholders such as ATS providers, Avionics manufacturers and airspace user group representatives.

1.5 - Document structure

The document is the Phase 1 report as outlined above and presents the output from data gathering on existing equipage and available surveillance and avionics standards, identifying the required evolutions in existing equipment and avionics that will be needed by the future use of airspace foreseen in the AMS, and proposing future options to evolve existing avionics standards and recommending an option for a future electronic conspicuity technical standard. To develop this, the document follows a structure as presented in Figure 1.

Section 1: - Introduction

- This chapter which presents the context in which this document is presented and the scope of the content

Section 2: - Assessment of the evolving environment

- This section establishes the operational environment in which electronic conspicuity is to be deployed and examines the needs of the different actors within the existing and evolving aviation environments. Several scenarios are presented to examine in more detail the future need for electronic conspicuity and its use. Key applications driving enhanced electronic conspicuity requirements are identified.

Section 3: - Existing EC Regulations and Standards

- This section provides a high level overview of the regulatory and standardisation landscape applied to the ground and airborne environments. It looks at these regulations and standards with respect to the proposed use and applications described in Section 2 to determine what evolution of regulations and standards might be needed to meet the future electronic conspicuity needs.

Section 4: - Equipment availability and uptake

- This section establishes the baseline of what electronic conspicuity solutions are currently available, to whom, and provides an indicative indication of the penetration of each solution in the UK aviation market. It establishes the backdrop against which future evolutions of regulations and standards may lead to a requirement for wholesale system upgrades or replacement.

Section 5: - Interoperability including Spectrum

- This section assesses the interoperability requirements from international, technical and spectrum perspectives. This sets the scene for futher impacts on equipment changes or consolidation on policy at an international level.

Section 6: - Drivers and constraints to change

- Building on the context established in previous sections, this section presents the drivers for electronic conspicuity and the constraints that any solution would have to be measured against.

Section 7: - Requirements for the change to enhanced EC

- This section presents the high level functional requirements for a future enhanced electronic conspicuity solution considering the analysis presented in the previous sections.

Section 8: - Options for deployment

- Thies section presents potential electronic conspicuity options that address the requirements of the evovling environment of Section 2, the need for compliance with existing or emerging regulations, policy or standards in Section 3, minimise the requirements for avionics and ground equipment change under Section 4, maximise interoperability under Section 5 within the context of Section 6 drivers and constraints

Section 9: - Conclusions and Recommendations

- This Section presents the conclusions from the analysis and the recommended option proposed for further development within Phase 2 of the study.

Figure 1: Document Structure

2 - ASSESSMENT OF THE EVOLVING ENVIRONMENT

2.1 - General

This section establishes the operational environment within the UK (Airspace, User Groups etc) in which EC is to be deployed and examines the needs of the different actors within the existing and evolving aviation environments. Several example scenarios[2] are presented to demonstrate some use cases to give a flavour of potential applications of EC and to examine in more detail the future need for EC. Representative key applications driving enhanced EC requirements are also identified within this section.

2.2 - Airspace

2.2.1 - Classification

As notified by the CAA in the Aeronautical Information Publication and defined by ICAO in ICAO Annex 11: Air Traffic Services, Chapter 2, Section 2.6, UK Airspace is currently composed of Class A, C, D, E & G Airspace:

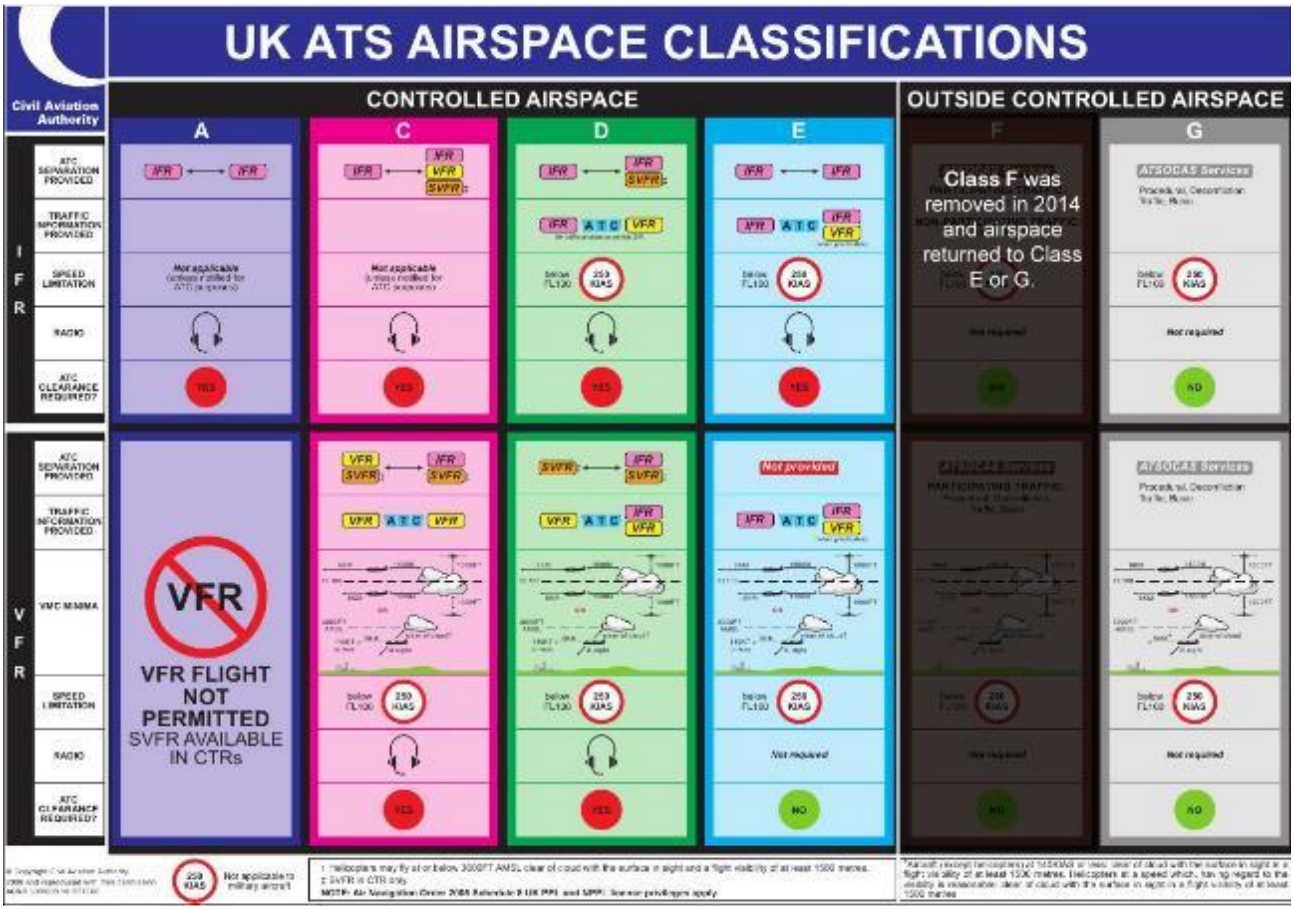

Figure 2: UK Airspace Classifications

Class A: Most airways up to FL 195 with the exception of airways lying within the Belfast CTR/TMA and around Scotland. The Terminal Control Areas (TMAs) around London Heathrow, Birmingham and Manchester. The Channel Island Zone is Class A above FL80. The CTAs of Daventry, Clacton, Cotswold and Worthing.

In class A airspace, only Instrument Flight Rules (IFR) flying is permitted. It is the most strictly regulated airspace where pilots must comply with ATC instructions at all times. Aircraft are separated from all other traffic and the users of this airspace are mainly major airlines and business jets.

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[2] *Provided by the CAA.*

It should be noted that Controlled airspace requirements (Class A,C,D,E) do not apply to UAS operating within the Open[3] category. Within the Specific category, an operator may be required to obtain permission to enter controlled airspace within the terms of the authorisation, or if detailed within the ops manual. This is dependent on the type of operation and the mitigations provided within the safety case.

Class C: All UK airspace between FL 195 and FL 660. Some airways and CTAs may have sections of Class C.

Both IFR and Visual Flight Rules (VFR) flying is permitted in Class C airspace but pilots require clearance to enter and must comply with ATC instructions.

Class D: The CTRs and CTAs around the busier airports such as Stansted, Brize Norton, Gatwick, Glasgow, Birmingham, Jersey, Manchester and Heathrow. Some airways in less busy areas are class D.

Class D airspace is for IFR and VFR flying. An ATC clearance is needed and compliance with ATC instructions is mandatory. Control areas around aerodromes are typically class D and a speed limit of 250 knots applies if the aircraft is below FL 100 (10,000 feet).

Class E: Parts of the Belfast TMA and ATS routes in Scotland.

Class E airspace is for IFR and VFR use. IFR aircraft require ATC clearance and compliance with ATC instructions is mandatory for separation purposes. VFR traffic does not require clearance to enter class E airspace, however pilots are strongly advised to contact the appropriate ATSU.

Class G: All remaining airspace, comprising by far the largest part of the airspace below FL 195.

Use of a radio or transponder is not required, even in IMC and in class G airspace, aircraft may fly when and where they like, subject to a set of simple rules. Although there is no legal requirement to do so, many pilots notify Air Traffic Control of their presence and intentions and pilots take full responsibility for their own safety, although they can ask for help.

[3] *As defined in Cap 722 Section 2.2 for Open and Specific Categories.*

2.2.2 - Distribution

Figure 3 uses Google Maps to demonstrate the UK's Airspace Structure, with controlled airspace (Airways, TMAs etc) shown in white, along with positions of airports and the location of segregated areas highlighted in red. Uncontrolled airspace lies outside of these areas and may lie underneath areas of the controlled airspace shown.

The figure demonstrates that as can be seen, a large proportion of the total UK airspace is segregated and not available to all airspace users. This is one of the drivers for the CAA's revised AMS; to enable access to more airspace for more users.

The current method of creating Temporary Danger Areas for BVLOS UAS operations would mean a further reduction in available airspace for many users as BVLOS operations proliferate., therefore EC solutions are required to support continued access or to increase airspace access.

Figure 3: Segregated Airspace within UK[4]

2.2.3 - Regulatory

The current EC equipage requirements are shown below in Table 1.

Sub - para	Applicability	Requirements
	SSR Transponder Equipment for Aircraft Operating Under IFR	
(a)	All fixed-wing aeroplanes operating under IFR having a MTOM in excess of 5700 KG **or** having a maximum cruising true airspeed capability in excess of 250 KT with an individual certificate of airworthiness first issued on or after 7 June 1995.	Mode S Enhanced Surveillance, ADS-B version 2 and Mode S Enhanced Surveillance
(b)	Other aircraft operating in accordance with instrument flight rules within UK airspace.	Mode S Elementary Surveillance
	SSR Transponder Equipment for Aircraft Operating Under VFR	
(c)	All aircraft operating under VFR within United Kingdom controlled airspace of Classification B and C.	Mode S Elementary Surveillance
(d)	All aircraft operating under VFR within United Kingdom airspace at and above FL 100.	Mode S Elementary Surveillance
(e)	All aircraft operating under VFR within United Kingdom airspace notified as a 'Transponder Mandatory Zone'. *Note: Applies to Airspace Classes D, E, F and G as appropriate.*	Mode S Elementary Surveillance
(f)	All aircraft operating under VFR flying for the purpose of Public Transport.	Mode S Elementary Surveillance

Table 1: Current EC (Mode S & ADS-B) Requirements within UK Airspace[5]

As well as the Airspace Classifications and EC requirements described in Section 2.2, there may also be established radio mandatory zones (RMZ) and/or transponder mandatory zones (TMZ), which have their own

[4] *Taken from DfTs Upgrading UK Airspace Strategic Rationale 2017*

[5] *UK AIP 5.3.1.1*

EC requirements. 'Transponder mandatory zone (TMZ)' means an airspace of defined dimensions wherein the carriage and operation of pressure-altitude reporting transponders is mandatory[6].

RMZ/TMZs are established when the establishment of a more restrictive classification of airspace is not warranted but additional measures to enhance flight safety are required, with the objective to enhance the conspicuity of aircraft operating within, or in the vicinity of, complex, or otherwise busy airspace in order to maintain a balance between safe, efficient operations and fair, equitable access for all airspace users.[7] Enhanced conspicuity can enable, as appropriate:

- airborne collision warning and/or avoidance systems;
- a 'known' or 'recognised' air traffic environment which, in turn, permits ATS to
- provide more specific traffic information on collision hazards; and,
- ground-based safety nets such as short-term conflict alert (STCA) and minimum safe altitude warning (MSAW).

In addition, a RMZ may also be notified to facilitate:

- the provision of flight information, alerting and search and rescue services; or
- coordination with appropriate military units or with ATS units in adjacent States in order to avoid the possible need for interception for the purpose of identification.

Traditionally, a TMZ is associated only with pressure-altitude reporting secondary surveillance radar (SSR) transponders capable of operating in Mode S or, in exceptional circumstances, SSR Modes A and C. However, the advent and increasing affordability of technology such as automatic dependent surveillance – broadcast (ADS-B) means that the concept of a TMZ may now evolve to utilise alternate types of electronic conspicuity systems, where such systems are:

- deemed suitable, appropriate and proportionate;
- prescribed as alternative provisions for that particular airspace by the ANSP; and,
- notified in the Aeronautical Information Publication (AIP)

2.3 - Current Electronic Conspicuity Solutions

2.3.1 - General

EC is a term for a range of technologies (including Low Power Devices i.e. CAP1391, ETSO-C199 etc devices) that provide (airborne or ground based users with situational awareness of what is operating in surrounding airspace. EC includes devices fitted to aircraft and unmanned systems that send out information, and the supporting infrastructure to help them work together. The information generated by these systems strengthens the principle of 'see and avoid' by adding the ability to 'detect and be detected'. Airborne transponders, air traffic data displays, ground-based antennas and satellite surveillance services are all examples of EC currently in use in the UK.

Although certain EC devices, such as Mode S transponders, are mandatory for specified aircraft and specified airspace, they are not universally mandatory in the UK for aircraft that only operate in Class G (uncontrolled) airspace. Class G airspace users include a wide range of operators, pursuing a mix of different interests in a variety of aircraft types. Due to the freedom of operating within Class G airspace, it is also a portion of the overall aviation system that generates comparatively little operational data.

The main area of concern within uncontrolled airspace is the risk of Mid-Air collision (MAC), where military, GA, UAS and some CAT aircraft are operating in an environment where the overarching operating principle is 'See & Avoid', at times with limited supporting air traffic services and surveillance coverage. This can be of particular

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[6] UK Reg (EU) No 923/2012 Article 2(136)

[7] CAA - 13 January 2022 POLICY FOR RADIO MANDATORY ZONES AND TRANSPONDER MANDATORY ZONES

concern around smaller aerodromes with no current surveillance capability or in areas with a high density of hard to see airspace users, such as light aircraft, gliders, hang-gliders, UASs, etc.

Increased adoption of EC could be one mitigation to reducing the MAC risk, in particular as "See & Avoid" moves towards a "See, Be Seen & Avoid" principle or enabling "Detect and Avoid", which is necessary for the integration of UAS into UK Airspace.

EC can help deliver key benefits to:

Aircraft Operators

- Access: UK airspace will be more readily and more safely able to accommodate additional demand from airspace users, including CAT, GA access to CAS, new technologies (such as UAS), space-launch activities, and MOD.
- Cost: The airspace structure is a key determinant of an operator's costs, punctuality and environmental performance. More direct and efficient flight paths will mean lower costs.

Airport Operators

- Sharing digital information about the inbound and outbound traffic flows using the airspace is expected to improve runway throughput and resilience to disruption through greater traffic predictability. Additional airspace capacity will give airports more scope to develop their operations.

ANSPs

- More capacity and more efficient use of modernised airspace will help to alleviate the current significant air traffic control workloads and enable the integration of Urban Air Mobility (UAM) Aircraft.

Government

- A significant proportion of aviation emissions reductions will come from improving the efficiency of the UK's existing aviation system, with airspace modernisation playing a key role.
- Airspace modernisation must implement both domestic and internationally agreed requirements designed to increase the overall safety, capacity and efficiency of the global air traffic management system.
- The UK manages part of the North Atlantic's oceanic airspace, the world's busiest oceanic, intercontinental air corridor, and its efficient operation is crucial for international air traffic management.

2.3.2 - Current EC Solutions

There are range of EC solutions currently available to aircraft on the market from a large number of manufacturers (such as Thales, Collins, uAvionix, Garmin, Air Avionics, Trig, L3, Skytrax, Funke, PilotAware, Avidyne, Sagetech etc). Equipment able to be used on an aircraft for EC purposes currently includes (but is not limited) to:

- ADS-B Out capable transponder inclusive of GNSS position source
- ADS-B Out capable transponder reliant on external certified GNSS source
- FLARM
- Power FLARM
- Pilot Aware Rosetta
- Portable ADS-B In/Out Devices

Within Class G airspace in the UK, several Air Traffic Services Providers (ATSPs) operate: NATS, Airport Operators (such as MAG or HIAL), localised ATSPs and the Ministry of Defence (MOD). The majority of the larger ATSPs utilise traditional electronic surveillance (PSR, SSR, WAM etc), whilst several smaller providers currently only provide Flight Information Services (non-surveillance).

ADS-B

Although there are several trials by ATSPs utilising Automatic Dependent Surveillance – Broadcast (ADS-B) for a range of applications (mostly to increase situational awareness), only NATS have so far gained CAA approval to use ADS-B to provide a radar service across some North Sea airspace. NATS have also adopted space-based ADS-B (1090MHz ES) protocols to provide real-time surveillance within the Shanwick Oceanic FIR to reduce the longitudinal spacing between ADS-B equipped aircraft down to 14 nautical miles and eliminating the organised track structure below FL330.

Out-with ATSPs, there are over 3000 private ADS-B Ground Based Transceivers (GBT)[8] that currently form an informal network across the UK providing ADS-B services, that are used not only by equipped aircraft for situational awareness but by multiple websites and apps such as FlightAware, Flight Radar 24, PlaneFinder, Flight View etc.

			ADS-B (1090 MHz) Mode-S		ADS-B (978 MHz) UAT		MLAT (1090 MHz) Mode-S		Other (1090 MHz) Mode-S	
			AIRCRAFT SEEN		AIRCRAFT SEEN		AIRCRAFT SEEN		AIRCRAFT SEEN	
RANK	COUNTRY	SITES	TOTAL	DAILY AVG.	TOTAL	DAILY AVG.	TOTAL	DAILY AVG.	TOTAL	DAILY AVG.
1	United States	14,476	**548,478,418**	17,692,852	**710,232**	22,910	**4,403,592**	142,051	**23,051,142**	743,585
2	United Kingdom	3,001	**72,804,387**	2,348,528	**12**	-	**5,874,589**	189,502	**4,768,934**	153,836

Table 2: UK uptake of ADS-B[9]

2.4 - Airspace users

2.4.1 - Current users

UK airspace is utilised by a broad range of Users. The current main user groups are:

- CAT. Mainly concentrated within Controlled Airspace, although some Class G transits. CAT are Transponder equipped and most are ADS-B (1090 MHz equipped). 2020 statistics saw 812k movements by CAT from UK airports (which is down from 2214k movements pre-covid). Airbus forecast CAT to grow by 3.9% annually[10].
- Fixed Wing GA. Approximately 4000 aircraft registered in UK. Operate in a wide range of airspace, but most abundant within Class G Wide variety of EC equipment fits (see Section 2.4) depending upon airspace entry requirements.
- Rotary Wing GA. Approximately 1200 registered aircraft. Operate in a variety of airspace classifications but again mostly operate within Class G at lower levels. Wide variety of EC types fitted including Protected Aviation Band and ISM Band Systems, depending upon airspace requirements.
- Gliders. Approximately 2200 aircraft within UK. Mostly operate in Class G. Wide variety of EC types fitted including Protected Aviation Band and ISM Band Systems, depending upon airspace requirements.
- Non-Powered GA, including c.8500 flying pilots, 6400 skydivers. Normally within Class G airspace. Limited use of EC.
- Large Model Aircraft (Up to 150kg). 800 Model Flying Clubs, normally within Class G airspace. Limited use of EC.
- Military Aircraft. Approximately 800 using all classifications of airspace. Most are transponder equipped, transport aircraft ADS-B equipped.

[8] See https://uk.flightaware.com/adsb/stats/

[9] *Data from FLIGHTAWARE.com, Jan 2022*

[10] Global Market Forecast (airbus.com)

- UAS. Mostly in Class G airspace below 400ft - line of sight. BVLOS currently in temporary segregated airspace. 5800 registered operators. Very limited use of EC.

2.4.2 - Future users

Table 3 describes how the current UK Airspace user group numbers may be expected to change. By 2050 there are expected to be a variety of new users within UK airspace (See UK Transport Vision 2050)[11]. These new users are expected to include Advanced Air Mobility (AAM); Unmanned air transportation services for people and/or cargo using revolutionary new aircraft which is forecast to be worth globally US$510 billion by 2040[12] and there are forecast to be 76,000 operational UAS by 2030[13]. It is expected that AAM will first be adopted for freight delivery and remote inspections, with passenger-carrying services adopted by 2030.

There are many drivers for change currently on the UK Airspace infrastructure[14]:

- Meeting the demand for airspace,
- More sustainably,
- Encouraging aviation innovation to support UK economic growth,
- International obligations (such as Global Air Navigation Plan),
- Facilitating defence and security objectives.

EC can play a vital role in three key areas to support the UK's Airspace Modernisation Strategy (AMS):

- Enabling the on-going modernisation of the UK's airspace structure and route network.
- Helping to mitigate the risk of mid-air collisions in Class G, and infringements into controlled airspace.
- Enabling the safe and efficient integration of unmanned aircraft.

In line with the CAA's AMS (2022), it is expected that the demand on use of UK Airspace will expand, not only from existing airspace users such as CAT, GA, and the Military, but also from new users such as UAS, Advanced Air Mobility (AAM), Spaceflight, and High-Altitude Platform Systems (HAPS).

The headline predicted user numbers[15] (non-commercial) are as follows:

AIRCRAFT TYPE	CURRENT NUMBERS	EXPECTED GROW/FALL BY 2030?
Fixed Wing Power GA	c.13000	Broadly Stable
Rotary GA	c.800	Fall Slightly
Gliders	c. 2500	Grow Slightly
Non-Powered GA	c.8500 flying pilots, 6400 skydivers	Grow Slightly
Large Model Aircraft (Up to 150kg).	c. 800 Model Flying Clubs	Grow Steadily
Military Aircraft	c.800	Fall Slightly
Space Launch.16	0	Grow – estimated up to 970 launches per annum within UK
UAS and AAM Operators*	c. 5800 registered UAS operators	Grow Significantly. Approximately 76,000 UAS have

[11] IUK-110122-UK-Transport-Vision-2050.pdf (ukri.org)

[12] *https://www.adsgroup.org.uk/blog/advanced-air-mobility/ads-launches-advanced-air-mobility-aam-market-outlook/*

[13] The impact of drones on the UK economy - PwC UK

[14] Defined within CAP 2298a AMS (2022) Chapter 2 Part B

[15] Survey about the potential use of 978MHz in UK airspace (jotform.com)

[16] Space Launch Market Analysis

AIRCRAFT TYPE	CURRENT NUMBERS	EXPECTED GROW/FALL BY 2030?
		been estimated by the DFT to be operating in the UK by businesses and the public sector by 2030[17].

Table 3: UK Airspace Users

* New technologies are currently being deployed that are changing the types of aircraft and how they currently operate (e.g. UAS BVLOS outside controlled / segregated airspace). These new aircraft include UAS, Advanced Air Mobility (AAM) and high-altitude platform systems (for example, to provide a telecommunications network). The DFT estimate that use of UAS offers the UK savings of £16B and increasing the UK GDP by £42B across industries as diverse as Construction & Manufacturing, Public Sector, Retail Trade and the Media. Furthermore, the UK is pursuing a space launch capability, which will include unique geographical constraints requiring down-range surveillance in offshore areas (where radar are typically difficult to locate) to ensure safe launches.

ATSPs may embrace the use of EC equipment for surveillance and separation (where able), as has been seen in the USA[18] where ADS-B is now the preferred method of surveillance for air traffic control and where, after the ADS-B mandate went into effect in 2020, the FAA began utilizing ADS-B to enable three nautical mile (3NM) separation standards in en-route airspace below FL 230.

Greater use of EC could be expected to allow the provision of surveillance services by Flight Information Service Officers (FISOs), enabling safe integration of approach operations at smaller GA aerodromes[19]. As EC ground stations are relatively small and easily maintained, they could be placed in areas where radar was never possible, such as the North Sea.

2.4.3 - BVLOS scenario

There are a variety of approaches under development to enable BVLOS UAS operation around the world. At the time of writing there is no clear consensus on either the overall approach to BVLOS safety, or the role of exact role EC within BVLOS, however, there is a trend towards manned aviation being conspicuous and UAS being responsible for avoiding manned traffic, with EC devices contributing toward tactical mitigation.

Europe is presently working towards a concept of geographically restricted "U-Space" airspaces where BVLOS flights can take place. Under Regulation 2021/664[20] the concept involves manned traffic being conspicuous with unmanned traffic required to avoid. This does rely on the use of performant EC. EUROCAE WG 105 and RTCA 228 is presently developing an Operational Services and Environment Description and MASPs for Detect And Avoid (DAA) in both controlled and uncontrolled airspace. It is noted that these documents specifically focus on UAS, assuming a pilot-in-the-loop.

The US is working towards a BVLOS concept with an "Acceptable Level of Risk", proven through either assurance of empirical means (these are aligned to GA fatality rates for both MAC and third-party ground fatalities). This assumes equipage of ADS-B OUT or TABS and a minimum capability level on UAS, but recognising "layering mitigations" could be an appropriate strategy. At present this forms a report by the Aviation Rulemaking Committee[21], providing recommendations for the FAA.

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[17] The impact of drones on the UK economy - PwC UK

[18] ADS-B – Air Traffic Control (ATC) Applications (faa.gov)

[19] *See* 20191002-Airspace4All-GA-Airfield-ATS-ADS-B-Traffic-Display-Trial-Report-Summary-V1.0.pdf *Section 7.2*

[20] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R0664&from=EN

[21] https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/UAS_BVLOS_ARC_FINAL_REPORT_03102022.pdf

In Australia, regulation mentions "reduced navigation performance" in draft BVLOS guidelines[22], but leaves the responsibility of mitigating risk to the operator. Swiss regulation follows a similar approach[23].

BVLOS scenarios infer the identification and surveillance of UAS, but no regulation, concept of operations, or standards explicitly require UAS to be conspicuous to other airspace users. Instead the implicit assumptions appear to be that UAS will utilise a parallel architecture (that is most likely invisible to other airspace users) and ANSPs, most likely based upon the UAS' navigation system and C2 link, connected via an undefined communications channel such as mobile networks, to a third party UAS traffic service provider.

The role of EC contributing to Detect and Avoid capabilities, which will support BVLOS operations, is further explored in 5.3.1 - Additionally, future scenarios 2.5.4 - 2.5.4 - and 2.5.6 - below explore UAS interactions using EC.

2.5 - Future Electronic Conspicuity Scenarios

The following scenarios are based upon use cases developed by the CAA (including those within CAP 2298a AMS (2022)) and look at the potential use of EC within different phases of flight within a broad range of potential aviation operations by a variety of users groups. The scenarios are illustrative and are designed to give a flavour of potential EC usage; they are not intended to be a comprehensive guide to all possible uses for EC, but instead capture those most pertinent to this study.

The scenarios have been constructed to be as EC technology agnostic as possible, encompass manned and unmanned aircraft from various user groups, conducting a variety of operations in a variety of airspace types. They aim to demonstrate the interactions between users of all types with varying complexities of EC solutions and equipment fitted.

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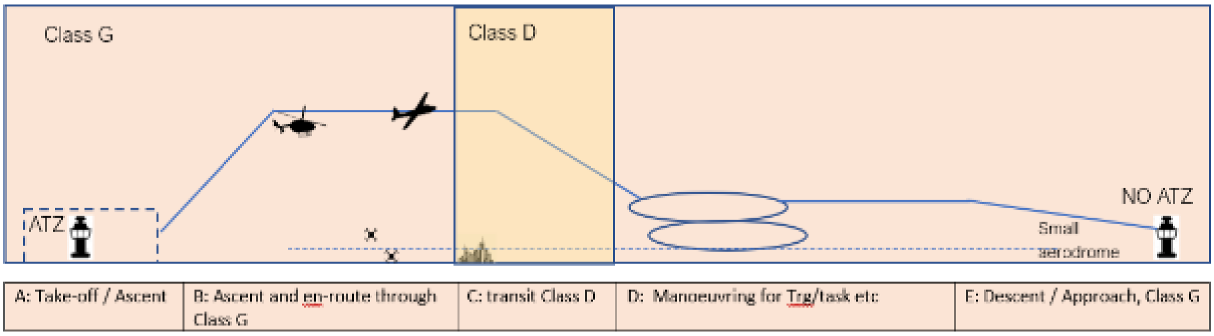
[22] https://consultation.casa.gov.au/regulatory-program/bvlos-app/consult_view/

[23] https://www.bazl.admin.ch/dam/bazl/de/dokumente/Gut_zu_wissen/Drohnen_und_Flugmodelle/gm_om_bvlos.pdf.download.pdf/Guidance%20Material%20OM%20BVLOS%20drone%20operations%20over%20sparsely%20populated%20areas_v1.pdf

2.5.1 - Aviation scenario 1: GA take-off, transit, task and descent

GA Fixed and Rotary Wing take-off from small Class G airspace aerodrome with ATZ, and transit to a non-ATZ aerodrome with a crossing through Class D and manoeuvring En-route as required to allow for specific task/ training/sightseeing etc.



	Aircraft A	**Aircraft B**
		
A/C Type	Light FW Aircraft (<5700kg) Piloted	Model Aircraft <20 kg Remotely Piloted
Task	Training Flight	Recreational Flying
EC In/Out Fitted?	Yes	Yes - Out
Environment		
Location	Rural	
Airspace	Class D, Class G	
Max Height	5000 ft	
Traffic Density	Low	
Enabler	EC (In/Out) equipped aircraft, EC Ground stations (including re-broadcast). Enables entry to Controlled Airspace. Enhanced Situational Awareness, enhanced See, Be Seen & Avoid. deconfliction.	

Scenario

Aircraft A is a light high-wing aircraft undertaking a training flight at the weekend. After departure from its home aerodrome, ATC, utilising their EC display, warn **Aircraft A** of very low-level traffic manoeuvring along its track. **Aircraft A**, which is receiving TIS-B and FIS-B services from its fitted EC equipment, confirms that it too is aware of these airspace users. As it continues to climb to 5000ft, **Aircraft A** monitors the previously reported aircraft, has nothing visual, but can see that they are maintaining very low level and not a confliction. The instructor, with their local knowledge, correctly believe these aircraft to be operating at a popular local model flying club, which operate large model aircraft and UASs recreationally at the weekend and have a local agreement with the home aerodrome not to fly above 500 ft without prior notification.

Aircraft B is a large model aircraft being flown at the local model club. Almost 20kgs in weight, it has been fitted with lightweight EC-out equipment so as to be visible to other airspace users. The Model flying club has a private EC ground station and display, and can monitor the airspace around them, looking for conflicting aircraft and acting if required. Due to its EC Equipment, **Aircraft B** is electronically visible to **Aircraft A,** who decides it does not represent a confliction, but continues to monitor its position. The model flying club have detected **Aircraft A**'s presence, but likewise decide it represents no confliction and decide that no action is required upon their behalf.

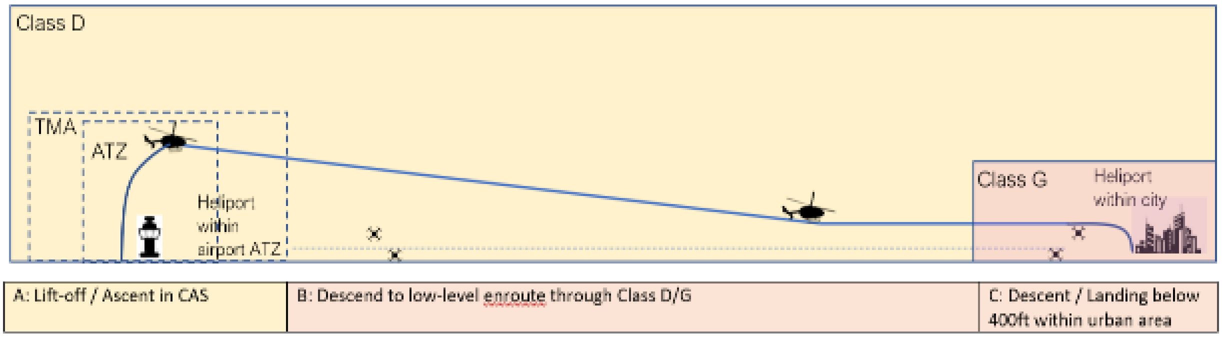
Upon reaching its transit level, **Aircraft A** approaches an area of Class D airspace. Contacting the appropriate ATC unit, being identified using it's EC and receiving an appropriate Air Traffic Service, it receives permission to transit IFR (due to entering IMC conditions). A descent to 2000 ft within the Class D zone is granted by ATC, thereby allowing them to regain VMC.

Upon exiting Class D airspace, whilst en-route to their destination, **Aircraft A**'s pilot, using the See & Avoid principle, becomes visual with another light GA aircraft, and due to its relatively close proximity, initiates avoiding action to maintain separation. The other aircraft is not EC equipped, and so was unable to be detected sooner.

Aircraft A conducts a number of training serials, before proceeding with its land-away at a small aerodrome, and despite having no surveillance capacities itself, the FISO at the destination is able to provide an enhanced Flight Information Service as they are receiving EC data and re-broadcasting TIS-B and FIS-B data. The EC information displayed at the FISO's position gives increased situational awareness, allowing them to better manage the traffic within their area of responsibility.

2.5.2 - Aviation scenario 2: Helicopter take-off, transit/operations and descent, including urban operations

Helicopter take-off from Airport and transits to a Heliport within the city. Due to location and size of Airport this could involve transit through Class D or G or a mixture of both.



	Aircraft A	**Aircraft B**
		
A/C Type	Helicopter (<5700kg) Piloted	UAS <20kg Remotely Piloted
Task	Commercial Passengers	Police Operations
EC In/Out Fitted?	Yes inc. Mode S	Yes
Environment		
Location	Metropolitan	
Airspace	Class D Class G	
Max Height	2000 ft	
Traffic Density	High – Airport Traffic, Advanced Air Mobility, other UASs, other Helos.	
Enabler	EC equipped aircraft, EC Ground stations. Enables entry to Controlled Airspace. Enhanced Situational Awareness, enhanced See, Be Seen & Avoid, UAS co-ordination and deconfliction.	

Scenario

Aircraft A is a light commercial helicopter. It is picking up 2 passengers at a heliport situated within a busy Biz-Jet airport and transporting them to another commercial heliport in a city approximately 100 miles away. Mode S and EC (In/Out) equipped; it meets the standards required to operate in controlled airspace. It is in contact with ATC and is cleared to depart and transit through the TMA along a recognised helicopter route.

Once clear of the TMA, and with cloud building, **Aircraft A** prepares to descend to a lower altitude, however, it's onboard collision avoidance system alerts it to the presence of the EC out equipped **Aircraft B** operating at very low level ahead of it. Not visual with the other aircraft, the pilot of **Aircraft A** decides to delay the descent, and monitors electronically the position of **Aircraft B**. Once clear of any potential confliction and satisfied that **Aircraft B** no longer represents a threat, **Aircraft A** descends to 500ft to maintain good VMC.

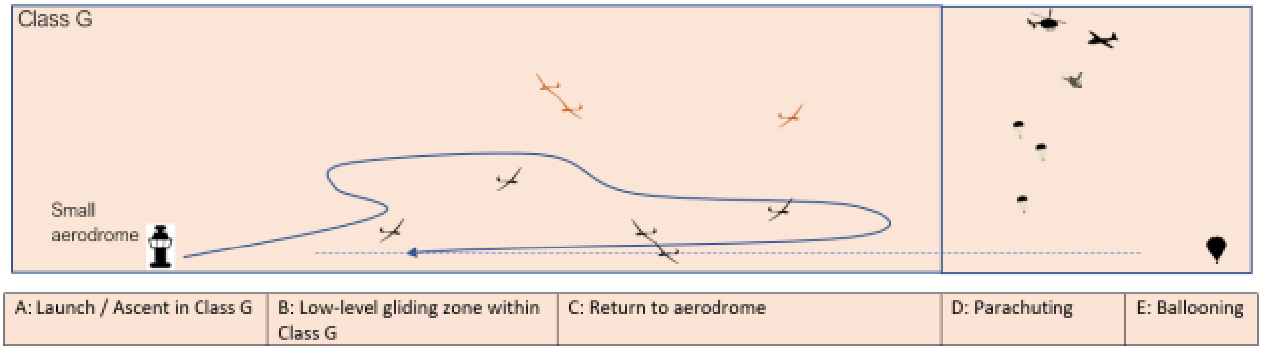
Aircraft B is a new police UAS that the operator is conducting a training flight upon. The UAS is EC Out equipped so that the aircraft meets the equipment standards required to operate within the surrounding airspace, but the operator also has an app upon their tablet which receives EC In data from a variety of sources. The operator had intended to climb the aircraft to 500ft, however, they are alerted to the fact that there is another aircraft in the vicinity and transiting above them. The operator of **Aircraft B** becomes visual with **Aircraft A** and decides to delay the climb until the helicopter is well clear.

Aircraft A continues its transit, and approaches the destination, which is surrounded by Class G airspace. The pilot is aware that whilst the airspace is unrestricted, it is relatively busy with UAS traffic due to the presence of a large distribution centre for a multinational company that has started to extensively use relatively large BVLOS EC equipped UASs for delivery. With this in mind, the pilot avoids the distribution centre and monitors the collision avoidance system for other traffic, manoeuvring as required to ensure adequate separation and to help visually acquire the other traffic.

The heliport is equipped with EC re-broadcast facilities. **Aircraft A** receives TIS-B and FIS-B data, ensuring that the approach to the heliport is smooth and uneventful. The FISO at the heliport is able to monitor the progress of **Aircraft A** through the displayed EC data and is able to offer deconfliction advice against another helo which had just departed.

2.5.3 - Aviation scenario 3: Glider/parachuting/balloon operations

Glider launches and practice in vicinity of a small airfield at low-level, glide down to same airfield



	Aircraft A	Aircraft B	Aircraft C
			
A/C Type	Glider(<5700kg) Piloted	Parachute Jump Aircraft (<5700kg) Piloted	Balloon (<5700kg) Piloted
Task	Leisure	Parachute Jump	Leisure
EC In/Out Fitted?	Yes	Yes	Yes (Portable)
Environment			
Location	Rural		
Airspace	Class G		
Max Height	5000 ft		
Traffic Density	High: Multiple leisure aviators - Gliders, Balloons, Parachutists, GA (FW & RW)		
Enabler	Situational Awareness, enhanced See & Avoid		

Scenario

Aircraft A is a glider operating out of a small aerodrome. As well as multiple gliders operating that day, the local parachuting club is active nearby, balloons are expected to launch from a field in the local vicinity later in the afternoon and a small number of local GA Light Aircraft are active.

The weather is currently good; it is a bright sunny day, good VFR conditions and good thermals are building, although it is forecast to cloud over with degrading visibility later in the afternoon.

Aircraft A is launched into the local area and quickly finds a thermal climbing to 3000 ft. Several other gliders are on the same thermal, as displayed on **Glider A's** collision avoidance system which shows other EC equipped gliders positions and heights.

The Glider club radio notifies gliders on frequency that **Aircraft B,** the parachute aircraft is shortly to begin dropping and broadcasts a position report, which the radio operator has gained from the EC receiver and display that the club recently purchased. **Aircraft A** confirms the position on their own display, and despite the parachute aircraft being some distance off, is able to visually acquire it using the cues provided from the EC data on the collision avoidance system. **Aircraft A** positions itself to avoid the parachutists and other participating aircraft.

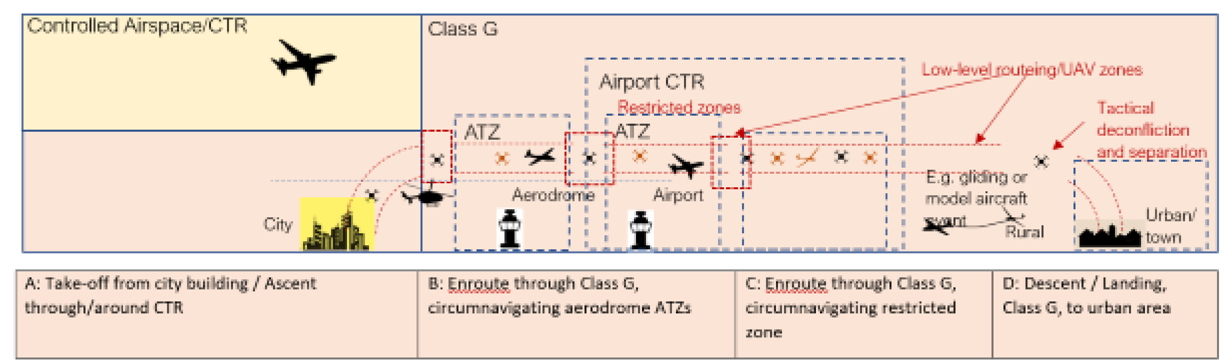
Aircraft A returns to the aerodrome, follows instructions to make itself number 2 to the glider in front (which it had been tracking through the EC data) and lands uneventfully.

Aircraft B departed the airfield, and quickly climbed to 10000ft. Using the EC data received from other participating aircraft, from the gliding clubs recently purchased EC re-broadcast system, and from visual scan, the pilot is satisfied that it is safe for the jump and gives instructions for the parachutists to exit the aircraft. The pilot begins the descent to the aerodrome for the next sortie. As they descend, they receive TIS-B information about a slow moving slow climbing aircraft. Using this data, the pilot can visually acquire a balloon rising from its launch field some way off and assess it as no factor.

Aircraft C is a balloon launching for an afternoon trip with fare paying passengers. The pilot has brought onboard a portable EC-out device, which, whilst not affording them a greater level of situational awareness does make them more visible (and hence safer) to EC equipped aircraft and ground stations.

2.5.4 - Aviation scenario 4: UAS, including restricted zones, VLOS and BVLOS

Routeing (e.g. delivery) from a central city location in proximity to a CTR, through class G airspace in the vicinity of other CTR/ATZ operations, via rural area(s) to another location in an urban environment



	Aircraft A	**Aircraft B**
		
A/C Type	UAS (<20kg) Highly Automated with Ground Based Controller	Glider(<5700kg) Piloted
Task	NHS – Delivery	Leisure
EC in/Out Fitted?	Yes	Yes
Environment		
Location	Large Metropolitan Area – Rural - Urban	
Airspace	Class G – EC mandatory within city, Class G – Open	
Max Height	500 ft	
Traffic Density	High	
Enabler	BVLOS enabler – EC mandatory for all participants within EC designated Airspace EC for Class G operations for enhanced See, Be seen and Avoid, and Detect and Avoid	

Scenario

Aircraft A has an urgent task to transport donated organs from the donor hospital within the city to the recipient hospital located in a town 20 miles away. Speed is of the essence, and UAS transportation takes only a quarter of the time of ground transportation. This is a route that is regularly followed and has been notified to other airspace users.

Utilising it's EC In/Out capability**, Aircraft A** receives TIS-B information from a variety of data sources via surrounding ground stations (a mix of government furnished and private installations) and other participating aircraft. With no conflicting aircraft detected, **Aircraft A** departs from the hospital's roof landing point, and climbs to 400ft. It follows its pre-determined route, avoiding local airports ATZ's and CTRs, where the ATCOs are monitoring its presence on their displays through the received EC data and confirm that it is not infringing their airspace*.

Aircraft A uses it's detection capabilities to recognise other EC equipped aircraft, allowing the Ground Controller to safely deconflict it from other EC equipped users, including other UAS on recognised UAS routes.

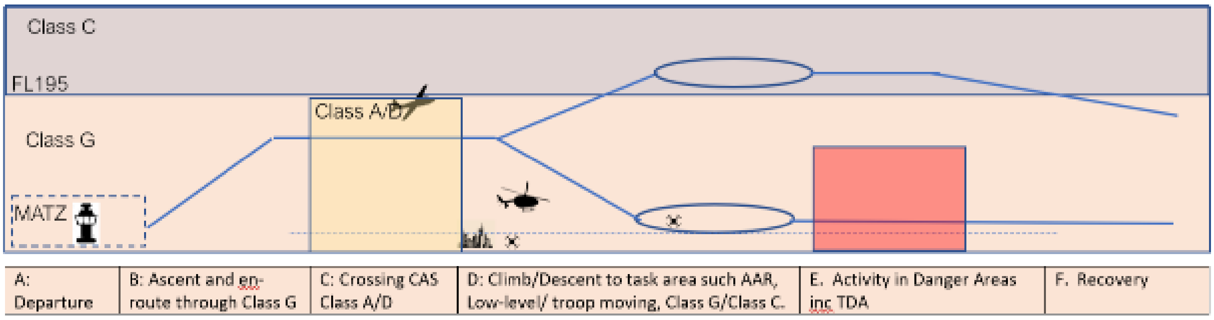
Aircraft B is an EC equipped glider on a leisure flight, operating at various levels close to its home aerodrome. Whilst soaring, it receives notification of traffic (**Aircraft A**) from its onboard systems. Using the positional data provided by EC, **Aircraft B** visually acquires **Aircraft A**, and takes positive action required to assure safe separation between the two aircraft. **Aircraft A's** EC systems have also detected **Aircraft B**, and due to Aircraft B's vectors (opening in distance) calculate that it is non-threatening, that no action is required and so continues on its route.

At **Aircraft A's** destination, awaiting hospital staff are monitoring its progress on the EC display that they have installed (& which also re-broadcasts and acts as an EC conduit), and upon landing it is met with no delay.

*N.B If crossing restricted/controlled airspace, the UAS operator will need clearance to enter. Having been pre-notified to the airspace management system, the flight will be visible to the airspace controlling authority, allowing appropriate clearances to be provided. From the operator's perspective, the activity status of the airspace will be provided both pre-flight and en route, allowing early re-routeing of the flight if clearance is likely to be refused. This would also be the case for other airspace restrictions such as danger areas, flight restriction zones etc. For routine flights, such as advanced air mobility routes in and out of airports, delivery services or airfield security, clearances may be secured through prior written agreement

2.5.5 - Aviation scenario 5: Military Sorties

Military fixed and Rotary Wing take-off from MOD Airfield predominantly in Class G with MATZ/ATZ, and transit to a training area either low/ medium or high level. Crossing Controlled Airspace (A/D) where required. Manoeuvring and conducting military tasks in either Class G or C inc. Danger Areas and returning normally to base.



	Aircraft A	Aircraft B	Aircraft C
			
A/C Type	FW (>5700kg) Piloted	UAS (>25kg). Remotely Piloted	Helicopter (>5700kg) Piloted
Task	Military Training Sortie – High Level	TV Filming, VLOS	Military Training Sortie – High Level
EC In/Out Fitted?	Mode S	Yes – Out only	Mode S
Environment			
Location	Southern UK		
Airspace	Class G, Class D, Class C		
Max Height	SL – FL290		
Traffic Density	Variable		
Enabler	EC in order to facilitate positive identification to enter Controlled airspace and to become aware of other EC equipped airspace users.		

Scenario

Aircraft A & Aircraft C depart from a military Air Station into Class G airspace within the SW of England. ATC have given them the appropriate standard departure routes, having ascertained from the received surveillance and EC data that the ATZ & MATZ were known traffic environments and having initiated the appropriate Air Traffic Management protocols. The ATC unit re-broadcasts surveillance data, acting as a conduit for TIS-B and FIS-B services for appropriately EC equipped Aircraft operating within the local area.

Aircraft A climbs to FL 130 and receives an Air Traffic Service from the next adjacent military unit in order to cross their Class D zone IFR. Upon exiting the Class D airspace, they are handed over to Swanwick Mil and climb to FL290 in Class C airspace to conduct a high energy Check Test Flight, before returning to base upon completion.

Aircraft C departs the MATZ low level (500 ft). It also contacts the Class D airspace controlling ATC unit for a SVFR transit. It is aware of other low-level aircraft within the Class D airspace as they are all EC equipped and the controlling unit is an EC conduit, re-broadcasting data. **Aircraft C's** collision avoidance system displays the position of participating EC equipped Aircraft.

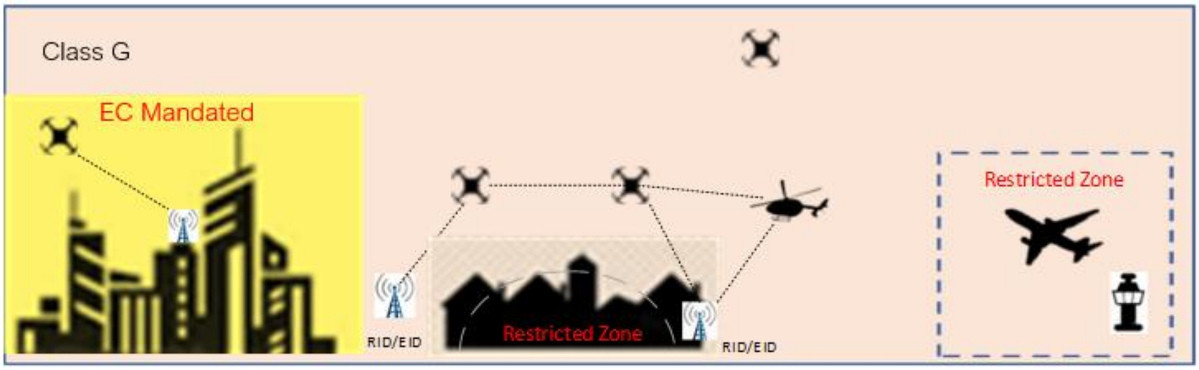
Upon re-entry to Class G Airspace, **Aircraft C's** routing takes it close to an area which has been NOTAM'd as containing UAS conducting filming operations. The crew of **Aircraft C** are cognisant of the NOTAM'd area and their collision avoidance system displays the position of a very low level, EC-equipped aircraft (**Aircraft B**) operating within the area. They adjust their routing to pass around the area.

Aircraft B is a large UAS conducting filming operations up to 400ft for 3 days in this location, which the film company have NOTAM'd. It is EC out equipped and it's 2-man remote pilot crew are monitoring the airspace activity of EC equipped aircraft within the local area on an app. Despite not being visual with it, they become aware of **Aircraft C** and it's routing, and whilst their display shows them that there will be no confliction and that **Aircraft C** will pass wide of their area of operations, they decide to stop filming and land **Aircraft B**, as the expected track of Aircraft C may bring it into shot or be heard, which is not conducive to their filming.

Aircraft C continues without further incident on its low-level sortie, including transit of the South Coast Danger areas having been positively identified using EC and given clearance to cross by the Danger Area Controlling ATSU, before recovering to a maritime asset.

2.5.6 - Aviation scenario 6: UAS Urban operations

UAS operation in an urban environment, where EC is mandated.



A: Take-off from city building / Ascent through EC Mandated Airspace	B: Ascent and en route through Class G, avoiding restricted zones

	Aircraft A	**Aircraft B**	**Aircraft C**
			
A/C Type	UAS (<5700kg) Highly Automated with Ground Based Controller	UAS (<2.5kg). Remotely Piloted	Helicopter (<5700kg) Piloted
Task	Passenger Transit	Building Survey	Police Operations
EC In/Out Fitted?	Yes	Yes	Yes
Environment			
Location	Large Metropolitan Area		
Airspace	Class G – TMZ within city, Class G – Open		
Max Height	500 ft		
Traffic Density	High: Multiple UAS users, helicopters (civil into local heliport & Government)		
Enabler	TMZ – EC mandatory for all participants within designated Airspace		

Scenario

Aircraft A receives it's 4 passengers at the urban airport situated outside of the international train station within the centre of the city. The surrounding airspace is class G but is designated a TMZ; all users are mandated to have EC Out capabilities as a minimum.

Aircraft A receives TIS-B information from a variety of sources from surrounding ground stations (a mix of government furnished and private installations) and other participating aircraft. With no conflicting aircraft detected, **Aircraft A** takes off and climbs to 300ft. Its routing takes it south through the city; overlaying GNSS position data with its internal geo-mapping allows it to successfully navigate between taller buildings and over smaller ones, whilst avoiding restricted zones around Royal Palaces, Parliament Buildings and sensitive military installations.

Aircraft B is being piloted by a remote operator and is conducting a building survey between 100-1000 ft on a high-rise building within the EC Mandated zone, and is ¼ of mile away, but directly on the route planned for **Aircraft A.** The remote pilot of **Aircraft B** is receiving EC information from surrounding ground stations and other participating aircraft on an App which is displayed on their portable display. Their aircraft is transmitting EC out data. Despite not being currently visible, the remote pilot is alerted to **Aircraft A** and aware of its height and vectors, and decides to act early, climbing **Aircraft B** to 400 ft. **Aircraft A** detects

Aircraft B, and routes to maintain 100ft vertical separation and 200m lateral separation*. It passes **Aircraft B**, whose pilot is now visible with **Aircraft A** and is satisfied that no confliction exists and continues with the building survey.

Aircraft A continues en-route, departing the EC mandated airspace into open Class G airspace. So as to minimise contact with other airspace users that may not be EC equipped, it maintains its presence in very low level airspace at 300ft over the low rise urban area it is transiting, and routes to avoid the restricted zone at the local airport, whose ATCOs are monitoring its presence on their displays through received EC data and confirm that it is not infringing their airspace. The ATC unit re-broadcasts the surveillance data they receive to participating EC equipped aircraft, acting as a EC conduit.

Aircraft A monitors the presence of **Aircraft C**, which is manoeuvring at 200ft in the conduct of its duties.

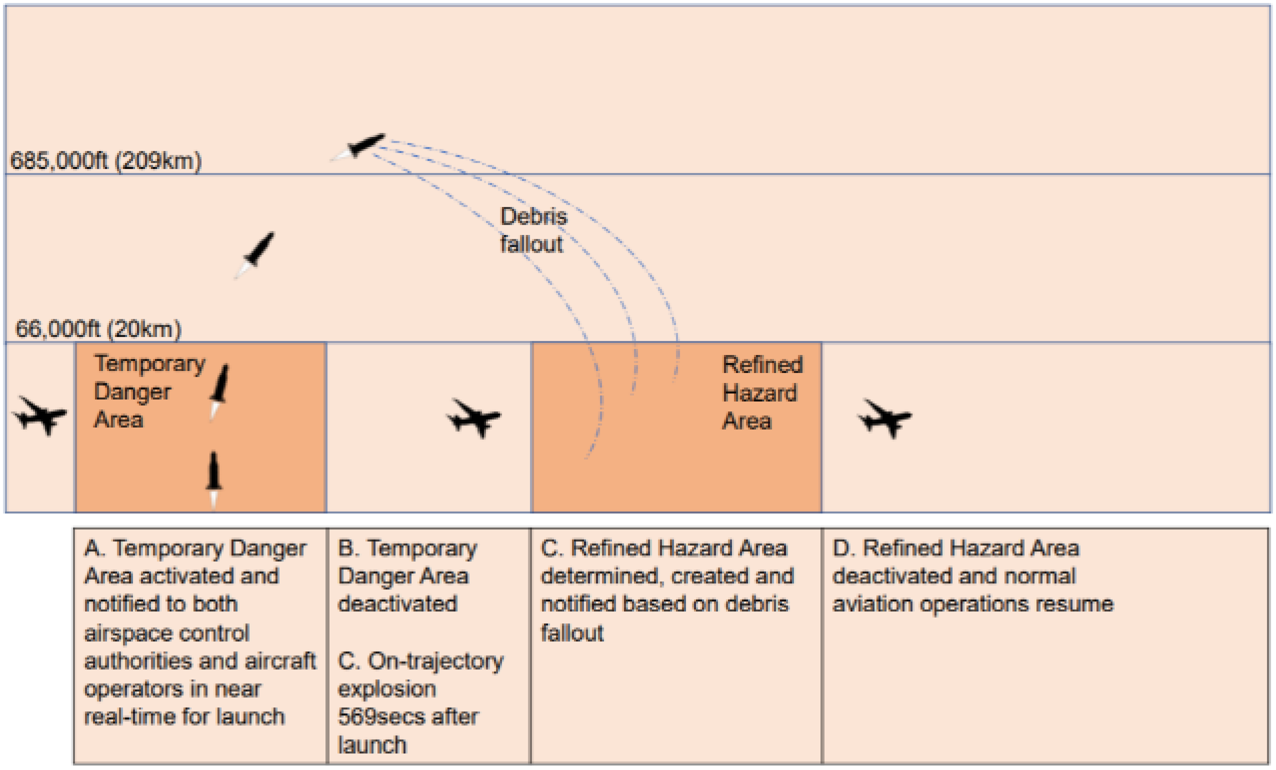
The pilot of **Aircraft C**, which is fully transponder and EC equipped, receives TIS-B and FIS-B data and has **Aircraft A** displayed on their onboard collision avoidance system, but is content that it represents on confliction and has no indications of having to take any deconfliction action. The EC data received gives the pilot of **Aircraft C** direction and height cues and they pick up **Aircraft A** visually allowing them to see it and confirm they will avoid it.

Aircraft A reaches its destination, an urban airport outside of the passenger's residence, where it lands and completes its journey.

*Separation distances given as an example; future actual required separation standards are not yet defined.

2.5.7 - Aviation scenario 7: Spacecraft (ground or air-launched)

Space launch concept based around dynamically used airspace, which is tied to the platform rather than location. A dynamic volume of airspace could be managed to protect other airspace users from rocket flight, falling spent stages or falling debris from an unplanned event. Airspace activity data shared through an airspace management function on SWIM[24] profiles.



Flight Phase	EC – Potential Benefits
A: Launch from within activated Danger Area (including TDA)	With other airspace users visible due to EC, Launch Authority can assure the "Clear Range" and sterilization of the TDA in real-time for the launch window.
B: Danger Area De-activated	
C: Refined Hazard Area created and airspace users notified	Airspace users within refined hazard area can be identified, notified of debris fallout and vacated from the area.
D: Refined Hazard Area De-activated	

[24] *System Wide Information Management* SESAR-Factsheet-2015-SWIM-Profiles.pdf (sesarju.eu)

2.5.8 - Resultant applications enabled by enhanced EC

Given the scenarios above, as well as policy reflected in the Airspace Modernisation Strategy, the following applications have been identified. These applications enable the scenarios and ultimately the benefits of the integrated digital airspace foreseen in the AMS.

Any enhanced EC standard would need to support these applications, including consistency with existing legislation (e.g. ICAO FIS).

This section therefore introduces the applications, and highlights application-level requirements relevant to the enhanced EC context. These requirements are technology agnostic – within this section, the goal is to understand the norms in terms of surveillance information and data quality requirements, justified through detailed analysis (e.g. safety or performance requirements) or precedents.

2.5.8.1 - ICAO Flight Information Service using surveillance (in Class G, as well as potentially Class E)

The Flight Information Service provides information pertinent to the safe and efficient conduct of the flight, including information on potentially conflicting traffic (ICAO Annex 11, PANS-ATM Doc 4444).

This includes a possibility for the FISO or ATCO to receive surveillance information appropriate to provide a Flight Information Service i.e. traffic information with deconfliction advice. PANS-ATM Doc 4444 §8.11 states that: "*The information presented on a situation display may be used to provide identified aircraft with information regarding any aircraft observed to be on a conflicting path with the identified aircraft and suggestions or advice regarding avoiding action*" (alongside navigation and weather information).

PANS-ATM Doc 4444 (§8.11) notes however that: "*the use of an ATS surveillance system in the provision of flight information service does not relieve the pilot-in-command of an aircraft of any responsibilities, including the final decision regarding any suggested alteration of the flight plan*".

An IFATCA PLC paper noted in 2019 that "*The standards prescribed (*for FIS) *are ambiguous and not sufficient to define the limits of obligation and information to aircraft. Only basic criteria can be found in ICAO DOC 9426, not doing justice to the service level that is provided by- and expected of ATCOs and FISOs*" and "*Both on ICAO and European level, there are no standards and technical requirements for the use of ATS Surveillance for provision of FIS in class G airspace.*"

ICAO Doc 9426 (ATS Planning Manual, written in 1984) states: "*Traffic information provided in uncontrolled airspace regarding other air traffic operating in the vicinity of a given aircraft... should be given whenever it is likely that such information will assist pilots concerned to avoid the risk of collision. In addition, since, in uncontrolled airspace, such information can only be given about aircraft whose presence is known and since even that information may be of doubtful accuracy as to position and intentions of the aircraft concerned, the unit providing FIS will not assume responsibility for its provision at all times nor for its accuracy once it is issued. Pilots should be given an appropriate indication of this fact when such information is provided to them.*"

Elsewhere, IFATCA noted the standard of care requirement, and also stressed the limits of information being passed (i.e. not an instruction, not binding). This point leads to some confusion around the potential safety impact of surveillance being used to determine deconfliction advice. No clear safety requirements have been found in our research to provide clarity on the level of surveillance information required for ICAO FIS. Some work was initially carried out in EUROCONTROL in 2018-2019, but was stopped due to concerns around the use of 1090MHz for GA (causing spectrum overload).

In terms of the legacy situation, Regulatory Article 3228 states that, in Class G airspace when providing a Deconfliction Service, controllers should provide information and advice aimed at achieving the lateral and vertical separation standards defined in CAP 774 (i.e. UK FIS). These are 5NM laterally and/or 3000ft vertically (against uncoordinated traffic) or 3NM laterally and 1000ft vertically against traffic benefiting from the same ATS. Whilst stressing that these are UK FIS (and not ICAO FIS), it nevertheless gives a benchmark in understanding potential surveillance performance needs.

The Flight Information Service will include the ability for the ATCO or FISO to determine if altitude differences exist using the surveillance information received. Electronic conspicuity devices which report geometric height information are not permitted to be used to determine whether altitude differences exist between aircraft (ICAO Doc 4444 PANS-ATM section 8.5.5.1.2 refers) and thus their use in the provision of ATS is limited.

UK Reg (EU) No 923/2012 (SERA) Article 2(136) refers to this, noting that a TMZ must include the carriage and operation of pressure-altitude reporting transponders. The new January 2022 TMZ policy from the CAA then applies this specifically to Electronic Conspicuity devices in a TMZ.

Flight Information Services could make use of appropriately performant Electronic Conspicuity information.

If enhanced EC is the only source of surveillance information for the provision of FIS, the ICAO documents (and CAP774 UK FIS 4th edition) would suggest:

- It must enable the positive identification of an aircraft.
- It must be able to provide pressure-altitude derived level information.
- It must be able to support deconfliction advisories with sufficient surveillance information and data quality.

Note that these elements could be provided by another surveillance source if available – for example, a ground-based radar. These other means of meeting the requirements must be considered in the options under assessment.

Crossing service (Danger Areas, ATZ, etc)

For a Danger Area or ATZ Crossing Service to be provided, it must be in accordance with the relevant civil and military legislation. Any surveillance equipment used to monitor activity, provide DACS or detect incursions, must be designed, installed, operated and maintained in accordance with civil and/or military regulations (see TA/TDA Policy 20200721.

The Crossing Service will usually include a clearance enabling the aircraft to enter the danger area, and then provide FIS to ensure a safe and efficient crossing.

Given the risks in a Danger Area or ATZ may be higher than in other parts of Class G, the need to have assured known traffic is higher. It is considered to have safety impact, and may therefore impose similar (or higher) requirements to the provision of ICAO FIS in Class G.

2.5.8.2 - Detect And Avoid applications in UAS (unlikely to be sole source)

One component to Detect And Avoid (DAA) is a form of assured Electronic Conspicuity – see CAP1861a outlining the ecosystem within which UAS DAA would operate. This document sets out certain parameters that could be expected via EC: identification, position, speed, heading and altitude.

As EC is not the only source, there will almost always be mitigations in case of false surveillance information being sent via the EC device. But the simplest solution for an integrated airspace will be to provide an assured and known traffic environment, which then supports a robust safety argument and collision risk model. Data without integrity may in fact make things worse, confusing the system even when backed up by other sensors (e.g. visual).

The drones will be carrying out collision avoidance using this information, and therefore there will be a safety impact to the information. Requirements for DAA for UAS are currently in undergoing OSEDs and SPRs development within EUROCAE WG-105. At OSED level, these are expected to be published within the next six months.

2.5.8.3 - Hybrid ACAS (ACAS X) and future collision avoidance applications

There are several different collision avoidance applications already on the market, with more in research and development. Enhanced EC should enable the applications likely to be used in Class G in the UK. This includes (where possible) current applications, which bring a safety benefit to the airspace.

The existing collision avoidance applications include:

- ACAS / TCAS I
- ACAS / TCAS II
- Hybrid ACAS / ACAS X
- Traffic Advisory Systems (TAS, which do not give Resolution Advisories but can use active interrogation)
- Passive conflict alert systems such as Portable Collision Avoidance System (PCAS) and Traffic Collision Alert Device (TCAD)
- ADS-B IN – Traffic Situational Awareness with Alerts (TSAA) for Airborne Operations

Clearly a mix of functionality, inputs and end effectiveness exists. For the purposes of this study, the passive surveillance which alerts to nearby traffic is essentially an extension of an "aid to situational awareness". For this reason, it benefits from non-assured position as described in CAP1391. As it is only an aid, it also does not need to be fully interoperable with surrounding traffic.

Of more interest are the applications which provide collision avoidance resolutions, and thus require assured data on which to base that resolution.

The minimum requirements for an aircraft-based surveillance system to support air-to-air surveillance for airborne collision detection, for GA aircraft not equipped with TCAS, have been standardised in "Traffic Situation Awareness with Alerts" (TSAA) in ED-232 / DO-348 [12] and MOPS ED-194A/DO-317A [16]). This could therefore be used as a basis for enhanced EC to support such an application – although recognising this standard was developed for particular contexts that may not replicate the UK airspace precisely in terms of assumptions used.

Hybrid ACAS uses surveillance means such as ADS-B and Electronic Conspicuity to track potential intruders and does not rely solely on active interrogation as with traditional ACAS. Versions of ACAS X are being defined for UAS (ACAS X_O in EUROCAE ED-256) and GA aircraft (ACAS X_R yet to be standardised and published).

In each case, it would seem beneficial to use a surveillance source which gave assured traffic information, reducing the possibility of nuisance advisories and alerts, and the potential to take an inappropriate action based on false position information delivered electronically. This is particularly the case if used in IMC.

The current Electronic Conspicuity (CAP1391) is designed for non-Part 21 aircraft and is specified to have no safety impact. The surveillance requirements for the enhanced application noted here would likely have safety impact (including deconfliction advice and potentially collision avoidance alerts), and therefore would need more stringent requirements.

A precedent is available through the US work on the Traffic Awareness Beacon System (TSO-C199) which aims to deliver a basic assured signal to collision detection and avoidance devices on nearby aircraft, thus increasing safety by enabling aircraft outside of current mandates to equip in an affordable manner. The TSO describes a surveillance performance where the position report must be within 0.5NM of the true position (NIC = 6), 99.9% of the time ($1x10^{-3}$ or better), and with a Source Design Assurance of $1x10^{-3}$ (0.1%) – i.e. probability of position errors greater than 0.5NM being caused by malfunctions in the ADS-B system.

The analyses to determine these data quality values are based on detailed collision risk modelling and Acceptable Levels of Safety for various aircraft types. Changes to general precedents would generally require proving through detailed Safety, Performance and Interoperability Requirements determination processes.

3 - EXISTING ELECTRONIC CONSPICUITY REGULATIONS, STANDARDS AND GUIDANCE

3.1 - General

This section establishes the context in which existing regulations, standards and guidance support electronic conspicuity solutions for the aviation market and establishes what evolutions of these may be needed in the future. This includes both ground and airborne equipment and regulations governing the use of electronic conspicuity for operational purposes by Air Traffic Services (ATS).

Section 2 has described the environment in which regulations, standards and guidance are deployed and also addressed the evolution of new actors and users of electronic conspicuity data which need to be catered for through updates to existing documents or evolutions of policy and development of new specifications. This addresses both the needs of the new users and the evolving needs of existing airspace users who can benefit from advances to airspace management, design, and ATC tools and automation, allowing new applications to be developed and exploited. Within this context, this section determines the appropriateness of the existing standards, regulations and guidance to support future applications and EC proposals.

At the end of the UK/EU Agreement transitional period on 31 December 2020 following the UK's departure from the European Union, the law that applies to aviation rights and obligations is now all UK law and includes retained EU Regulations, as amended by an increasing amount of UK law. Therefore, in reading the references in this section, it should be noted that:

- EU regulations as published on EU web pages are not an accurate presentation of the law that applies in the UK.
- The CAA adopted the version of Acceptable Means of Compliance (AMC), Guidance Material (GM), Certification Specifications (CS) adopted by EASA up to 31 December 2020, but has since adopted amendments to the AMC, GM and CS.

3.2 - Regulatory requirements

3.2.1 - Ground elements

3.2.1.1 - General

This section summarises the key regulations currently applicable to surveillance and ground component equipment. It covers surveillance systems for ATC services, surveillance systems supporting flight information and deconfliction services and also ground components supporting airborne collision avoidance systems (e.g. TIS-B).

This section also highlights the most relevant provisions from all identified regulations, standards and guidance which are relevant to surveillance and ground components. A detailed review of all the listed regulations, standards and guidance is provided in the Section 11.3.1 - of this report.

The reviewed regulation and standards include national regulations (e.g. CAPs), international regulations (e.g. EU regulations, EASA AMCs, FAA AMCs and TSOs), international standards and recommendations (e.g. ICAO) and other international standards (e.g., EUROCAE, RTCA).

The aim of this section is to highlight regulations that could provide framework for future EC devices and operations and highlight provisions of international regulations, standards and guidance which might be useful to support implementation of the selected EC solution.

3.2.1.2 - Reviewed regulations, standards and guidance

The following subsections include lists of all reviewed national and international regulations, standards and guidance.

3.2.1.2.1 - National regulations and guidance

- CAP 1391 Electronic conspicuity devices
- CAP 493 Manual of Air Traffic Services (MATS) Part 1
- CAP 670 Air Traffic Services Safety Requirements
- CAP 722 Unmanned Aircraft System Operations in UK Airspace – Guidance
- CAP 722C UAS Airspace Restrictions Guidance and Policy
- CAP 761 Operation of IFF/SSR interrogators in the UK: Planning principles and procedures
- CAP 774 UK Flight Information Services
- CAP 1868 A Unified Approach to the Introduction of UAS Traffic Management
- Ofcom - Frequencies for Emergency services in the UK
- Ofcom - Frequency sharing arrangements between civil and military services
- Ofcom - UK Frequency Allocation Table
- Ofcom – IR 2030 UK Interface Requirements 2030 Licence Exempt Short Range Devices

3.2.1.2.2 - ICAO

- ICAO Annex 10, Vol. III, Aeronautical Telecommunications - Communication Systems
- ICAO Annex 10, Vol. IVAeronautical Telecommunications – Surveillance and Collision Avoidance Systems
- ICAO Annex 11Air Traffic Services
- ICAO Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization
- Doc 9861 Manual on the Universal Access Transceiver (UAT)
- ICAO Doc 4444 PANS Air Traffic Management
- ICAO Doc 9871 Technical Provisions Mode S Services Extended Squitter
- ICAO Doc 9924 Aeronautical Surveillance Manual

3.2.1.2.3 - European Commission, EASA and Eurocontrol

- EU Reg. 262/2009 Requirements for the coordinated allocation and use of Mode S interrogator codes for the single European sky
- EU Reg. 1207/2011 Requirements for the performance and the interoperability of surveillance for the SES
- EU Reg. 2019/945 Regulation on unmanned aircraft systems and on third-country operators of unmanned aircraft systems
- EU Reg. 2019/947 Regulation on the rules and procedures for the operation of unmanned aircraft
- EU Reg. 2018/1139 Regulation on common rules in the field of civil aviation and establishing EASA
- GUID-147 EUROCONTROL Specification for ATM Surveillance System Performance
- CORUS / Eurocontrol - U-space Concept of Operations

3.2.1.2.4 - FAA

- FAA UAS / UTM Concept of operations
- TSO-C154c UAT ADS-B equipment operating on frequency of 978 MHz
- FAA AC 90-114B Automatic Dependent Surveillance-Broadcast Operations

3.2.1.3 - Mapping

Table 4 shows the main regulations, standards and guidance applicable in the UK, Europe, the US, and at international level, grouped by domains.

	UK	European (EU, EASA, EUROCONTROL, EUROCAE)	International (ICAO, RTCA, FAA,
ATS and CNS Service provision	CAP 670 Air Traffic Services Safety Requirements CAP 493 MATS CAP 774 UK Flight Information Services	EU reg. 1207/2011 SPI IR EU Reg. 2018/1139 Regulation on common rules in the field of civil aviation and establishing EASA EUROCONTROL Specification for ATM Surveillance System Performance (ESASSP)	ICAO Annex 11 ATS, ICAO Annex 10 Vol. III and Vol. IV TSO-C154c UAT ADS-B operating on frequency of 978 MHz
Frequency management	Ofcom - Frequencies for Emergency services in the UK Ofcom - Frequency sharing arrangements between civil and military services Ofcom - UK Frequency Allocation Table Ofcom – IR2030		ICAO Annex 10, Vol. V
UTM service provision	CAP 722 Unmanned Aircraft System Operations in UK Airspace CAP1868 A Unified Approach to the Introduction of UAS Traffic Management	EU Reg. 2019/945 Regulation on unmanned aircraft systems EU Reg. 2019/947 Regulation on the rules and procedures for the operation of uUAS EUROCONTROL CORUS UTM CONOPS	ICAO UTM – A Common Framework with Core Boundaries for global Harmonization, FAA UTM Concept of Operations 2.0 C2 networks
Mode-S radars and extended squitter	CAP761 Operation of IFF/SSR Interrogators in the UK	EU reg. EC 262/2009 allocation and use of Mode S interrogator code	ICAO Annex 10 Volume IV, Chapter 6
Multilateration	CAP 670 Air Traffic Services Safety Requirements, SUR06	ED 142 WAM technical specification WAM Guidelines for achieving operational approval of a WAM System	ICAO Annex 10, Volume IV, Chapter 5
ADS-B ground-based broadcast solutions (TIS-B/FIS- B)	CAP 670 Air Traffic Services Safety Requirements, SUR07	EU reg. 1207/2011 SPI IR EUROCAE ED-102A MOPS for 1090 MHz Extended Squitter ADS-B and TIS-B	ICAO Annex 10, Volume IV, Chapter 5 FAA AC 90-114B Automatic Dependent Surveillance-Broadcast Operations
TIS-B		EUROCAE ED-102A MOPS for 1090 MHz Extended Squitter ADS-B and TIS-B	
UAT			ICAO 9861 Manual on the Universal Access Transceiver

Table 4: List of the regulations, standards and guidance related to surveillance and collision avoidance

3.2.1.4 - Summary

This section summarises the review of the existing regulations related to the surveillance ground system, surveillance services and also ground components supporting collision avoidance functions grouping the key requirements under the following categories:

- Surveillance requirements for Air Traffic Control;
- Surveillance for Flight Information Services;
- ADS-B ground- based broadcast solutions (TIS-B/FIS- B); and
- UAT.

3.2.1.4.1 - Surveillance for Air Traffic Control

The main document summarising the requirements on surveillance systems and their components is CAP 670 Air Traffic Services Safety Requirements. Part C, Section 3, of CAP 670 covers safety and engineering. This also specifies the surveillance coverage requirements for surveillance systems according to airspace and Air Traffic Services. The following sections are relevant to the scope of the project:

- SUR 01 defines coverage requirements:
  - All Terminal Control Areas below FL100 are required to **have at least a single layer of coverage by a suitable non-co-operative surveillance technique** and shall also have coverage provided with suitable co-operative surveillance technique/s. The co-operative surveillance provision **shall contain sufficient redundancy** such that the operational requirement for coverage and accuracy to support the Air Traffic Service is met at all times.
  - The surveillance coverage in the en-route environment is required to have **at least a single layer of coverage by a non-cooperative surveillance technique** and coverage also from a suitable co-operative surveillance technique. The co-operative surveillance provision shall contain sufficient redundancy such that the operational requirement for coverage and accuracy to support the Air Traffic Service is met at all times
- SUR 02 provides the generic data and performance requirements for co-operative and non-co-operative surveillance systems used in the provision of air traffic services. It introduces the concept of Required Surveillance Performance (RSP). SUR 02 does not include specific performance requirements but refers to other international standards or recommendations such as EU Reg. 1207/2011 (SPI IR), ICAO Annex 10 or EUROCONTROL ATM Surveillance System Performance Specifications. However, it specifies performance parameters which should be considered when defining the performance requirements for the local surveillance systems (Update period, Accuracy, 2D Resolution, Continuity, Reliability, Availability, Integrity, etc.).
- SUR 03 specifies the general requirements for surveillance data transmission links and systems used for combining surveillance data from multiple sources.
- SUR 07 provides requirements on ADS-B systems considering the following means for download of the ADS-B messages - down linked using Mode S Extended Squitter, Universal Access Transceiver or VHF digital link Mode 4. **It specifically considers the Mode S ES using 1090 MHz**. It also specifies that ADS-B receiver stations shall be capable of receiving ADS-B messages transmitted **via version 2 of the Mode S Extended Squitter message transmission protocol**.
- SUR 11 summarizes requirements on display system requirements for surveillance systems.

Detailed requirements and performance characteristics on surveillance systems are well known and the relevant provisions are provided in the following documents:

- Provisions on Mode A/C conventional SSR systems, Mode S systems, Mode S Extended Squitter systems and on multilateration systems are in ICAO Annex 10 Volume 4 – Surveillance Radar and Collision Avoidance Systems;
- Requirements on Automatic Dependent Surveillance Systems are provided in the ICAO Annex 10 Volume 3;

- EU Reg. 1207/2011 (SPI IR) specifies requirements for the performance and the interoperability of surveillance:
  - Annex II defines ADS-B surveillance data items and their quality indicator data items such as Source Integrity Level (SIL), Navigation Accuracy Category for Position (NACp), System Design Assurance level (SDA), NIC , Geometric Vertical Accuracy (GVA)
  - SPI IR refers to ICAO Annex 10, Volume IV and the ICAO Doc 9871 Technical provision for Mode S Services and Extended Squitter.
- ICAO Doc 9871 Technical provision for Mode S Services and Extended Squitter describes coding of the quality indicator data items with regard to the suitability of the RNAV services (e.g. RNP 1, RNP 0.3, etc.).

The prescriptive surveillance requirements have changed to performance based requirements considering the services to be supported by surveillance and therefore it is up to the service provider to assess the suitability of the surveillance information for the provided services. The guidelines on application of air traffic surveillance and technical performance requirements for surveillance system is provided in the ICAO Doc 9924 Aeronautical Surveillance Manual. Annex 1 of the manual specifies quality parameters and a methodology for assessing the technical performance requirements for the surveillance outputs. **This methodology could be used to assess the suitability of any proposed electronic conspicuity concept**.

In Europe, EUROCONTROL considered the ICAO Doc 9924 methodology and developed the EUROCONTROL Specification for ATM Surveillance System Performance (ESASSP) which provide **detailed performance requirements for 3 NM and 5 NM separation services**. It is intended to be technology independent, but it is acknowledged that it builds on existing separation standards developed using radar technologies. In theory, a State or ANSP could use the document to drive requirements for their surveillance infrastructure.

Within the UK, the surveillance system and surveillance system performance requirements are defined for the ATS environment of manned aircraft in CAP 670 and have been implemented in UK ATS.

However, secondary surveillance services depend on the secondary information available from ICAO Annex 10 compliant transponders working on 1090 MHz and some existing EC devices (e.g. ADS-B low powered transceivers) are not visible to existing surveillance systems as ADS-B based services are used in a very limited part of the airspace. Existing CAP 1391 compliant EC devices work as ADS-B IN/OUT transceivers with a low transmit power which could be detected by the ground ADS-B receivers but only within the limited operational range (up to 40 NM) from the receiver.

The potential surveillance coverage for low powered transponders (considering the potential network of ADS-B receivers) was simulated in 2021 for the purpose of the Future Low Airspace Surveillance Services (LAS). It indicated where the LAS could be extended and where coverage would not be provided and complementary sensors would be needed to extend the service.

For the ADS-B information from EC devices to be used by ATC surveillance services, the quality of the information must meet the minimum performance requirements defined by CAP 670 Subsection SUR 02.

Devices working on frequencies other than 1090 MHz are also invisible to ANSPs as they are not interoperable with the existing surveillance systems. Even though there are solutions which could provide composite situational picture (e.g. ATOM/ GRID of PilotAware, etc.) the information may not be possible or might be difficult to integrate into ATM systems. The main issues with such solutions which create significant barrier to its integration into the ATM surveillance / display systems are:

- Declaration and monitoring of surveillance data quality (e.g. assured performance on data items, system performance parameters, etc.);
- Radio frequency monitoring;
- Use of uncertified frequencies supporting safety critical applications; and
- Integration and certification costs.

For these reasons, the integration of data from non-standardised surveillance sources into the ATM system may not be possible without evidence that the surveillance data would meet the quality or performance requirements defined in CAP 670, Section SUR 02. However, current legislation (EU Reg 373/2017 which was transposed by CAP2026A00) supports the creation of new CNS services and new entrants may consider the option becoming a Surveillance Service Provider if able to meet the regulatory requirements. It is not clear though, if or how this would be possible utilising systems that are not compliant with ICAO Annex 10.

However, existing surveillance standards have not considered the operations of UAS. To allow operational BVLOS in a controlled environment there are generic UK requirements specifying the conditions under which UAS can enter the controlled airspace outlined in CAP 722. Equipment for manned aircraft (e.g. SSR Transponder) mandated in specific airspace would be considered a minimum requirement for UAS intending to operate in the same airspace. Therefore, UAS operated in the controlled airspace can be expected to be equipped with transponders compatible with Mode-S Extended Squitter (ES) using 1090 MHz version 2. This is the ADS-B message transmission protocol required for existing ADS-B receiver stations.

However, UAS operating with ADS-B transceivers (or other EC solutions) may not be visible to ATCOs, because the existing surveillance infrastructure does not utilise ADS-B data (see section 4.5.1 - for more information). The use of an SSR transponder does make the UAS visible to secondary ground surveillance systems and other airspace users but would require the UAS operator to intervene if a potential conflict were detected and the operator must be able to follow ATCO instructions.

Surveillance / ATM standards supporting Detect and Avoid communication between UAS and other aircraft are also either in development or only recently released. See for example, EUROCAE ED-258 OSED for Detect And Avoid (DAA) Traffic in Class D-G airspaces under VFR/IFR and RTCA DO-365A MOPS for DAA Systems UAS. These two industry standards provide a basis for assessing and establishing operational, safety, performance, and interoperability requirements for the [Traffic] (DAA), Remain Well Clear (RWC) and Collision Avoidance (CA) functions in Class D-G Airspaces, for UAS, which is already setting an expectation on EC being available from aircraft in the airspace in which the UAS is operating. RTCA DO-365 MOPS for Detect and Avoid Systems goes beyond ED-258 and considers UAS operating in airspace classes B, C, D, E, and G. It includes equipment to enable UAS operations in Terminal Areas during approach and departure in Class C, D, E and G airspace and off-airport locations. The standard defines requirements on DAA equipment characteristics and equipment performance including ground base surveillance and equipment. The standard has not been developed jointly with EUROCAE so there is no 'twin' ED standard available In Europe.

EUROCAE has also developed ED-275 Vol. I Minimum Operational Performance Standards (MOPS) for Airborne Collision Avoidance System Xu (ACAS Xu) equipment, designed for platforms with a wide range of surveillance technologies and performance characteristics, such as UAS which has to be read together with RTCA DO-365 which assumes that DO-365 principles should be considered. The standard assumes that ACAS Xu compliant equipment will remain compatible with the ATC systems when operating in controlled airspace as the Mode-S transponder is responsible for communication between ACAS equipment to the ground and to the other aircraft in the vicinity of the UAS.

The selected option for the new EC strategy should consider those standards to ensure necessary interoperability between the existing and the future environment.

3.2.1.4.2 - Flight Information Service provision

The UK is changing from the UK FIS to ICAO FIS. Nevertheless, UK FIS can act as a basis for considerations of potential requirements, particularly as ICAO FIS does not have clarity in some areas.

Considering the definitions of the Flight Information Services (FIS) provided in CAP 774 and SERA.9005, surveillance information is not needed to provide a Basic or Procedural service but is needed for Traffic and Deconfliction services. CAP 774 does not provide specific surveillance performance requirements for the provision of Traffic and Deconfliction services but does specify service requirements.

For a Traffic Service, the controller is required to pass information on relevant traffic before the conflicting aircraft is **within 5 NM** to give the pilot sufficient time to meet his collision avoidance responsibilities and to allow for an update in traffic information if considered necessary.

The Deconfliction Service is a surveillance based ATS provided to IFR flights outside controlled airspace where the controller provides specific surveillance-derived traffic information aimed at achieving a planned deconfliction minima. In UK FIS, the deconfliction minima against uncoordinated traffic are:

- 5 NM laterally (subject to surveillance capability and regulatory approval); or
- 3,000 ft vertically and, unless the SSR code indicates that the Mode C data has been verified, the surveillance returns, however presented, should not merge.

The deconfliction minima against aircraft that are being provided with an ATS by the same controller, or that have been subject to co-ordination, are:

- 3 NM laterally (subject to surveillance capability and regulatory approval); or
- 1,000 ft vertically; (2,000 ft within active MDA/MTA above FL410, and above FL290 where both aircraft are not RVSM approved); or
- 500 ft vertically (subject to regulatory approval).

Whilst these requirements would not be applicable under ICAO FIS, it appears unlikely that deconfliction advisory minima would be any higher in the future under ICAO FIS.

These service requirements have not been converted into specific surveillance performance requirements. The main national regulation that summarises requirements on the surveillance systems and their components, which should be considered in the performance requirement specification process, is CAP 670. Part C, Section 3 of that CAP contains safety and engineering requirements for surveillance systems and their constituent elements. It specifies the surveillance coverage requirements for surveillance systems according to the airspace and level of ATS. The following sections are relevant for the provision of FIS:

- SUR 07 outlines general requirements for ADS-B systems including ADS-B based surveillance services. It covers the ADS-B receiver requirements, general system performance requirements (update rate, position accuracy, integrity), ADS-B ground processing system requirements and quality indicators. However, this section does not provide any detailed performance requirements on different ADS-B based surveillance services.
- SUR 08 provides requirements on the use of surveillance data for aerodrome traffic monitoring and requirements for ATM processing and display equipment. It also defined the coverage requirements for the surveillance sensors that provide data for the Aerodrome Traffic Monitor; they shall be capable of detecting all targets within a range of 20 NM from the runway threshold.

Although no surveillance performance requirements have been defined for UK Traffic and Deconfliction services, considering the existing technologies, the surveillance systems used for those services outside of the controlled airspace will heavily depend on the GA and UAS equipment capabilities and performance levels of the electronic conspicuity device and associated GNSS sensors. Due to installation limitations and affordability, a significant part of the airspace users uses GNSS sensors / ADS-B transceivers which are not certified according to the ICAO Annex 10, ED-73E or ED-102 requirements.

To utilise the information from uncertified sensors and systems or those which are only partly compliant with the relevant requirements, the quality and integrity of the information provide by these sensors and systems needs to be known to ensure that the service separation requirements for the applications are met. For this purpose quality indicators defined for ADS-B in ED-102A are used. In 2021 EUROCONTROL issued a CONOPS for GA Surveillance which identifies different operational use cases. It also describes the associated surveillance performance and interoperability levels and discusses surveillance equipage options for different services including VFR Collision Avoidance (CA) and VFR Traffic Awareness (TA) which are intended for GA operations not using surveillance based ATS services.

EUROCONTROL specifically recommends criteria for ADS-B quality indicators that should be met for the particular service. The criteria values are in line with the TABS certification baseline (Table 5).

REQUIREMENT	GA ATS	GA CA	GA TA
Navigation Integrity Category	< 0.6 NM (NIC ≥ 6)	< 1.0 NM (NIC ≥ 5) *	
Source Integrity Level	< 1E-7/hr (SIL≥3)	< 1E-3/hr (SIL≥1) *	
System Design Assurance	< 1E-5 (SDA≥2)	< 1E-3 (SDA≥1)	< 1E-3 (SDA≥1)
Horizontal Position Uncertainty (95%)	< 0.1 NM (NACP ≥ 7)	< 0.5 NM (NACP ≥ 5)	< 0.5 NM (NACP ≥ 5)
Vertical Position Uncertainty (95%)	Pressure Altitude	Pressure or Geo Altitude (GVA ≥ 2 (≤ 45 m))	Pressure or Geo Altitude (GVA ≥ 2 (≤ 45 m))
Horizontal Velocity Uncertainty (95%)	< 10 m/s (NACV ≥ 1)	< 10 m/s (NACV ≥ 1)	< 10 m/s (NACV ≥ 1)

Table 5: Nominal ADS-B quality indicators supporting GA use cases (EUROCONTROL)

The EUROCONTROL requirements have been developed for manned aircraft and may not be suitable for integrated operations of manned aircraft and UAS. For this purpose, RTCA developed and published standard DO-381 MOPS for Ground Based Surveillance Systems (GBSS) for Traffic Surveillance. The standard contains MOPS for the GBSS for Traffic Surveillance systems implemented with UAS transiting and performing extended operations in Class D, E and G airspace, along with transiting Class B and C airspace. It includes equipment to enable UAS operations near terminal areas during approach and departure in Class C, D, E and G airspace and off-airport locations. The provisions in this standard could be considered to support implementation of an EC solution and provision of Traffic and Deconfliction services within and outside the controlled airspace when EC data would be detected and utilised by ground surveillance systems.

3.2.1.4.3 - Additional electronic conspicuity standards

Universal Access Transceiver (UAT)

UAT working on 978 MHz has not been implemented in Europe and therefore there are neither European regulations nor standards dedicated to UAT. Internationally, ICAO Annex 10, Vol. III and ICAO Doc 9861 provide agreed technical specifications for the UAT and establish a common basis for UAT inter-system interoperability across implementations manufactured and certified in different regions of the world.

Chapter 12 of ICAO Annex 10, Vol. III defines the UAT requirements including the system characteristics (airborne and ground installation characteristics and physical layer characteristics). In addition, RTCA developed DO-282 MOPS for Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast which could be utilised for the development of the national regulation if the selected option assume implementation of UAT.

The current ground surveillance infrastructure operated by UK ANSPs does not support UAT technology on 978 MHz. If the selected option assumes implementation of UAT either for aircraft of for UAS, the surveillance service providers will need to complement their existing infrastructure with compatible sensors and components to be able to provided desired service and support the new applications.

There is very limited number of airspace users being equipped with UAT avionics as it is not mandated in Europe so if UAT is introduced as part of the selected solution, relevant stakeholders will need to purchase compliant avionics.

Ground-based Traffic Information Services Broadcast (TIS-B)

Several scenarios mentioned in Section 2.5 - which could support future operations. Currently, there are no national standards which would define requirements on TIS-B systems. However, there are applicable international standards developed and published by ICAO in Annex 10, Vol. IV. Chapter 5 defines requirements on Mode S extended squitter transmitting system characteristics (ADS-B out requirements, TIS-B out requirements) and Mode S extended squitter receiving system characteristics (ADS-B in and TIS-B in requirements).

In addition, EUROCAE ED-102A describes the basis for ADS-B version number 2. The standard contains the MOPS for airborne equipment for ADS-B and TIS-B utilizing 1090MHz Mode-S Extended Squitter (1090ES). It also defines the ground architecture for surface surveillance and provides examples of a ground architecture Traffic Information Service Broadcast (TIS-B). If TIS-B were then to be part of a selected solution, there are existing standards for both, ground and airborne segments, which could be utilised and transposed into the national requirements as appropriate to support future operations.

Currently, no ground infrastructure supporting TIS-B technology on either 1090ES or 978MHz exists in UK. If the selected option assumes implementation of TIS-B according to these standards, the relevant ATS service providers will need to complement their existing infrastructure with compatible ground infrastructure. There is a limited number of airspace users equipped with TIS-B compatible avionics as it has not previously been mandated in Europe. Therefore, should TIS-B be introduced as part of the selected solution there may be implications on the availability of compatible avionics.

3.2.2 - Airborne

3.2.2.1 - General

This section summarises the key regulations that currently apply to airborne equipment. It covers both manned and unmanned operations, at national and international level. The aim of this section is to highlight requirements that may be relevant to a future EC UK standard. A detailed review of all the applicable airborne regulations is provided in Section 11.3.2 - which highlights the most relevant elements.

3.2.2.2 - Reviewed regulations, standards and guidance

The following subsections include lists of all reviewed national and international regulations, standards and guidance.

3.2.2.2.1 - National regulations and guidance

- CAP 1391 Electronic conspicuity devices
- CAP2038A00 Air Navigation Order
- CAP 393 Regulations made under powers in the Civil Aviation Act 1982 and the Air Navigation Order
- CAP 2020A00 Law 2018-1139 Basic Regulation
- CAP 747 Mandatory Requirements for Airworthiness
- CAP 562 Airworthiness Information and Procedures
- CAP 2025A00 Air Operations Regulation (transposition of EU reg. 965/2012)
- CAP 472 BCAR Section R – Radio Issue 4
- CAP 722 Unmanned Aircraft System Operations in UK Airspace
- CAP 722C UAS Airspace Restrictions Guidance and Policy
- CAP 670 Air Traffic Services Safety Requirements
- CAP 1861 Beyond Visual Line of Sight in Non-Segregated Airspace Fundamental Principles & Terminology
- CAP 1861a Detect & Avoid Ecosystem For BVLOS in Non-Segregated Airspace

3.2.2.2.2 - ICAO

- ICAO Annex 8 Airworthiness of Aircraft, ICAO Airworthiness Manual Part V

- ICAO Annex 6 Operation of Aircraft
- PANS OPS Doc 8168 Aircraft Operations – Volume III – Aircraft Operating Procedures
- ICAO Annex 10 Aeronautical Telecommunications – Volume IV – Surveillance and Collision Avoidance Systems
- Doc 9861 Manual on the Universal Access Transceiver (UAT)
- Annex 10 Aeronautical Telecommunications – Volume IV – Surveillance and Collision Avoidance Systems
- ICAO Remotely Piloted Aircraft System (UAS) Concept Of Operations (Conops) for International IFR Operations
- ICAO Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization
- ICAO Model UAS regulations, and associated Advisory circulars (Part 101 and 102)

3.2.2.2.3 - European Commission, EASA and Eurocontrol

- EU reg. 2021/666 Requirements for manned aviation operating in U-space airspace
- EU reg. 1207/2011 Performance and the interoperability of surveillance for the single European sky (SPI IR) + amendments
- EU reg. 262/2009 Requirements for the coordinated allocation and use of Mode S interrogator codes for the single European sky
- EU 965/2012 Annex VII
- EU reg. 2019/945 UAS and third-country operators of UAS
- EU reg. 2019/947 Rules and procedures for the operation of unmanned aircraft
- EU reg. 2019/947 rules and procedures for the operation of unmanned aircraft
- EU reg. 1207/2011 Performance and the interoperability of surveillance for the single European sky (SPI IR) + amendments
- EASA CS-23 Normal, Utility, Aerobatic and Commuter Category Aeroplanes
- EASA CS-25 Large Aeroplanes EASA CS-27 Small Rotorcraft
- EU reg 748/2012 Airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations - Annex I
- CS-ACNS Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance
- CS-STAN Certification Specifications for Standard Changes and Standard Repairs, Issue 3
- CS-ACNS Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance
- CS-STAN Certification Specifications for Standard Changes and Standard Repairs, Issue 3
- AMC 20-24 Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHZ Extended Squitter (May 2008)
- Annex to Decision 2014/029/R - AMC and GM to Part-CAT–Issue 2, Amendment 1 - Transmitting portable, electronic devices (T-PEDs)
- Annex to Decision 2014/030/R AMC and GM to Part-NCC – Amendment 1
- ACID/ELS/02 EUROCONTROL Mode S Elementary Surveillance (ELS) Operations Manual
- EASA ETSO-C199

3.2.2.2.4 - FAA

- AC 25-1302-1 Installed Systems and Equipment for Use by the Flightcrew
- AC 25-11B Electronic Flight Displays
- AC 23.1311-lC Installation of Electronic Display in Part 23 Airplanes

- AC 120-76C Guidelines for the Certification, Airworthiness, and Operational Use of Electronic Flight Bags
- AC 91-50 Importance of Transponder Operation and Altitude Reporting
- AC 20.131A Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders
- AC 20-151C Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II), Versions 7.0 & 7.1 and Associated Mode S Transponders
- AC 20-140C Guidelines for Design Approval of Aircraft Data Link Communication Systems Supporting Air Traffic Services (ATS)
- AC 20-165B Airworthiness Approval of Automatic Dependent Surveillance - Broadcast OUT Systems
- TSO-C199 Traffic Awareness Beacon System (TABS)
- AFS-360_2016-03-02 Installation Approval for ADS-B Out Systems
- AFS-360-2017-1 Installation of ADS-B OUT Equipment
- Docket No. FAA-2019-0539 Statement of Policy on Performance Requirements for Operators of Aircraft That are Equipped With Automatic Dependent Surveillance-Broadcast (ADS-B) Out
- Docket No. FAA-2019-0239 Statement of Policy for Authorizations to Operators of Aircraft That are Not Equipped With Automatic Dependent Surveillance-Broadcast (ADS-B) Out Equipment
- Docket No.: FAA-2017-1194 Change to Automatic Dependent Surveillance Broadcast Services
- Docket No.: FAA-2018-0914 Changes to Surveillance and Broadcast Services
- AC 20-149B Installation Guidance for Domestic Flight Information Service-Broadcast
- AC 20-172B Airworthiness Approval for ADS-B In Systems and Applications
- AC 20-164A Designing and Demonstrating Aircraft Tolerance to Portable Electronic Devices

3.2.2.3 - Mapping

The main regulations applicable at national, European and international level can be grouped by domains as shown in Table 6. Due to the global nature of aviation, there are often strong links between regulations. For example, a large proportion of EASA regulations were adopted into UK law following Brexit. For this reason, requirements that have already been covered are not duplicated.

Regulatory domains	UK	European (EU, EASA, Eurocontrol)	International (ICAO, FAA)
Frameworks	CAP2038A00 Air Navigation Order 2016 CAP 393 Regulations made under powers in the Civil Aviation Act 1982 and the Air Navigation Order 2016		
Aircraft design and certification	CAP2020A00 Law 2018-1139 Basic Regulation CAP 747 Mandatory Requirements for Airworthiness CAP 562 Airworthiness Information and Procedures	EASA CS-23 Normal, Utility, Aerobatic and Commuter Category Aeroplanes EASA CS-25 Large Aeroplanes EASA CS-27 Small Rotorcraft EU reg 748/2012 Airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations - Annex I	ICAO Annex 8 Airworthiness of Aircraft, ICAO Airworthiness Manual Part V AC 25-1302-1 Installed Systems and Equipment for Use by the Flightcrew AC 25-11B Electronic Flight Displays AC 23.1311-IC Installation of Electronic Display in Part 23 Airplanes AC 120-76C Guidelines for the Certification, Airworthiness, and Operational Use of Electronic Flight Bags

Regulatory domains	UK	European (EU, EASA, Eurocontrol)	International (ICAO, FAA)
Aircraft operations	CAP2025A00 Air Operations Regulation (transposition of EU reg. 965/2012) 923-2012 Standardised European Rules of the Air	EU reg. 2021/666 Requirements for manned aviation operating in U-space airspace	Annex 6 Operation of Aircraft PANS OPS Doc 8168 Aircraft Operations – Volume III – Aircraft Operating Procedures Title 14 CFR General Operating and Flight Rules
Mode S transponders	CAP 472 BCAR Section R – Radio Issue 4	EU reg. 1207/2011 Performance and the interoperability of surveillance for the single European sky (SPI IR) + amendments EU reg. 262/2009 Requirements for the coordinated allocation and use of Mode S interrogator codes for the single European sky ACID/ELS/02 EUROCONTROL Mode S Elementary Surveillance (ELS) Operations Manual CS-ACNS Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance CS-STAN Certification Specifications for Standard Changes and Standard Repairs, Issue 3	Annex 10 Aeronautical Telecommunications – Volume IV – Surveillance and Collision Avoidance Systems AC 91-50 Importance of Transponder Operation and Altitude Reporting AC 20-151C Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II), Versions 7.0 & 7.1 and Associated Mode S Transponders AC 20.131A Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders
UAT			Doc 9861 Manual on the Universal Access Transceiver (UAT)
ADS-B OUT transponders	CAP 670 Air Traffic Services Safety Requirements	EU reg. 1207/2011 Performance and the interoperability of surveillance for the single European sky (SPI IR) + amendments CS-ACNS Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance CS-STAN Certification Specifications for Standard Changes and Standard Repairs, Issue 3 AMC 20-24 Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHZ Extended Squitter (May 2008)	Annex 10 Aeronautical Telecommunications – Volume IV – Surveillance and Collision Avoidance Systems AC 20-140C Guidelines for Design Approval of Aircraft Data Link Communication Systems Supporting Air Traffic Services (ATS) AC 20-165B Airworthiness Approval of Automatic Dependent Surveillance - Broadcast OUT Systems AFS-360_2016-03-02 Installation Approval for ADS-B Out Systems AFS-360-2017-1 Installation of ADS-B OUT Equipment Docket No. FAA-2019-0539 Statement of Policy on Performance Requirements for Operators of Aircraft That are Equipped With Automatic

Regulatory domains	UK	European (EU, EASA, Eurocontrol)	International (ICAO, FAA)
			Dependent Surveillance-Broadcast (ADS-B) Out Docket No. FAA-2019-0239 Statement of Policy for Authorizations to Operators of Aircraft That are Not Equipped With Automatic Dependent Surveillance-Broadcast (ADS-B) Out Equipment Docket No.: FAA-2017-1194 Change to Automatic Dependent Surveillance Broadcast Services Docket No.: FAA-2018-0914 Changes to Surveillance and Broadcast Services
ADS-B IN receivers (TIS-B, FIS-B)			AC 20-149B Installation Guidance for Domestic Flight Information Service-Broadcast AC 20-172B Airworthiness Approval for ADS-B In Systems and Applications
EC	CAP 1391 Electronic conspicuity devices	EU 965/2012 Annex VII EASA ETSO-C199	
RPAS/UAS	CAP 722 Unmanned Aircraft System Operations in UK Airspace CAP 722C UAS Airspace Restrictions Guidance and Policy	EU reg. 2019/945 UAS and third-country operators of UAS EU reg. 2019/947 Rules and procedures for the operation of unmanned aircraft	Remotely Piloted Aircraft System (UAS) Concept Of Operations (Conops) for International IFR Operations Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization ICAO Model UAS regulations, and associated Advisory circulars (Part 101 and 102)
BVLOS	CAP 1861 Beyond Visual Line of Sight in Non-Segregated Airspace Fundamental Principles & Terminology CAP 1861a Detect & Avoid Ecosystem For BVLOS in Non-Segregated Airspace	EU reg. 2019/947 rules and procedures for the operation of unmanned aircraft	
Portable Electronic Devices (PED)		Annex to Decision 2014/029/R - AMC and GM to Part-CAT–Issue 2, Amendment 1 - Transmitting portable, electronic devices (T-PEDs) Annex to Decision 2014/030/R AMC and GM to Part-NCC – Amendment 1	AC 20-164A Designing and Demonstrating Aircraft Tolerance to Portable Electronic Devices

Table 6: List of regulations related to airborne surveillance and collision avoidance

3.2.2.4 - Summary

Airspace access based on airborne surveillance equipment capabilities

Airspace access according to the equipment carried onboard an aircraft is a concept already present in the UK regulatory framework. Commission Implementing Regulation (EU) No 923/2012, which was adopted in UK law following Brexit, defines Transponder Mandatory Zones (TMZ) based on the carriage of an SSR transponder. However, these requirements provide some flexibility on the type of devices carried as it allows "*alternative provisions prescribed for that particular airspace by the ANSP*". The Air Navigation Order 2016 (CAP2038A00) also states that "*where required by the notified airspace being flown, aircraft must be equipped with a secondary surveillance radar transponder.*" Presumably, that requirement could be extended to cover EC devices. More generally, CAP2025A00 (Air Operations Regulation 965/2012) stipulates that "*aeroplanes / helicopters shall be equipped with surveillance equipment in accordance with the applicable airspace requirements.*"

At international level, ICAO recognises the same need. Annex 6 (Operation of Aircraft) indicates that "*an aeroplane shall be provided with surveillance equipment which will enable it to operate in accordance with the requirements of air traffic services*", laying the legal basis for airspace access based on EC capabilities.

In the US, Title 14 CFR (General Operating and Flight Rules) states that "*aircraft operating at and above Flight Level 180 must be equipped with 1090ES. Aircraft operating below 18,000 feet mean sea level (MSL) and within U.S. ADS-B-required airspace must be equipped with either 1090ES or UAT equipment*".

Airworthiness of airborne surveillance equipment

Airworthiness requirements are defined in CAP 747 (Mandatory Requirements for Airworthiness). Together with CAP 562 (Civil Aircraft Airworthiness Information and Procedures), these regulations specify requirements on equipment carried onboard aircraft. Some requirements are particularly relevant to EC devices, for example around the charging and usage of batteries, antistatic protection or protection from the Effects of HIRF (High Intensity Radiated Fields) associated with Aircraft Modifications.

Some of the requirements defining the airworthiness of radio equipment might also be relevant to EC devices (e.g. CAP 472 (BCAR Section R – Radio) provides requirements on radio antenna installation).

CAP 1391 identifies portable low power EC devices as T-PEDs. Annex to Decision 2014/029/R AMC and GM to Part-CAT–Issue 2, Amendment 1 - Transmitting portable, electronic devices (T-PEDs) mentions that a controlled Portable Electronic Devices (C-PED) is a PED subject to administrative control by the operator using it. This will include, inter alia, tracking the allocation of the devices to specific aircraft or persons and ensuring that no unauthorised changes are made to the hardware, software or databases. C-PEDs can be assigned to the category of non-intentional transmitters or (T-PEDs). Guidance to follow in case of fire caused by PEDs is provided by the International Civil Aviation Organisation, 'Emergency response guidance for aircraft incidents involving dangerous goods', ICAO Doc 9481-AN/928.

It is worth noting that design aspects need to be considered when developing airborne equipment. For example CAP2025A00 (Air Operations Regulation 965/2012) provides requirements on "*operation and access to instruments and equipment from the station where the flight crew member that needs to use it is seated*". Such factors may need to be taken into account when designing EC devices.

Other considerations regarding the airworthiness of EC devices, include the display of flight information in the cockpit, especially if the equipment is installed on a permanent basis (e.g. electronic flight display).

Certification and approvals

Future EC devices may require to be certified of built to a specified standard subject to standardised conformity testing. This is for example mentioned in CAP 722 regarding UASs: "*In order to be authorised as 'EC compatible' a piece of equipment, device or service will first have to satisfy certain minimum performance, reliability, safety, interoperability and efficiency standards.*"

CAP 562 (Civil Aircraft Airworthiness Information and Procedures) defines the certification requirements to be met before using airborne equipment. Regulation 748/2012 lays down the requirements and administrative procedures to ensure the airworthiness and environmental compatibility of aeronautical products, parts and appliances. Such requirements and procedures specify the conditions to issue, maintain, amend, suspend or revoke the appropriate certificates. This applies to PEDs. The FAA issued a specific advisory circular (AC 20-164A) on Designing and Demonstrating Aircraft Tolerance to Portable Electronic Devices to aid aircraft manufacturers and modifiers who want to design and demonstrate that their aircraft can tolerate passengers and flightcrew using PEDs without adverse electromagnetic interference to aircraft systems.

Annex 8 (Airworthiness of Aircraft) includes broad standards which define the minimum basis for the recognition by States of Certificates of Airworthiness for the purpose of flight of aircraft of other States into and over their territories. This may enable the recognition of electronic conspicuity devices certified by a third country authority.

Electronic Conspicuity consideration for UAS

CAP 722 (Unmanned Aircraft System Operations in UK Airspace) stipulates that "*special equipment (e.g. Secondary Surveillance Radar (SSR) Transponder) mandated for manned aircraft in certain classifications of airspace must also be considered a minimum requirement for UAS intending to fly in the same airspace. BVLOS UAS operations in a non-segregated airspace will not normally be permitted without an acceptable DAA capability.*" This is echoed in ICAO's Remotely Piloted Aircraft System (UAS) Concept Of Operations (CONOPS) for International IFR Operations.

Some exceptions apply, for examples as noted in CAP 722C (UAS Airspace Restrictions Guidance and Policy):

- ICAO issued a letter to States prohibiting the use of 1090ES below 500 feet;
- Requirements of controlled airspace are currently not applied to UAS below 20 Kg and will continue to not apply to UAS being operated within the Open and Specific category, under the UAS Implementing Regulation.

In contrast, EASA issued Regulation No 2021/666 (Requirements for manned aviation operating in U-space airspace) which introduces EC requirements for manned aircraft wanting to access U-Space airspace. From January 2023, to "*allow manned aircraft which are not provided with an air traffic control service to safely operate alongside unmanned aircraft in U-space airspace, it is important that the position of manned aircraft is communicated to U-space service providers. This should be achieved by making manned aircraft electronically conspicuous, effectively signalling their presence by means of surveillance technologies.*" This requirement is not currently replicated into UK law. Additional detail on this topic and possible means of compliance envisaged by EASA can be found in Section 3.4.4 - . It is also noted that the recently published FAA BVLOS Aviation Rulemaking Committee final report places more of an emphasis on the electronic conspicuity solution being carried by manned aviation to support the UAS detect it and proposes changes to the rules of the air to accommodate this.

3.3 - Industrial standards

3.3.1 - Industry standard hierarchy

European harmonization of aviation requirements is based on European regulations, supported by standards that are primarily developed by EUROCAE in the EU. Increasingly with respect to standards adopted by UAS, EASA refers to other standards organisations such as ASTM International.

EUROCAE's focus is on the development of standards for aircraft equipment/system. This scope include any aviation related equipment, system or process aspects. EUROCAE activities cover production of standards for aviation-related ground systems, equipment for both ATM and airports. Therefore, the scope of standardisation activities relates to both airborne, ground, UAS and space systems, covering operational and functional considerations, systems architecture, hardware, software, databases, process and operational aspects.

Many of the EUROCAE standards are issued in the form of Minimum Aviation System Performance Standards (MASPS) and Minimum Operational Performance Standards (MOPS).

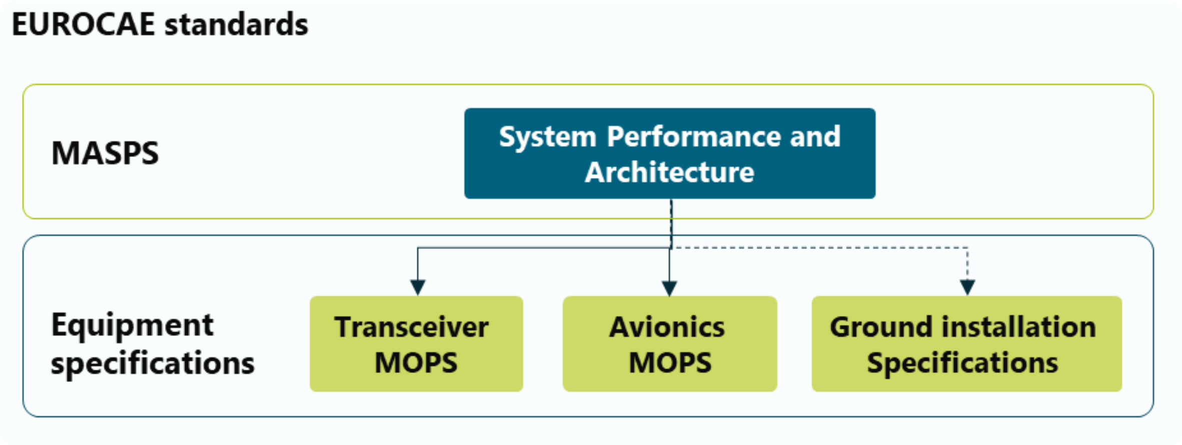


Figure 4: Relationship between MASPS and MOPS

MASPS specify characteristics that are useful to designers, installers, manufacturers, service providers and users of systems intended for operational use within a defined airspace. Where the systems are global in nature, international applications are taken in to consideration and EUROCAE is working with ICAO and other standardisation organisations such as RTCA. MASPS normally describe the system (subsystems / functions) and provide information needed to understand the rationale for system characteristics, operational goals, requirements and typical applications. Definitions and assumptions essential to proper understanding of MASPS are provided as well as minimum system test procedures to verify system performance compliance (e.g., end-to-end performance verification).

Compliance with EUROCAE MASPS is recommended or required (if mandated by regulations) as one means of assuring that the system and each subsystem will perform its intended function(s) satisfactorily under conditions normally encountered in routine aeronautical operations for the environments intended. For instance ED-242B - MASPS for AMS(R)S Data and Voice Communications supporting RCP and RSP.

MOPS provide standards for specific equipment useful to designers, manufacturers, installers and users of the equipment. The word “equipment” used in MOPS includes all components and units necessary for the system to properly perform its intended function(s). MOPS provide the information needed to understand the rationale for equipment characteristics and requirements stated, describe typical equipment applications and operational goals, and establish the basis for required performance under the standard. Definitions and assumptions essential to proper understanding are provided as well as installed equipment tests and operational performance characteristics for equipment installations.

Compliance with EUROCAE MOPS is recommended (if mandated by regulations) as one means of assuring the equipment will perform its intended function(s) satisfactorily under all conditions normally encountered in routine aeronautical operations, for instance, ED-102A Minimum Operational Performance Standards for 1090 MHz Extended Squitter ADS-B and TIS-B. MOPS may be implemented by one or more regulatory documents and/or advisory documents and may be implemented in part or in total.

To achieve the desired global harmonization of aviation standards, EUROCAE cooperates with ICAO, RTCA, EUROCAE, SAE and ARINC to better align international aviation standardization. As a result of the cooperation many Working Groups of those organisations cooperate on development of the standards (approximately 50% of the EUROCAE WGs work jointly with RTCA) and jointly publish the final standards. For example, EUROCAE WG-49 has been cooperating with RTCA on the development and updates of standards for Mode S Transponders. It resulted in the harmonised standards ED-73E / DO-181E. Another example of cooperation is EUROCAE WG-51 with RTCS SC-209 on standardisation of all elements of ground and aircraft infrastructure elements specific to ADS-B.

EUROCAE documents are also produced in the context of the applicable ICAO standards and are coherent with existing ARINC and SAE specifications to ensure global interoperability. The joint development of standards and the subsequent reference of those standards by the CAA, EASA and the FAA as Acceptable Means of Compliance allows for a globally harmonized implementation of specific applications or systems based on the state of the art technology. This includes aircraft, ground systems but also satellites.

3.3.2 - Ground

3.3.2.1 - General

This section summarises the key industry standards applicable to surveillance systems for ATC services, surveillance systems supporting flight information and deconfliction services, ground components supporting airborne collision avoidance systems (e.g. ADS-B and TIS-B) and also standards for CNS/ATM system software integrity and safety assurance.

This section highlights the most relevant provisions from all identified industry standards which could provide framework for future EC devices and operations and highlight provisions of international regulations, standards and guidance which might be useful to support implementation of the selected EC solution. A complete review of the industry standards is included primarily encompassing EUROCAE and RTCA standards is provided in Section 11.3.1 - .

3.3.2.2 - Reviewed standards

The following subsections include lists of all reviewed industry standards.

3.3.2.2.1 - EUROCAE

- ED-129 Technical Specification for a 1090MHz Extended Squitter ADS-B Ground station
- ED 142 WAM technical specification
- ED-109A / RTCA DO-278 Software Integrity Assurance Considerations for Communication and Navigation and Surveillance and Air Traffic Management (CNS/ATM) systems
- ED-153 Guidelines for ANS Software Safety Assurance
- ED 126 Safety, performance and interoperability requirements for ADS-B NRA application
- ED-73E MOPS for SSR Mode S Transponders

3.3.2.2.2 - RTCA

The following applicable RTCA standards have not been developed jointly with EUROCAE standards.

- DO-358A, Minimum Operational Performance Standards (MOPS) for Flight Information Services - Broadcast (FIS-B) with Universal Access Transceiver (UAT)
- DO-303, Safety, Performance and Interoperability Requirements Document for the ADS-B Non-Radar-Airspace (NRA) Application
- DO-286B, Minimum Aviation System Performance Standards (MASPS) for Traffic Information Service – Broadcast (TIS-B)
- DO-381 MOPS for Ground-based Surveillance System (GBSS) for Traffic Surveillance implemented
- DO-282B Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast

3.3.2.3 - Mapping

The table below shows the main regulations applicable in the UK, Europe, the US, and at international level, grouped by domains.

EUROCAE	RTCA	International (ICAO, RTCA, FAA, etc.)

ADS-B and TIS-B	ED-129 Technical Specification for a 1090 Mhz Extended Squitter ADS-B Ground station	
Mode-S radars and extended squitter	ED-73E MOPS for SSR Mode S Transponders	
Multilateration	ED 142 WAM technical specification	
CNS software safety and integrity	ED-109A Software Integrity Assurance Considerations for CNS/ATM systems ED-153 Guidelines for ANS Software Safety Assurance	DO-278 Software Integrity Assurance Considerations for Communication and Navigation
ADS-B ground- based broadcast solutions (TIS-B/FIS- B)	ED 126 Safety, performance and interoperability requirements for ADS-B NRA application	
UAS and UTM		DO-381 MOPS for Ground-based Surveillance System (GBSS) for Traffic Surveillance implemented with UAS
ATS services		DO-358A MOPS for FIS-B with UAT DO-303 Safety, Performance and Interoperability Requirements Document for the ADS-B Non-Radar-Airspace Application DO-286B MASPS for TIS-B

Table 7: List of the regulations, standards and guidance related to surveillance and collision avoidance

3.3.3 - Airborne

3.3.3.1 - General

This section summarises the key industry standards that are applicable to airborne systems and avionics supporting deconfliction services, ground components supporting airborne collision avoidance systems (e.g. ADS-B and TIS-B) and also standards for CNS/ATM system software integrity and safety assurance.

This section highlights the most relevant provisions from all identified industry standards which could provide framework for future EC devices and operations and highlight provisions of the industry standards which might be useful to support implementation of the selected EC solution.

The reviewed industry standards include primarily EUROCAE and RTCA standards and the detailed review output of all the listed industry standards is provided in Section 11.3.2 - .

3.3.3.2 - Reviewed standards

The following subsections include lists of all reviewed industry standards.

3.3.3.2.1 - EUROCAE

The following European industry standards were reviewed[25]:

- ED-102A Minimum Operational Performance Standards for 1090 MHz Extended Squitter ADS-B and TIS-B
- ED-115 MOPS for Light Aviation SSR
- ED-73E MOPS for SSR Mode S Transponders
- ED-12C (Equivalent to RTCA DO-178C) Software Considerations in Airborne Systems and Equipment Certification
- EUROCAE ED-161 / RTCA DO-318 Safety Performance and Interoperability Requirements for ADS-B in Radar Airspace (ADS-B RAD)
- EUROCAE ED-160 / RTCA DO-314 Safety Performance and Interoperability Requirements for ATSAW Visual Separation in Approach (ATSAW VSA)
- EUROCAE ED-164 / DO-319 Safety Performance and Interoperability Requirements for ATSAW during flight operations (ATSAW AIRB).

3.3.3.2.2 - RTCA

The following RTCA standards which have not been developed jointly with EUROCAE standards were reviewed:

- DO-307A Aircraft Design and Certification for Portable Electronic Device (PED) Tolerance
- DO-294C Guidance on Allowing Transmitting Portable Electronic Devices (T-PEDs) on Aircraft
- DO-358A Minimum Operational Performance Standards (MOPS) for Flight Information Services (ACAS X)
- DO-365A MOPS for Detect and Avoid (DAA) Systems UAS
- RTCA DO-282 Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast
- RTCA DO-242 Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS B)
- DO-385 Minimum Operational Performance Standards for Airborne Collision Avoidance System X (ACAS X).

3.3.3.3 - Mapping

Table 8 shows the main regulations applicable in the UK, Europe, the US, and at international level, grouped by domains.

	EUROCAE	RTCA	SAE etc.)
Mode S transponders Extended squitter	ED-102A MOPS for 1090 MHz Extended Squitter ADS-B and TIS-B ED-115 MOPS for Light Aviation SSR ED-73E MOPS for SSR Mode S Transponders		
ADS-B		DO-358A MOPS for FIS-B with Universal Access Transceiver (UAT) DO-242 MASPS for ADS-B	

[25] *At the time of writing ED271 (MASPs for DAA in class A-C airspace) was released for EUROCAE Council approval, and no other EDs from WG105 had yet been approved, except for ED280 (Guidelines for UAS safety analysis for the specific category).*

Airborne collision avoidance system		DO-385 MOPS for Airborne Collision Avoidance System X (ACAS X)
Airborne system and software certification	ED-12C (Equivalent to RTCA DO-178C)Software Considerations in Airborne Systems and Equipment Certification	DO-178C Software Considerations in Airborne Systems and Equipment Certification
UAT		RTCA DO-282 MOPS for UAT Automatic Dependent Surveillance – Broadcast
UAS		DO-365A – MOPS for Detect and Avoid Systems

Table 8: List of the regulations, standards and guidance related to surveillance and collision avoidance

3.4 - Policy evolution

3.4.1 - General

In addition to published standards and regulations, it is helpful to appreciate State-level policy development in the relevant areas of surveillance, electronic conspicuity and integration of new users.

Government policy looks forward, guiding better decisions and enabling more positive outcomes for the benefit of all stakeholders and society in general. Policies help understand the drivers and political decisions which may have an impact on future airspace globally.

Ultimately, this might influence the UK's options as it could be aligned to other States' approach, enabling interoperability, a wider market for appropriate devices and de-risking the development of international legislation, regulation and standards.

This section therefore examines UK policy, ICAO frameworks, and European and United States published strategies.

3.4.2 - UK

The overarching legal framework is set by ICAO under the auspices of the Chicago Convention and through the Standards and Recommended Practices.

Within this framework, the UK Department for Transport then sets overall strategy for airspace design (structure) and management. At a high level, Aviation 2050[26] (consultation in 2019) contributed towards this thinking, noting that airspace modernisation objectives included

- using the minimum volume of controlled airspace and
- aiming for a shared and integrated airspace, facilitating safe and ready access to airspace for all legitimate classes of airspace users, including CAT, GA and the military, and new entrants such as drones and spacecraft.

The Airspace Modernisation Strategy (AMS, CAP2298) was published in January 2022, building on past versions. It sets out a comprehensive vision for UK airspace, as developed by the co-sponsors DfT and UK CAA in consultation with a broad range of stakeholders. It is currently open for consultation.

In addition, in 2018 the Department for Transport published "Taking Flight: The Future of Drones in the UK". This led to legislative changes through the UK Air Traffic Management and Unmanned Aircraft Act 2021 and an update to CAP 722 (UAS Operations in UK Airspace), the latter also covering airspace planning and safety

[26] *HM Government Aviation 2050: Future of UK Aviation*

risk management. The latter specifically notes that an EC-based solution could, if the airspace within which it is used was suitably mandated to be fully cooperative, enable Detect-And-Avoid capabilities to be achieved by UAS in a shorter timeframe.

CAP1861 (Beyond Visual Line of Sight in Non-Segregated Airspace – Fundamental Principles and Terminology) represents the CAA's communication on its thinking with respect to a Detect And Avoid ecosystem, including electronic identification and Conspicuity. The document assumes that an EC device would be capable of transmitting identification, position, speed, heading and altitude.

UK Spectrum policy is covered in more detail in section 5.4 below. The 2015 discussions on permission for PMSE (Programme Making and Special Events) devices to operate (licenced) on the aeronautical radio navigation and aeronautical mobile communication services are relevant to this study. In the OFCOM decision[27], PMSE devices were allowed to operate in the band, but had to limit radiated power to less than 17 dBm, and implement a guard band at 1030MHz and 1090MHz "to protect ADS-B services".

It is worth noting that the 978MHz band (for Universal Access Transceiver) was not explicitly protected under this resolution as it was not foreseen at the time. Consideration was given for the future LDACS technology in the DME band, indicating deference to aviation needs within the band.

However, looking at CAP722, it states that "*the UK is currently exploring the use of 978MHz for UAS to mitigate the risk of spectrum overloading at 1090MHz*".

A final strand of policy relates to GA, with the GA Roadmap (Spring 2021, building on the GA Action Plan) reiterating the strategic priorities of "*increasing access to airspace for all users*" and "*reforming and modernising airspace to ensure an efficient, safe, interoperable and integrated airspace for all users*."

3.4.3 - ICAO

As noted above, the ICAO Standards and Recommended Practices acts as the framework within which UK regulations and policy are set. The detailed references are contained for air and ground standards in the earlier sections.

This section looks at ICAO's future plans, and their influence on the UK decision and approach.

The ICAO Global Air Navigation Plan (Doc 9750) sets a global direction of travel for airspace and ANS, linked also to the Global ATM Operational Concept (Doc 9854).

Specific Aviation System Building Blocks (ASBUs) of interest include:

- ACAS-B2/2 – New collision avoidance capability as part of an overall detect and avoid system for UAS
- ASUR-B2/1 – Evolution of ADS-B and Mode S
- ASUR-B2/2 – New community based surveillance system for airborne aircraft (low and higher airspace)
- ASUR-B4/1 – Further evolution of ADS-B and MLAT
- CSEP-B2/2 – Cooperative separation at low altitudes
- CSEP-B3/2 – Remain Well Clear (RWC) functionality for UAS/UAS

These building blocks extend over multiple phases (builds), with implementation out to 2040. The GANP includes the need to integrate low-altitude UAS/UAS, and the identification of new capabilities in collision avoidance technology. ICAO does not prescribe technical solutions.

ICAO has published the document Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization. This document recognises that policies, rules and priorities required to support equitable access to airspace must be developed. It also highlights the need for commonality for positional references for manned and unmanned operations, such as common altitude, navigation and temporal references. Requirements for operations in controlled airspace are provided in AC 922-001 (section 6.1 Operations in controlled airspace). A key recognised challenge is the separation of aircraft

[27] *New Spectrum for Audio PMSE, OFCOM Statement, March 2016*

participating in the UTM system, with particular reference to methodologies to allow improved or enhanced detectability and conspicuity of UA by manned aviation.

Doc 9861 Manual on the Universal Access Transceiver provides some thoughts on potential future applications of UAT (see Table 9). Although specific to UAT, it might be interesting to assess whether similar applications could be at least partly supported by a UK enhanced EC standard.

Table 9: Summary of potential future applications of UAT

Potential future UAT service	*UAT transmitting subsystem requirements*	*UAT receiving subsystem requirements*	*Primary application*	*Limitations*
Range validation	Navigation input, UTC-coupled	Navigation input, UTC-coupled	Integrity check of ADS-B	Total timing errors limit range accuracy to ~ 0.7 NM (see Appendix J)
Backup air-to-ground surveillance	None	UTC-coupled	Surveillance backup for GNSS	Service available only in areas of significant ground station infrastructure
Backup navigation	UTC-coupled (stable source can operate without GNSS for hours)	None	Navigation backup for GNSS	Service available only in areas of significant ground station infrastructure

3.4.4 - European developments

EC is seen as key enabler to prevent mid-air collisions by EASA. The European Plan for Aviation Safety (EPAS) 2022-2026[28] highlights several actions in that area, as summarised in Table hereafter.

Table 10: iConspicuity actions defined in EASA's EPAS 2022-2026

Action	Description	Timescales
SPT .0119 Promoting iConspicuity	Facilitate installation of iConspicuity devices in all aircraft holding an EASA TC and promote their use by airspace users at an affordable cost for them. Support initiatives enhancing interoperability of iConspicuity devices/systems.	Promotional material: 2020-2023
RES.0031 Interoperability of different iConspicuity devices/systems	EASA, with the support of technical partners, should demonstrate and validate the feasibility of achieving interoperability of different iConspicuity devices/systems through network of stations while respecting data privacy requirements.	Starting date: 2021 Q1 Interim report: 2021 Q4 Final report:2023 Q3
RES.0032 Use of iConspicuity devices/systems in flight information services	EASA will investigate the use of iConspicuity devices/systems in ATM FIS, considering 'Net Safety Benefit' and 'Operational Safety Assessment' principles for the assessment of implementation issues.	Starting date: 2021 Q4 Interim Report: 2022 Q1 Final Report: 2022 Q2

[28] *EPAS 2022-2026 Volume II* - https://www.easa.europa.eu/downloads/134919/en

This translates into EASA's strategy for regulatory developments. The Agency is adopting a two-step high level roadmap[29]:

- Step 1, to specifically address manned aircraft operating in airspace designated as U-space airspace and mitigate the risk of mid-air collisions. Here the aim is to create an air to ground link to make manned aircraft electronically conspicuous to USSPs and UAS operators;
- Secondly, to expand this concept to address the GA conspicuity issue generally, including the possibility to use the information broadcasted by GA traffic for FIS. iConspicuity then becomes a much broader concept, with the capability to be visible but also receive information (on other aircraft, weather, airspace), enabled by an air to air link.

This first step is already enacted through Regulation (EU) 2021/666 amending Regulation (EU) No 923/2012, by requirement in SERA.6005(c) (entering into force in January 2023). In case manned aircraft are not provided with an air traffic control service, pilots shall make themselves continuously electronically conspicuous to the USSPs. It should be noted that this requirement does not apply to Military and State aircraft.

EASA is developing AMC and GM for this requirement, as described in NPA 2021-14[30]. The central part of this proposal is the introduction of a minimum position information message standard for the transmissions by manned aircraft. Additionally, the proposal describes new EASA technical specification standardising these transmissions on the SRD860 frequency band. This to ensure a mutual interoperability among the various systems using that spectrum today but often transmitting in different incompatible protocols. Some devices will need to be adapted to comply with the EASA new technical specification to fulfil the objective of SERA.6005(c).

This new minimum position information standard is referred by EASA as "ADS-B Light" or "ADS-L". It was derived from the ADS-B Out international standard to ensure mutual interoperability between the two. ADS-L will cover the "Message generation" function only (not the message exchange function – transmission), as shown in the figure below.

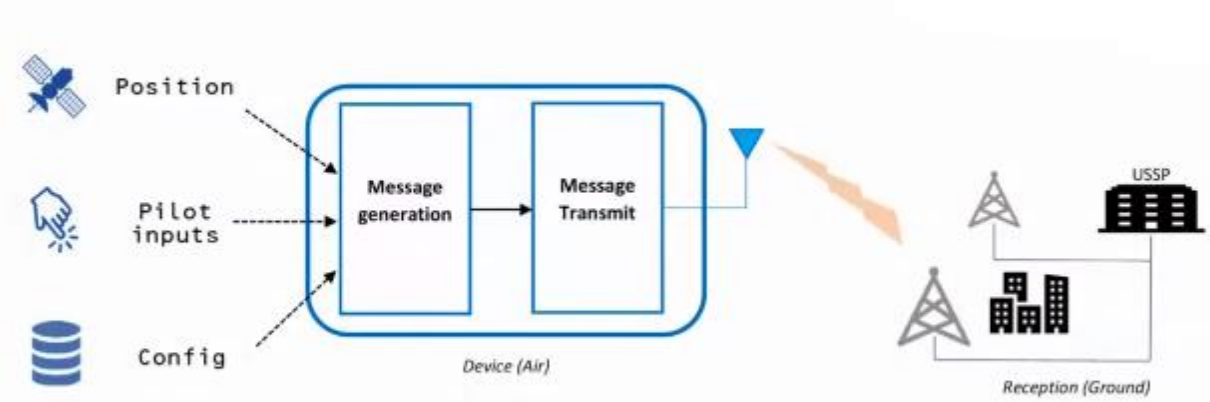


Figure 5: ADS-L concept

The minimum transmission parameters foreseen for ADS-L are given in Table 11:

Mandatory	Optional
- Aircraft address, address type (eg ICAO 24-bit) - Timestamp	- Emergency status - Velocity accuracy - Design assurance

[29] *iConspicuity for GA & Rotorcraft in U-space and beyond* - https://www.easa.europa.eu/newsroom-and-events/events/iconspicuity-ga-rotorcraft-u-space-and-beyond#group-event-materials

[30] *NPA 2021-14 Development of acceptable means of compliance and guidance material to support the U-space regulation (December 2021)* - https://www.easa.europa.eu/document-library/notices-of-proposed-amendment/npa-2021-14

- Aircraft category - Position, altitude - Velocities, track - Position accuracy - Version	- Integrity parameters

Table 11: Foreseen ADS-L transmission parameters

In addition, the message characteristics are expected to include:

- Minimum transmission rate of 1Hz for position (0.1Hz for other parameters);
- At least one error detection technique (eg CRC);
- Primary use if GNSS as based position source.

The "Message Transmit" function for using SRD-860 will be described in a technical paper. This paper, developed in cooperation with the industry, was being drafted at the time of writing.

The NPA introduces three alternative means for transmissions of minimum position information by operators of manned aircraft. These are expected to be acceptable means of compliance to SERA.6005(c):

1. **Certified ADS-B out systems compliant with ICAO Annex 10**: This option covers ADS-B out certified solutions transmitting on 1090 MHz frequency. It does not cover other internationally standardised solutions that are not yet implemented and deployed for that purpose in all EU (e.g. UAT). This option utilises the previous investments made by airspace users in response to pan-European 1090 MHz ADS-B mandate and other users using this technology on a voluntarily basis. Among the three alternatives this one is considered the most expensive for the aircraft currently not equipped with any of the proposed systems. This option could cover also other internationally standardised solutions (e.g. UAT) if implemented and deployed for that purpose in all the EU.
2. **Systems transmitting on SRD 860 frequency band (ISM)**: This option covers the existing systems transmitting on SRD 860 frequency if voluntarily adapted to comply with the new minimum position information standard as well as with the referenced EASA technical specification defining the required transmission protocol to ensure message readability by USSPs. This option utilises the previous investments of 50.000+ airspace users of existing systems originally developed for similar purposes but for specific user groups. These solutions will need to be adapted to the new technical specification for minimum position information. The cost of the adaptation for aircraft operators is expected to be minimal. These EC devices are expected to be either installed in an aircraft with an installation approved by the competent authority or carried on board the aircraft as a non-installed equipment
3. **Systems transmitting via standardised mobile telecommunication network services coordinated for aerial use in Europe**: This option covers the use of mobile telephony devices utilising the existing application-based mobile telephony services and transmitting position information via (free) applications adapted to the new minimum position information standard. The aerial use of mobile telephony is an affordable alternative for airspace users who prefer to use the existing mobile telephony devices and application-based mobile telephony technology services. The feasibility of this option was confirmed by the feasibility study[31] commissioned by EASA for this purpose. The existing, usually free, applications would need to be adapted, and new applications may be developed to transmit information required by the new minimum position information message standard to make their users conspicuous to USSPs.

The overall principle introduced by the proposal is that any USSP will need to support all specified means of transmissions by operators of manned aircraft. It is expected that USSPs will utilise as much as possible the existing infrastructure (e.g. ANSP surveillance systems, mobile telecommunication networks) and install a new but affordable infrastructure only when necessary, e.g. for reception of signals in SRD 860 frequency band.

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[31] *EASA Feasibility Study about the possibility of using mobile telecommunication technologies for making manned aircraft electronically conspicuous in U-space, September 2021 -* https://www.easa.europa.eu/downloads/134939/en

EASA has also highlighted guiding principles in this first step. For manned aircraft, these include:

- Affordability (to end users)
- Technology available no (aviation & other)
- Single device policy
- Simple installations
- Enables airborne collision risk mitigation for manned aircraft (in general)

Feasibility Study about the possibility of using mobile telecommunication technologies for making manned aircraft electronically conspicuous in U-space

The feasibility study on mobile telephony commissioned by EASA concludes that "*from a technological point of view, mobile telecommunication technology could generally be used as solution to make manned aircraft electronically conspicuous in U-space, especially, if not considered to be a "safety of life" application*". However, the study highlights that the use of mobile telecommunication technology cannot be recommended at this stage. The key issues preventing that are seen to be:

- Interferences through unpredictable data upload, where other apps or functions might run in the background of a mobile phone and lead to an unpredictably higher consumption of bandwidth. This could be averted by Authorities mandating the shutdown of other background app while using the tracking devices;
- Lagging roaming agreements, as currently roaming agreements for aerial services are not defied (expected to be agreed in 2022/23). This could create legal issues between telecommunication providers;
- Frequency restrictions, where country specific restrictions limit the use of certain frequencies below 1 GHz for aeronautical services. The Electronic Communication Committee (ECC) aims for a European decision by November 2022. The study recommends EASA to approach the ECC board directly and share the idea of making manned aircraft electronically conspicuous with mobile telephony technology.

Finally the study recommends a fallback option in case this last issue cannot be solved: "*an affordable (<€150) dedicated mobile tracking devices with the capability to switch off the critical frequencies. [...] Both, tracking modules and smartphone apps need to be "certified/aligned" with the USSP in order to make the device "talking" to the UTM for the operating aircraft in the respective U-space.*"

Despite EASA's recognition of mobile telephony as a suitable AMC, significant questions remain regarding the ability of such networks to adequately support EC:

- As highlighted in EASA's study, "referring to the existing network monetization the potential additional aircraft users would probably not be a business case for Telcos to heavily invest into the third dimension of their network now". This is likely to result in a de-prioritisation of EC needs in favour of other applications, unless mandated by Authorities.
- Questions remain on the capability of such networks to meet the certification or safety requirements of manned aviation, especially if it is to support safety of life applications.
- Some concerns have been reported on the impact of 5G on certain aircraft system. This seems to be predominantly an issue in the US where the frequency bands used for 5G is closer to the spectrum used for radio altimeters[32]. Although "EASA has not been able to determine the presence of an unsafe condition"[33], it nevertheless issued a SIB on this topic[34].

Initial views on NPA 2021-14

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[32] *Europe rolled out 5G without hurting aviation. Here's how, CNN, January 2022 -* https://edition.cnn.com/2022/01/19/business/5g-aviation-safety-europe/index.html

[33] *EASA Position on FAA AD 2021-23-12, December 2021 -* https://ad.easa.europa.eu/blob/EASA_Position_on_FAA_AD_2021-23-12.pdf/AD_US-2021-23-12_1

[34] *EASA SIB 2021-16 – Operations to aerodromes located in United States with potential risk of interference from 5G ground stations (as published through aerodrome NOTAMs), December 2021*

EASA's iConspicuity regulatory developments are first and foremost aimed at supporting the proliferation of UAS operations. This might explain its narrower focus, and shorter timescales, compared to the AMS. It aims to compel manned aircraft wishing to enter into segregated U-Space managed by USSPs to carry suitable equipment. This places the emphasis on USSPs to deconflict UAS operators from manned aircraft. This practical solution applies the short term; EASA's longer term iConspicuity strategy, referred above as Step 2, appears more aligned to the DfT/CAA position of integrated operations.

EASA's argument is based on a number of points:

- UAS operations are expected to grow significantly in the short term. However, current DAA capabilities are not effective enough in uncontrolled airspace according to EASA; it would therefore not be economically feasible to prevent UASs from flying until DAA capability is available.
- The growth of UAS operations should be supported by some regulatory baseline, even if light, to provide a degree of coordination and prevent the proliferation of disparate U-Space airspace implementations. This is the reason why EASA's U-Space regulation is entering into force in January 2023.
- EASA expects the uptake of U-Space airspace to be fairly limited and localised, hence the iConspicuity requirement have been placed on manned aircraft wishing to operate in such areas. EASA noted, in these circumstances, it would be more challenging to ask all UAS operators to equip instead.

Importantly, EASA does not see ADS-L supporting safety critical applications. This explains the absence of integrity requirements, and the use of GNSS as a position source. EASA sees ADS-L as an enabler for traffic awareness, with wider safety buffers to be applied by UAS operators when in the vicinity of manned aircraft.

EASA's NPA was open for comment at the time of writing (closing date 15th March 2022, with a ED Decision expected in early Q3/2022). As a result, changes may be introduced in the final AMC and GM to be released in the future. Some of the key concerns raised by stakeholders at the time of writing were:

Use of low power ADS-B:

- EASA excluded low power ADS-B as a MoC for SERA.0005(c) on the ground that ICAO currently does not recognise it. EASA is aware a technical paper has recently being produced on this.
- It would also take a significant amount of time for the new standard to be developed and recognised.
- Other concerns include spectrum overload in some parts of Europe.

Use of UAT

- EASA recognises UAT as an MoC.
- However, EASA sees discrepancies in UAT frequencies allocation across Europe as the main hurdle for its deployment. This would take a significant amount of time, most probably too late for adequately supporting the implementation of U-Space. This coordination process is also outside of EASA's control.
- Need for significant ground infrastructure installation to support UAT roll out.

Financing for new equipage

- No financing options were planned at the time of writing, although EASA noted that this topic had been brought to the European Commission for consideration.

Future research from EASA

EASA is expected to launch a call for tender to perform some research on iConspicuity solutions in Q1 2022. The objectives of that initiative will be to review deployment, needs and lessons-learnt, identify an harmonised interoperability framework for iConspicuity solutions, and build implementation scenarios. This work will be consulted with EASA's stakeholders through 3 workshops. The project is expected to run from June 2022 to November 2023.

3.4.5 - FAA

The FAA deployed a nationwide implementation program to support the adoption of ADS-B and UAT in controlled airspace (see Figure 6 for details). Aircraft operating at and above Flight Level 180 must be equipped with 1090ES. Aircraft operating below 18,000 feet mean sea level (MSL) and within U.S. ADS-B-required airspace must be equipped with either 1090ES or UAT equipment. The FAA recommends a WAAS GPS that is compliant with the latest version of TSO-C145 or TSO-C146. These requirements have entered into force in January 2020.

Figure 6: ADS-B equipage rules in the US[35]

Additionally, the FAA developed TSO-C199 for Traffic Awareness Beacon System (TABS). These are lower cost surveillance solutions, designed for aircraft excepted from above requirements (such as balloons and aircraft without electrical systems). This allows the use of commercial grade GNSS, that pass defined screening tests. Requiring SDA=1 and SIL =1, based on using SBAS integrity. TABS allows such aircraft to be visible to other aircraft equipped with collision avoidance systems such as TCAS or ADS-B IN.

On 10 March 2022, the Aviation Rulemaking Committee published their final report on UAS BVLOS[36]. This makes recommendations to the FAA on how to integrate BVLOS UAS into the US airspace. The report covers all aspects of BVLOS UAS integration from defining an acceptable level of risk, through operating rules and assessment of risk associated with automated flight and future considerations. At over 380 pages it is not practical to summarise here, however the key recommendations pertinent to this study are:

- Risk set at the level of GA performance for MAC and third-party ground risk.
- The rulemaking targeted is on minimum capability, not minimum equipment, although it remains to be seen how this will be established, tested and assured. This infers no requirement of conspicuity on the part of the UAS.
- Manned aircraft who are using ADS-B (UAT or 1090) or TABS are given right of way, while UAS have right of way over unequipped manned aircraft[37].

3.5 - Conclusions of regulatory and standards review

This section has highlighted a plethora of surveillance related regulations, standards and guidance. The current focus of most updates to existing and developing standards is to accommodate the new airspace users. There

[35] https://www.faa.gov/nextgen/equipadsb/

[36] https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/UAS_BVLOS_ARC_FINAL_REPORT_03102022.pdf

[37] *As there are no specific equipage requirements for UAS, it is noted that such unequipped manned aircraft (who could still have situational awareness displays) would detect the UAS to cede right of way to it.*

is significant effort being spent globally on BVLOS UAS but the specific standards and regulations applicable are either only just emerging or are still being debated in the various working groups or sub-committees of the standardisation organisations. Today the UK framework allows for BVLOS operations subject to a suitable risk assessment, but as yet there are no standards for equipment providing a DAA capability.

There is broad consensus on the need for UAS to avoid manned aircraft, but there are a variety of ways in in which this is proposed to be achieved. The effective proposal within Europe for the establishment of U-Space creates a form of flight segregation whilst the recent proposals from the FAA show a marked change potentially affecting the rules of the air with an emphasis on the manned aircraft without electronic conspicuity giving way to UAS. This places a firm requirement on the manned aircraft to have electronic conspicuity or be prepared to see and avoid against an UAS. This is also simpler with a single frequency solution proposed.

As noted by IFATCA "*International regulations and requirements on how to implement and operate FIS are limited. For AFIS, there are recent initiatives from both ICAO and EASA to harmonise the procedural framework. IFATCA encourages these developments and recognises the need to do the same for dedicated Enroute FIS, as this service becomes more and more common and mature among Member States. In addition, IFATCA recognises the need for guidance material at a global level to be made available by regulators on requirements, procedures, training and licensing for dedicated Flight Information Service*"[38].

From an electronic conspicuity perspective, more work will be needed to integrate an specific requirements for non-standardised solutions and currently, there is no precedent set for the delivery of an ATS service based on data from non-standardised and uncertified equipment. There is however, precedent, although limited, for allowing other devices to operate on aviation protected spectrum (PMSE) providing suitable assurances can be made.

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[38] http://wiki.ifatca.org/kb/wp-2019-156/

4 - EQUIPMENT AVAILABILITY AND UPTAKE

4.1 - General

This section provides a summary of the current state of availability and adoption of EC technologies within aviation. The key capabilities of each technology are also captured here, together with the ability to deliver the applications summarised below (with enhanced EC applications highlighted in bold):

- Surveillance for ATS separation;
- **ICAO Flight Information Services using surveillance (Class G or Class E)**;
- **Crossing service (e.g. Danger Area, ATZ)**;
- **Supporting drone detect-and-avoid**;
- **Supporting on-board deconfliction and collision avoidance systems (Hybrid ACAS / ACAS X)**;
- Aid to situational awareness (including airspace awareness);
- Additional services (such as METAR).

This section also includes a summary of the adoption of different EC technology across the UK fleet, with a focus on today's situation, but forecasted evolution is also captured. The section is organised as follows:

- 4.2 provides an overview of the EC technology solutions available today.
- 4.3 provides details of airborne EC technologies. Examples are provided and not intended to be an exhaustive list.
- 4.4 provides a details of ground-based technologies that support either detection, or re-broadcast of EC data.
- 4.5 presents a synthesis of data available on the adoption of EC technologies both in terms of ground-based infrastructure and airborne equipage. It visualises the capability of existing surveillance coverage and what could be achieved with EC. Finally, it provides a brief exploration and summary of forecasts and plans.

4.2 - Technology solutions

The UK presently hosts a relatively unique mix of EC technologies in operation. This includes technology built against international standards (as implemented through UK regulation), those built against UK specific specifications (such as CAP1391), and proprietary systems. The technologies are in use elsewhere, including our bordering countries in Europe and partially in the USA, but with variations in either adoption rates or applicable performance (e.g. SIL in the case of devices like SkyEcho).

The table below provides a summary of the technologies, and captures their key parameters, as relevant to this study.

TECHNOLOGY	DESCRIPTION	FREQUENCY	CERTIFIED?	APPLICATIONS	GROUND ELEMENTS
ADS-B: 1090ES	ADS-B provides a broadcast of the aircraft's location information based on on-board systems (primarily GPS).	1090MHz (protected spectrum)	Yes	Separation, ICAO FIS, Crossing service, DAA, ACAS+	Numerous WAM systems with ADS-B reception. TIS-B and rebroadcast options, not yet implemented. Typically receiver included in new SSRs.
ADS-B: UAT	As ADS-B: 1090ES, but operates using UAT protocol	978MHz	Yes	Separation, ICAO FIS, Crossing service, DAA, ACAS+, data services	Can be added to future procurements with limited incremental costs. TIS-B and ADS-R would support integration
CAP1391	Devices under CAP1391 (eg SkyEcho) include ADS-B 1090ES, but without defined integrity, meaning they are ignored by safety applications.	1090MHz	No, declarative process applied	Aid to situational awareness	Received
FLARM	FLARM is a low-cost EC device that utilises consumer grade electronics to provide Air to Air situational awareness. A variant, PowerFLARM includes ADS-B IN.	868MHz 1090MHz (in only for PowerFLARM)	No, STC to fit on certified aircraft	Aid to situational awareness	Open Glider Network, also detected by PlaneFinder and PilotAware ATOM Grid.
PILOTAWARE	Intended to provide interoperable EC, combined with additional services such as METAR from ground infrastructure. Intended to be integrated with EFB/cockpit displays or mobile devices to provide situational awareness	869.5MHz 1090MHz (in only)	No	Aid to situational awareness, additional services.	PilotAware ATOM Grid, coverage extended by airborne rebroadcast, includes MLAT function for Mode-S only transponders
TRAFFIC AWARENESS BEACON SYSTEMS	TABS are voluntarily equipped ADS-B out devices designed to make equipped aircraft visible to other aircraft equipped with ACAS or ADS-B IN.	1090MHz	Yes (SIL=1 in US, but not in UK)	ICAO FIS, Crossing service, DAA, ACAS+	As with ADS-B

Table 12: Overview of EC technologies

4.3 - Airborne

4.3.1 - ADS-B

4.3.1.1 - 1090MHz Extended Squitter

Technology name:	Function	Operating frequency(s)
ADS-B	ADS-B provides a broadcast of the aircraft's location information based on on-board systems (primarily GPS).	1090MHz (bidirectional)
Certified?	**Open standards/proprietary**	Downlink [✓] Uplink [✓]
Yes	Open	
Typical Range	**Relevant standards[39]**	**Cost**
170-200NM	RTCA DO-260B EUROCAE ED-102B Change 1	£3-5,000 inc installation
Notes		
Channel congestion is a concern. Explicitly a surveillance technology.		

4.3.1.2 - 978MHz UAT

Technology name:	Function	Operating frequency(s)
ADS-B	ADS-B provides a broadcast of the aircraft's location information based on on-board systems (primarily GPS).	978MHz (bidirectional)
Certified?	**Open standards/proprietary**	Downlink [✓] Uplink [✓]
Yes	Open	
Typical Range	**Relevant standards**	**Cost**
10-120NM	Title 14 CFR (General Operating and Flight Rules Manual on the Universal Access Transceiver (UAT)	£550 + installation
Notes		
Extensively used within US (largest GA market in the world) for aircraft operating below FL180. Include the capability to receive ground to air rebroadcast services providing traffic information (TIS-B) and fight information (FIS-B) based on internationally recognised standards, protocols and practices.		

[39] *Aviation standards*

4.3.2 - CAP 1391

Technology name:	**Function**	**Operating frequency(s)**
SkyEcho	SkyEcho is a relatively low-cost EC device that blends certified GPS with a small form factor which connects to other devices (EFB) to provide the full application.	1090MHz (bidirectional) 978MHz (UAT) 868 (in only, FLARM)
Certified?	**Open standards/proprietary**	Downlink [✓] Uplink [✓]
GPS SIL=1 (in US) SIL = 0 in UK – this is reliance on SBAS	Open	
Typical Range	**Relevant standards**	**Cost**
20W (40NM)	CAP 1391[40] TSO-C199 GPS	£500
Notes		
Also receives FLARM data		

Technology name:	**Function**	**Operating frequency(s)**
ping1090i	ping1090i is a small ADS-B transceiver designed for small UAS.	1090MHz (bidirectional) 978MHz (UAT)
Certified?	**Open standards/proprietary**	Downlink [✓] Uplink [✓]
SIL=0 (within the UK)	Open	
Typical Range	**Relevant standards**	**Cost**
20W (40NM)	CAP 1391[40] TSO-C199 GPS	$2000
Notes		
Can be integrated with standard UAS Autopilots – this would combine the navigation and surveillance solution to a single source, which may have implications for BVLOS use cases.		

4.3.3 - FLARM

Technology name:	**Function**	**Operating frequency(s)**
FLARM	FLARM is a low-cost EC device that utilises consumer grade electronics to provide Air to Air situational awareness.	868MHz (bidirectional)
Certified?	**Open standards/proprietary**	Downlink [✓] Uplink [✓]
No	Proprietary (encrypted)	
Typical Range	**Relevant standards**	**Cost**

[40] *CAP 1391 is not technically a standards, but a specification which links to acceptable standards*

25mW (claimed 100Km) (limited by IR2030/1/14)	EASA minor change approval 10055051 (to install FLARM on a certified aircraft)	£300+ for basic FLARM £1600+ for PowerFLARM
Notes		
Most popular with glider communities PowerFLARM version available which includes ADS-B in. Variations available designed for UAS, including light UASs.		

4.3.4 - PilotAware

Technology name:	**Function**	**Operating frequency(s)**
PilotAware Rosetta	Intended to provide interoperable EC, combined with additional services such as METAR from ground infrastructure. Intended to be integrated with EFB/cockpit displays or mobile devices to provide situational awareness	869.5MHz (bidirectional) 1090MHz (up)
Certified?	**Open standards/proprietary**	Downlink [✓] Uplink [✓]
No	Proprietary	
Typical Range	**Relevant standards**	**Cost**
Not specified (IR2030/1/19 limits to 500mW e.r.p.)	None	£380-1500 + £24 annual subscription
Notes		
Substantial part of service provided via ground network (see 4.4.5 - Receives ADS-B, Mode-S/C directly. Receives FLARM via ground infrastructure. Includes relay capability to extend effective coverage via airborne assets.		

4.3.5 - Traffic Awareness Beacon Systems

Technology name:	**Function**	**Operating frequency(s)**
TABS	TABS are voluntarily equipped ADS-B out devices designed to make equipped aircraft visible to other aircraft equipped with ACAS or ADS-B IN.	1090MHz (bidirectional)
Certified?	**Open standards/proprietary**	Downlink [✓] Uplink [✓]
SIL = 1, NACp=9, NACv=1, NIC=6, SDA=1	Open	
Typical Range	**Relevant standards**	**Cost**

70W peak power (claimed 100Km)	TSO/ETSO-C199	$500
Notes		
Similarities to CAP 1391, aimed to provide a low-cost solution EC. For aircraft VR below FL290, <5700kg, <250kts. Allows commercial grade GNSS as long as it passes screening tests and must use SBAS. Example: TRIG TN72		

4.4 - Ground

4.4.1 - ADS-B

ADS-B provides certified position reports, according to RTCA DO-260B (EUROCAE ED-102A), capable of supporting the provision of separation services by ANSPs and, in some cases, granting access to airspace. It is also closely linked with the airborne collision avoidance safety net, TCAS.

ADS-B: ADS-B systems depend on the aircraft having a high-integrity navigation source (typically GNSS) and a broadcast capability (currently 1090MHz or UAT). An aircraft equipped with an ADS-B system automatically broadcasts its identification, location, altitude, speed and other parameters. These broadcasts are then received by a network of ground stations (or spaceborne receivers) and other ADS-B equipped aircraft, the broadcasting aircraft has no knowledge of who receives the data and there is no two-way contact. ADS-B is still fundamentally limited at present, in that only aircraft over 5700Kg are mandated to equip. ADS-B is a well proven system with thousands of aircraft equipped and ground stations installed world-wide.

ADS-B provides 'IN' and 'OUT' functions. The 'Out' function broadcasts the location of the aircraft to other parties, the 'IN' function receives other ADS-B transmissions and TIS-B (see below), which may be used by on-board multi-function displays or electronic flight bags, typically for situational awareness.

Many SSR include ADS-B receivers as part of their overall solution (including for the tracking of aircraft within the radar cone of silence to speed reacquisition), but this data is typically only used internally within the radar.

ADS-C: As with ADS-B, ADS-C systems depend on the aircraft having a high-integrity navigation source (typically GNSS) and a data link capability. Unlike ADS-B, however, ADS-C systems do not broadcast information, instead they communicate directly with the ATC centre via a VHF data link or communications satellite. The ATC centre sets up a 'contract' with the ADS-C equipment stipulating the information required and at what periodicity.

An example low-cost ground station would be uAvionix pingStation3, which receives both 978MHz and 1090MHz ADS-B transmissions and costs $2,250. uAvionix claim a network of such stations can perform MLAT (see below) with the use of additional software.

4.4.2 - MLAT

Multi-lateration Systems: Multi-lateration systems (MLAT) utilise a Time Difference of Arrival (TDOA) approach, using a network of static antennas to receive signals emitted by an aircraft transponder or ADS-B system. MLAT systems may utilise aircraft responses to interrogation by other systems or incorporate its own interrogation transmitters.

MLAT provide an independent position determination for aircraft transmitting on 1090MHz. The performance of the MLAT systems is specified and controlled by the ATSP and used for the provision of separation services. Whilst MLAT typically refers to systems used at and around an aerodrome, MLAT systems can be expanded to cover a wider area – including for example entire countries such as is the case for Norway – and are referred to as Wide Area Multi-lateration (WAM) systems.

In the context of EC, MLAT could potentially provide a "bridge" between different EC technologies, and specifically *may* augment lower performance signals with higher integrity position information. This would not address the issue of interoperability, and there is no precedent for use of MLAT systems with data from uncertified devices.

4.4.3 - TIS-B

TIS-B is a ground-based service that provides aircraft equipped with ADS-B IN with surveillance information about aircraft that are not ADS-B equipped eg non-ADS-B targets detected via Secondary Surveillance Radar (SSR). TIS-B is available on both 1090ES and UAT.

TIS-B uses secondary surveillance radars and multilateration systems to provide proximate traffic situational awareness, including position reports from aircraft not equipped with ADS-B Out. TIS-B data may not provide as much information as could be received directly from an aircraft's ADS-B Out broadcast, because of the required data processing. The TIS-B signal is presently used as an advisory service that is not designed for aircraft surveillance or separation, and cannot be used for either purpose.

Implementation of TIS-B would require use of the network of stand-alone ADS-B receivers (potentially both 1090 MHz and 978 MHz), multilateration systems and secondary surveillance working in the airspace where TIS-B service would be provided. Additional to that, network of the communication sites used for broadcasting TIS-B information would be required.

Considering the existing surveillance network, the current surveillance information for TIS-B broadcasting would originate from SSRs or WAM systems based on the Mode S transponder replies (DF=17). These transmissions can be replies to a 'Mode S all-call' interrogation sent by a ground based system.

Depending on the final option selected by CAA and DfT the current surveillance systems will need to be complemented or replaced by the new sensors capable to detect the target group of aircraft and flying vehicles which are not equipped with the ICAO Annex 10 transponders. The sensor outputs will need to be processed and broadcasted to airspace users and/or displayed to ATCO or FISO.

The new sensors may consist of ADS-B receivers collocated with the existing SSRs. Taking into account the recent number of SSRs in UK, approximately 60 receivers would be needed.

The following table provides indicative cost of ADS-B implementation in UK if the new ADS-B receivers are purchased and installed at all SSR sites.

	Cost scale	Number of receivers	Cost scale for all receivers
ADS-B receivers at radar sites	16.5k - 55k	60	990k - 3.300k
Integration of single ADS-B receiver into SDPS	8,5k - 42k	60	510k – 2.520k
Installation cost of single receiver	6k -13k	60	360k – 780k
Total cost			1.86 mil – 6.60 mil

Table 13 Estimated cost of ADS-B implementation at all SSR sites

Other option would be to reconfigure the existing multilateration receivers to receive ADS-B information from devices transmitting ADS-B information using DF=18 format. This would allow reception of the ADS-B data on 1090 MHz. If the selected solution would require reception of ADS-B on 978 MHz, the receivers would need to be replaced or upgraded for dual band.

There was 10 miltilateration systems with about 70 receivers in 2021 in UK so implementation would require reconfiguration, upgrade or replacement of the receivers as well as reconfiguration of the multilateration processing unit to process ADS-B data.

The following table indicates possible cost of ADS-B implementation if the existing multilateration receivers are upgrade or replaced new ADS-B receivers are purchased and installed at all SSR sites.

	Upgrade / replacement of the receiver	Number of receivers	Final cost scale

ADS-B receivers as part of WAM	8.25k - 55k	70	577.5k - 3.850k
Integration of single ADS-B receiver into SDPS	4.25k - 42k	70	315k – 2.940k
Installation cost of single receiver	3k -13k	70	210k – 910k
Total cost			1.1025 mil – 7.70 mil

Table 14 Estimated cost of WAM receiver upgrade or replacement to support ADS-B

If the selected solution would require dual band receivers , the solutions are on the market available as several multilateration manufacturers have the equipment in their portfolio. The price of the dual band receiver is on the higher part of the cost scale.

To provide TIS-B service, transmitter centres would be required. Considering the existing LARS service areas, 15-20 transmitter sites might be needed to provide TIS-B for low flying aircraft and vehicles (500 ft) within the existing LARS airspace boundaries. The number of sites may differ depending on operation coverage requirements.

The cost of the transmitting site in US was about 2 mil USD. The cost covered deployment of the new communication site so we assume that the actual cost would be lower in UK if the existing communication sites would be utilised for the TIS-B transmission as the major part of the infrastructure is existing.

4.4.3.1 - ADS-R

Automatic Dependent Surveillance – Rebroadcast is a client-based service that relays ADS-B information from an aircraft using one link (for example 1090MHz) to an aircraft with ADS-B IN on another link (for example 978Mhz). This is used extensively within the US in combination with TIS-B to provide interoperability between 1090MHz and UAT users and provide a traffic information service.

The costs associated with the ground infrastructure required to enable a consistent and suitable ADS-R service are not published but are known to be very significant. A typical US ADS-B receiver station has four directional Mode S ES antennas and one omnidirectional UAT antenna[41]. The service is also delivered by the FAA, who have operate as a single entity ANSP within the US.

It should also be noted that the US ADS-B programme was initially awarded in 2007 at a cost of £1.8BN, and the applicable mandate to equip users (in controlled airspace) was only completed in 2020.

4.4.4 - OGN (Open Glider Network)

The Open Glider Network is a network of servers (may be as simple as a Raspberry Pi or equivalent) that receive, and forward data collected by a network of ground receivers. These are complemented by a set of websites and applications that provide a presentation layer for the data.

[41] https://web.stanford.edu/group/scpnt/gpslab/website_files/ion_gnss/Lo_IEEEIONPLANS_2016_final.pdf

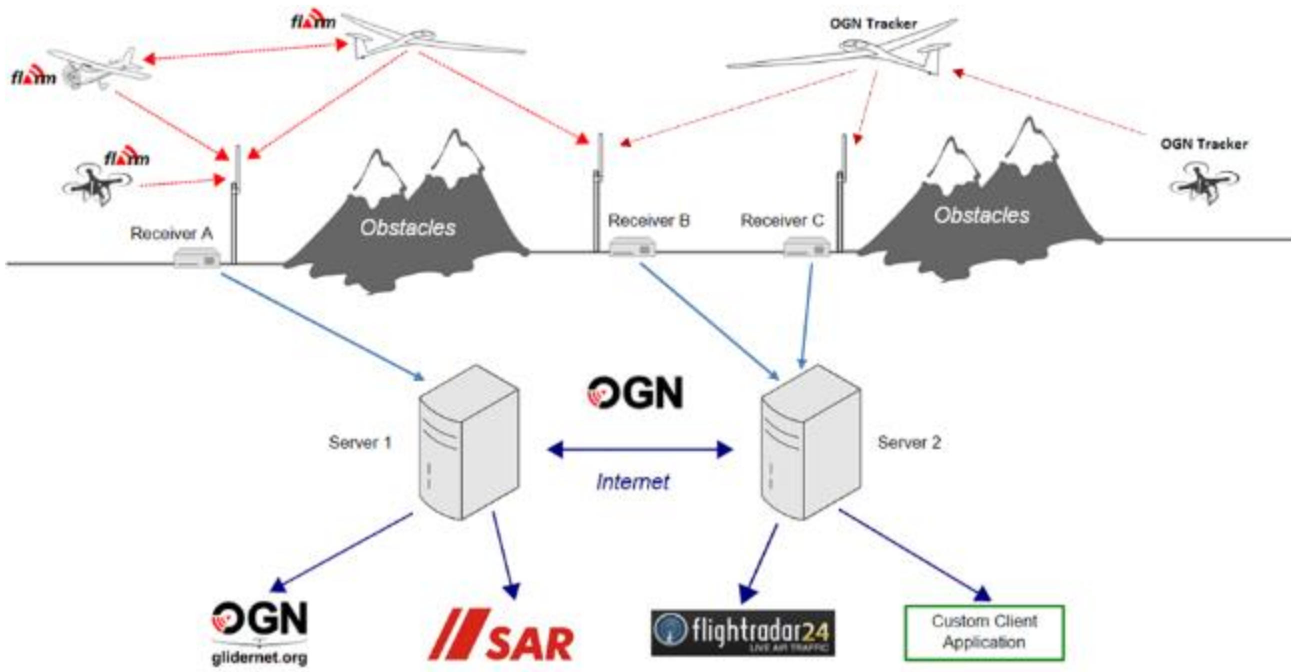

Figure 7: Open Glider Network layout

Typically used to present a situational awareness display in "real time" (although the precise meaning of this term is not specified). The service is not intended for use in safety of life applications, but provide situational awareness, and other benefits to airspace users.

Whilst the software is open source, the overall network does not conform to an agreed performance standard and is based on reception of FLARM transmissions, which are themselves not certified devices. The position data from FLARM comes a "cell phone grade" GPS according FLARM themselves.

4.4.5 - ATOM (PilotAware Network)

PilotAware's Air Traffic Overview and Management (ATOM) system is a service, based on a network of ground stations, that provides an uplink of data to aircraft with PilotAware devices on board. The ground stations are privately operated and can be as simple as a Raspberry Pi in terms of hardware. There are no specified requirements that would enable an assessment of the performance of an ATOM station.

Each ground station, referred to as a node, receives PilotAware, ADS-B, Mode-S and FLARM transmissions. The data is shared through the network.

ATOM includes 240+ ground stations in the UK (PilotAware ATOM GRID), 1300 ground stations in the UK (360RADAR). PilotAware also uses an airborne relay capability to extend coverage. The ground stations receive Mode-S, Mode-C, ADS-B, FLARM and PilotAware transmissions. ATOM operates a pseudo-MLAT[42] service to independently identify the position of Mode-S transmissions. This is used to allow uplinked situational awareness information to include positions of transponder equipped aircraft that are not equipped with EC.

4.4.6 - BVLOS ground infrastructure

At present there is little consensus or prescriptive plans for ground infrastructure required to support BVLOS operations. As a result, there are a variety of possible solutions. Some key examples are listed below, with their benefits and disadvantages *from the perspective of the enhanced EC* applications under consideration in this study.

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[42] *Performance characteristics of MLAT service is not specified.*

Solution	Description	Benefits	Disadvantages
Transponder - based	Certified UAS will operate under the normal rules of the air. In this case they will have a suitable transponder (eg Mode S) and a means of ATC <-> pilot communication (even if the pilot is remote)	The UAS will be quipped as any other aircraft	Could equip a transponder without electronic conspicuity This might not apply to all BVLOS operations
EC based – certified	Certified UAS could equip 1090ES transponders (or similar depending on the future airspace requirements)	UAS will be conspicuous Conspicuity data will be assured Ground infrastructure could be common between manned and UAS UAS would contribute to ground infrastructure costs	Could cause frequency congestion and would require filtering/HMI changes for ANSPs if used by entire user group Prohibited in the US[43]
EC based – certified UAT	UAS could equip certified UAT EC devices (with 1090 ADS-B IN). ConOps would determine if UAS should be conspicuous to manned aircraft or not.	UAS will be conspicuous Conspicuity data will be assured UAS would contribute to ground infrastructure costs	Ground infrastructure would need to support 1090MHz and 978MHz Manned aircraft would have to equip 968MHz IN for UAS to be conspicuous to them
EC based - uncertified	Certain BVLOS applications may be facilitated by uncertified EC, relying upon other sources for assuring overall safety and performance (be this DAA, navigation or otherwise)	UAS will be conspicuous BVLOS UAS operators would support development of ground infrastructure (no in support of safety applications)	Conspicuity data would not be sufficient for safety applications
C2 link based	In some cases, assured performance necessary for BVLOS operation may rely on a performant C2 link and navigation system. In such cases it could be possible to use the C2 link to share assured position information (surveillance) with relevant ground stakeholders (whether this is an ANSP, or a UTM system).	No special ground infrastructure required for UAS surveillance	UAS not conspicuous to other airspace users without rebroadcast UAS would not contribute to costs of ground infrastructure required for enhanced EC applications
Ground based surveillance	Although limited in application, some BVLOS applications could be supported by ground based surveillance[44] without EC.		UAS not conspicuous UAS would no contribute to ground infrastructure costs for enhanced EC applications

[43] https://www.federalregister.gov/documents/2019/12/31/2019-28100/remote-identification-of-unmanned-aircraft-systems

[44] https://www.commercialuavnews.com/infrastructure/avitas-faa-civil-bvlos-approval

Solution	Description	Benefits	Disadvantages
	Specialised radar can monitor the UAS(ground-based position determination), acting as a replacement for observers required in VLOS missions.		

Table 15: Potential BVLOS surveillance solutions

Inferred from many of these solutions, is the need for UAS to take responsibility for avoiding manned aviation, as the UAS themselves are not conspicuous, and typically smaller making see and avoid less practical. These issues are considered further in section 5.3.1 - .

4.5 - Solution Uptake

This section is not intended to provide fully comprehensive analysis of the market but summarises data available.

The inputs for this section include:

- The UK CAA's Airspace Analyser tool;
- Inputs from STF members;
- Airspace for All LAA Rally EC data collection;
- CAA data base on surveillance infrastructure;
- The CAA LARS coverage analysis study;
- Independent analysis of received ADS-B/Mode-S transmissions;
- An Egis desk research analysis of EC devices publicly available.

4.5.1 - Ground

4.5.1.1 - Surveillance technologies

There are several surveillance technologies within use for Air Traffic Services today.

Tech.	Description	Details	
Primary Radar	Primary radar radiate electromagnetic signals detect reflections from aircraft. Various methods are used to filter out reflection from other sources (such as terrain, sea, buildings, ground-vehicles, windfarms etc). Primary radar do not typically provide altitude information and are generally less accurate than other surveillance means. The main advantage of primary radar is the detection of uncooperative aircraft (which may be exempt from transponder equipage, or have a transponder failure). This advantage is being eroded due to reduce radar cross section of aircraft from materials and size. Specialised primary radar can	**Cooperative[45]**	**Dependent[46]**
		No	No
		Range (NM)	**Cost (£k) [47]**
		60-80 (Airport) 150+ (En-route) 5 (Drone detection)	2500-4000 (airport) 6000-10,000 (en-route)

[45] *Cooperative surveillance technologies rely on aircraft being equipped with transponders to function. Unequipped users are not detected.*

[46] *Dependent surveillance technologies rely on the aircraft to provide its position information and cannot independently verify the location.*

[47] *Cost of an individual system without lifecycle costs.*

Tech.	Description	Details	
	detect drones, although typically with much reduced range. Multi-static primary radar are under development, that could potentially use background signals and include some benefits of multilateration systems, but none are yet mature.		
Secondary Radar	Secondary radar are similar in size and cost and general function to primary radar, except they send interrogations to aircraft transponders and receive responses. The 2D location of the aircraft is calculated based on the detected signal and the altitude decoded from the response. Includes Mode A, Mode C, Mode S, Mode 5. Modern secondary radar typically include ADS-B receivers and could be procured with both 1090ES and UAT receivers. **Secondary radar could be utilised as ground based infrastructure supporting enhanced EC applications.**	**Cooperative[45]**	**Dependent[46]**
		Yes	No
		Range (NM)	**Cost (£k)[47]**
		250+	Station: 2 Installation, connectivity etc likely to be major contributor to cost
MLAT and WAM	Multilateration (MLAT) systems utilise an array of synchronised receivers detecting the same transmission from an aircraft and performing a time difference of arrival calculation to locate it independently. Systems can be local (typically for an airport) or wide area (extending to full country coverage). There is little precedent for a WAM system targeting the low-level coverage that would be required to support enhanced EC applications. Such a system would require a more extensive network of receivers than previously been deployed. Receivers include ADS-B reception capability and could potentially receive other EC technologies as well. **MLAT/WAM could be utilised as ground based infrastructure supporting enhanced EC applications.**	**Cooperative[45]**	**Dependent[46]**
		Yes	No
		Range (NM)	**Cost (£k)[47]**
		Dependent upon configuration Airport ground surveillance: 3 WAM: entire country	Dependent upon configuration. Airport systems: 2,000-3,000 WAM: between 5,000 and 50,000[48]
ADS-B	ADS-B ground infrastructure utilise relatively low-cost receivers as they are dependent upon the airborne equipment to provide position information. They typically utilise omnidirectional antennas, and while subject to the same terrain and line of sight constraints as other surveillance equipment, their lower siting requirements make it easier to deploy a network of receivers to achieve coverage. Space based reception of ADS-B is also available. This would provide an interesting proposition as it	**Cooperative[45]**	**Dependent[46]**
		Yes	Yes
		Range (NM)	**Cost (£k)[47]**
		Dependent upon airborne transponder up to 170	50 per site

[48] *Assumes roughly 300 stations deployed at airports, receiver stations range in costs depending on assurance scenario.*

Tech.	Description	Details	
	eliminates terrain constraints in coverage. However, the systems do not currently have the capability to process the number of simultaneous airspace users relevant in the enhanced EC scenarios. Presently the systems filter out transmissions from aircraft at lower altitude ranges. A further constraint would be the reception of lower power transmissions.		

Table 16: Summary of ATS surveillance technologies

4.5.1.2 - Existing surveillance coverage

Within the UK, there is an extensive network of ATM surveillance infrastructure operated by a mixture of civil entities and the military[49]. This coverage is composed of primary and secondary radars, MLAT and WAM systems, and ADS-B receivers (often integrated into the WAM systems).

In 2020 EGIS supported the UK CAA with a surveillance assessment for the Future Lower Airspace Service[50]. The assessment included 58 SSR radars and 10 multilateration systems with 80 receivers. The following figures indicate the surveillance coverage provided at 1000 ft AGL by the existing secondary radars and multilateration systems in UK. At the time when the study was conducted, the ground ADS-B sensor data were used only for provision of services in the East Shetland region.

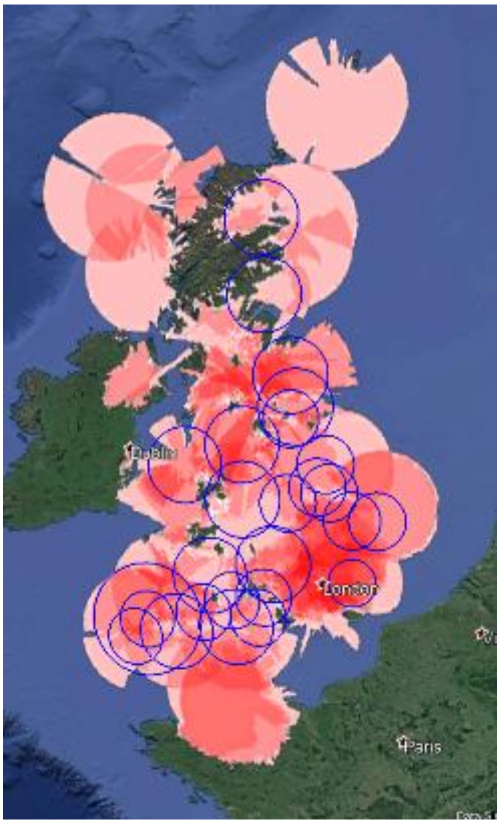

Figure 8: Radar coverage at 1000ft AGL

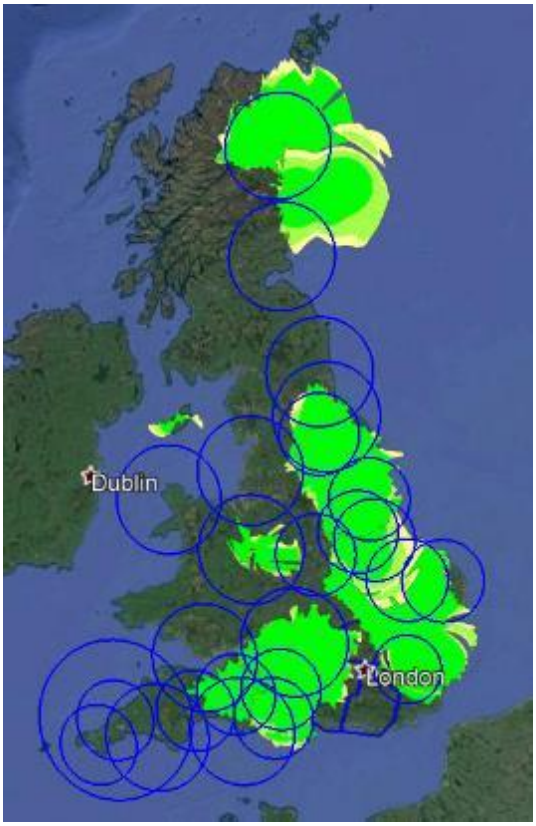

Figure 9: WAM coverage at 1000ft AGL

It is a fact that all existing multilateration systems on the market today provide the capability for ADS-B message reception and position processing. Therefore, one of the simulated scenarios assumed all WAM receivers could be used as ADS-B receivers working on either 1090ES or 978MHz. The hypothetical ADS-B

[49] *There are additional private networks of transceivers which are not used for ATM; these are covered in section 4.5.1.4 -*

[50] *Surveillance Assessment for Future Lower Airspace Service, EGIS, 2021*

coverage and performance calculations were conducted for both, normal transponders as well as Low Powered Transponders (ADS-B Class A0) which could represent EC devices. The following figure indicates what would be the ADS-B coverage and coverage redundancy if all existing multilateration receivers would be used as ADS-B receivers assuming that all aircraft would be equipped with Low Powered Transponders (LPTs).

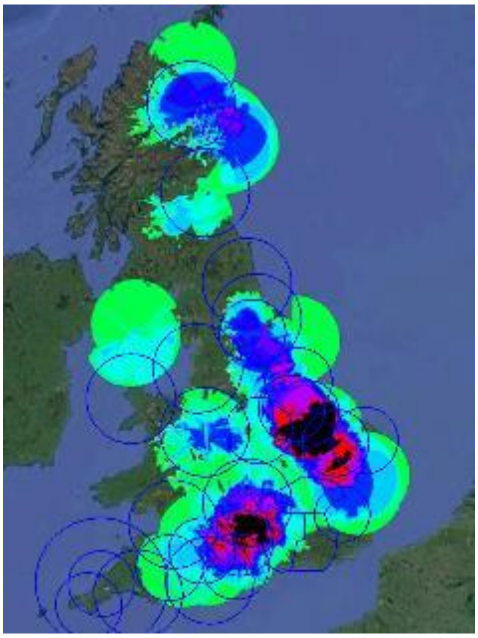

Figure 10: ADS-B coverage provided by WAM receivers at 1000 ft AGL LPTs

Currently, all major suppliers of secondary surveillance radars equip there civil radars with the ADS-B receiver to mitigate some of the radar technology weaknesses (e.g. improve surveillance information within a cone of silence) and thus improve quality of tracks. Due to that, one of the scenarios assumed that all existing and new radars could be complemented by ADS-B receivers in the future. The following figures indicate, what would be the theoretical ADS-B coverage if there was an ADS-B receiver installed at each of the existing radar sites.

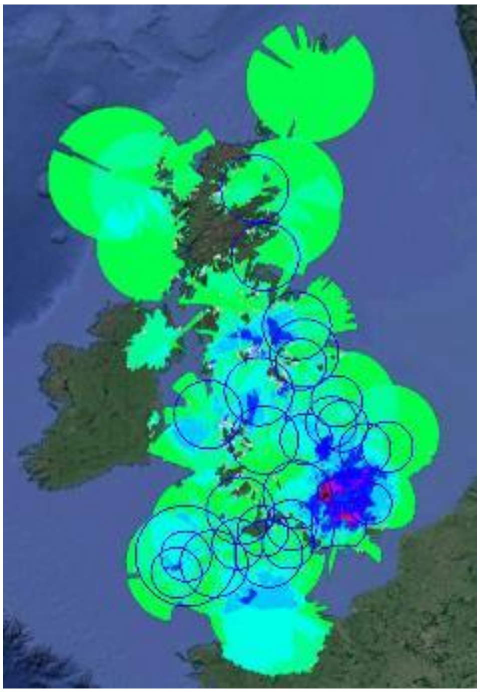

Figure 11: ADS-B coverage at 1000 ft AGL provide by ADS-B installed at radar sites - normal transponders

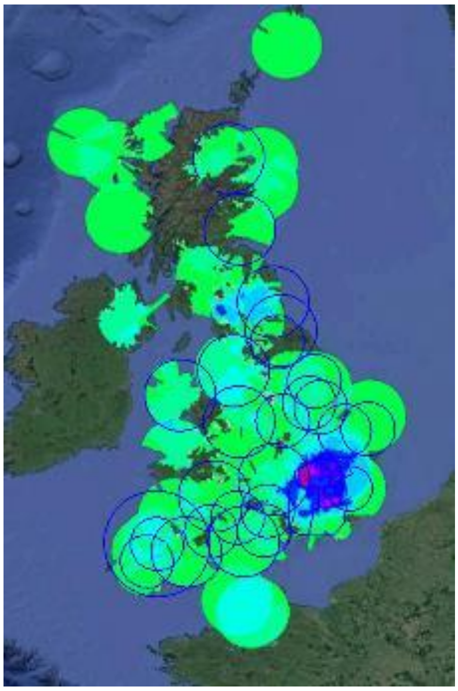

Figure 12: ADS-B coverage at 1000 ft AGL provide by ADS-B installed at radar sites - LPTs

Throughout the Surveillance Assessment for Future Lower Airspace Service project duration, Egis contacted operators and manufacturers of different multilateration systems installed in UK to find out whether their system supports also UAT services on 978MHz, to determine whether the existing surveillance systems are 1090ES only or whether they would be capable of supporting UAT on 978MHz in the future. No credible information was gathered.

All existing multilateration system manufactures which have their installations in UK are aware of the UAT requirements and some of them have solutions for UAT. However, it was not possible to determine whether the existing multilateration systems installed in UK could support dual channel ADS-B to receive also UAT data link over 978 MHz.

There is a limited number of multilateration and ADS-B ground systems manufacturers and only some of them offer dual channel ground ADS–B systems to receive and process data links over UAT frequency because of the low market interest for such solution:

- Saab Sensis offers ADS-B transceivers for both the Mode S Extended Squitter (1090 ES) and Universal Access Transceiver (UAT) datalinks.
- Thales – developed products supporting ADS−B services over the 978 MHz UAT data link.
- Comsoft / Frequentis would be capable to developing the technology but with an almost non-existent market in Europe do not have a UAT product in their portfolio.
- ERA – have not developed any UAT specific system as there was no commercial demand for such solutions. The existing systems designed for military would be capable to detect and extract UAT data, however, such solution would probably not be commercially competitive on the market

The ADS-B coverage maps indicate that by utilising the existing sites for the installation of the ADS-B receivers working on 1090 MHz and / or 978 MHz significant part of the lower airspace would be covered.

4.5.1.3 - ATSPs

There are various surveillance related plans in the UK. The introduction of new Lower Airspace Services may enable new service providers for funded LAS.

NERL is undergoing a major radar refresh programme. Of particular interest for this study is the replacement of old Watchman radars, and the introduction of new Mode S SSR radars, which we understand to have integrated ADS-B sensors. These will initially be 1090ES, but NERL has informed us that it would not be challenging to add UAT capability as long as the decision is taken strategically.

For HIAL (Highlands and Islands), there is an existing initiative (ATMS Strategy 2030) seeking to introduce radars and support surveillance-based control in the coming years. The island airport mostly use procedural control at present. The introduction of surveillance within the CTZ and out to (at least) 40 NM could enable new applications, including ICAO FIS outside of controlled airspace.

In the past decade, Project Marshall has implemented the roll-out and deployment of new ATM capabilities for the UK military, across most airports. Many of the facilities now benefit from MLAT, although each of the local systems also has the ability to turn on the capability to receive ADS-B data.

Local airport ATSPs may also implement local or regional surveillance that would enable surveillance-based ATS, but also ICAO FIS and potentially ADS-R.

4.5.1.4 - Private networks

In addition to the networks that support air traffic service provision within the UK, there are several other networks which form part of the existing EC provision. These are presented in Table 17. The location of all these stations is not known, but is understood to provide near complete UK coverage. The networks of Flight Aware and Pilot Aware also implement MLAT capabilities which enhance the network and in the case of Pilot Aware can provide a TIS through their network and is currently the mechanism used for the uplink of FLARM traffic information.

Network	Technology	Estimated receivers
Flight Aware	ADS-B	>3000
PilotAware ATOM	PilotAware (also collects ADS-B, Mode-S and FLARM)	~240 stations in the UK
OGN	FLARM	~180 stations in the UK

Table 17: UK proprietary EC networks

4.5.2 - Airborne

The CAA estimated that as of 2021 the number of airborne EC devices in use across the UK were as follows[51]:

- **Mode S Transponder (non-ADS-B)**. c.9000 of 19500 (46%) aircraft on the 2021 UK register. This is consistent with the 66% recorded of those attending the 2019 LAA Rally, considering the specific aircraft mix.[52]
- **Transponder Mode S ES (ADS-B)**. c.1000 of 19500 (5%) aircraft on the 2021 UK register. 15% recorded attending the 2019 LAA Rally.
- **CAP1391 ADS-B Device.** No firm data, however 31% of the delegates participating in the March 2021 CAA poll indicated that they already carry a CAP1391 device.[53]
- **FLARM.** c.7000 of 19500 (35%) aircraft on the 2021 UK register, including c.80% of the UK registered gliders and some power GA, UAS and Military operators.
- **PilotAware.** c.4200 (21%) aircraft on the 2021 UK register, predominantly fixed wing power GA and gliders. 21% of the aircraft attending the 2019 LAA Rally were using PilotAware Rosetta as a GPS source for the Mode S transponder and/or as an EC device.
- **Nothing.** It is estimated that c.10-20% of GA aircraft on the 2021 UK register operating in UK Class G airspace are not equipped with any EC device. However, this estimate does not take full account of the recent increases in user adoption that continue to be incentivised by the EC rebate scheme; 29% of GA aircraft attending the 2019 LAA Rally were not equipped with any EC device, by the 2021 CAA Poll, only 9% indicated such.

To complement this CAA analysis, a dump of raw ADS-B/Mode S data was assessed provided from a proprietary source. PilotAware were also approached to if they would be able to complement the data analysis but it was not possible within the time constraints of this reports. The data analysed was obtained from a limited network of four strategically placed receivers with data collected over more than a year. This data was analysed for Mode S addresses and compared against the ADS-B tracks to provided a rough estimate of the level of equipage of both in the UK fleet. Utilising the Mode S address, a comparison was made against the UK G-INFO database to categorise the data. This analysis has shown the following results.

AIRCRAFT CATEGORY	IN UK REGISTRY	WITH MODE S	WITH ADS-B	SAMPLE % WITH ADS-B
CS-22	2528	210	69	33%
CS-23	3885	2306	1005	44%
CS-25	964	867	802	93%
CS-27	832	517	152	29%
CS-29	207	100	77	77%
CS-31	1340	9	6	67%

[51] *978MHz UAT, User Demand and Capacity Study, June 2021, v1.2*

[52] airspace4all Report - Electronic Conspicuity Data Collection at the LAA Rally 30 August to 1 September 2019

[53] 'Interoperable tech' for conspicuity tops CAA poll : FLYER

AIRCRAFT CATEGORY	IN UK REGISTRY	WITH MODE S	WITH ADS-B	SAMPLE % WITH ADS-B
CS-LSA	18	12	3	25%
CS-VLA	49	30	13	43%
Non-Part 21	9309	1798	690	38%
Part 21	107	41	15	37%
TOTAL	**19239**	**5890**	**2832**	**48%**

Table 18: Number of aircraft observed in sample data

Unlike the LAA Survey of 2019, this sample is only able to collect data from aircraft already equipped with Mode S and/or ADS-B 1090ES. Nevertheless, it provides a useful cross check with a modest increase in some areas against previously report figures. Excluding CS-25 and CS-29 from the analysis, the overall sample this shows would make the penetration within the GA sector sampled equal 40%.

The sample was reassessed to take into account the non-equipped aircraft with a comparative analysis against tracks captured on the CAA's airspace analyser tool to set upper and lower bounds of the percentage of the UK fleet that would have been visible at some point in the year to the receivers. The table below presents the assumed actual sample size of the fleet and presents the calculated 95% confidence level ranges for the Mode S and ADS-B within the UK fleet.

CATEGORY	UK FLEET	FLEET LOWER BOUND	FLEET UPPER BOUND	MODE S EQUIPAGE ESTIMATE		ADS-B (1090ES) EQUIPAGE ESTIMATE	
				LOWER BOUND	UPPER BOUND	LOWER BOUND	UPPER BOUND
CS-22	2528	40%	70%	12% +/- 4%	21% +/- 5%	4% +/- 4%	7% +/- 5%
CS-23	3885	80%	95%	62% +/- 2%	74% +/- 2%	27% +/- 2%	32% +/- 2%
CS-25	964	90%	95%	95% +/- 1%	100% +/- 0%	88% +/- 1%	92% +/- 0%
CS-27	832	80%	95%	65% +/- 3%	78% +/- 3%	19% +/- 3%	23% +/- 3%
CS-29	207	55%	65%	74% +/- 7%	88% +/- 6%	57% +/- 7%	68% +/- 6%
CS-31	1340	40%	70%	1% +/- 1%	2% +/- 1%	1% +/- 1%	1% +/- 1%
CS-LSA	18	70%	95%	71% +/- 22%	92% +/- 14%	18% +/- 22%	23% +/- 14%
CS-VLA	49	70%	95%	64% +/- 14%	86% +/- 12%	28% +/- 14%	37% +/- 12%
Non-Part 21	9309	50%	95%	20% +/- 1%	39% +/- 1%	8% +/- 1%	15% +/- 1%
Part 21	107	50%	95%	40% +/- 10%	76% +/- 11%	15% +/- 10%	28% +/- 11%

Table 19: Extrapolated 95% confidence levels of equipage of Mode S and ADS-B (1090ES)

4.6 - Conclusions on equipment availability and uptake

The section has presented a summary of number of electronic conspicuity devices available for use within the UK. Apart from controlled airspace, there is freedom to choose what electronic conspicuity device may be fitted subject to compliance with PED rules.

To make the fitted electronic conspicuity devices useful requires commensurate coverage on the ground and there remain significant gaps in the current coverage at lower levels. These could be filled, relatively easily for ADS-B on 1090ES and UAT and the existing proprietary networks offer good coverage as well. However, these networks currently provide no guarantees in terms of performance, which would make developing a safety case addressing their use for ATS provision, or in a rebroadcasting capability (to support DAA/CA or otherwise) difficult to argue. Presently, PilotAware ATOM Grid provides an MLAT function for mode-s only and nothing is known of the performance in order to support its use as a ground-based validation function. MLAT systems using 1090 or UAT could, of course, provide an independent position capability.

At present only the certified technologies can support the enhanced EC applications. The non-certified technologies may well have the capability, but would require significant development of new standards and approaches to assurance to enable their use for these applications. However, not all users will want to equip and some users will not necessarily believe they will benefit from enhanced EC and mainly require the support for situational awareness capabilities.

5 - INTEROPERABILITY INCLUDING SPECTRUM

5.1 - General

This section highlights interoperability challenges to be considered when developing the minimum technical standards for electronic conspicuity and associated surveillance. Interoperability recognises that regulatory or standards decisions are not taken in isolation, neither is the airborne enhanced Electronic Conspicuity implemented without consideration of the wider users, airspace or context. Technical interoperability is also required to ensure that all elements forming the surveillance chain operate as expected. Spectrum issues are also considered, including the current approach to managing spectrum for safety of life applications, saturation and a summary of the potential EC spectrum options.

5.2 - International interoperability

A UK national enhanced EC standard should consider the developments at international level, particularly in Europe and the US.

5.2.1 - Cross-border equipage

As shown in section 3.4 - Policy evolution, EC concepts are evolving rapidly. A future UK EC standard should be interoperable with solutions being developed in other parts of the world, and in particular with Europe to continue to enable safe cross-border operations.

In Europe, operators operating as general air traffic under IFR are required to equip their aircraft with Mode S transponders, in accordance with the SPI IR (EU reg. 2011/1207). Aircraft with a MTOM of 5,700 kg or less and with a maximum cruising TAS 250 kts or less had to be ELS capable prior to 7 December 2020. However, there is currently no mandate for VFR flights. That said, EASA estimates that 50,000+ airspace users have already equipped with EC devices transmitting on the SRD 860 frequency band[54].

Going forward, EASA's stated intention to rely on ADS-L, utilising an array of solutions including ADS-B out systems on 1090MHz, an adaptation of existing solutions using the SRD 860 frequency (eg FLARM), and new systems transmitting via mobile telecommunication networks, is an illustration of the diversity of solutions that would need to be interoperable with the UK solution. By proposing three alternative means of compliance, EASA's proposal tries to cater for the needs (and existing avionics equipage) of a wide range of airspace users. Although it should be highlighted that ADS-L will not support safety of life applications. Its intended use is primary for traffic situational awareness. Future EC products might be tailored to the needs of each category of airspace users to generate a larger market share. This is evident, on the proviso that all these EC solutions remain interoperable.

5.2.2 - Market developments

The current focus of most updates to existing and developing standards is to accommodate the new airspace users. There is significant effort being spent on BVLOS UAS but the specific standards and regulations applicable are either only just emerging or are still being debated in the various working groups or sub-committees of the standardisation organisations.

There is broad consensus on the need for UAS to avoid manned aircraft, but there are a variety of ways in in which this is proposed to be achieved. The effective proposal within Europe for establishing U-Space creates a form of flight segregation. The recent proposals from the FAA show a marked change potentially affecting the rules of the air with an emphasis on the manned aircraft without electronic conspicuity giving way to UAS. This places a firm requirement on the manned aircraft to have electronic conspicuity or be prepared to see and avoid against an UAS. This is also simpler with a single frequency solution proposed.

As noted by IFATCA "*International regulations and requirements on how to implement and operate FIS are limited. For AFIS, there are recent initiatives from both ICAO and EASA to harmonise the procedural framework.*

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[54] *NPA 2021-14 Development of acceptable means of compliance and guidance material to support the U-space regulation (December 2021)* - https://www.easa.europa.eu/document-library/notices-of-proposed-amendment/npa-2021-14

IFATCA encourages these developments and recognises the need to do the same for dedicated Enroute FIS, as this service becomes more and more common and mature among Member States. In addition, IFATCA recognises the need for guidance material at a global level to be made available by regulators on requirements, procedures, training and licensing for dedicated Flight Information Service".

From an electronic conspicuity perspective, more work will be needed to integrate an specific requirements for non-standardised solutions and currently, there is no precedent set for the delivery of an ATS service based on data from non-standardised and uncertified equipment. There is however, precedent, although limited, for allowing other devices to operate on aviation protected spectrum (PMSE) providing suitable assurances can be made.

Equipment availability and uptake describes, approximately 80%-90% of GA aircraft on the 2021 UK register operating in UK Class G airspace are already equipped with some sort of EC (and there are reasons to believe this is increasing further). A future UK EC standard should therefore consider the interoperability with existing solutions to capitalise on the investments that have already being made by stakeholders. This would facilitate buy-in and accelerate the adoption of new EC devices.

Ensuring interoperability with international regulations, standards and guidance would also enable larger markets for avionics or ground infrastructure, including the EU or US in the markets a particular supplier could target with a common device. Benefits would be generated for users, with stronger competition fuelling innovation and driving costs down, while in the meantime, enable UK manufacturers to sell their products to a wider customer base.

5.2.3 - Procedural interoperability

Going beyond the EC technologies used in different countries, interoperability challenges may arise in how an EC device is operated. This is illustrated for example by EASA's approach to mandate manned aircraft to make themselves electronically conspicuous to enter a U-Space airspace (requirement SERA.6005(c)). This is different from the vision laid out in the AMS which favours integrating both manned and unmanned traffic. That said, the same EC devices will be used to operate in both the UK and Europe, despite having to follow two different sets of rules. Unless carefully monitored, this might generate interoperability issues from a human factors perspective.

Another example could be UAT. This technology is in widespread use in the US, with specific conditions on where and when to operate it (refer to the FAA "Equip ADS-B" website for a summary diagram[55]). Should UAT be used for EC in the UK too, different operating conditions might need to apply to accommodate the local environment. This might create risks that would need to be considered when developing the UK EC standard, potentially influencing its specifications or generating new requirements (such as awareness campaigns).

5.3 - Technological interoperability

There is a recognition that new surveillance applications are part of wider drive to enable a digital integrated airspace: FIS with and without surveillance, BVLOS integration, more easily switchable airspace volumes, etc. The current landscape of EC devices shows limited levels of interoperability between applications. This "application-based" view needs to evolve to consider the role of each application within the wider digital integrated airspace. This could include the ability for the technical solution to support non-EC applications – for example, other information services or innovative COTS-based applications (e.g. on 5G).

Nevertheless, EC devices form an essential building block of the vision. For that reason, the UK EC standard should consider that the specifications placed on EC devices and eventual solution options are capable to support other concepts put forward in the AMS.

Interoperability will also play a key role so that EC devices can interface with air and ground systems adequately as well as meet the level of performance expected.

[55] https://www.faa.gov/nextgen/equipadsb/

This consideration opens up questions regarding interoperability on a wide range of topics, from airborne collision avoidance to flight information displays. The reminder of this sub-section highlights some of the key challenges uncovered as part of this study, but is not a comprehensive review.

5.3.1 - Detect and avoid capabilities

The AMS describes EC as "*adding the ability to 'detect and be detected*", thereby strengthening the current see and avoid principle. This will increase the situational awareness of aircraft operators (both manned and unmanned) and to ATCOs and FISOs if fed to a FID. If used for safety of life applications, the information transmitted by EC devices will need to have the necessary integrity. In turn this high-quality data could be used for other applications, for example DAA. This could be akin to hybrid surveillance TCAS systems using ADS-B information to reduce the interrogations needed to acquire the tracks of possible nearby intruders. For example, ACAS X has been designed to accommodate an array of surveillance sources instead of relying on a single type of information.

However, from a European perspective, the extent to which information provided by EC devices could also be used to support DAA applications is unclear. EASA's new ADS-L standard proposal does not prescribe integrity requirements. Being developed for the purpose of traffic information, ADS-L EC devices have lower surveillance performance compared to system used for safety of life applications.

As described in section 2.4.3 - there appears to be a broad trend toward manned aviation being conspicuous to unmanned. In these concepts, unmanned BVLOS aircraft are responsible for avoiding manned aircraft. There is variation on the exact role of EC, in particular requirement SIL>0 or not. Meanwhile the use of EC within unmanned BVLOS aircraft is not defined. EUROCAE WG-105 draft OSED and MASPs are working toward a concept whereby the DAA capability is both on-board and, on the ground, (with data provided through both the UAS C2 link and other ground-based sensors). This enables the UAS to continue providing DAA even in the event of C2 link failure.

The Aviation Rulemaking Committee has published a report[56], which bases Conspicuity from manned aviation to BVLOS UAS on the use of ADS-B and TABS. This effectively requires assured EC on the part of manned aviation and places the responsibility for interoperability on the UAS. Paradoxically it also both simultaneously notes the low likelihood of a GA pilot detecting a small UAS and recognises that there will be some cases where the UAS has right of way (particularly when the manned aircraft is unequipped).

It is noted, that in these concepts the UAS operators are effectively responsible for avoidance. This would require either:

- A "dumb" avoidance capability that simply seeks to maintain distance from other known traffic (or airspace restrictions). This is somewhat akin to the behaviour of flocking birds and would introduce commercial and safety risks as there would be no guarantee of the UAS reaching a safe position (either its planned destination or other designated landing areas).
- A "smart" avoidance capability that seeks an optimal trajectory, avoiding both known traffic and airspace restrictions. This may be facilitated by a ground-based system, or by the UAS itself. In either case, it infers performant navigation (ie assured), which would require assured position, which could be used for EC.

Given the drawbacks of a "dumb" avoidance system, it seems logical to assume that UAS operators would ultimately target "smart" DAA capabilities, even if this is driven by independent positioning from the ground uplinked to the UAS (for example via 5G/LDACS) with "dumb" avoidance a back-up in the case of C2 link failure. Put simply, BVLOS UAS will want to be able to fly their mission, and this infers performant navigation, which could *potentially* be a source of assured EC. It is noted that these concepts do not require BVLOS UAS to be conspicuous to manned aviation, this raises the possibility of UAS, flying with assured navigation being responsible for avoiding manned aviation, who cannot see them and do not have assured EC.

[56] https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/UAS_BVLOS_ARC_FINAL_REPORT_03102022.pdf

Furthermore, if UAS are operating on the basis of avoiding manned aircraft via EC, and the EC is erroneous this could lead to safety issues (whereby a UAS taking avoiding action against a *false* position report may actually come closer to the aircraft it is trying to avoid in the worst case).

This serves to highlight the importance that assured EC can have in enabling integration of new airspace users, whilst ensuring access to airspace for all users.

5.3.2 - Improved communication links

As described in the AMS, "*the aviation community is progressively digitalising its data exchanges with less reliance on voice exchanges over radio*". Improvements in datalink communications technologies might provide opportunities for a wide range of applications, including surveillance.

One aspect is the use of datalinks to share EC information. Next generation solutions (eg Mobile Network Operator-based delivery of UAS BVLOS applications) could be set up to reserve some capacity allocated to a high-integrity service suitable for C2. Such an environment would enable a service with suitable coverage and performance available to UAS operators, which can deliver both C2 applications and general datalink applications (and therefore accommodate the communication requirements for EC).

Here the question is not so much about the interoperability of future communications systems with EC devices, but more to highlight the need for "coherence" between the two, particularly recognising a potential common box (marketed device) and the common need for cockpit integration, antenna, etc. EC requirements should be considered when developing future communications means, for example to dimension infrastructure appropriately.

5.3.3 - Space-based reception of EC information

The AMS advocates for a gradual shift from ground-based to space-based CNS infrastructure (see Figure 13) and details a wide range of concepts this would enable.

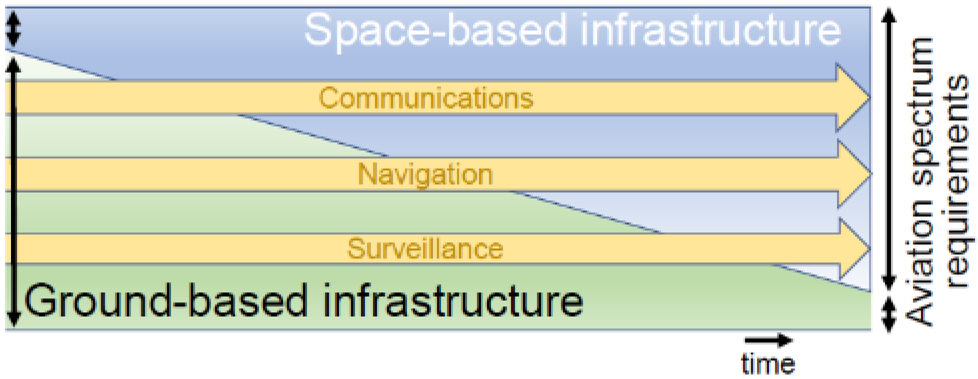

Figure 13: CNS shift from ground to space-based infrastructure[57]

Space-based communications might play a key role in supporting the sharing of EC data amongst users, for example through the implementation of broadband satellite communications. Likewise, space-based surveillance (such as space-based ADS-B as currently offered by Aireon) might be one of the surveillance sources used by EC devices.

The use of such technologies raises questions, particularly in terms of costs. Another element is the impact on the design and installation of EC devices onboard aircraft, for example the position of the antenna(s) transmitting the EC information, and whether existing installations would need to be upgraded. In turn this raises questions of certification if used for safety of life applications.

[57] *CAP 2298a - Draft Airspace Modernisation Strategy 2022–2040 Part 1: Strategic objectives and enablers* - https://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=detail&id=11069

5.3.4 - Impact of performance-based standards on surveillance interoperability

For some applications, EC information will be displayed on a specific device (including portable products). However, there might be benefits in integrating that data into an existing surveillance chain, displayed onto a single, integrated display. This could be both in the cockpit or on the ground. Ensuring interoperability with existing equipage therefore becomes essential, especially if that equipment is certified. Questions arise such as how to show compliance, or whether existing devices need to be re-certified.

For example, the addition of a new feed into an existing radar screen used by ATCOs would require the modification of certified displays. This in turn could have an impact of the safety arguments used at the time of the certification, possibly invalidating these arguments or requiring the implementation of additional mitigations (new procedures, training, etc).

5.4 - Spectrum

5.4.1 - Use for Safety of Life

As identified in Section 2 - , there are several different applications which future EC may support. Some of these, such as access to airspace, enhanced FIS services, and ACAS X, have a direct safety impact with EC playing a pivotal role. Other applications, for example integrating new airspace users, are likely to have a safety impact but dependencies on the safety role of EC are unclear until concept of operations are defined.

This sub-section summaries the current approach to spectrum management for Safety of Life (SoL) applications. Any options selected would need to satisfy an equivalent overall safety case to ensure no degradation in safety performance for safety of life applications. Whilst the management of frequency used by an EC device only forms part of such a safety case, any delta should be accounted for when assessing potential options for future EC provision.

Below is a presentation, in Goal Structured Notation, summarising the way that *current* SoL applications are assured from a spectrum management perspective. It is important to note that this is not the *only* way an argument could be made that the radio frequency spectrum is suitable, although there is limited precedence for other approaches. Furthermore, this argument is illustrative of the high-level current approach, not definitive. It is provided here to help identify drivers and constraints for options analysis within this document.

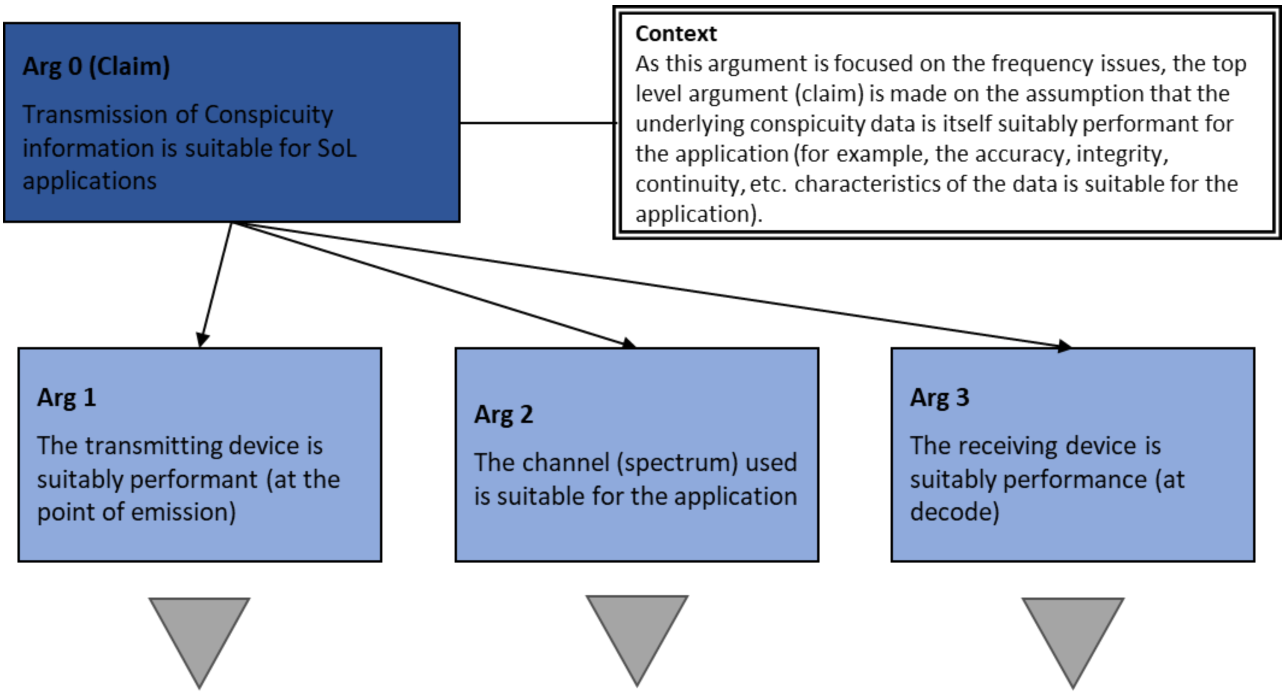

Figure 14: Top-level argument of frequency usage for SoL applications

As this safety argument focusses on the spectrum issues, it is made in the context of the data within the EC transmissions being suitably performant for the application. Within this context, there is one broad principle that need to be met to support SoL applications: the transmission chain performance is suitable for the application – which infers that the transmitter, the channel, and the receiver are all suitably performant. Note that the specific applications, within the context of their overall system may require different performance, and it is beyond the scope of this report to systematically describe them here (for example TCAS, as an air-to-air safety net has different needs than ADS-B in the context of a multi-sensor surveillance environment). "Suitably" is therefore not defined in this report.

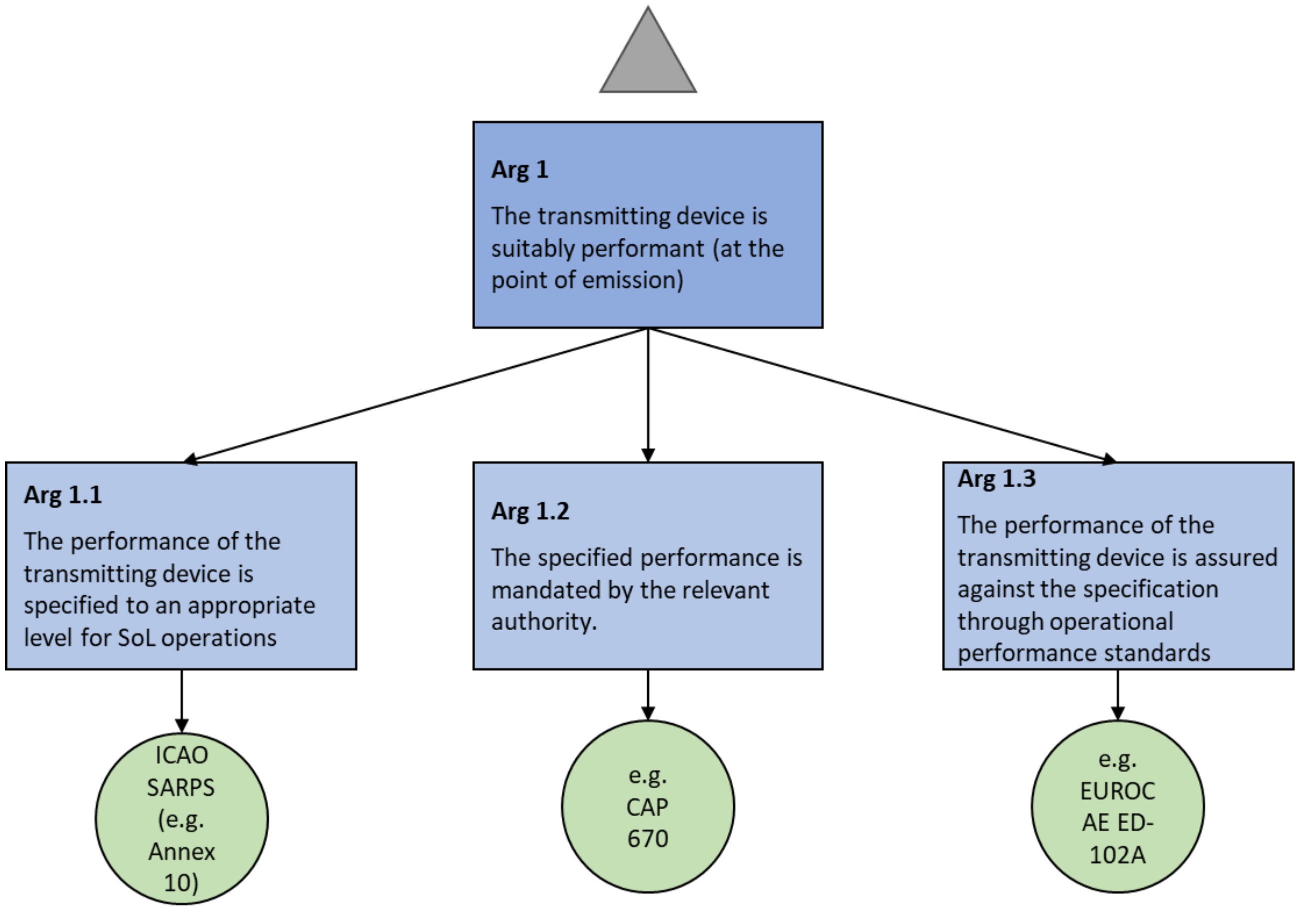

Figure 15: Expansion of argument 1 of frequency usage for SoL applications

Argument 1 expands on the case that the transmitting device is suitably performant. Specifically, it states that the performance is specified (e.g. met by ICAO SARPS), the specification is adopted by the relevant authority (and mandated as appropriate) and that devices can be shown to meet the specification through compliance with relevant performance standards.

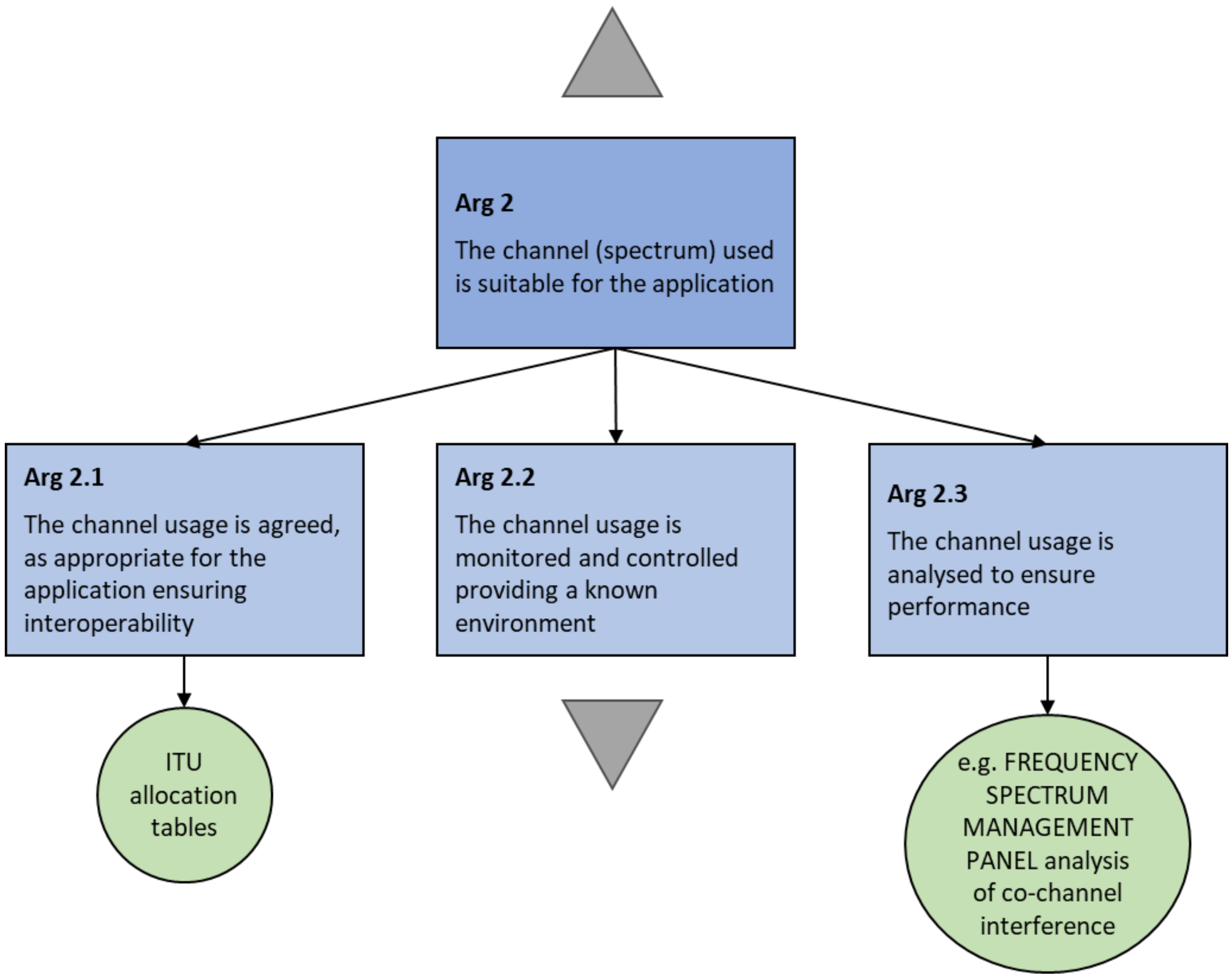

Figure 16: Expansion of argument 2 of frequency usage for SoL applications

When considering the argument that the channel is suitable for the application, there three main components:

- 2.1 That the channel is agreed, as appropriate for the application (which may be internationally, regionally, or locally) ensuring interoperability, and preventing cross-border issues. In an aviation context, adjacent nations having incompatible use of spectrum could[58] be a safety issue. Furthermore ICAO Doc 9718 (Handbook on Radio Frequency Spectrum Requirements for Civil Aviation), itself coordinated with the International Telecommunication Union (ITU) sets out a globally coordinated and agreed strategy and policy on the use of spectrum for civil aviation.
- 2.2 The channel usage is monitored and controlled providing a known environment (further expanded below): for the performance of EC communications to be known, the channel environment must be known, and this is presently achieved via controlling access and usage of the channel.
- Argument 2.3 state that the channel usage is analysed to ensure performance: this is both theoretical and practical, the principles and in-practice performance of the channel with the given usage must be understood and shown to be suitable.

[58] *Such issues could potentially be solved operationally, although this would come at another cost.*

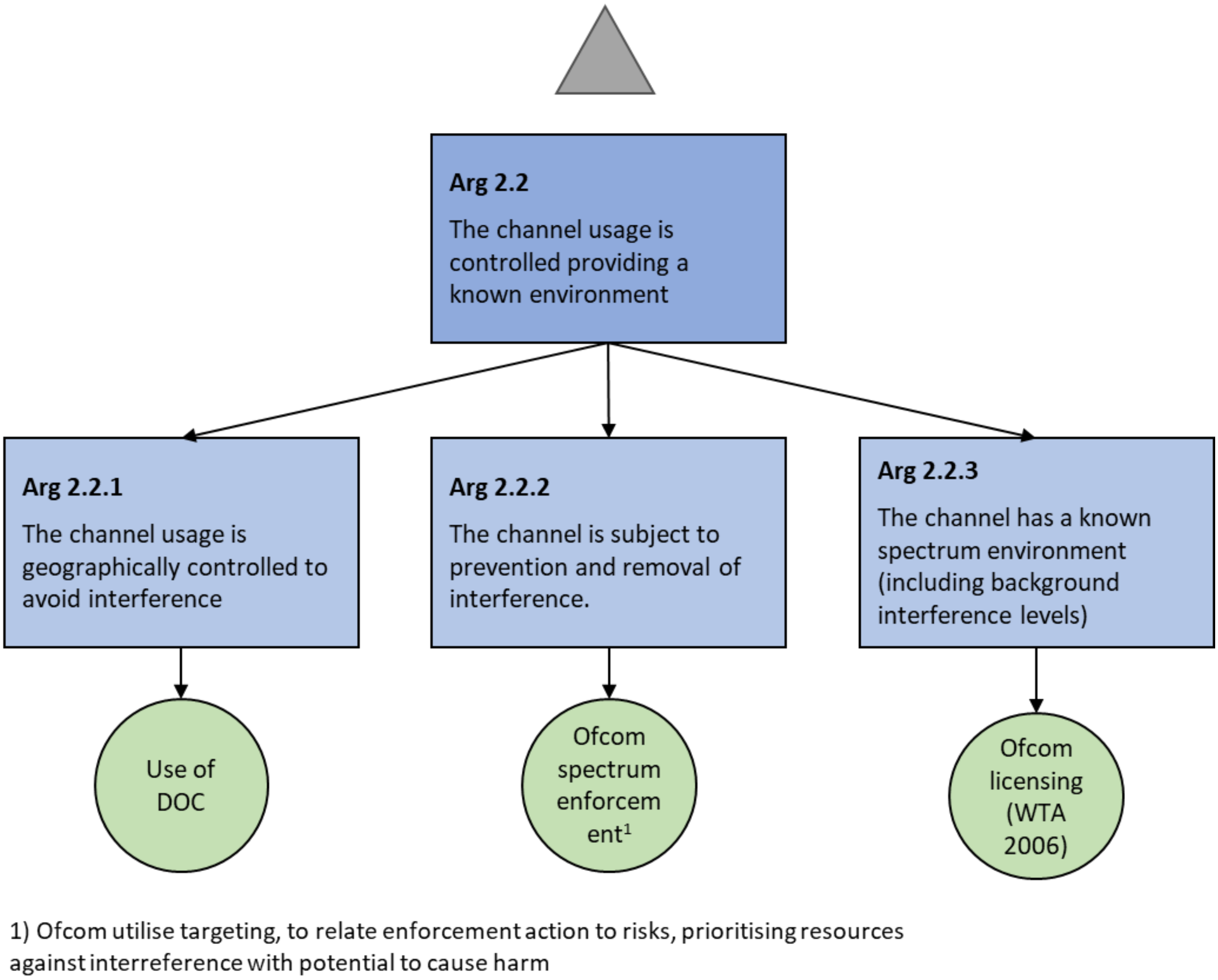

Figure 17: Expansion of argument 2.2 of frequency usage for SoL applications

Further expanding argument 2.2 (on providing a known channel environment) provides three sub-arguments:

- 2.2.1 That the channel usage is geographically controlled to avoid interference, clearly this is dependent upon the protocol used, an example being secondary surveillance. This is controlled using Designated Operational Coverage for systems. A further example is the geographical allocation of DME channels (now including control of Program Making and Special Event equipment) to ensure physical separation to avoid interference.
- Argument 2.2.2 states that the channel is subject to prevention and removal of interference. This infers monitoring based on coordinated usage, and enforcement. In the UK Ofcom performs this role, and acknowledges it's resources have limitations, operating a targeting policy, which prioritise corrective and preventative action in relation to risk, with spectrum used for SoL considered high priority. The CAA also delivers functions to prevent interference, including monitoring of bands including 1030/1090 using the EMIT tool. A further example is Eurocontrol VHF monitoring flights.
- Argument 2.2.3 covers the use of a known environment for the channel through spectrum coordination and licensing. In the UK this is achieved through Ofcom licensing, CAA spectrum management and coordination with Eurocontrol as the network manager, and the applicable standards (for example specifying minimum and maximum transmit power). This allows for Argument 2.3. Devices operating outside of Aeronautical Radionavigation Service spectrum, such as those operating under IR2030 (Licence Exempt Short Range Devices) have restrictions such as maximum transmit power, but no minimum or other constraints, meaning the spectrum environment at any given time is not known.

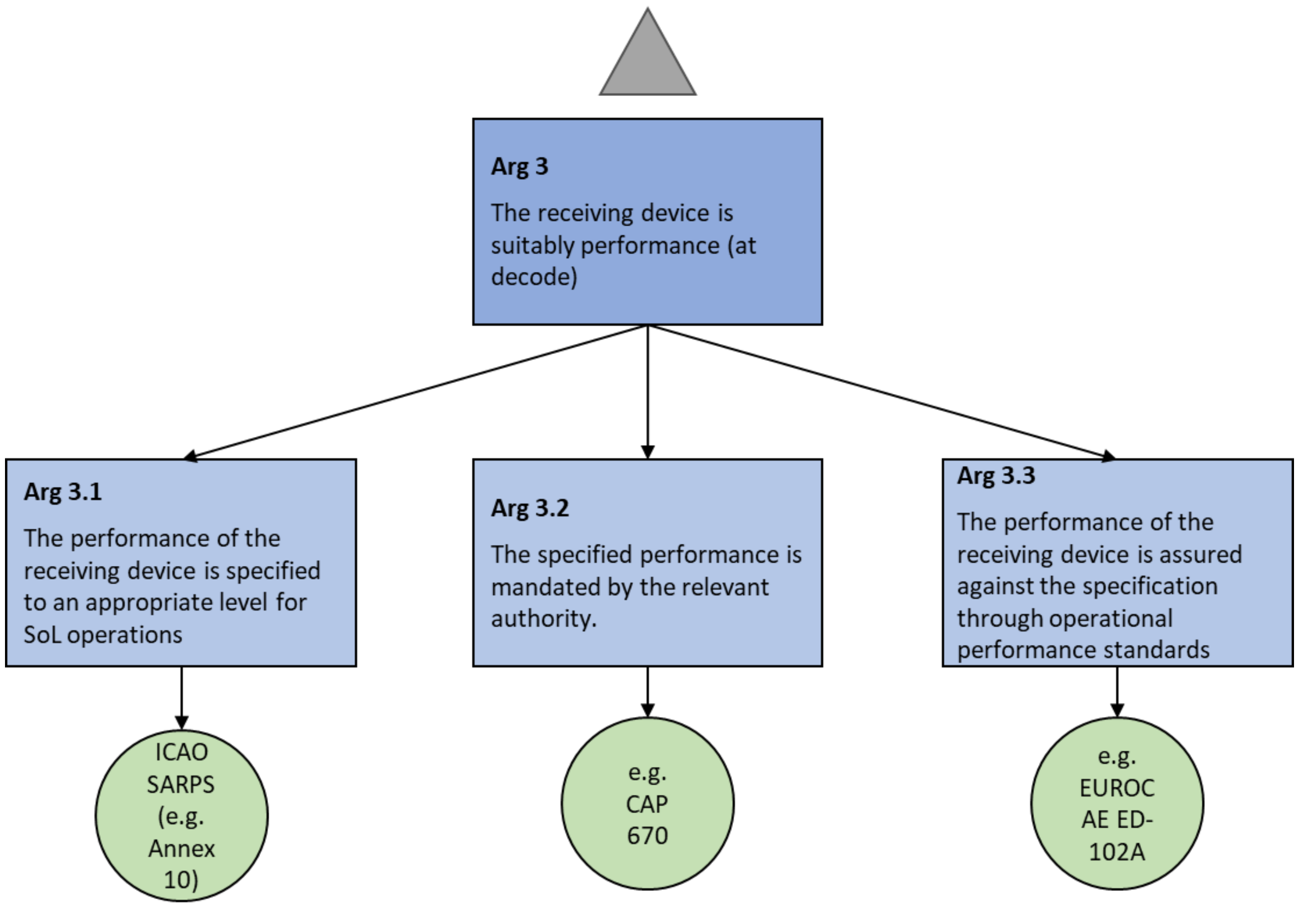

Figure 18: Expansion of argument 3 of frequency usage for SoL applications

Argument 3 expands on the case that the receiving device is suitably performant. Specifically, it states that the performance is specified (e.g. met by ICAO SARPS), the specification is adopted by the relevant authority (and mandated as appropriate) and that devices can be shown to meet the specification through compliance with relevant performance standards.

As noted above this section reflects the current approach for aviation protected spectrum as a means of forming a safety argument that the spectrum used is suitable for SoL applications. Not all the future EC benefits are safety applications, and there will be other ways to produce an overall safety argument. There is limited precedent for other approaches at the time of writing, which don't directly match the EC use cases (limited UAS trials utilising non-protected spectrum for C2 links).

This forms a constraint (not requirement), and options assessment must factor this in.

5.4.2 - Spectrum saturation

Historically, there have been concerns around saturation of 1090MHz spectrum, given surveillance technologies and the number of airspace users. The frequency is used for:

- Mode A/C radars,
- Mode S radars (Elementary Surveillance - ELS and Enhanced Surveillance – EHS),
- Automatic Dependent Surveillance – Broadcast (ADS-B),
- Multilateration systems for airport surface surveillance (MLAT) or over a wide area (WAM),
- Military systems (Identification Friend or Foe – IFF, combat ID),
- Air-air airborne collision avoidance systems (ACAS) and future ADS-B IN applications.

There is limited practical evidence of events of congestion. Between 5 and 10 June 2014 there were several occurrences of unplanned and uncontrolled radar losses from ATC displays in central Europe. At that time, the technical investigation concluded that the source of the RF interference was a commercial surveillance system which over-interrogated the transponders on board aircraft not only at rates beyond their requirements but also beyond design limits. In this case, the cause was an erroneous equipment rather than inherent limitations of the spectrum.

Theoretical studies have indicated that 1090MHz saturation, leading to degraded surveillance performance, has been expected, and largely been avoided due to airspace user numbers not reaching their expected peaks. In October 2019 a QinetiQ study[61] showed that if all airspace user groups were to equip with 1090MHz EC, the probability of reception would be significantly reduced.

The issue of saturation is not an inherent property of the 1090MHz spectrum itself, but the modulation and protocols of the technologies which utilise it. Many systems in use on the ARNS spectrum very outdated, for example the latest MOPS for DME operation was published in 1985. Mobile networks have evolved from 0.46 bps/Hz to 30+ bps/Hz since that time, but they are not designed for the aviation environment or to prioritise the same performance characteristics to achieve assured performance (ie integrity, latency, continuity). UAT, operating on 978MHz is widely regarded to utilise a more efficient modulation technique.

Forecasts for new airspace users typically exceed all existing airspace users combined, already registered commercial UAS operators equal 25% of the rest of the UK fleet.

Furthermore, there are various moves to restrict use of ADS-B by UAS due to spectrum congestion concerns:

- FAA rule[59] proposes a prohibition of ADS-B Out and transponders for UAS as "*the potential proliferation of ADS-B Out transmitters on UAS may negatively affect the safe operation of manned aircraft*"
- ICAO notes[60] "*There is increasing pressure to use 1090 MHz Mode S or ADS-B OUT applications by UAs. Given the large forecasted number of UAs and the fact that transmissions from their transponders or ADS-B OUT devices will impact the already congested use of 1090 MHz by existing aeronautical surveillance and collision avoidance systems*", but leaves the decision to states as to whether or not to allow UAS to equip 1090MHz ADS-B OUT.

ICAO's statement quoted above is based upon analysis they commissioned that found "*the addition of sUAS transmissions on 1090 MHz resulted in a range reduction of the ADS-B ground station to maintain the same probability of update (98.5%). For 0.1W transmit power, the range reduction was up to 3% for a scenario with 1 UAS /km2 and up to 8% for a scenario with 3 UAS/km2*".

Therefore, a logical approach is to split user groups between frequencies. Given the new airspace users are not already tied to a specific frequency, it seems logical to put them onto a different frequency to 1090. This could be UAT over 978MHz (which is more efficient than 1090 ES), or an option from outside aviation protected spectrum.

5.4.3 - Summary of potential EC spectrum

As noted above, specific aviation "protected" frequencies are currently in use for SoL applications where EC, and more broadly cooperative surveillance, plays a role. However, other frequencies are also within use for EC, and in future yet more frequencies could be utilised, especially by new airspace users. Table 20 below provides a summary table of the key frequencies which are, or could, be utilised for EC together with characteristics of the frequency in terms of EC usage.

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[59] https://www.federalregister.gov/documents/2019/12/31/2019-28100/remote-identification-of-unmanned-aircraft-systems

[60] https://www.icao.int/NACC/Documents/Meetings/2019/ADSBOUT/ADSB-OUT-M-IP04.pdf

Frequency (MHz)	Main use	Pros	Cons	Notes
1090	Mode A/C/S down ADS-B	Safety case complete.	Subject to channel saturation in certain circumstances[61] Protocols relatively inefficient	Aviation "protected" spectrum
978	UAT (ADS-B)	Already deployed in a similar use case in US - Suitable standards could be adopted.	Would require change in UK regulations. More spectrum efficient than 1090 ES.	Aviation "protected" spectrum
868	FLARM	More freedom to innovate	Currently RFID in EU Not aviation protected	Liability remains a question in such a scenario. Similarly, ATCO perspective and Legal Duty of Care is unanswered.
869.525	PilotAware	More freedom to innovate	Not aviation protected	Liability remains a question in such a scenario. Similarly, ATCO perspective and Legal Duty of Care is unanswered.
700, 3400-3800 24250-27500	5G	Spectrum efficient protocol with high capacity. Potential built-in independent positioning. High-integrity applications designed in	EC use not designed or validated. 24GHz+ spectrum have frequency attenuation properties do not suit aviation applications. EC use not designed or validated. Issue of "mobile not aeronautical" in ITU frequency allocation tables on some frequencies.	Infrastructure coverage and incremental costs to support aviation use case not known.

[61] *RF Environment Modelling for Widespread GA1090MHz Conspicuity, October 2019: indicated that if all users equipped with 1090MHz there would be a deterioration in performance due to frequency congestion.*

Frequency (MHz)	**Main use**	**Pros**	**Cons**	**Notes**
800, 1400, 1800, 2300, 2600	4G (LTE)	Spectrum efficient protocol with high capacity. Emergencies Services Network provides an example of "mission critical" use of voice and data over 4G, which includes a safety application suite.	EC use not designed or validated. Issue of "mobile not aeronautical" in ITU frequency allocation tables on some frequencies.	Infrastructure coverage and incremental costs to support aviation use case not known.
1000	LDACS	Built-in independent positioning could form part of a wider improvement in use of radionavigation frequency. Spectrum efficient protocol, similar to 3G/4G	LDACS-NAV concept not demonstrated and validated. Could not be deployed solely on the basis of serving EC. EC use not designed or validated.	ICAO SARPs developed and endorsed in 2018. Flight tested in March 2019. Deployment timescales not clear, but appear to be in 2027-28[62]

Table 20: Summary of main spectrum for EC

[62] https://www.sesarju.eu/index.php/node/3852

6 - DRIVERS AND CONSTRAINTS TO CHANGE

6.1 - General

This section builds on the vision set out in the refreshed Airspace Modernisation Strategy (CAP2298), namely the desire to work towards "a single integrated airspace sharing data to avoid segregation" across the UK.

The scope of change being examined in this report is limited to enhanced Electronic Conspicuity for air and ground applications.

For this change, there are several drivers and constraints identified through reference documents and stakeholder consultations including with the Surveillance Task Force. These show the purpose of the change, and factors that must be overcome or taken into account.

The options for change can then be measured against these vision goals (the purpose or factors to be addressed), to show their comparative alignment to the vision.

6.2 - Drivers for the change to enhanced EC (for air and ground applications)

6.2.1 - Driver 1 – Ability to integrate new users (BVLOS / VLOS / AAM) in a known traffic environment

A clear driver for the AMS is the integration of UAS into non-segregated airspace, enabling safe operations and economic benefit from the new users. In DfT's Future of Transport Regulatory Review (Future of Flight), it highlighted that its ambition is "*to lead the world in innovative aviation technology that has a transformative effect on the movement of people and goods, and delivers tangible benefits to communities, industry and users, expecting that… unmanned aircraft will routinely fly beyond visual line of sight to open up new markets for delivery, surveying, data collection and search-and-rescue… Advanced Air Mobility (AAM) aircraft will offer new ways for people and goods to move around the country, creating new journeys within urban environments and at regional and sub-regional levels*."

A PwC report on UAS concludes that UAS operations could bring a £42bn benefit to the UK economy by 2030, through applications such as medical supplies, consumer deliveries, infrastructure inspection, agricultural surveying, and environmental monitoring. The UAS industry has called for a roadmap to agree the safe shared use of airspace between different users to enable UAS to fulfil their agenda, with a significant hurdle being the "lack of mandatory electronic transponders" (sic) on all users of airspace [Regulatory Horizons Council, Report on Regulation of Drones]. The Innovate UK Transport Vision forecasts a large growth in "UAS freight delivery" in the 2025 and 2030 timeframes.

This is then referenced in the main objectives of the refreshed AMS (CAP2298a), which calls for the "integration of diverse users", recommending that "*airspace modernisation should wherever possible satisfy the requirements of operators and owners of all classes of aircraft, including the accommodation of existing users (e.g. commercial, General Aviation, military, taking into account interests of national security) and new users (e.g. remotely piloted aircraft systems, advanced air mobility, spacecraft, high-altitude platform systems)*."

The UK CAA has been working on methods of integrating BVLOS UAS into UK airspace, moving from Temporary Danger Areas to the creation of UAS TMZ which enable a sponsor to propose an airspace change for UAS integration enabled by some form of Electronic Conspicuity (e.g. ADS-B) being mandated for the defined zone. This was trialled in 2021 at Goodwood, with manned and unmanned aircraft involved. An ICAO FIS service could be provided with surveillance for the known traffic.

However, this Electronic Conspicuity TMZ is currently limited to either a) Mode S transponders or b) 1090 Extended Squitter (ADS-B). It does not include other products such as FLARM or PilotAware. The UK does not have an ADS-B mandate, meaning that a TMZ requiring ADS-B is unlikely to be acceptable to other airspace users on a wider basis.

The creation of Temporary Danger Areas, used in the Oban-Mull and Scilly Isles areas for BVLOS operations, manages risk by segregating traffic. Ultimately, this is a time-intensive and intrusive method of managing airspace, and leads to less access to all users overall, generating significant concern amongst GA users. CAP1861 states that "for a sustainable BVLOS business model, the TDA is not a practical long-term solution, due to its 90-day validity and inability to re-establish without significant changes once expired".

It is also recognised that a mid-long term solution could be "Detect And Avoid", with the BVLOS UAS steering itself well clear of any other traffic. A fully integrated airspace could be developed based on identified rules, as are being developed within the Aviation Rulemaking Committee in the United States. A known traffic environment based on assured position reports is likely to be a requirement of such as CONOPS.

Minimising the need for BVLOS-driven TDAs by managing risk in other ways, and critically creating a clear and consistent risk approach (such that following the "standard" approach should mean safety cases can be more readily approved), is seen as a driver for the change under consideration.

KPIs to be considered when judging the options against this driver:

- Ease of integration of BVLOS, VLOS, AAM and other users into the airspace
- Reduction in the level of segregation

6.2.2 - Driver 2 – Enabling access to airspace

Another driver focuses on the access to airspace for all airspace users. The refreshed AMS (CAP 2298a) states that, ideally, the "air navigation system should avoid to the greatest extent possible imposing restrictions on individual flight operations".

There are two scenarios under consideration for this driver. Firstly, access to existing controlled airspace through the use of flexible airspace management, as advanced in the AMS. This would enable airspace to be managed according to true risk needs, by turning on and off (for example) Class D airspace based around IFR CAT arrivals or departures. To manage the transition between controlled and uncontrolled airspace effectively, it is likely to be necessary to apply a known traffic environment through a TMZ (transponder or other form of acceptable surveillance means).

Secondly, this driver also recognises that, given new users are a reality and in the absence of a mandatory arrangement for Electronic Conspicuity, the likelihood is that access to airspace would degrade if nothing else is done. Therefore, solving the interoperability issue for Electronic Conspicuity and creating a known traffic environment should avoid reductions in available airspace to many GA users (e.g. through the creation of TDAs for BVLOS).

KPIs to be considered when judging the options against this driver:

- Avoidance of new segregated areas from the changing user base for Class G
- Increased flexible management of airspace possible from this option (in practice, by enabling a known traffic environment)

6.2.3 - Driver 3 – Ability to drive safety improvements

The primary requirement for aviation is safety. This is captured in the constraints, focusing on managing safety risk. But there are also potential safety improvements (benefits) to be sought through the change to Electronic Conspicuity enabled applications, which should contribute to reducing risk As Low As Reasonably Practicable.

This driver for safety benefits becomes important considering the unknown risk margin in the future environment due to the relatively large and complex number of changes occurring – changes such as integration of multiple new users, changes in technology, changes in services and evolution of existing barrier risk model (refer also to the UKRI Future Flight Safety Framework[63]). Whilst much work is being done to

[63] *https://www.ukri.org/news/future-flight-challenge-launches-aviation-safety-framework/*

understand the future risk picture, anything which can create additional margin (i.e. effective barriers to unwanted effects) will be helpful in achieving strong safety levels in practice.

Examples could include new applications enabled by enhanced EC, including collision avoidance in the cockpit (e.g. Hybrid ACAS using EC) and improved ICAO FIS with surveillance in uncontrolled airspace, particularly in risk hotspots – e.g. through the provision of a safe crossing service. It is noted that this may need to be compatible with transponders (Mode S and Mode 3/A/C) in the mid-term to deliver benefits vis-à-vis military traffic.

KPIs to be considered when judging the options against this driver:

- Ability of the option to enable clear safety benefits through new applications (beyond situational awareness)

6.2.4 - Driver 4 – Solution enables the market to innovate and invest, giving a clear path forward on the basis of an understood standard leading to benefits

All stakeholders have expressed a desire for policy and regulatory clarity, to enable investment and forward planning. This includes the avionics manufacturers, as they seek to innovate and invest in new products. They need a well-defined future market with the potential to differentiate. A clear interoperable roadmap will enable existing manufacturers to take business decisions on re-designing existing equipment or releasing new product lines, with the assurance that the applications and standards will not alter for a reasonable period.

KPIs to be considered when judging the options against this driver:

- Ability of the option to enable innovation
- Relative clarity of the roadmap (short, medium and long term)
- Extent of supplier investment in product and service development enabled by this option

6.2.5 - Driver 5 – Solution enables the future digitalised airspace (e.g. digital FIS)

Any future EC standard must not only enable the core applications listed in section 2, but also be part of the roadmap for the future digitalised airspace, since there may be integrated CNS solutions in both the airborne and ground domain. It should enable cost-effective solutions which support a range of changes included in the AMS, including digital Flight Information Services and flexible flight planning. Certainly, any solution identified for enhanced Electronic Conspicuity should avoid "dead-ends" in development.

KPIs to be considered when judging the options against this driver:

- Number of related (non-EC) applications which could be enabled by the proposed option (and technologies underpinning)

6.2.6 - Driver 6 – Sustainability through reduced managed airspace volumes, and possible reduced ground infrastructure footprint

The policy driver for sustainability is transposed to this options assessment, focusing on potential benefits through a reduction of the environmental impact from fuel efficiency and ground infrastructure footprint.

The exact impact of this change on sustainability is unclear at present, but it should enable a flexibility in airspace management that allows flight efficiency to be optimised. Use of space-based assets may also help reduce the ground infrastructure footprint.

KPIs to be considered when judging the options against this driver:

- Extent of potential known traffic environment, such that managed airspace volumes can be made flexible
- Potential to use space-based or airborne-based assets (avoiding ground infrastructure)

6.3 - Constraints to be addressed in the change to enhanced EC

6.3.1 - Constraint 1 – No decrease in safety performance levels (ie per user or per flight hour)

The proposed changes in airspace described in the AMS Part 1 are wider than Electronic Conspicuity. The overall risk picture must be assessed and evolved to take account of the new users, techniques and airspace management being proposed, such that there is no decrease in safety performance levels.

EC plays an important role in this. It is unclear whether the change being considered would include all applications of EC (e.g. ICAO FIS with surveillance in Class G, crossing service, flexible airspace management, less TDAs for BVLOS, use of ACAS X etc), and thus the safety performance levels overall should be maintained, or whether each of these applications should be considered as a separate change.

Regardless, there is a need to recognise that the new applications enabled by enhanced EC have a clear safety impact, and therefore the requirements will be different than those applied for EC as an aid to situational awareness (with no safety impact, per CAP 1391).

The accident rate for GA users is significantly higher than the rest of the UK aviation sector. For example, in 2016 there were 244 accidents and serious incidents involving GA compared with 50 involving large commercial aeroplanes[64]. The growth in UAS and UAM operations also presents new safety risks. Incidents recorded by the UK Airprox Board involving UAS operations grew from 6 in 2014 to 125 in 2018.

KPIs to be considered when judging the options against this constraint:

- No decrease in safety performance levels per user – in practice due to extent of interoperability and level of equipage

6.3.2 - Constraint 2 – Affordability for ground stakeholders (including absolute costs)

The proposed solution must be affordable for each user group, or implementation will be delayed or stifled. Affordability has several factors, including absolute cost, perceived benefit (or avoidance of dis-benefits), and availability of incentives.

For ground users, this may be driven by the need for interoperability between EC means (e.g. using TIS-B) as well as the need to receive EC signals, potentially utilising multiple frequencies and protocols. A key discussion over the past decade has been the appropriateness and availability of funding for the new equipment, also impacting affordability for ground users.

For some applications, it may entail a change to certified equipment. As noted in Section 5, the narrative to date has focused on a separate Flight Information Display being provided as an enabler to ICAO FIS (thus avoiding the need to open up and change certified equipment). However, the limited experience with a new display alongside a certified Air Traffic Monitor (Radar Screen) has shown that it leads to confusion, human factors issues, and potential airproxes – for both civil and military controllers. The eventual safety requirement may bring some key cost drivers.

KPIs to be considered when judging the options against this constraint:

- Absolute costs for ANSPs and airports
- Extent of change required for ANSPs and airports (e.g. integration into certified systems)
- Affordability to upgrade to required option (including likely funding routes)

6.3.3 - Constraint 3 – Affordability for airborne users (including absolute costs)

The affordability for airborne users is considered as a separate constraint, as it brings different costs, incentives and possible benefits. It is a clear constraint to change if the total costs or affordability does not allow the majority airspace user population to equip with enhanced EC at a reasonable market price.

[64] *UK Aviation Safety Review 2016*

It is important here to consider the overall affordability, including through-life costs (development, deployment, installation, certification, training etc). This will include the core EC device, but also antennae cost and possibly interfacing systems (e.g. battery, pressure altimeter).

KPIs to be considered when judging the options against this constraint:

- Affordability of equipment for individual airspace users
- Absolute costs to develop technical solutions within option (R&D, validation, certification, integration, deployment, licencing, training etc)

6.3.4 - Constraint 4 – Difficulty of change

The easier the changes to enable the new applications of EC, the more likely the expected benefits will be achieved. Conversely, options for change requiring more barriers to be addressed are less likely to succeed. These barriers could include acceptability, since there is a need to persuade stakeholders of change in order to progress. For example, aircraft mandates are generally less acceptable, and a fairly blunt tool to force through change.

This constraint highlights a desire to reduce complexity where possible. If there are major dependencies for one option (i.e. things that must be resolved outside the control of the EC stakeholders), this also increases the difficulty of change.

There is also the effort (resource, costs) for ground stakeholders for each option. This effort must be proportionate and achievable. For example, a performance-based standard could be inhibited by the ability of the CAA to approve new solutions' conformity – in general, a lot more work would be required to show compliance.

KPIs to be considered when judging the options against this constraint:

- Number of barriers to achieving the change (option) / degree of complexity
- Number of dependencies outside the control of the involved parties (users, suppliers, CAA etc)
- Costs and resources required by CAA and DfT to implement the option
- Acceptability of the option to each stakeholder group

6.3.5 - Constraint 5 – Solution enables interoperability with all users (e.g. Military) and cross-border traffic (e.g. from Europe and US)

Interoperability has been at the core of existing Electronic Conspicuity issues, as described in Section 5. This relates to the air and ground applications, but also to the UK's interoperability with other States.

The move to ICAO FIS (with or without surveillance) is intended to improve this situation, meaning pilots flying to or from the EU should benefit from a consistent service. A driver is then to transpose this procedural interoperability into consistent technical standards, at least from a performance-based perspective.

Even in Class G, there is considerable traffic from outside the UK (personal transport, leisure, cargo, specialised applications, military, ferry flights etc), as well as an expectation of new platforms from outside the UK (e.g. specialised applications such as coastal monitoring or longer range UAS cargo flights). The future solution should be interoperable with this traffic for the most efficient and safe service to be provided.

In the very long-term, anyone can be interoperable. But this solution must take into account the ability of users to update their equipment (including investment timescales) and the resultant need for interoperability with existing equipage (e.g. Mode S or even Mode 3/A/C on combat aircraft).

A further issue is the market development – by maintaining interoperability with overseas markets (through consistent regulations or standards), it enables larger markets for avionics or ground infrastructure, and ultimately lower costs and increased innovation potential for users.

KPIs to be considered when judging the options against this constraint:

- Extent of interoperability across user base (ground and air) enabling the enhanced applications
- Extent of interoperability geographically

6.3.6 - Constraint 6 – Feasible and viable in the context of wider legislation and regulation

The change must be consistent with the wider legislative and regulatory package. Whilst specific adjustments can be made to legislation, for example as ICAO FIS is introduced, the requirement for complex changes to existing legislation should be avoided as there may be other impacts or barriers that may be seen.

This includes the existing ICAO SARPS. The UK aims to be aligned to ICAO norms, and Annex 2, Annex 11 and PANS-ATM should all be considered when identifying the requirements for the enhanced EC system.

KPIs to be considered when judging the options against this constraint:

- Consistency with existing ICAO standards
- Consistency with existing OFCOM requirements
- Consistency with the Aviation Act
- Consistency with existing surveillance standards and ICAO norms for ATS

7 - REQUIREMENTS FOR THE CHANGE TO ENHANCED EC

7.1 - General

One of the issues with this study has been a lack of clear application requirements against which to define the future standard.

Whilst ATC separation services have developed clear surveillance requirements (ref ECTL ATM Surveillance Performance Standards, ICAO PANS-ATM Section 8, EUROCAE ED102A / RTCA DO260B), the application of surveillance for ICAO FIS, crossing services or airborne detect and avoid is less mature.

Conversely, the applications being considered are clearly a step-up from aids to situational awareness or airborne traffic detection. The provision of deconfliction advisories and crossing services in Class G, and the use of enhanced EC in Detect-And-Avoid and potentially manned collision avoidance devices, all point to safety impact from the use of enhanced EC surveillance data.

A set of functional requirements can be developed independent of the regulatory option chosen for standards specification. Once the regulatory option is known, these can be developed further via a Concept of Operations (Operational Services description) and more detailed technical requirements.

This section therefore sets out a high level of functional requirements to deliver the identified applications in the UK context.

They are requirements: i.e. they are intended to be true and valid 100% of the time. Any option should then conform to these requirements.

These requirements are only focused on enabling the enhanced set of applications.

Note: they assume that CAP1391 (EC) as an aid to situational awareness will continue to exist. Thus those devices developed for situational awareness (no safety impact) could still exist. They would not however be able to enable the applications listed in this report.

7.2 - Functional requirements for the option

The option shall enable an assured SUR signal to be received by other stakeholders, both ground and air.

This functional requirement sets out the basic surveillance need, that a signal needs to be received by airborne and ground stakeholders to support the envisaged applications. This signal must be assured; it must have properties which have a certain probability of being valid upon reception by the user.

The option shall enable applications with clear safety impact. These shall include:

- **ICAO FIS using surveillance – in Class G and Class E**
- **Crossing service (Danger Area, ATZ etc)**
- **A source of information supporting UAS detect-and-avoid**
- **Input into Hybrid ACAS (ACAS X) and future collision avoidance applications**

These applications arise from the Airspace Modernisation Strategy, enabling the integration of new users into uncontrolled airspace and supporting a more flexible airspace management process.

They are defined to give certainty in the future direction of airborne-derived surveillance, enabling a wide set of potential uses dependent on the decisions taken on policy, and innovation in the market.

Each of the applications has a clear safety impact (see section 2.8.5). For example, ICAO FIS will require positive identification of the aircraft using the surveillance inputs, and therefore rely on those inputs to provide a safe and efficient service. Likewise, detect-and-avoid and airborne collision avoidance applications must benefit from assured information to avoid nuisance alerts, false alerts and missed alerts (as well as concerns about spectrum use). Per ICAO Annex 10 Vol 4, the hybrid ACAS validates the position provided by the airborne source using direct active range measurement (once every 60 seconds, or once every 10 seconds once a near-threat).

This contrasts with the CAP1391 stipulation that the use of Electronic Conspicuity devices under CAP1391 must have no safety impact, and purely be used as an aid to situational awareness (for see-and-avoid, and more recently as an input to Flight Information Displays for Basic FIS).

The option shall support a defined low level surveillance coverage, potentially addressing terrain issues over the specified area

Whilst it is not thought that full Class G coverage is initially required at low level (e.g. below 400ft), any option chosen must be able to support a defined low-level surveillance coverage to the required standard. For full benefit, the option chosen must also be able to address terrain issues.

The option shall enable reasonable application-level requirements (i.e. as received by the user undertaking the application, such as a GA aircraft, UAS or ground ATS provider).

Any option chosen must enable a set of requirements at the receiving domain (e.g. aircraft or ground), taking account of the potential functional architecture of the option.

7.3 - Airborne domain

The option shall enable (and assure) aircraft identity, position, velocity, and data quality parameters (accuracy and integrity) to support the identified applications.

Any option for applications enabled by enhanced EC must assure a surveillance performance. This could in theory be achieved through ground surveillance (e.g. MLAT) as well as the aircraft enhanced EC, and it is considered as an option. However, in the absence of ground surveillance across the required coverage area, particularly given the low-level coverage requirements, the output of the airborne EC device must be able to meet the application requirements. In practice, this will include aircraft identification and assured surveillance accuracy and integrity parameters.

This study will use precedents and benchmarks to determine the suitability of potential requirements. The current deconfliction advisory minima are being updated (since they currently relate to UK FIS rather than ICAO FIS), but the advisory minima are likely to be less than the 3NM/1000ft used currently for known traffic. Likewise, the UAS ability to detect and avoid will probably use limits far less than 3NM/1000ft.

As the applications have safety impact, the need for containment bounds (i.e. probabilities of the position being within a certain error bound) becomes higher. The standard risk argument sets an acceptable level of safety risk (e.g. for Mid Air Collision), identifies potential causes arising from the application, and allocates integrity requirements to functional aspects contributing to that application. The acceptable level of risk in Class G (with the types of aircraft involved) might be less than for CAT in controlled airspace, and this would eventually reflect in a reduced surveillance standard performance, even though the applications have safety impact.

NOTE ON REQUIREMENTS

The existing CAP1391 specifies the following information. This could be a baseline for the enhanced EC standard.

- Airborne position;
- Aircraft identification and category;
- Airborne velocity;
- Aircraft operational status;
- Extended squitter aircraft status message.

EASA's ADS-L concept specifies a similar list of likely requirements, but adds in the list of potential specifications the following, which give a Quality of Service and containment bounds:

- position accuracy;
- velocity accuracy;
- integrity parameters;
- system design assurance.

At this stage of the assessment, it is not known what mix of surveillance sources or information might be used. Therefore, it is impossible to yet say firmly which parameters must be sent by the enhanced EC device, since integrity could be assured from the ground or through multiple sensors.

The option shall take into account wider factors impacting the successful (valid) reception of the signal, including in-aircraft obscuration, spectrum and receiving equipment (e.g. ground assets).

It is not enough to merely define an emitting standard. The interoperability of domains must be considered, impacting the performance of the surveillance signal, as received at the user. This can include the ability of the aircraft to transmit the signal consistently and coherently, the environment (particularly the probability of successful reception), and the performance of the receiving system, either airborne or ground.

8 - OPTIONS FOR DEPLOYMENT

8.1 - General

This section describes the options that have been developed to consider an approach for the provision of a UK wide electronic conspicuity solution. The options presented have taken into account the factors that have been previously described in detail in Sections 2 to 7, namely:

- Must be capable of meeting the expectations of new airspace users (Section 2)
- Must have existing standard or be capable of developing standards supporting enhanced EC (Section 3)
- Must be cognisant of the current state of availability and adoption of EC technologies within aviation, focussing on today's situation, but also looking to the forecasted evolution (Section 4). The options shall take into consideration the key capabilities and uptake of each technology and shall include airborne and ground-based technology solutions.
- Must consider the interoperability challenges required to develop the minimum technical standards for EC and associated surveillance (Section 5). Interoperability recognises that regulatory or standards decisions are not taken in isolation; a UK national enhanced EC standard should consider the developments at international level, particularly in Europe, the US and ICAO. Options shall be required to ensure that all requirements for technical interoperability are met (confirming that all elements forming the surveillance chain operate as expected) and that Spectrum issues (particularly use for Safety of Life) have been considered.
- Must build upon on the vision set out in the refreshed Airspace Modernisation Strategy (CAP2298), namely the desire to work towards "a single integrated airspace sharing data to avoid segregation" across the UK. Options to be developed should conform to the Drivers and Constraints detailed in Section 6:
  - **Driver 1** – Ability to integrate new users (BVLOS / VLOS) in a known traffic environment.
  - **Driver 2** – Enabling access to airspace.
  - **Driver 3** – Ability to drive safety improvements.
  - **Driver 4** – Solution enables the market to innovate and invest, giving a clear path forward on the basis of an understood standard leading to benefits.
  - **Driver 5** – Solution enables the future digitalised airspace (e.g. digital FIS).
  - **Driver 6** – Sustainability through reduced managed airspace volumes, and possible reduced ground infrastructure footprint.
  - **Constraint 1** – No decrease in safety performance levels (ie per user or per flight hour).
  - **Constraint 2** – Affordability for ground users (including absolute costs).
  - **Constraint 3** – Affordability for airborne users (including absolute costs).
  - **Constraint 4** – Difficulty of change.
  - **Constraint 5** – Solution enables interoperability with all users (e.g. Military) and cross border traffic (e.g. from Europe and US).
  - **Constraint 6** – Feasible and viable in the context of wider legislation and regulation.
- Must be be able to conform to the functional requirements detailed in Section 7:
  - The option shall enable an assured SUR signal to be received by other stakeholders, both ground and air.
  - The option shall enable applications with clear safety impact. These shall include:
    - ICAO FIS using surveillance – in Class G and Class E
    - Crossing service (Danger Area, ATZ etc)
    - A source of information supporting UAS detect-and-avoid
    - Input into Hybrid ACAS (ACAS X) and future collision avoidance applications

- The option shall support a defined low level surveillance coverage, potentially addressing terrain issues over the specified area
- The option shall enable reasonable application-level requirements (i.e. as received by the user undertaking the application, such as a GA aircraft, UAS or ground ATS provider).
- The option shall enable (and assure) aircraft identity, position accuracy and integrity to support the identified applications.
- The option shall take into account wider factors impacting the successful (valid) reception of the signal, including in-aircraft obscuration, spectrum and receiving equipment (e.g. ground assets).

8.2 - Options development

Factors considered when defining the options for development were that the options must be comprehensive, must meet the requirements, take account of the existing environment, and enable future scenarios (applications). Utilising the factors listed above and following extensive consultation with the CAA and the Surveillance Task Force and its members, an iterative approach was followed, exploring the "sub-options" that could be potentially meet the requirements considering the drivers and constraints:

- At a minimum, what happens if you do nothing?
- Can you meet the requirement from changing ground infrastructure alone?
- What can be done within the scope of existing regulations and standards?
- What is the art of the possible with the development of new standards?
- What does a full-mandate approach look like?

The goal was to be as comprehensive in the range of options at this phase. The following options were identified for assessment, aiming to meet the requirements and align to the vision:

ID	Option title	
1	Do nothing	
2	Do minimum (airborne requirements unchanged)	
3a	Adopt existing global standards for regulated EC devices, voluntary equipage, TMZ (enhanced EC) used	Manned aircraft 1090MHz, UAS 978MHz
3b		Manned aircraft 978MHz, UAS 1090MHz
3c		All aircraft 1090MHz
3d		US model. Class A and above FL180, 1090MHz. All others to include 978MHz. TIS-B on ground.
3e		Certified aircraft 1090MHz. Uncertified aircraft – no requirement.
4a	Performance-based standard, voluntary equipage, TMZ (enhanced EC) used	Certified aircraft 1090MHz, uncertified a/c performance-based standard (ISM band)
4b		Certified aircraft 1090MHz, uncertified a/c performance-based standard (protected aviation band)
4c		Existing equipped a/c 1090MHz, remaining a/c performance-based standard (ISM band)
4d		Existing equipped a/c 1090MHz, remaining a/c performance-based standard (protected aviation band)
4e		Existing equipped a/c 1090MHz, remaining a/c design assured performance-based standard (protected aviation band)
5a	Mandate all airspace users to equip with regulated EC devices	All aircraft 1090MHz
5b		Manned have 1090MHz, UAS have 978MHz
5c		Existing equipped a/c 1090MHz, remaining a/c design assured performance-based standard (protected aviation band)

Table 21: Table of Options

8.3 - Options analysis

8.3.1 - Process applied

All options have been assessed using a Multi Criteria Decision Analysis (MCDA) process. This process provides an established method by which different options can be assessed. It allows for a structured evaluation of different options and to compare the choices that exist easing decision making. The general process that is applied when undertaking a MCDA is summarised in the following illustration.

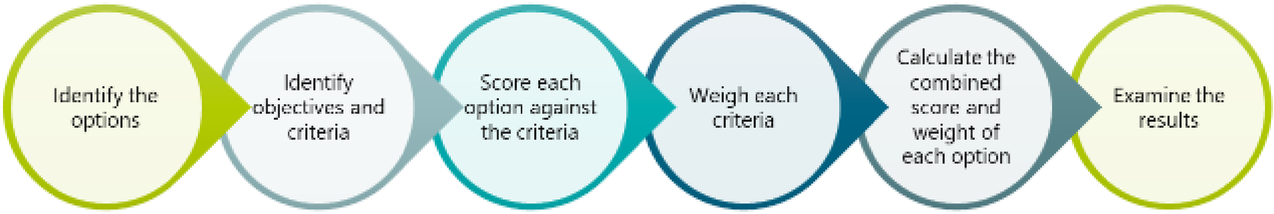

Figure 19: Stages in applying the MCDA process

- **Identify the options:** The objective of this step is to ensure that as wide a set of options are considered as possible. This helps to avoid bias and is established with the acceptance that there may need to be changes to the options that are identified when they are carried forward. The options considered and proposed for the MCDA have been presented in Section 8.2.
- **Identify objectives and criteria:** The objective of this step is to determine how the different criteria against which each of the options should be assessed. Assessing the objectives and criteria needs to consider the consequences of the options being assessed – not the options themselves. The criteria should be specific and measurable. In the application of the MCDA in this case, we have selected the high level objectives as defined in Section 6. The drivers and constraints assessed for each of the options then considers the impacts and the impact of each against what the consequences of the option are on the criteria – for example – does it have a high impact on achieving the criteria or block the criteria completely?
- **Score the options:** The objective of this step is to compare how each of the options are able to deliver against each selected criteria. It is a qualitative process that is based on comparisons between the different options. The strength of the scale applied in this case has been given a ranking ranging 1 through 5. For each option, a high score means that the option delivers against the drivers and has minimal impact from a constraint perspective. The inverse being true for the lower scores.
- **Weigh against each criteria:** This step considers how each of the drivers and constraints should be considered from a holistic perspective. It determines overall which drivers and constraints are more important factors that should be considered. In this analysis, we have considered the drivers and constraints separately and weighed each criteria relative to the others. A linear weighting has been applied with the following weightings applied – higher weighting having more of an influence on the eventual result:
  - Drivers:
    - Ability to integrate new users (**Weight 5 – 26%**)
    - Enabling of access to airspace (**Weight 5 – 26%**)
    - Ability to drive safety improvements (**Weight 3 – 16%**)
    - Enables the market to innovate and invest (**Weight 3 – 16%**)
    - Enables future digitalised airspace (**Weight 2 – 11%**)
    - Enhances sustainability (**Weight 1 – 5%**)
  - Constraints:
    - no decrease in safety performance levels (**Weight 6 – 27%**)
    - affordability for the ground (**Weight 3 – 14%**)
    - affordability for the air (**Weight 5 – 23%**)

- difficulty of change (**Weight 4 – 18%**)
- interoperability (users and ICAO) (**Weight 2 – 9%**)
- Feasibility with respect to applicable legislation and regulations (**Weight 2 – 9%**)

- **Calculate the combined score and weight of each option:** In combined the scores and weightings the objective of the MCDA process is to allow a comparison between the different options excluding correlation between each of the criteria. In this case, the sum product has been applied for each option to produce a composite score taking into account the individual weightings and criteria scores.
- **Examine the results:** The final step in the process is examining the output. This is presented in Section 8.3.3. The top level scores are given as a result of the proposed sum product being applied to each of the options.

8.3.2 - Option scoring

The MCDA process described above has been applied as illustrated in Figure 19: Stages in applying the MCDA process. This shows the individual scores that have been applied per option and per criteria and the resulting score applied to each solution or part solution.

The rationale for the individual scores applied to each of the criteria is described above in Section 3.2 which outlines the relative strengths and weaknesses of each of the options that have been considered in determining the ranking.

OPTION ID	OPTION TITLE				DRIVERS						CONSTRAINTS			
		ABILITY TO INTEGRATE NEW USERS	ENABLING OF ACCESS TO AIRSPACE	ABILITY TO DRIVE SAFETY IMPROVEMENTS	ENABLES THE MARKET TO INNOVATE AND INVEST	ENABLES FUTURE DIGITALISED AIRSPACE	ENHANCES SUSTAINABILITY	NO DECREASE IN SAFETY PERF LEVELS	AFFORDABILITY GROUND	AFFORDABILITY AIR	DIFFICULTY OF CHANGE	INTEROPERABLE (USERS AND ICAO)	FEASIBLE VS APPLICABLE LEGISLATION AND REGS	
	WEIGHTING	**5**	**5**	**3**	**3**	**2**	**1**	**6**	**3**	**5**	**4**	**2**	**2**	**SCORE**
1	Do nothing	1	1	1	2	1	1	1	5	5	5	2	3	**98**
2	Do minimum (airborne requirements unchanged)	3	2	3	2	2	1	2	1	5	3	3	5	**113**
3a	Manned aircraft 1090MHz, drones 978MHz	5	4	5	3	2	5	4	3	2	4	2	5	**151**
3b	Manned aircraft 978MHz, drones 1090MHz	5	4	5	3	4	5	2	1	1	1	1	1	**110**
3c	All aircraft 1090MHz	4	4	4	1	1	4	3	4	3	4	4	5	**140**
3d	US model. Class A and above FL180, 1090MHz. All others to include 978MHz. ADS-R/TIS-B	5	4	5	3	4	5	4	1	3	2	4	4	**148**
3e	Manned aircraft and UAS>25kg (certified/specifc) equip with 1090MHz. UAS <25kg MTOW – no requirement (assume smaller UAS are responsible for separation from manned aircraft).	3	3	3	3	1	4	2	3	2	2	3	3	**105**
4a	Certified aircraft 1090MHz. Uncertified aircraft – equip according to performance based standard (ISM band)	5	4	5	5	3	5	3	1	2	3	3	1	**137**
4b	Certified aircraft 1090MHz. Uncertified aircraft – equip according to performance based standard (protected band)	5	4	5	4	3	5	4	1	2	2	3	2	**138**
4c	Existing equipped aircraft remain on 1090. Remaining aircraft - equip according performance based standard (ISM)	5	4	5	5	4	5	3	1	3	3	2	1	**142**
4d	Existing equipped aircraft remain on 1090. Remaining aircraft - equip according performance based standard (protected band)	5	4	5	4	4	5	4	1	3	2	2	2	**143**
4e	Existing equipped aircraft remain on 1090. Remaining aircraft - equip with design assured performance based standard (protected band)	5	4	5	3	4	5	4	2	2	1	2	4	**138**
5a	All aircraft 1090MHz	4	5	4	1	1	4	3	4	1	2	4	5	**127**
5b	Manned have 1090MHz, Drones have 978MHz	5	5	5	3	2	5	5	3	2	2	4	5	**158**
5c	Existing equipped aircraft remain on 1090. Remaining aircraft - equip with design assured performance based standard (protected band)	5	5	5	3	4	5	5	2	1	1	2	4	**144**

Table 22: MCDA Scoring

8.3.3 - Analysis Results

Given the linear approach followed with the criteria weighting, there are marginal differences in the resulting scores. The differences between the options given their respective drivers and constraints could be expected to vary if a different approach were taken to the scoring or if additional weight had been applied. For example, the sustainability weighting being approximately five time less significant than the ability to integrate new users.

Based on the existing analysis, the top five options in rank are:

- **Option 5B:** Mandated. Manned have 1090MHz, UAS have 978MHz (**score 158**)
- **Option 3A:** Manned aircraft 1090MHz, drones 978MHz (**score 151**)
- **Option 5C:** Mandate existing equipped aircraft remain on 1090. Remaining aircraft, equip with design assured performance based standard (protected band)
- **Option 3D:** US Model. Class A and above FL180, 1090MHz and all others 978MHz including TABS (**score 148**)
- **Option 4D:** Existing equipped aircraft remain on 1090. Remaining aircraft - equip according to performance based standard (protected band) (**score 143**)

8.3.4 - Analysis Results by Option

The analysis results (as shown in Table 22) are expanded (with a rationale for the scoring) in the proformas below (section 8.3.5 - . The drivers, constraints and KPIs are reiterated in Table 23:

DRIVERS:		KPIS
1	Ability to integrate new users (BVLOS / VLOS) in a known traffic environment	- Ease of integration of BVLOS, VLOS, AAM and other users into the airspace - Reduction in the level of segregation
2	Enabling access to airspace	- Avoidance of new segregated areas from the changing user base for Class G - Increased flexible management of airspace possible from this option (in practice, by enabling a known traffic environment)
3	Ability to drive safety improvements	- Ability of the option to enable clear safety benefits through new applications (beyond situational awareness)
4	Solution enables the market to innovate and invest, giving a clear path forward on the basis of an understood standard leading to benefits	- Ability of the option to enable innovation - Relative clarity of the roadmap (short, medium and long term) - Extent of supplier investment in product and service development enabled by this option
5	Solution enables the future digitalised airspace (e.g. digital FIS)	- Number of related (non-EC) applications which could be enabled by the proposed option (and technologies underpinning)
6	Sustainability through reduced managed airspace volumes, and possible reduced ground infrastructure footprint	- Extent of potential known traffic environment, such that managed airspace volumes can be made flexible

		- Potential to use space-based or airborne-based assets (avoiding ground infrastructure)
CONSTRAINTS:		
1	No decrease in safety performance levels (i.e. per user or per flight hour)	- No decrease in safety performance levels per user – in practice due to extent of interoperability and level of equipage
2	Affordability for ground stakeholders (including absolute costs)	- Absolute costs for ANSPs and airports - Extent of change required for ANSPs and airports (e.g. integration into certified systems) - Affordability to upgrade to required option (including likely funding routes)
3	Affordability for airborne users (including absolute costs)	- Affordability of equipment for individual airspace users - Absolute costs to develop technical solutions within option (R&D, validation, certification, integration, deployment, licencing, training etc)
4	Difficulty of change	- Number of barriers to achieving the change (option) / degree of complexity - Number of dependencies outside the control of the involved parties (users, suppliers, CAA etc) - Costs and resources required by CAA and DfT to implement the option
5	Solution enables interoperability with all users (e.g. Military) and cross-border traffic (e.g. from Europe and US)	- Extent of interoperability across user base (ground and air) enabling the enhanced applications - Extent of interoperability geographically
6	Feasible and viable in the context of wider legislation and regulation	- Consistency with existing ICAO standards - Consistency with existing OFCOM requirements - Consistency with the Aviation Act - Consistency with existing surveillance standards and ICAO norms for ATS

Table 23: Drivers, Constraints and KPIs

8.3.5 - Option Analysis Rationale

8.3.5.1 - Option 1.

Option	Title	Score
1	**Do nothing**	98
Description		
No change to present operations. Low impact option for all current users; maintains the current Status Quo.		
Strengths of option (in relation to delivering enhanced EC services)		
No additional regulation development required. No change to equipage for ground or air. Utilises ground and airborne equipment that is currently available and in widespread use. No investment required.		
Weakness of option (in relation to delivering enhanced EC services)		
Does not meet the stated requirements of enabling an assured SUR signal, nor supports a defined low level surveillance coverage. Does not enable (or assure) for all users aircraft identity, position accuracy and integrity, nor takes into account wider factors impacting the successful (valid) reception of the signal. The option does not for 100 % of UK airspace enable ICAO FIS using surveillance (within defined airspace), Crossing services, nor acts as a source of information supporting UAS detect-and-avoid and input into Hybrid ACAS (ACAS X) and future collision avoidance applications. Voluntary nature of the options allows users to choose not to equip at all, therefore relies upon primary radar sources to allow creation of known traffic environment for ICAO FIS with Surveillance. Large-scale airborne interoperability issues between solutions; Not all airborne solutions are within recognised Protected Aviation Band or have proven integrity levels, therefore cannot provide required of safety arguments to provide Safety of Life services. The ability to meet the requirement to enable reasonable application-level requirements will vary between users due to the diverse range of airborne equipment.		
Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Does not easily integrate BVLOS, VLOS, AAM and other users into the airspace; requires introduction of new segregations of airspace.	1
2	Requires new segregated areas for introduction of new users. No increase in the flexible management of airspace possible from this option. Doe not enable a 100% known traffic environment.	1
3	Does not enable clear safety benefits through any new applications.	1
4	The option does not further enable innovation beyond that available today. Gives no clarity of the roadmap for development in the short, medium and long terms. Supplier investment in product and service development maintained at current levels.	2
5	Enables no additional related (non-EC) applications and technologies underpinning them.	1
6	Does not enable a known traffic environment, therefore managed airspace volumes cannot be made flexible. Does not further enable ability to use space-based or airborne-based assets (avoiding ground infrastructure). Does not open airspace to be available for direct routings over that available currently.	1
Constraints:		
1	More users airborne increase safety risk per user. No change to current operations to alleviate this. Continued reliance on See and Avoid. No increase in airborne equipage or level of direct air-air interoperability. Doesn't enable enhanced EC as no change to the existing standards or equipment.	1
2	No change, no costs.	5
3	No change, no costs.	5
4	No change no difficulty.	5
5	No change to the current interoperability issues across existing user base. Will not enable the enhanced applications. Continues to be unique UK solution.	2

6	Consistency with existing ICAO standards but will not meet requirements for ICAO FIS or enable new applications such as ACAS X. Consistent with existing OFCOM requirements, the Aviation Act, existing surveillance standards and ICAO norms for ATS.	3

8.3.5.2 - Option 2.

Option	Title	Score
2	**Do minimum (airborne requirements unchanged)**	113
Description		
All airspace users (including new entrants) may choose to have a form of EC or transponder; only mandated for access to specified airspace types. Focus therefore on development and use of ground infrastructures and rebroadcast facilities (which may include use of proprietary/mobile telephone solutions or 978MHz). Ground infrastructure is responsible for providing the validation/integrity/accuracy of displayed aircraft positions through MLAT-like approaches.		
Strengths of option (in relation to delivering enhanced EC services)		
Utilises airborne equipment that is currently available and in widespread use; no requirement for current airborne equipage to change. Meets the stated requirements of enabling an assured SUR signal, supporting a defined low level surveillance coverage (assuming a comprehensive ground network), enabling (and assuring) aircraft identity, position accuracy and integrity, and shall take into account wider factors impacting the successful (valid) reception of the signal. The option can enable ICAO FIS using surveillance (within defined airspace), Crossing services, can act as a source of information supporting UAS detect-and-avoid and input into Hybrid ACAS (ACAS X) and future collision avoidance applications.		
Weakness of option (in relation to delivering enhanced EC services)		
Limited airborne interoperability between solutions; relies entirely on ground system re-broadcast to overcome interoperability issues. Large-scale investment and development of ground station network required. Not all airborne solutions will be within recognised Protected Aviation Band therefore significant development required of safety arguments for many of the solutions that currently aren't providing Safety of Life services. Voluntary nature of the options allows users to choose not to equip at all, therefore relies upon primary radar sources to allow creation of known traffic environment for ICAO FIS with Surveillance. The ability to meet the requirement to enable reasonable application-level requirements will vary between users due to the diverse range of airborne equipment.		
Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Will reduce levels of segregation, however, score reduced as will still not be possible to integrate all users, even if managing to integrate PilotAware, FLARM, etc. Do not know at this stage if BVLOS operations will require assured data and how this will be provided.	3
2	Issues remain over the assurance of data therefore will be unable to access certain airspaces; BVLOS will require assured data to detect & avoid. Solution does not support flexible use of airspaces it still does not create 100% known traffic environment.	2
3	There are safety benefits; more users will be aware of each other, some of the application benefits will be available. Would still enable drone-to-drone deconfliction. However, integrity forced on ground system (e.g. assured MLAT system) which could enable ICAO FIS, but still users with no form of EC.	3
4	No driver for airborne market to develop, innovate or grow. Can build in ground-based integrity, but this will be reliant on many different manufacturers so is very vulnerable to changes to airborne equipment. This again may constrain innovation. Doesn't give clear roadmap for way ahead.	2
5	The option (and technologies underpinning) enables some non-EC related applications, the score is driven down by the diverse levels and types of airborne equipage.	2
6	Totally reliant on new ground infrastructure. Air-Air incompatibility issues remain. Voluntary take up so , many airborne wont gain additional access to existing or new airspace blocks, and won't contribute to creation of known traffic environment.	1
Constraints:		

1	More users airborne increase safety risk per user. Ground based stations will alleviate this to an extent, but voluntary nature increase risk for uncontrolled airspace. Continued reliance on See and Avoid. No increase in airborne equipage or level of direct air-air interoperability	2
2	Large-scale investment required for ground station network, upgrading of existing equipment and integration into existing certified systems.	1
3	Very affordable for existing users (no requirement to change), utilises existing airborne technology therefore no absolute costs for development.	5
4	Complex Ground network to be implemented. Large number of dependencies outside the control of the involved parties (users, suppliers, CAA etc). Some costs and resources required by CAA and DfT to implement the option.	3
5	Existing airborne users have access to increased interoperability through ground station network enabling some enhanced applications. Unique UK solution so may interoperability issues may exist for international users.	3
6	Utilises existing ICAO standards. Airborne users continue with existing compliance to OFCOM requirements. Maintains consistency with the Aviation Act and with existing surveillance standards and ICAO norms for ATS.	5

8.3.5.3 - Option 3A.

Option	Title	Score
3A	**Adopt existing global standards for regulated EC devices. Manned aircraft - 1090 ES (Out minimum), Unmanned 978 UAT In/Out.**	**151**
Description		
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. 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.		
Strengths of option (in relation to delivering enhanced EC services)		
By utilising the extant internationally recognised standards for EC, COTS equipment would be widely available for current airspace users. UAS users may have to build-in infrastructure or equipment costs as they develop their networks, infrastructure and ground-stations required to enable their operations. Meets currently recognised international standards and levels of interoperability. All within protected Aviation bands of the spectrum. Ease of constructing safety arguments. Meets all of the stated requirements. Minimises potential 1090 MHz saturation and enables new digital services (TIS-B, FIS-B) to be available on 978 MHz Aircraft not requiring controlled airspace access or IFR services may maintain on current equipment fit. 978 Mhz infrastructure to provide re-broadcasting ground architecture enabling TIS-B, FIS-B. 1090 MHz users will be electronically visible and can choose how to receive 978 data or digital services for situation awareness.		
Weakness of option (in relation to delivering enhanced EC services)		
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. Will change the current airborne or ground-based equipage and uptake. Will require manned aircraft and BVLOS UAS to equip ADS-B (if not already). Ground-based equipment required to receive ADS-B (if not already doing so). Some military users may be slow/unable to comply		
Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Within TMZs, BVLOS, VLOS, AAM and other users integrated into the airspace. Suitably equipped aircraft will be able to access segregated airspace.	5
2	Class G only users equipment requirements unchanged. Segregated airspace blocks available to suitably equipped aircraft. Increased flexible management of airspace possible from this option by enabling a known traffic environment within TMZs. Voluntary equipage so there will remain some element of airspace users who are restricted in access to segregated airspace.	4
3	Enables known traffic environment within TMZ, enables ICAO FIS, enables new applications with clear safety benefits (beyond situational awareness).	5
4	Limited ability to innovate, inhibits UAS development to within 978 standards. Manufacturers have to innovate around know technologies. Gives clarity of the roadmap in the short, medium and long term. Allows supplier investment in products and services.	3
5	Related (non-EC) applications which could be enabled by this option, and the technologies underpinning it, are mainly on the UAS using 978MHz. Little applications directly available for manned aircraft on 1090MHz.	2
6	Creates known traffic environment within TMZs, such that managed airspace volumes can be made flexible. Increases EC within other airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure).	5
Constraints:		
1	Still requires TMZs where BVLOS will be integrated. Mixed equipage and voluntary uptake outside of the TMZs, with potentially more users. Increase in EC may alleviate some of the current interoperability issues.	4

2	ANSPs and airports may be required to equip with ADS-B (if not already), but this could be built into planned equipment upgrades and hence more affordable. Recognised technology and standards, so potentially smoother integration into certified systems. Required additional ground stations may be integrated into UAS network development costs.	3
3	Many airborne users equipped, but many requiring segregated airspace access will need to equip with ADS-B solutions. COTS equipment available so development costs low.	2
4	Uses existing international standards. Work will be required to initiate use of 978MHz in UK Airspace.	4
5	UAS 978MHz users unlikely to be visible to unequipped military users or international traffic unable to access the enhanced applications. Unique UK solution so limited interoperability geographically.	2
6	Consistent with existing ICAO standards, Consistent with existing OFCOM requirements, Consistent with the Aviation Act, Consistent with existing surveillance standards and ICAO norms for ATS.	5

8.3.5.4 - Option 3B.

Option	Title	Score
3B	**Adopt existing global standards for regulated EC devices. Manned aircraft - 978 UAT (Out minimum), Unmanned 1090 ES In/Out.**	**110**
Description		
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. Existing user types equip with 978 MHz (Out minimum) devices, new user groups (UAS) equip with 1090 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.		
Strengths of option (in relation to delivering enhanced EC services)		
By utilising the extant internationally recognised standards for EC, COTS equipment would be widely available for current airspace users. UAS airspace users may have to build in infrastructure or equipment costs as they develop their networks, infrastructure and ground-stations required to enable their operations. Meets currently recognised international standards and levels of interoperability. All within protected Aviation bands of the spectrum. Ease of constructing safety arguments. Meets all of the stated requirements. Enables new digital services (TIS-B, FIS-B) to be available on 978 MHz for manned aircraft. Aircraft not requiring controlled airspace access or IFR services may maintain on current equipment fit. 978 MHz users will be electronically visible and can choose how to receive 1090 data or other digital services for situation awareness.		
Weakness of option (in relation to delivering enhanced EC services)		
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. ADS-B ground station network required. No current airborne or ground-based equipage and uptake meets these requirements; will require manned aircraft and BVLOS UAS to equip with new ADS-B fits. Ground-based equipment required to receive ADS-B (if not already doing so). All military users may be slow/unable to comply. Depending upon uptake by UAS, may cause issues with 1090MHz saturation.		
Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Within TMZs, BVLOS, VLOS, AAM and other users integrated into the airspace. Suitably equipped aircraft will be able to access segregated airspace.	5
2	Class G only users equipment requirements unchanged. Segregated airspace blocks available to suitably equipped aircraft. Increased flexible management of airspace possible from this option by enabling a known traffic environment within TMZs. Voluntary equipage so there will remain some element of airspace users who are restricted in access to segregated airspace.	4
3	Enables known traffic environment within TMZ, enables ICAO FIS, enables new applications with clear safety benefits (beyond situational awareness).	5
4	Limited ability to innovate, inhibits UAS development to within 1090 standards and manned aircraft within 1090 standards. Manufacturers have to innovate around know technologies. Gives clarity of the roadmap in the short, medium and long term. Allows supplier investment in products and services.	3
5	Related (non-EC) applications which could be enabled by this option, and the technologies underpinning it, are mainly on the manned aircraft using 978MHz. Little applications directly available for UAS aircraft on 1090MHz.	4
6	Creates known traffic environment within TMZs, such that managed airspace volumes can be made flexible. Increases EC within other airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure).	5
Constraints:		

1	Still requires TMZs where BVLOS will be integrated. Mixed equipage and voluntary uptake outside of the TMZs, with potentially more users. Increase in EC may alleviate some of the current interoperability issues. Incompatible with traffic arriving internationally and with military equipment fits.	2
2	ANSPs and airports may be required to equip with both 1090 & 978 ADS-B; could be built into planned equipment upgrades but not all systems receive 978.Recognised technology and standards, so potentially smoother integration into certified systems. Required additional ground stations may be expensive.	1
3	No airborne users equipped, those requiring segregated airspace access will need to equip with appropriate ADS-B solutions.	1
4	Would be a unique UK solution. Complex integration work will be required to initiate use of 978MHz in UK Airspace.	1
5	UAS 978MHz users unlikely to be visible to unequipped military users or international traffic unable to access the enhanced applications. Unique UK solution so limited interoperability geographically.	1
6	Recognised technology falls within existing ICAO standards, & consistent with existing OFCOM requirements. Not consistent with existing surveillance standards and ICAO norms for ATS. Not a recognised operational model internationally.	1

8.3.5.5 - Option 3C.

Option	Title	Score
3C	**Adopt existing global standards for regulated EC devices. Manned aircraft - 1090 ES (Out minimum), Unmanned also 1090 ES In/Out.**	**140**

Description

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.
Building upon current equipment fits, existing user types maintain with 1090 MHz (Out minimum) devices, new user groups (UAS) also equip with 1090MHz. 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).

Strengths of option (in relation to delivering enhanced EC services)

By utilising the extant internationally recognised standards for EC, COTS equipment would be widely available for current airspace users. UAS users may have to build-in infrastructure or equipment costs as they develop their networks, infrastructure and ground-stations required to enable their operations.
Meets currently recognised international standards and levels of interoperability. All within protected Aviation bands of the spectrum. Ease of constructing safety arguments. Meets all of the stated requirements.
All 1090 MHz users will be electronically visible and interoperable and if no In capability can choose how to receive digital services for situation awareness.

Weakness of option (in relation to delivering enhanced EC services)

Additional regulation development required to enable entry of new user operations (i.e. BVLOS or UAS segregated airspace). Will change the current airborne or ground-based equipage and uptake. Will require manned aircraft and BVLOS UAS to equip ADS-B (if not already). Ground-based equipment required to receive 1090 ADS-B (if not already doing so). Some military users may be slow/unable to comply. Real potential of 1090 MHz saturation. Limited enabling of new digital services.

Rationale for individual scores from MCDA Scoring:		Scores
Drivers:		
1	Within TMZs, BVLOS, VLOS, AAM and other users integrated into the airspace. Suitably equipped aircraft will be able to access segregated airspace, although may encounter 1090 MHz capacity constraints.	4
2	Class G only users equipment requirements unchanged. Segregated airspace blocks available to suitably equipped aircraft. Increased flexible management of airspace possible from this option by enabling a known traffic environment within TMZs. Voluntary equipage so there will remain some element of airspace users who are restricted in access to segregated airspace.	4
3	Enables known traffic environment within TMZ, enables ICAO FIS, although may encounter 1090 MHz capacity constraints.	4
4	Removes ability to innovate, inhibits all development to 1090 technologies. Gives clarity of the roadmap in the short, medium and long term.	1
5	No datalink capabilities via 1090 technology therefore no related (non-EC) applications would be enabled by this option.	1
6	Creates known traffic environment within TMZs, such that managed airspace volumes can be made flexible. Increases EC within other airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure). May encounter 1090 MHz capacity constraints.	4
Constraints:		
1	Still requires TMZs where BVLOS will be integrated. Mixed equipage and voluntary uptake outside of the TMZs, with potentially more users. Increase in EC may alleviate some of the current interoperability issues. May encounter 1090 MHz capacity constraints or issues such as dropped tracks due to saturation.	3

2	1090MHz already received by many ANSPs. Other ANSPs and airports may be required to equip, but this could be built into planned equipment upgrades and hence more affordable. Recognised technology and standards, so potentially smoother integration into certified systems. Required additional ground stations may be integrated into UAS network development costs.	4
3	Many current airborne users already equipped, but many requiring segregated airspace access will need to equip with 1090 MHz ADS-B solutions. COTS equipment available so development costs low.	3
4	Uses existing international standards, relative ease of change.	4
5	Recognised international standard and all users on same frequency so interoperable. Some military users may be unable to see the ADS-B. Interoperability may be hindered by 1090 MHz capacity constraints.	4
6	Consistent with existing ICAO standards, Consistent with existing OFCOM requirements, Consistent with the Aviation Act, Consistent with existing surveillance standards and ICAO norms for ATS.	5

8.3.5.6 - Option 3D.

Option	Title	Score
3D	**Adopt existing global standards for regulated EC devices. USA Model**	**148**
Description		
All aircraft requiring access to Class A or above FL180 (for example) equip with ADS-B 1090 ES (In/Out). All other aircraft requiring access to other UK airspace of defined dimensions to equip with 978 UAT (out minimum) plus transponder. Government furnished ground architecture provided to enable TIS-B, FIS-B. System would allow Traffic Awareness Beacon System (TABS) devices to be used. 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.		
Strengths of option (in relation to delivering enhanced EC services)		
By utilising the extant internationally recognised standards for EC, COTS equipment would be widely available for current airspace users. UAS users may have to build-in infrastructure or equipment costs as they develop their networks, infrastructure and ground-stations required to enable their operations. Meets currently recognised international standards and levels of interoperability. All within protected Aviation bands of the spectrum. Ease of constructing safety arguments. Meets all of the stated requirements. Minimises potential 1090M Hz saturation and enables new digital services (TIS-B, FIS-B) to be available. Aircraft not flying in airspace which meets the above criteria can continue on current equipment fit.		
Weakness of option (in relation to delivering enhanced EC services)		
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. Will change the current airborne or ground-based equipage and uptake. Will require manned aircraft and BVLOS UAS to equip ADS-B (if not already). Ground-based equipment required to receive ADS-B (if not already doing so). Some military users may be slow/unable to comply		
Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Within TMZs, BVLOS, VLOS, AAM and other users integrated into the airspace. Suitably equipped aircraft will be able to access segregated airspace.	5
2	Segregated airspace blocks available to suitably equipped aircraft. Increased flexible management of airspace possible from this option by enabling a known traffic environment within TMZs. Voluntary equipage so there will remain some element of airspace users who are restricted in access to segregated airspace.	4
3	Enables known traffic environment within TMZ and other mandated airspace. Enables ICAO FIS, enables new applications with clear safety benefits (beyond situational awareness).	5
4	Limited ability to innovate; manufacturers have to innovate around know technologies. Will increase market size and may encourage manufacturer investment in products and services. Gives clarity of the roadmap in the short, medium and long term.	3
5	Option enables many related (non-EC) applications and the technologies underpinning it. 1090 MHz reliant on ground based infrastructure to do so.	4
6	Creates known traffic environment within TMZs, such that managed airspace volumes can be made flexible. Increases EC within other airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure).	5
Constraints:		
1	Still requires TMZs where BVLOS will be integrated. Mixed equipage and voluntary uptake outside of the TMZs, with potentially more users. Does not enable all available applications.	4
2	Significant ground infrastructure development costs.	1
3	Many airborne users equipped, but many will have to equip or re-equip, choosing which ADS-B solution is most appropriate. COTS equipment available.	3

4	Uses existing international standards. Work will be required to initiate use of 978MHz in UK Airspace. Difficulty in integrating different solutions and doing system validation before rebroadcast.	2
5	Recognised international standard and ground stations provide interoperability. Some military users may be unable to see the ADS-B. Potential limitations to EC compatibility for international operations for aircraft on 978 MHz	4
6	Consistent with existing ICAO standards, Consistent with existing OFCOM requirements, Consistent with the Aviation Act, Consistent with existing surveillance standards and ICAO norms for ATS. Would require CAA work to introduce ADS-R etc.	4

8.3.5.7 - Option 3E.

Option	Title	Score
3E	**Adopt existing global standards for regulated EC devices. Manned aircraft and UAS>25kg (certified/specific) equip with 1090MHz. UAS <25kg MTOW – no requirement (assume smaller UAS are responsible for separation from manned aircraft).**	105

Description

Mandate the use of regulated EC devices (ADS-B) for airspace users (manned & UAS >25kg) requiring IFR services (enhanced FIS with Surveillance) or operating in Class A, C, segregated airspace blocks, or operating unmanned BVLOS.
Building upon current equipment fits, manned users and UAS>25kg (certified/specific) equip with 1090 MHz (Out minimum) devices. UAS in the open category<25kg do not need to equip EC but must detect and avoid manned aircraft.
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.

Strengths of option (in relation to delivering enhanced EC services)

By utilising the extant internationally recognised standards for EC, COTS equipment would be widely available for current airspace users. UAS users may have to build-in infrastructure or equipment costs as they develop their networks, infrastructure and ground-stations required to enable their operations, particularly to ensure detect and avoid.
Meets currently recognised international standards and levels of interoperability. All within protected Aviation bands of the spectrum. Ease of constructing safety arguments. Meets all of the stated requirements.
Minimises potential 1090M Hz saturation.
Aircraft not requiring controlled airspace access or IFR services may maintain on current equipment fit.

Weakness of option (in relation to delivering enhanced EC services)

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. Will change the current airborne or ground-based equipage and uptake.
Will require manned aircraft and UAS>25kg to equip ADS-B (if not already).
Does not enables new digital services (TIS-B, FIS-B).
Ground-based equipment required to receive ADS-B (if not already doing so).
Some military users may be slow/unable to comply.

Rationale for individual scores from MCDA Scoring:

Drivers:		Score s
1	Within TMZs, BVLOS, VLOS, AAM and other users integrated into the airspace. UAS not EC equipped not directly supported for integration. Suitably equipped aircraft will be able to access segregated airspace.	3
2	Class G only users equipment requirements unchanged. Segregated airspace blocks available to suitably equipped aircraft. Increased flexible management of airspace possible from this option by enabling a known traffic environment within TMZs. Voluntary equipage so there will remain some element of airspace users who are restricted in access to segregated airspace. May impose restrictions on some UAS.	3
3	Enables known traffic environment within TMZ. However majority of UAS will be electronically invisible to manned aircraft, who must trust that the UAS will avoid them.	3
4	Some UAS required to have EC out, but all UAS must have some form of EC in in order to enable detect and avoid responsibilities against manned aircraft and other UAS. Market free to innovate around how this is achieved. Little innovation available for manned aircraft. Gives some clarity of the roadmap in the short, medium and long term. Allows some supplier investment in products and services.	3
5	No datalink capabilities via 1090 technology therefore no related (non-EC) applications would be enabled for manned users by this option.	1

6	Creates known traffic environment within TMZs, such that managed airspace volumes can be made flexible. Increases EC within other airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure). But does not mandate all users to equip with EC to gain these advantages.	4
1	Still requires TMZs where BVLOS will be integrated. Mixed equipage and voluntary uptake outside of the TMZs, with potentially more users. Increase in EC may alleviate some of the current interoperability issues. Manned aircraft unaware of all UAS or unsure of actions of UAS they are aware of.	2
2	ANSPs and airports may be required to equip with ADS-B (if not already), but this could be built into planned equipment upgrades and hence more affordable. Recognised technology and standards, so potentially smoother integration into certified systems. Required additional ground stations may be integrated into UAS network development costs. Uncertainty of technology path that detect and avoid may take and requirements for the ground.	3
3	Many current airborne users already equipped, but those requiring segregated airspace access and larger UAS will need to equip with 1090 ADS-B solutions. COTS equipment available so development costs low.	2
4	Uses existing international standards, however UAS integration remains very complex.	2
5	Recognised international standard and many users on same frequency so interoperable. Some military users may be unable to see the ADS-B. Interoperability may be hindered by 1090 MHz capacity constraints.	3
6	For manned aircraft and larger UAS, consistent with existing ICAO standards, consistent with existing OFCOM requirements, consistent with the Aviation Act, consistent with existing surveillance standards and ICAO norms for ATS. Uncertainty regarding smaller UAS solutions and regulatory applicability.	3

8.3.5.8 - Option 4A.

Option	Title	Score
4A	**Performance Based Standard (PBS). Certified aircraft 1090MHz. Uncertified aircraft – equip according to performance based standard (ISM band).**	137
Description		
Mandate the use of EC devices for all airspace users requiring IFR services (enhanced FIS with Surveillance) or operating, segregated airspace blocks, or operating unmanned BVLOS; Certified aircraft equip 1090 MHz, uncertified may choose 1090MHz devices or solutions that are in the ISM band and meet a PBS. Such solutions may currently be in use as aids to situational awareness.		
Strengths of option (in relation to delivering enhanced EC services)		
Utilises airborne equipment that is currently available and in widespread use (providing it meets the PBS); may be no requirement for current airborne equipage to change. Meets the stated requirements of enabling an assured SUR signal, supporting a defined low level surveillance coverage (assuming a comprehensive ground network), enabling (and assuring) aircraft identity, position accuracy and integrity, and shall take into account wider factors impacting the successful (valid) reception of the signal. The option can enable ICAO FIS using surveillance (within defined airspace), Crossing services, can act as a source of information supporting UAS detect-and-avoid and input into Hybrid ACAS (ACAS X) and future collision avoidance applications. Equipment manufacturers would be unrestricted and allowed to introduce innovative solutions that are demonstrated to meet the PBS.		
Weakness of option (in relation to delivering enhanced EC services)		
Limited airborne interoperability between solutions; relies entirely on ground system re-broadcast to overcome interoperability issues. Large-scale investment and development of ground station network required. Not all airborne solutions will be within recognised Protected Aviation Band therefore significant development required of safety arguments for many of the solutions that currently aren't providing Safety of Life services. Voluntary nature of the options allows users to choose not to equip at all, therefore relies upon primary radar sources to allow creation of known traffic environment for ICAO FIS with Surveillance. The ability to meet the requirement to enable reasonable application-level requirements will vary between users due to the diverse range of airborne equipment. PBS would have to be written and published, which would be a considerable task for the regulator. PBS devices not within protected Aviation bands of the spectrum, therefore manufacturer has complex task in demonstrating safety arguments and conformance to the PBS.		
Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Allows integration of BVLOS, VLOS, AAM and other users into the airspace, potentially utilising existing equipment. Would minimise the level of segregation experienced by users.	5
2	Class G only users equipment requirements unchanged. Segregated airspace blocks available to suitably equipped aircraft. Increased flexible management of airspace possible from this option by enabling a known traffic environment within TMZs. Voluntary equipage so there will remain some element of airspace users who are restricted in access to segregated airspace.	4
3	Enables known traffic environment within TMZ, enables ICAO FIS, enables new applications with clear safety benefits (beyond situational awareness). Can use the devices to deliver any applications that are developed. PBS delivers known performance.	5
4	The option enables innovation. PBS provides clear road map in the short, medium and long term. Encourages supplier investment in new product and service development.	5
5	There will be a number of related (non-EC) applications which could be enabled by the option and the technologies underpinning it, but these will not be readily available to certified aircraft on 1090 MHz	3
6	Creates known traffic environment within TMZs, such that managed airspace volumes can be made flexible. Increases EC within other airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure).	5
Constraints:		

1	Still requires TMZs where BVLOS will be integrated. Mixed equipage and voluntary uptake outside of the TMZs, with potentially more users. Increase in EC may alleviate some of the current interoperability issues. Incompatible with traffic arriving internationally and with military equipment fits. Not in control of the spectrum and any other uses which may impact Safety of Life services.	3
2	Large-scale investment required for ground station network, upgrading of existing equipment and integration into existing certified systems could be very problematic if data source is unknown and unverified. Solution may be very innovative and incompatible.	1
3	Expensive for the avionics manufacturers to demonstrate assurance and also requires certified aircraft to have 1090 MHz	2
4	Use of multiple solutions incorporating the ISM Band represents an unknown quantity and a higher degree of complexity. Large number of dependencies outside the control of the involved parties (users, suppliers, CAA etc). CAA required to create the PSB in order to implement the option.	3
5	PBS should ensure some level of interoperability for UK aircraft, but not recognised internationally and unlikely to be interoperable with many military systems or international aircraft.	3
6	In effect a mandate on certified a/c to equip 1090MHz and is also utilising ISM band for aviation Safety of Life applications. Requires whole new safety arguments and applicable approvals approach. No design approvals and therefore empirical approach and evidence required.	1

8.3.5.9 - Option 4B.

Option	Title	Score
4B	**Performance Based Standard (PBS). Certified aircraft 1090MHz. Uncertified aircraft – equip according to performance based standard (Aviation Protected band).**	**138**
Description		
Mandate the use of EC devices for all airspace users requiring IFR services (enhanced FIS with Surveillance) or operating, segregated airspace blocks, or operating unmanned BVLOS; Certified aircraft equip 1090 MHz, uncertified may choose 1090MHz devices or solutions that are in the Aviation Protected band and meet a PBS. Such solutions may currently be in use as aids to situational awareness.		
Strengths of option (in relation to delivering enhanced EC services)		
Utilises airborne equipment that is currently available and in widespread use (providing it meets the PBS); may be no requirement for current airborne equipage to change. Meets the stated requirements of enabling an assured SUR signal, supporting a defined low level surveillance coverage (assuming a comprehensive ground network), enabling (and assuring) aircraft identity, position accuracy and integrity, and shall take into account wider factors impacting the successful (valid) reception of the signal. The option can enable ICAO FIS using surveillance (within defined airspace), Crossing services, can act as a source of information supporting UAS detect-and-avoid and input into Hybrid ACAS (ACAS X) and future collision avoidance applications. Equipment manufacturers would be unrestricted and allowed to introduce innovative solutions that are demonstrated to meet the PBS.		
Weakness of option (in relation to delivering enhanced EC services)		
Limited airborne interoperability between solutions; relies entirely on ground system re-broadcast to overcome interoperability issues. Large-scale investment and development of ground station network required. Airborne solutions will be within recognised Protected Aviation Band therefore may ease development required of safety arguments for many of the solutions that currently aren't providing Safety of Life services, but considerable work will still be required. Manufacturer has complex task in demonstrating safety arguments and conformance to the PBS. Voluntary nature of the options allows users to choose not to equip at all, therefore relies upon primary radar sources to allow creation of known traffic environment for ICAO FIS with Surveillance. The ability to meet the requirement to enable reasonable application-level requirements will vary between users due to the diverse range of airborne equipment. PBS would have to be written and published, which would be a considerable task for the regulator.		
Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Allows integration of BVLOS, VLOS, AAM and other users into the airspace, potentially utilising existing equipment. Would minimise the level of segregation experienced by users.	5
2	Class G only users equipment requirements unchanged. Segregated airspace blocks available to suitably equipped aircraft. Increased flexible management of airspace possible from this option by enabling a known traffic environment within TMZs. Voluntary equipage so there will remain some element of airspace users who are restricted in access to segregated airspace.	4
3	Enables known traffic environment within TMZ, enables ICAO FIS, enables new applications with clear safety benefits (beyond situational awareness). Can use the devices to deliver any applications that are developed. PBS delivers known performance.	5
4	The option enables innovation. PBS provides clear road map in the short, medium and long term. Encourages supplier investment in new product and service development, but restricted to protected aviation spectrum.	4
5	There will be a number of related (non-EC) applications which could be enabled by the option and the technologies underpinning it, but these will not be readily available to certified aircraft on 1090 MHz	3

6	Creates known traffic environment within TMZs, such that managed airspace volumes can be made flexible. Increases EC within other airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure).	5
Constraints:		
1	Still requires TMZs where BVLOS will be integrated. Mixed equipage and voluntary uptake outside of the TMZs, with potentially more users. Increase in EC may alleviate some of the current airborne interoperability issues. Incompatible with traffic arriving internationally and with military equipment fits. Some uncertainty on how the frequencies within the protected aviation band will be used.	4
2	Large-scale investment required for ground station network, upgrading of existing equipment and integration into existing certified systems could be very problematic if data source is unknown and unverified. Solution may be very innovative and incompatible.	1
3	Expensive for the avionics manufacturers to demonstrate assurance and also requires certified aircraft to have 1090 MHz	2
4	Use of multiple solutions will require significant effort to standardise the use of the Aviation Protected Spectrum and ensure interoperability with other aviation uses. Represents an unknown quantity and a higher degree of complexity. Large number of dependencies outside the control of the involved parties (users, suppliers, CAA etc). CAA required to create the PSB in order to implement the option.	2
5	PBS should ensure some level of interoperability for UK aircraft, but not recognised internationally and unlikely to be interoperable with many military systems or international aircraft. Could be argued that there is a unique use of the certified band which could introduce interoperability issues.	3
6	In effect a mandate on certified a/c to equip 1090 MHz Consistent with existing ICAO standards, consistent with existing OFCOM requirements, consistent with the Aviation Act, consistent with existing surveillance standards and ICAO norms for ATS. Requires whole new safety arguments and applicable approvals approach. No design approvals and therefore empirical approach and evidence required.	2

8.3.5.10 - Option 4C.

Option	Title	Score
4C	**Performance Based Standard (PBS). Existing equipped aircraft remain on 1090 MHz Remaining aircraft – equip according to performance based standard (ISM band).**	**142**

Description
Mandate the use of EC devices for all airspace users requiring IFR services (enhanced FIS with Surveillance) or operating, segregated airspace blocks, or operating unmanned BVLOS; Existing equipped aircraft remain on 1090 MHz, other aircraft may choose 1090MHz devices or solutions that are in the ISM band and meet a PBS. Such solutions may currently be in use as aids to situational awareness.
Strengths of option (in relation to delivering enhanced EC services)
Utilises airborne equipment that is currently available and in widespread use (providing it meets the PBS); may be no requirement for current airborne equipage to change. Meets the stated requirements of enabling an assured SUR signal, supporting a defined low level surveillance coverage (assuming a comprehensive ground network), enabling (and assuring) aircraft identity, position accuracy and integrity, and shall take into account wider factors impacting the successful (valid) reception of the signal. The option can enable ICAO FIS using surveillance (within defined airspace), Crossing services, can act as a source of information supporting UAS detect-and-avoid and input into Hybrid ACAS (ACAS X) and future collision avoidance applications. Equipment manufacturers would be unrestricted and allowed to introduce innovative solutions that are demonstrated to meet the PBS.
Weakness of option (in relation to delivering enhanced EC services)
Limited airborne interoperability between solutions; relies entirely on ground system re-broadcast to overcome interoperability issues. Large-scale investment and development of ground station network required. Not all airborne solutions will be within recognised Protected Aviation Band therefore significant development required of safety arguments for many of the solutions that currently aren't providing Safety of Life services. Voluntary nature of the options allows users to choose not to equip at all, therefore relies upon primary radar sources to allow creation of known traffic environment for ICAO FIS with Surveillance. The ability to meet the requirement to enable reasonable application-level requirements will vary between users due to the diverse range of airborne equipment. PBS would have to be written and published, which would be a considerable task for the regulator. PBS devices not within protected Aviation bands of the spectrum, therefore manufacturer has complex task in demonstrating safety arguments and conformance to the PBS.

Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Allows integration of BVLOS, VLOS, AAM and other users into the airspace, potentially utilising existing equipment. Would minimise the level of segregation experienced by users.	5
2	Class G only users equipment requirements unchanged. Segregated airspace blocks available to suitably equipped aircraft. Increased flexible management of airspace possible from this option by enabling a known traffic environment within TMZs. Voluntary equipage so there will remain some element of airspace users who are restricted in access to segregated airspace.	4
3	Enables known traffic environment within TMZ, enables ICAO FIS, enables new applications with clear safety benefits (beyond situational awareness). Can use the devices to deliver any applications that are developed. PBS delivers known performance.	5
4	The option enables innovation. PBS provides clear road map in the short, medium and long term. Encourages supplier investment in new product and service development.	5
5	There will be a number of related (non-EC) applications which could be enabled by the option and the technologies underpinning it, but these will not be readily available to certified aircraft on 1090 MHz	4
6	Creates known traffic environment within TMZs, such that managed airspace volumes can be made flexible. Increases EC within other airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure).	5
Constraints:		

1	Still requires TMZs where BVLOS will be integrated. Mixed equipage and voluntary uptake outside of the TMZs, with potentially more users. Increase in EC may alleviate some of the current interoperability issues. Incompatible with traffic arriving internationally and with military equipment fits. Not in control of the spectrum and any other uses which may impact Safety of Life services.	3
2	Large-scale investment required for ground station network, upgrading of existing equipment and integration into existing certified systems could be very problematic if data source is unknown and unverified. Solution may be very innovative and incompatible.	1
3	Expensive for the avionics manufacturers to demonstrate assurance and also requires certified aircraft to have 1090 MHz	3
4	Use of multiple solutions incorporating the ISM Band represents an unknown quantity and a higher degree of complexity. Large number of dependencies outside the control of the involved parties (users, suppliers, CAA etc). CAA required to create the PSB in order to implement the option.	3
5	PBS should ensure some level of interoperability for UK aircraft, but not recognised internationally and unlikely to be interoperable with many military systems or international aircraft.	2
6	In effect a mandate on certified a/c to equip 1090MHz and is also utilising ISM band for aviation Safety of Life applications. Requires whole new safety arguments and applicable approvals approach. No design approvals and therefore empirical approach and evidence required.	1

8.3.5.11 - Option 4D.

Option	Title	Score
4D	**Performance Based Standard (PBS). Existing equipped aircraft remain on 1090 MHz Remaining aircraft – equip according to performance based standard (Aviation Protected band).**	**143**
Description		
Mandate the use of EC devices for all airspace users requiring IFR services (enhanced FIS with Surveillance) or operating, segregated airspace blocks, or operating unmanned BVLOS; Existing equipped aircraft remain on 1090 MHz, other aircraft may choose 1090MHz devices or solutions that are in the Aviation Protected band and meet a PBS. Such solutions may currently be in use as aids to situational awareness.		
Strengths of option (in relation to delivering enhanced EC services)		
Utilises airborne equipment that is currently available and in widespread use (providing it meets the PBS); may be no requirement for current airborne equipage to change. Meets the stated requirements of enabling an assured SUR signal, supporting a defined low level surveillance coverage (assuming a comprehensive ground network), enabling (and assuring) aircraft identity, position accuracy and integrity, and shall take into account wider factors impacting the successful (valid) reception of the signal. The option can enable ICAO FIS using surveillance (within defined airspace), Crossing services, can act as a source of information supporting UAS detect-and-avoid and input into Hybrid ACAS (ACAS X) and future collision avoidance applications. Equipment manufacturers would be unrestricted and allowed to introduce innovative solutions that are demonstrated to meet the PBS.		
Weakness of option (in relation to delivering enhanced EC services)		
Limited airborne interoperability between solutions; relies entirely on ground system re-broadcast to overcome interoperability issues. Large-scale investment and development of ground station network required. Airborne solutions will be within recognised Protected Aviation Band therefore may ease development required of safety arguments for many of the solutions that currently aren't providing Safety of Life services, but considerable work will still be required. Manufacturer has complex task in demonstrating safety arguments and conformance to the PBS. Voluntary nature of the options allows users to choose not to equip at all, therefore relies upon primary radar sources to allow creation of known traffic environment for ICAO FIS with Surveillance. The ability to meet the requirement to enable reasonable application-level requirements will vary between users due to the diverse range of airborne equipment. PBS would have to be written and published, which would be a considerable task for the regulator.		
Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Allows integration of BVLOS, VLOS, AAM and other users into the airspace, potentially utilising existing equipment. Would minimise the level of segregation experienced by users.	5
2	Class G only users equipment requirements unchanged. Segregated airspace blocks available to suitably equipped aircraft. Increased flexible management of airspace possible from this option by enabling a known traffic environment within TMZs. Voluntary equipage so there will remain some element of airspace users who are restricted in access to segregated airspace.	4
3	Enables known traffic environment within TMZ, enables ICAO FIS, enables new applications with clear safety benefits (beyond situational awareness). Can use the devices to deliver any applications that are developed. PBS delivers known performance.	5
4	The option enables innovation. PBS provides clear road map in the short, medium and long term. Encourages supplier investment in new product and service development, but restricted to protected aviation spectrum.	4
5	There will be a number of related (non-EC) applications which could be enabled by the option and the technologies underpinning it, but these will not be readily available to aircraft on 1090 MHz	4

6	Creates known traffic environment within TMZs, such that managed airspace volumes can be made flexible. Increases EC within other airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure).	5
Constraints:		
1	Still requires TMZs where BVLOS will be integrated. Mixed equipage and voluntary uptake outside of the TMZs, with potentially more users. Increase in EC may alleviate some of the current airborne interoperability issues. Incompatible with traffic arriving internationally and with military equipment fits. Some uncertainty on how the frequencies within the protected aviation band will be used.	4
2	Large-scale investment required for ground station network, upgrading of existing equipment and integration into existing certified systems could be very problematic if data source is unknown and unverified. Solution may be very innovative and incompatible.	1
3	Expensive for the avionics manufacturers to demonstrate assurance and also requires existing equipped aircraft to remain on 1090 MHz (less aircraft than in Option 4B).	3
4	Use of multiple solutions will require significant effort to standardise the use of the Aviation Protected Spectrum and ensure interoperability with other aviation uses. Represents an unknown quantity and a higher degree of complexity. Large number of dependencies outside the control of the involved parties (users, suppliers, CAA etc). CAA required to create the PSB in order to implement the option.	2
5	PBS should ensure some level of interoperability for UK aircraft, but not recognised internationally and unlikely to be interoperable with many military systems or international aircraft. Could be argued that there is a unique use of the certified band which could introduce interoperability issues. Less users will be on 1090 MHz than option 4B.	2
6	Consistent with existing ICAO standards, consistent with existing OFCOM requirements, consistent with the Aviation Act, consistent with existing surveillance standards and ICAO norms for ATS. Requires whole new safety arguments and applicable approvals approach. No design approvals and therefore empirical approach and evidence required.	2

8.3.5.12 - Option 4E.

Option	Title	Score
4E	**Performance Based Standard (PBS). Existing equipped aircraft remain on 1090 MHz Remaining aircraft – equip according to Design Assured PBS (Aviation Protected band).**	**138**

Description
Mandate the use of EC devices for all airspace users requiring IFR services (enhanced FIS with Surveillance) or operating, segregated airspace blocks, or operating unmanned BVLOS; Existing equipped aircraft remain on 1090 MHz, other aircraft may choose 1090MHz devices or solutions that are in the Aviation Protected band and meet a Design Assured PBS. Such solutions may currently be in use as aids to situational awareness.
Strengths of option (in relation to delivering enhanced EC services)
Utilises airborne equipment that is currently available and in widespread use (providing it meets the Design Assured PBS); may be no requirement for current airborne equipage to change. Meets the stated requirements of enabling an assured SUR signal, supporting a defined low level surveillance coverage (assuming a comprehensive ground network), enabling (and assuring) aircraft identity, position accuracy and integrity, and shall take into account wider factors impacting the successful (valid) reception of the signal. The option can enable ICAO FIS using surveillance (within defined airspace), Crossing services, can act as a source of information supporting UAS detect-and-avoid and input into Hybrid ACAS (ACAS X) and future collision avoidance applications. Equipment manufacturers would be unrestricted and allowed to introduce innovative solutions that are demonstrated to meet the Design Assured PBS.
Weakness of option (in relation to delivering enhanced EC services)
Limited airborne interoperability between solutions; relies entirely on ground system re-broadcast to overcome interoperability issues. Large-scale investment and development of ground station network required. Airborne solutions will be within recognised Protected Aviation Band therefore may ease development required of safety arguments for many of the solutions that currently aren't providing Safety of Life services, but considerable work will still be required. Manufacturer has complex task in demonstrating safety arguments and conformance to the PBS. Voluntary nature of the options allows users to choose not to equip at all, therefore relies upon primary radar sources to allow creation of known traffic environment for ICAO FIS with Surveillance. The ability to meet the requirement to enable reasonable application-level requirements will vary between users due to the diverse range of airborne equipment. Design Assured PBS would have to be written and published, which would be a considerable task for the regulator. Equipment costs expected to be driven up due to Design Assured nature of the PBS.

Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Allows integration of BVLOS, VLOS, AAM and other users into the airspace, potentially utilising existing equipment. Would minimise the level of segregation experienced by users.	5
2	Class G only users equipment requirements unchanged. Segregated airspace blocks available to suitably equipped aircraft. Increased flexible management of airspace possible from this option by enabling a known traffic environment within TMZs. Voluntary equipage so there will remain some element of airspace users who are restricted in access to segregated airspace.	4
3	Enables known traffic environment within TMZ, enables ICAO FIS, enables new applications with clear safety benefits (beyond situational awareness). Can use the devices to deliver any applications that are developed. PBS delivers known performance.	5
4	The option enables innovation. PBS provides clear road map in the short, medium and long term. Encourages supplier investment in new product and service development, but restricted to protected aviation spectrum. Equipment costs expected to be driven up due to Design Assured nature of the PBS.	3

5	There will be a number of related (non-EC) applications which could be enabled by the option and the technologies underpinning it, but these will not be readily available to aircraft on 1090 MHz	4
6	Creates known traffic environment within TMZs, such that managed airspace volumes can be made flexible. Increases EC within other airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure).	5
Constraints:		
1	Still requires TMZs where BVLOS will be integrated. Mixed equipage and voluntary uptake outside of the TMZs, with potentially more users. Increase in EC may alleviate some of the current airborne interoperability issues. Incompatible with traffic arriving internationally and with military equipment fits. Some uncertainty on how the frequencies within the protected aviation band will be used.	4
2	Large-scale investment required for ground station network, upgrading of existing equipment and integration into existing certified systems could be very problematic if data source is unknown and unverified. Solution may be very innovative and incompatible, although due to the Design Assured nature of the PBS, there will be less reliance on the ground stations for integrity checks.	2
3	Expensive for the avionics manufacturers to demonstrate assurance and also requires existing equipped aircraft to remain on 1090 MHz (less aircraft than in Option 4B). Equipment costs expected to be driven up due to Design Assured nature of the PBS.	2
4	Use of multiple solutions will require significant effort to standardise the use of the Aviation Protected Spectrum and ensure interoperability with other aviation uses. Represents an unknown quantity and a higher degree of complexity. Large number of dependencies outside the control of the involved parties (users, suppliers, CAA etc). CAA required to create the PSB in order to implement the option; significant effort required to develop and oversee standard production.	1
5	PBS should ensure some level of interoperability for UK aircraft, but not recognised internationally and unlikely to be interoperable with many military systems or international aircraft. Could be argued that there is a unique use of the certified band which could introduce interoperability issues. Less users will be on 1090 MHz than option 4B.	2
6	Consistent with existing ICAO standards, consistent with existing OFCOM requirements, consistent with the Aviation Act, consistent with existing surveillance standards and ICAO norms for ATS. Requires whole new safety arguments and applicable approvals approach, which may be easier due to Design Assured nature of the PBS.	4

8.3.5.13 - Option 5A.

Option	Title	Score
5A	**Adopt existing global standards for regulated EC devices. Mandate that all Manned aircraft - 1090 ES (Out minimum), Unmanned also 1090 ES In/Out.**	**127**
Description		
Mandate the use of regulated EC devices (ADS-B) for all airspace users. Building upon current equipment fits, existing user types maintain with 1090 MHz (Out minimum) devices, new user groups (UAS) also equip with 1090 MHz Adopts existing global standards for regulated EC devices. 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).		
Strengths of option (in relation to delivering enhanced EC services)		
By utilising the extant internationally recognised standards for EC, COTS equipment would be widely available for current airspace users. UAS users may have to build-in infrastructure or equipment costs as they develop their networks, infrastructure and ground-stations required to enable their operations. Meets currently recognised international standards and levels of interoperability. All within protected Aviation bands of the spectrum. Ease of constructing safety arguments. Meets all of the stated requirements. All users will be electronically visible and interoperable and if no In capability can choose how to receive digital services for situation awareness.		
Weakness of option (in relation to delivering enhanced EC services)		
Mandatory for all users; many will be unable to comply and be denied airspace access. Additional regulation development required to enable entry of new user operations (i.e. BVLOS or UAS segregated airspace). Will significantly change the current airborne or ground-based equipage and uptake. Ground-based equipment required to receive 1090 ADS-B (if not already doing so). Some military users may be slow/unable to comply. Real potential of 1090 MHz saturation. Very limited enabling of new digital services.		
Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Allows BVLOS, VLOS, AAM and other users integrated into the airspace. Suitably equipped aircraft will be able to access segregated airspace, although may encounter 1090 MHz capacity constraints.	4
2	All aircraft are equipped therefore can access all airspace they meet the requirements for. Allows flexible management of airspace possible from this option by enabling a known traffic environment.	5
3	Enables known traffic environment, enables ICAO FIS, although may encounter 1090 MHz capacity constraints.	4
4	Removes ability to innovate, inhibits all investment to existing 1090 technologies. Gives clarity of the roadmap in the short, medium and long term.	1
5	No datalink capabilities via 1090 technology therefore no related (non-EC) applications would be enabled by this option.	1
6	Creates known traffic environment. Managed airspace volumes can be made flexible. Increases EC within all airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure). May encounter 1090 MHz capacity constraints.	4
Constraints:		
1	All users should be interoperable and conspicuous. May encounter 1090 MHz capacity constraints or issues such as dropped tracks due to saturation.	3
2	1090MHz already received by many ANSPs. Other ANSPs and airports may be required to equip, but this could be built into planned equipment upgrades and hence more affordable. Recognised technology and standards, so potentially smoother integration into certified systems. Required additional ground stations may be integrated into UAS network development costs.	4
3	Some current airborne users already equipped, but many will need to equip with 1090 MHz ADS-B solutions. COTS equipment available so development costs low.	1

4	Uses existing international standards, relative ease of change. However, will encounter significant resistance to the mandate from many user groups.	2
5	Recognised international standard and all users on same frequency so interoperable. Some military users may be unable to see the ADS-B. Interoperability may be hindered by 1090 MHz capacity constraints.	4
6	Consistent with existing ICAO standards, Consistent with existing OFCOM requirements, Consistent with the Aviation Act, Consistent with existing surveillance standards and ICAO norms for ATS.	5

8.3.5.14 - Option 5B.

Option	Title	Score
5B	**Adopt existing global standards for regulated EC devices. Mandate that all Manned aircraft - 1090 ES (Out minimum), Unmanned 978 UAT In/Out.**	**158**
Description		
Mandate the use of regulated EC devices (ADS-B) for all airspace users. Building upon current equipment fits, existing user types maintain with 1090 MHz (Out minimum) devices, new user groups (UAS) also equip with 978 MHz Adopts existing global standards for regulated EC devices. 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).		
Strengths of option (in relation to delivering enhanced EC services)		
By utilising the extant internationally recognised standards for EC, COTS equipment would be widely available for current airspace users. UAS users may have to build-in infrastructure or equipment costs as they develop their networks, infrastructure and ground-stations required to enable their operations. Meets currently recognised international standards and levels of interoperability. All within protected Aviation bands of the spectrum. Ease of constructing safety arguments. Meets all the stated requirements. Minimises potential 1090 MHz saturation and enables new digital services (TIS-B, FIS-B) to be available on 978 MHz. 978 MHz infrastructure to provide re-broadcasting ground architecture enabling TIS-B, FIS-B. 1090 MHz users will be electronically visible and can choose how to receive 978 data or digital services for situation awareness.		
Weakness of option (in relation to delivering enhanced EC services)		
Mandatory for all users; many will be unable to comply and be denied airspace access. Additional regulation development required to enable entry of new user operations (i.e. BVLOS or UAS segregated airspace). Will significantly change the current airborne or ground-based equipage and uptake. Ground-based equipment required to receive 1090 & 978 ADS-B (if not already doing so). Some military users may be slow/unable to comply.		
Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Allows BVLOS, VLOS, AAM and other users integrated into the airspace. Suitably equipped aircraft will be able to access segregated airspace, although may encounter 1090 MHz capacity constraints.	5
2	All aircraft are equipped therefore can access all airspace they meet the requirements for. Allows flexible management of airspace possible from this option by enabling a known traffic environment.	5
3	Enables known traffic environment, enables ICAO FIS with surveillance.	5
4	Limited ability to innovate, inhibits UAS development to within 978 standards. Manufacturers have to innovate around known technologies. Gives clarity of the roadmap in the short, medium and long term. Allows supplier investment in products and services.	3
5	Related (non-EC) applications which could be enabled by this option, and the technologies underpinning it, are mainly on the UAS using 978MHz. Little applications directly available for manned aircraft on 1090MHz.	2
6	Creates known traffic environment, such that managed airspace volumes can be made flexible. Increases EC within all airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure).	5
Constraints:		
1	All users should be interoperable and conspicuous. Dual frequency use should eliminate 1090 MHz capacity constraints or issues such as dropped tracks due to saturation.	5

2	ANSPs and airports may be required to equip with ADS-B (if not already), but this could be built into planned equipment upgrades and hence more affordable. Recognised technology and standards, so potentially smoother integration into certified systems. Required additional ground stations may be integrated into UAS network development costs.	3
3	Some current airborne users already equipped, but many manned will need to equip for the first time with 1090 MHz ADS-B solutions. COTS equipment available so development costs low.	2
4	Uses existing international standards. Work will be required to initiate use of 978MHz in UK Airspace. However, will encounter significant resistance to the mandate from many user groups.	2
5	UAS 978MHz users unlikely to be visible to unequipped military users or international traffic unable to access the enhanced applications. Unique UK solution so limited interoperability geographically.	4
6	Consistent with existing ICAO standards, Consistent with existing OFCOM requirements, Consistent with the Aviation Act, Consistent with existing surveillance standards and ICAO norms for ATS.	5

8.3.5.15 - Option 5C

Option	Title	Score
5C	**Performance Based Standard (PBS). Mandate that Existing equipped aircraft remain on 1090 MHz Remaining aircraft – equip according to Design Assured PBS (Aviation Protected band).**	**144**

Description
Mandate the use of EC devices for all airspace users. Existing equipped aircraft remain on 1090 MHz, other aircraft may choose 1090MHz devices or solutions that are in the Aviation Protected band and meet a Design Assured PBS. Such solutions may currently be in use as aids to situational awareness. 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).

Strengths of option (in relation to delivering enhanced EC services)
Utilises airborne equipment that is currently available and in widespread use (providing it meets the Design Assured PBS); may be no requirement for current airborne equipage to change. Meets the stated requirements of enabling an assured SUR signal, supporting a defined low level surveillance coverage (assuming a comprehensive ground network), enabling (and assuring) aircraft identity, position accuracy and integrity, and shall take into account wider factors impacting the successful (valid) reception of the signal. The option can enable ICAO FIS using surveillance (within defined airspace), Crossing services, can act as a source of information supporting UAS detect-and-avoid and input into Hybrid ACAS (ACAS X) and future collision avoidance applications. Equipment manufacturers would be unrestricted and allowed to introduce innovative solutions that are demonstrated to meet the Design Assured PBS.

Weakness of option (in relation to delivering enhanced EC services)
Mandatory for all users; many will be unable to comply and be denied airspace access. Limited airborne interoperability between solutions; relies entirely on ground system re-broadcast to overcome interoperability issues. Large-scale investment and development of ground station network required. Airborne solutions will be within recognised Protected Aviation Band therefore may ease development required of safety arguments for many of the solutions that currently aren't providing Safety of Life services, but considerable work will still be required. Manufacturer has complex task in demonstrating safety arguments and conformance to the PBS. The ability to meet the requirement to enable reasonable application-level requirements will vary between users due to the diverse range of airborne equipment. Design Assured PBS would have to be written and published, which would be a considerable task for the regulator. Equipment costs expected to be driven up due to Design Assured nature of the PBS.

Rationale for individual scores from MCDA Scoring:		**Scores**
Drivers:		
1	Allows integration of BVLOS, VLOS, AAM and other users into the airspace, potentially utilising existing equipment. Would minimise the level of segregation experienced by users.	5
2	All aircraft are equipped therefore can access all airspace they meet the requirements for. Allows flexible management of airspace possible from this option by enabling a known traffic environment.	5
3	Enables known traffic environment, enables ICAO FIS, enables new applications with clear safety benefits (beyond situational awareness). Can use the devices to deliver any applications that are developed. Design assured PBS delivers known performance.	5
4	The option enables innovation. PBS provides clear road map in the short, medium and long term. Encourages supplier investment in new product and service development, but restricted to protected aviation spectrum. Equipment costs expected to be driven up due to Design Assured nature of the PBS.	3
5	There will be a number of related (non-EC) applications which could be enabled by the option and the technologies underpinning it, but these will not be readily available to aircraft on 1090 MHz	4

6	Creates known traffic environment, such that managed airspace volumes can be made flexible. Increases EC within all airspace volumes. Potential to use space-based or airborne-based assets (avoiding ground infrastructure).	5
Constraints:		
1	All users should be interoperable and conspicuous.	5
2	Large-scale investment required for ground station network, upgrading of existing equipment and integration into existing certified systems could be very problematic if data source is unknown and unverified. Solution may be very innovative and incompatible, although due to the Design Assured nature of the PBS, there will be less reliance on the ground stations for integrity checks.	2
3	Expensive for the avionics manufacturers to demonstrate assurance and also requires existing equipped aircraft to remain on 1090 MHz Equipment costs expected to be driven up due to Design Assured nature of the PBS.	1
4	Use of multiple solutions will require significant effort to standardise the use of the Aviation Protected Spectrum and ensure interoperability with other aviation uses. Represents an unknown quantity and a higher degree of complexity. Large number of dependencies outside the control of the involved parties (users, suppliers, CAA etc). CAA required to create the PSB in order to implement the option; significant effort required to develop and oversee standard production. Will encounter significant resistance to the mandate from many user groups.	1
5	PBS should ensure some level of interoperability for UK aircraft, but not recognised internationally and unlikely to be interoperable with many military systems or international aircraft. Could be argued that there is a unique use of the certified band which could introduce interoperability issues.	2
6	Consistent with existing ICAO standards, consistent with existing OFCOM requirements, consistent with the Aviation Act, consistent with existing surveillance standards and ICAO norms for ATS. Requires whole new safety arguments and applicable approvals approach, which may be easier due to Design Assured nature of the PBS.	4

9 - CONCLUSIONS AND RECOMMENDATIONS

9.1 - Conclusions

This document has presented the Phase 1 report outlining an analysis of the role for and existing solutions for electronic conspicuity today within the UK and an initial estimate of the penetration of these solutions within the aviation sector applicable to the airborne and ground segments. Considering these solutions and the future evolution of requirements in the airspace, a number of options have been proposed and assessed from which a possible electronic roadmap could be developed. This is fully in line with the task the CAA received from the Department for Transport to "develop Surveillance specifications that take into account future requirements for all aviation including drones and not be an unintended barrier to innovation in future electronic conspicuity functionality".

The publication of the UK's Airspace Modernisation Strategy (CAP2298) has at its heart the ambition to enable better integration of all airspace users. This is central to the future evolution of airspace providing greater openness and access to controlled airspace for existing users but also facilitating the introduction of new airspace users such as drones and urban air mobility in particular. An expansion of electronic conspicuity is considered an enabler for dynamic use of the airspace, accommodate different stakeholder needs in a more sustainable way and supporting the provision of additional services that these users may require. Creating a known traffic environment with interconnectivity between aircraft can be expected to lead to additional innovative use of new platforms and development of advanced control systems and automation applied to drones and drone traffic management. All this is in line with the UK governments strategy to support aviation innovation.

The concept of electronic conspicuity has for several years been recognised as being of benefit to all airspace users, but there has not been a definitive step taken forward that provides a clear roadmap of what solution would be needed to support the operational environment of tomorrow. Indeed, without any requirements being tabled, a number of innovative solutions have been developed and are available today although not fully interoperable. The lack of interoperability has been addressed in some solutions that provide a way to merge data received from multiple sources to provide a composite solution to flight crew as an aid to situational awareness.

Despite these innovations, the airspace today is not integrated, and the integration of the new users requires the creation of TDAs for BVLOS operations. In an already congested airspace environment, this does not encourage interoperability and has safety implications of constricted airspace and increasing reliance on the use of electronic conspicuity and position information for avoidance of other traffic and, in some cases, controlled airspace. The alternative is the creation of known traffic environments using TMZs. The recent change enabling the use of EC devices as part of a TMZ (subject to sponsor need and safety case) enables more aircraft to use the TMZ.

The recent publication of updates to the CAA CAPs (797, 670) on the use of a flight information display brings the possibility of electronic conspicuity data received and displayed on the ground for situational awareness aids. The need to enable deconfliction advisories and (potentially) crossing services, requires some guarantee of the quality of the data transmitted and received, which then becomes critical to maintaining confidence in the performance of systems. This point is highlighted in the CAA's own guidance on the safety considerations for the use of applications without obtaining the necessary approvals and authorisations associated with a conventional surveillance system. Thus situational awareness can cause confusion when used as supplementary input without assurance on the quality.

The solutions have been shown to reach a good level of penetration across the different aviation stakeholders supporting new ground and air applications of surveillance and system interoperability – in addition to situational awareness – that enable the goals of the AMS, and the vision of an integrated future airspace such as:

- ICAO Flight Information Services using surveillance (Class G or Class E), particularly deconfliction advisories,

- Crossing service (e.g. Danger Area, ATZ),
- Supporting UAS detect-and-avoid,
- Supporting on-board deconfliction and collision avoidance systems (Hybrid ACAS / ACAS X).

The report has shown that there are a number of possible options which could be deployed to provide the proposed roadmap towards an electronic conspicuity policy and deployment. To assess the options, a number of drivers and constraints were defined which the different solutions would need to pass to meet the goals of the AMS and the applications listed above.

The impact of each of the options has taken into account the analysis earlier in the document including the existing regulatory environment, ability to support the applications, cost implications of making any changes to the existing fleet equipage and changes that would be necessary on the ground and assessed against the drivers and constraints. Based on the MCDA analysis the top 5 options, in order, were assessed as:

- **Option 5B:** This is a general mandate for all airspace users to equip with regulated electronic conspicuity devices. In this option, manned aircraft use 1090MHz, drones will use 978MHz.
- **Option 3A:** This option is a mirror of Option 5B with the adoption of existing global standards for electronic conspicuity. The option is only mandated in specified airspace volumes and remains voluntary elsewhere.
- **Option 3D:** In this model, the same approach as taken by the FAA in the United States is followed. This results in a general mandate for 1090MHz for aircraft operating in Class A airspace and above FL180. Other specified airspace requires equipage of 978MHz electronic conspicuity solutions. Given the wider mix of solutions, this option also utilises ADS-R/TIS-B to provide a complete air picture for situational awareness.
- **Option 5C:** This option provides a mandate for all airspace users to equip with electronic conspicuity devices like option 5B. However, unlike Option 5B, this option proposes that aircraft already equipped with electronic conspicuity on 1090Mhz do not change. All other aircraft not equipped fit equipment that meets a new Design Assured Performance Based Standard operating within the aviation protected spectrum.
- **Option 4D:** This option is a mirror of Option 5C requiring the development of a new Design Assured Performance Based Standard that can be voluntarily used by aircraft except where mandated for specific airspace. Existing aircraft equipped with electronic conspicuity on 1090MHz do not have to change.

9.2 - Recommendations

The analysis performed in this study has determined that for the new applications to be provided that are envisaged within the AMS, position data of a known quality needs to be provided to ATM systems (or other systems as may be providing deconfliction services to other aircraft – manned or unmanned). This data of a known quality needs to be standardised and protected to ensure that the performance remains controlled and a known quantity. The option assessed as bringing the most benefit is a full mandate.

However, the introduction of a full mandate brings with it numerous constraints – not least of which is the opposition of the airspace users which would be affected by the mandate. The cost and the transition need to be timed to ensure that the burden is proportionate to the general population of the airspace users wishing to gain access – and noting that a cost effective solution may – or may not exist. Integration on the ground and in the air also takes time with systems interfaces systems upgrades being required.

The analysis has also shown that the penetration of 1090ES within the UK aviation fleet is still low overall. It has improved rapidly over the previous survey undertaken by Airspace4All at the LAA rally, but is still below a threshold of 80% equipage in which a general mandate would normally be expected to apply with existing penetration summarised in the table below.

	LOW	HIGH
CS-22	**4%**	**7%**
CS-23	**27%**	**32%**
CS-25	**88%**	**92%**
CS-27	**19%**	**23%**
CS-29	**57%**	**68%**
CS-31	**1%**	**1%**
CS-LSA	**18%**	**23%**
CS-VLA	**28%**	**37%**
NON-PART 21	**8%**	**15%**
PART 21	**15%**	**28%**

Table 24: Estimated ADS-B (1090MHz ES) Penetration

Nevertheless, it is clear from the options appraisal that moving towards an environment in which electronic conspicuity was based on 1090MHz for manned aviation and 978MHz for unmanned aviation would deliver against known performance standards, ease the integration with existing ATM systems – including additional certification – and allow for more airspace users to be accommodated without overloading spectrum.

Therefore, rather than taking the step straight to a mandate (Option 5B) it is recommended that the intermediate step of Option 3A is implemented as the UK solution to electronic conspicuity. This option allows for the certainty of knowing what the end goal of implementation is to address the current and future electronic conspicuity goals.

It is recommended that Option 3A be taken to Phase 2 of the study to further develop the concept of operations, information needs, architectures and high level safety and interoperability assessment within the context of current and future environments identifying what new requirements may be needed, indicative costs, and what regulatory changes (primary and secondary legislation) and policy would support an effective deployment of Option 3A.

10 - APPENDIX A: ACRONYM LIST

TERM	DEFINITION
AAM	Advanced Air Mobility
AC	Advisory Circulars
ACARS	Aircraft Communications Addressing and Reporting System
ACAS	Airborne Collision Avoidance System
ACID	Aircraft Identification
ACNS	Airborne Communications, Navigation and Surveillance.
ADS	Automatic Dependent Surveillance
AFS	Flight Standards (FAA)
AGL	Above Ground Level
AIP	Aeronautical Information Publication
AMC	Acceptable Means of Compliance
AMS	Airspace Modernisation Strategy
ANS	Air Navigation Service
ANSP	Air Navigation Service Provider
ARINC	Aeronautical Radio, Incorporated
ATAS	ADS-B Traffic Advisory System
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
ATIS	Automatic terminal information service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATOM	Air Traffic Overview and Management (PilotAware network)
ATS	Air Traffic Service
ATSAW	Airborne Traffic Situation Awareness
ATSP	Air Traffic Service Provider
ATSSA	ADS-B Traffic Surveillance Systems and Applications
ATSU	Air Traffic Services Unit
ATZ	Air Traffic Zone
BCAR	British Civil Airworthiness Requirements
BVLOS	Beyond Visual Line of Sight
CA	Collision Avoidance
CAA	Civil Aviation Authority
CAAIP	Civil Aircraft Airworthiness Information and Procedures
CAP	Civil Aviation Publication
CAS	Collision Avoidance System
CAT	Commercial Air Traffic
CAVS	CDTI Assisted Visual Separation
CDTI	Cockpit Display of Traffic Information

CFR	Code of Federal Regulations
CNS	Communication and Navigation and Surveillance
CONOPS	Concept of Operations
CORUS	Concept of Operations for European UTM Systems
COTS	Commercial Off the Shelf
CPDLC	Controller Pilot Data Link Communications
CRC	Cyclic Redundancy Check
CS	Certification Specification
CTR	Control Zone
DAA	Detect and Avoid
DACS	Danger Area Crossing Service
DC	Direct Current
DFT	Department for Transport
DME	Distance Measuring Equipment
DOC	Document
EASA	European Union Aviation Safety Agency
EATMN	European air traffic management network
EC	Electronic Conspicuity
ECC	Electronic Communication Committee
ECDP	Electronic Conspicuity Deployment Programme
ECTL	EUROCONTROL
EFB	Electronic Flight Bags
ELA	European Light Aircraft
ELS	Elementary Surveillance
EPAS	European Plan for Aviation Safety
EPU	Estimated Position Uncertainty
ES	Extended squitter
ESASSP	EUROCONTROL Specification for ATM Surveillance System Performance
ETSO	European Technical Standard Order
EU	European Union
EUROCAE	The European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Authority
FID	Flight Information Display
FIR	Flight Information Region
FIS	Flight Information Service
FISO	Flight Information Service Officer
FL	Flight Level
FW	Fixed Wing
GA	General Aviation
GBSS	Ground-based Surveillance System
GBT	Ground Based Transceivers

GDP	Gross Domestic Product
GM	Guidance Material
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GUID	Guidelines
GVA	Geometric Vertical Accuracy
HAPS	High-Altitude Platform Systems
HIAL	Highland and Islands Airports Limited
HIRF	High Intensity Radiated Fields
ICAO	International Civil Aviation Organisation
IFATCA	International Federation of Air Traffic Controllers' Associations
IFF	Identification, friend or foe
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Condition
IR	Interface Requirements
ISM	Industrial, Scientific and Medical
ISO	International Organization for Standardization
ITU	International Telecommunication Union
JTIDS	Joint Tactical Information Distribution System
LAA	Light *Aircraft* Association
LARS	Lower Airspace Radar Service
LAS	Low Airspace Surveillance Services
LDACS	L-band Digital Aeronautical Communications System
LSA	Light Sport Aeroplanes
MAC	Mid-Air Collision
MAG	Manchester Airports Group
MASPS	Minimum Aviation System Performance Standards
MATS	Manual of Air Traffic Services
MATZ	Military Air Traffic Zone
MCDA	Multiple-Criteria Decision A*nalysis*
MDA	Managed Danger Area
METAR	Meteorological Aerodrome Report
MHZ	Megahertz
MIDS	Multifunctional Information Distribution System
MLAT	Multilateration
MOD	Ministry of Defence
MOPS	Minimum Operational Performance Standards
MPA	motor-powered aircraft
MSAW	Minimum Safe Altitude Warning (
MSL	Mean Sea Level
MTA	Military Training Area

MTOM	Maximum Take-Off Mass
MTOW	Maximum Take-Off Weight
NACP	Navigation Accuracy Category for Position
NACV	Navigation Accuracy Category for Velocity
NAS	National Airspace
NASA	National Aeronautics and Space Administration
NAV	Navigational
NHS	National Health Service
NIC	Navigation Integrity Category
NISC	National IFF/SSR Committee
NM	Nautical Miles
NOTAM	Notice to Airmen
NPA	Notice of Proposed Amendment
NRA	Non-Radar Areas
NUC	Navigation Uncertainty Category
OFCOM	Office of Communications
OGN	Open Glider Network
OPS	Operations
OSED	Offensive Security Exploit Developer
PANS	Procedures for Air Navigation Services
PBS	Performance Based Specification
PCD	Probability of code detection
PD	position detection
PED	Portable Electronic Device
PFCD	Probability of False Code Detection
PFD	Probability of false detection
PLG	Probability of long position gaps
PSR	Primary Surveillance Radar
RAF	Royal Air Force
RCP	Required Communication Performance
RF	Radio Frequency
RFID	Radio Frequency Identification
RMZ	Radio Mandatory Zone
RNAV	Area Navigation
RNP	Required Navigation Performance
RSP	Required Surveillance Performance
RTCA	Radio Technical Commission for Aeronautics
RVSM	Reduced vertical separation minimum
RW	Rotary Wing
RWC	Remain Well Clear
SA	Situational Awareness

SAE	Society of Automotive Engineers
SAPT	Service Availability Prediction Tool
SAR	Subject Access Request
SARPS	SARPs - Standards and Recommended Practices
SBAS	Satellite-based Augmentation System
SBS	Surveillance and Broadcast Service
SDA	System Design Assurance
SDPS	Surveillance Data Processing System Requirements
SERA	Standardised European Rules of the Air
SES	Single European Sky
SIB	Safety information bulletin
SIL	Surveillance Integrity Level
SLR	Same Link Rebroadcast
SPI	Surveillance performance and interoperability
SPT	Safety Publications Tool
SRD	Short Range Device
SSR	Secondary Surveillance Radar
STAN	Standard
STC	Short Term Collision
STCA	Short Term Collision Alert
STF	Surveillance Task Force
SUR	Surveillance
SVFR	Special VFR
SW	South West
SWIM	System Wide Information Management
TA	Traffic Alert
TABS	Traffic Awareness Beacon System
TACAN	Tactical Air Navigation system
TAS	Traffic Advisory System
TC	Terminal Control
TCAS	Traffic Collision Avoidance System
TCL	Technical Capability Level
TDA	Temporary Danger Area
TDOA	Time Difference of Arrival
TIS	Traffic Information System
TMA	Terminal Manoeuvring Area
TMZ	Transponder Mandatory Zone
TRA	Temporary Reserved Area
TSO	Technical Standard Orders
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System

UAT	Universal Access Transceiver
UAS	Unmanned Air vehicle
UKFAT	UK Frequency Allocation Table
UVR	UAS Volume Restriction
USP	UTM Service Provider
USSP	U-Space Service Provider
UTM	Unmanned Aircraft System Traffic Management
VDL	VHF Digital Link
VFR	Visual Flight Rules
VHF	Very High Frequency
VLA	Very Light Aircraft
VLL	Very Low Level
VLOS	Visual line of sight operations
VMC	Visual Meteorological Conditions
VSA	Visual Separation in Approach
WAAS	Wide Area Augmentation System
WAM	Wide Area Multilateration
WG	Working Group

11 - APPENDIX C: REGULATORY SUMMARY

11.1 - Ground regulations

This appendix gives some details on the regulations reviewed during this study. It centres on UK regulations, but also highlights requirements of interest from EASA, ICAO and the FAA.

Due to the global nature of aviation, there are often strong links between regulations. For example, a large proportion of EASA regulations were adopted into UK law following Brexit. For this reason, requirements that have already been covered are not duplicated.

11.1.1 - UK

The following regulations, standards and guidance were identified as relevant for the scope of the study.

CAP 1391	**Electronic conspicuity devices**						**Third edition February 2021**		
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	**Policy**	**UK**	ICAO	EC / EASA	FAA	**Critical**	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							
Description of the regulation / standard	The CAP 1391 sets out the key outcomes of the CAA led project to develop a new industry standard for a low-cost electronic conspicuity (EC) device for use on light aircraft. It explores why such a standard is necessary, and looks at the key issues that need to be addressed to encourage more aircraft operators and owners to use EC devices. It then sets out a full technical specification that EC devices are required to meet, along with acceptable means of compliance.								
Key requirements									
Chapter 2	This chapter specifies recommendations for the minimum capability required of an EC device. It defines a Basic, Intermediate and Full EC device and compares them with other airborne surveillance technologies, to show where this EC technology is 'positioned' in the market.								
Chapter 5	The chapter considers the spectrum management issues that could result from the increased use of EC devices. It explains how assurance has been provided to the National IFF/SSR Committee (NISC) that the specification for an EC device based on ADS-B technology would not lead to the manufacture of a device which could compromise the performance of air-to-air or air–to-ground safety nets.								
Chapter 6	Chapter 6 defines the technical requirements, including interoperability considerations, for all EC devices. It also includes detailed Acceptable Means of Compliance (AMC) and associated guidance								
Notes	This CAP will need to be updated with the new requirements on EC devices stemming out from the study.								

CAP 774	**UK Flight Information Services**	**Fourth Edition** **15 December 2021**
Domain	**Applicability**	**Relevance for the study**

Airborne	**Ground**	**Policy**	**UK**	ICAO	EC / EASA	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The purpose and scope of the CAP is to provide a single set of clearly defined procedures for use by all controllers/ FISOs and pilots, provide guidance material to support the procedures to enable common and consistent application of the ATS and ensure that the responsibilities of the controller/FISO and the pilot are clearly defined, particularly with regard to duty of care, collision avoidance and terrain clearance.
Key requirements	
Section 2	Description of basic ATS services
Section 3	Description of Traffic Service provisions
Section 4	Description of the deconfliction service in class G airspace, active TRA and active MTA
Section 5	Description of Procedural Service
Notes	

CAP 493		**Manual of Air Traffic Services (MATS) Part 1**	**Ninth Edition, 20 May 2021**						
Domain		**Applicability**	**Relevance for the study**						
Airborne	**Ground**	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							

Description of the regulation / standard	The Manual of Air Traffic Services Part 1 CAP 493 is based upon national legislation and non-legislative regulatory material, such as ICAO SARPs and PANS. It provides UK ANS providers (ANSPs) with: (a) guidance and clarification on the means of achieving compliance with UK regulatory requirements and ICAO SARPS and PANS; and, (b) details of any additional national requirements, including appropriate supporting administrative procedures.
Key requirements relevant to EC/SUR regulatory policy and standards	
Chapter 2	Flight rules Subsection 6 deals with Aerodrome Traffic Zones (ATZ) and specifies requirements on flights within ATZ.
Chapter 3	Separation Standards - Subsection 10 specifies high level requirements on ATS surveillance based separations (details are in MATS Part 2).
Chapter 6	ATS Surveillance Systems • Subsection 1D Surveillance Services Within Class G Airspace refers to CAP 774 UK Flight Information Service (FIS) • Subsection 4.F defines requirements on Conspicuity codes • Subsection 6 describes Transponder Mandatory Zones (TMZ). The requirements have been complemented by IS 2022/01.

	• Subsection 15 describes procedures for Unknown aircraft • Subsection 16 includes procedures for ATCOs on provision of Traffic Information to aircraft • Subsection 18 describes procedures when Clutter appears on the Situation Display and subsection 18B clutters outside the controlled airspace (refers to CAP 774 – UK Flight Information Services)
Chapter 10	Airborne Collision Avoidance System The chapter provides requirements on aircraft ACAS equipage for certain parts of airspace.
Notes	The CAP will need to be checked in Phase 3 of the project and if the new requirements proposed under Phase 2 of the project have an impact on the CAP 493 provisions, the update should be included into the Regulatory roadmap.

CAP 670	**Air Traffic Services Safety Requirements**						**Third Issue, Amendment 1/2019, 1 August 2019**		
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This CAP is addressed to ATS providers who are expected to demonstrate compliance with applicable ATS Safety requirements. The document highlights the requirements to be met by providers of civil air traffic services and other services in the UK in order to ensure that those services are safe for use by aircraft.
Key requirements	
SUR 02	Generic Requirements for Surveillance Systems This section summarise legislative requirements which shall be considered for applicability for all ground based surveillance systems deployed in the UK and relevant provisions shall be complied with as applicable. Besides other requirements it defines: • Surveillance requirements in Terminal Environment • Required performance of surveillance systems • Radio frequency characteristics • Surveillance Data Processing System Requirements (SDPS)
SUR 03	Surveillance Data Transmission Links and Systems Using Combined Data • Requirements for Exchange of Surveillance Data between ANSPs • Combined Surveillance Data from Multiple Surveillance Systems
SUR 05	Requirements for Secondary Radar Systems
SUR 06	Requirements for Multilateration Systems • Performance requirements on MLAT systems • ADS-B capable MLAT systems • Low Level Coverage • MLAT Performance
SUR 7	Requirements for ADS-B Systems • ADS-B Receiver Requirements • ADS-B based surveillance services

	• Position Accuracy and Integrity Requirements (NIC, NACp, NUC, and SIL) • ADS-B Ground Processing System Requirements • Quality Indicators
SUR 08	Use of Surveillance Data for Aerodrome Traffic Monitoring • Surveillance Sensor Performance Requirements • Aerodrome Traffic Monitor Processing and Display System Requirements
SUR 11	Display System Requirements for Surveillance Systems • Requirements on Functional Parameters • Downlink and Display of ACAS Resolution Advisory Data
SUR 12	Performance Assessment of Surveillance Systems
Notes	Reference to EU Reg SPI IR , ICAO Annex 10 Volume 3 and 4,

CAP 722			**Unmanned Aircraft System Operations in UK Airspace – Guidance**				**Eighth Edition, 5 November 2020**		
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	**Policy**	**UK**	ICAO	EC / EASA	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This CAP provides guidance as to how civil UAS operations may be conducted in accordance with civil regulations, along with any associated policy requirements. The guidance has been harmonised with any relevant emerging international UAS regulatory developments. It is acknowledged that not all areas of UAS operations have been addressed fully. It is therefore important that operators, industry and government sectors remain engaged with the CAA and continue to provide comment on this document. The document is intended to assist those who are involved with the development, manufacture or operation of UAS to identify the route to follow in order that the appropriate operational authorisation(s) may be obtained and to ensure that the required standards and practices are met. Furthermore, CAP 722 highlights the safety requirements that must be met, in terms of airworthiness and/or operational standards, before a UAS is allowed to operate in the UK.
Key requirements	
Chapter 2 Operational guidance	This chapter defines operating principles for UAS • Visual line of sight operations (VLOS) • Beyond visual line of sight operations (BVLOS) • Operating principles associated with UAS flights both in segregated and non-segregated airspace • Aerodrome restrictions
CHAPTER 3 Engineering and	• Definitions of UAS classes • Summary of spectrum availability • Radar and Surveillance Technologies (including 24-bit AA for EC devices) • Detect and avoid capabilities

Technical Guidance	• Remote identification for UAS • Autonomy and Automation
Annexes A - C	Description of the UAS categories and definition of the operational and technical requirements
Annex D	The Annex provides details of guidance material and acceptable means of compliance for use in relation to the UAS Implementing Regulation, Regulation (EU) 2019/947 as amended and as 'retained' within UK domestic law.

CAP 722C	**UAS Airspace Restrictions Guidance and Policy**								**First Edition, December 2020**	
Domain			**Applicability**				**Relevance for the study**			
Airborne	**Ground**	**Policy**	**UK**	ICAO	EC / EASA	FAA	Critical	**Essential**	Potentially applicable	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								

Description of the regulation / standard	The purpose of this CAP is to describe what is meant by a UAS Geographical Zone, and how the UK is implementing EU 2019/947 (the UAS Implementing Regulation) Article 15- UAS Geographical Zones describe how UAS operations may be restricted or prohibited using an airspace structure, in order to facilitate or protect another type of aviation activity, or to protect an area on the ground and describe how UAS operations may be facilitated using an airspace structure to restrict other aviation activity.
Key requirements	
Section 1.4	Promulgation of UAS Geographical Zones
Section 2	Application for establishing a UAS Geographical Zone
Section 3	Managing the UAS Geographical Zones
Notes	EASA released AMC & GM to Regulation (EU) 2019/947 — Issue 1, Amendment 2 in February 2022. This includes new AMC and GM for the establishment of 'geographical zones'; and revised forms for the application and issue of operational authorisations in the 'specific' category, amongst others.

CAP 761	**Operation of IFF/SSR interrogators in the UK: Planning principles and procedures**								**Issue 4, January 2019**
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The aim of this CAP is to set out application procedures and the basic planning principles that will be applied before approval of any new interrogator installation or changes to an existing approved interrogator installation.
Key requirements	
Section 3.14	Principles for the planning of interrogators
Section 3.21	Unsolicited 1090MHz transmissions
Section 4.3	Description of the known IFF/SSR environment problems
Annex C	Application to operate a secondary surveillance interrogator in the UK – ground based platform
Annex D	Application to operate a secondary surveillance interrogator in the UK – marine or airborne platform
Annex E	Application to operate ACAS (TCAS) within the United Kingdom
Annex H	ACAS I equipment holding a generic approval to transmit
Notes	

CAP 1868		**A Unified Approach to the Introduction of UAS Traffic Management**				**December 2019**		
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	**Policy**	**UK**	ICAO	EC / EASA	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The intention of the CAP is to recommend actions to create a policy framework that will facilitate the introduction of a unified approach to the safe integration of UAS. The paper also aims to give an appreciation of the scale and breadth of impact that the integration of UAS into UK airspace could have across the aviation ecosystem. This aims to justify why the development and implementation of policies, regulations, technology and systems will require extensive collaboration and leadership on a national and international scale. It is expected that the paper will inform the government's Aviation Strategy 2050 via the joint UTM Policy Group.
Key requirements	
What is UTM?	Definition of the UTM and UTM environment
Airspace Design	Use of airspace by UAS
Summary of recommendations	The CAP defines 15 Recommendations which shall be taken forward through the AMS UTM Policy Group, with support from the CAA UTM Task Force and the Innovation Hub.
Notes	The outcomes of the EC study may have an impact on the recommendations.

Ofcom	**Frequencies for Emergency services in the UK**	**V3.0,**

		28 September 2020							
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The document summarises all frequencies which are dedicated to emergency services and which may have an impact on the final EC solutions in case of UAS used for emergency purposes.
Key requirements	
Overview of the frequencies for the emergency services	The table in the section provides an overview of the use of frequencies by the Emergency Services. The use of certain frequency assignments may need to be coordinated with the Ministry of Defence (exception being for mobiles/ temporary static deployments of less than 8 weeks' duration with a radiated power of 3 dBW or less).
Notes	Cross-check interdependencies with UAS/ BVLOS requirements.

Ofcom	**Frequency sharing arrangements between civil and military services**	**V1.0 January 2017**							
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This document provides information on frequency sharing arrangements between civil and military users of the radio spectrum in the United Kingdom.
Key requirements	
Emergency Services	List of frequencies, frequency bands and locations where the use of emergency frequencies is permitted.
Military	List of frequencies, frequency bands and locations where the military use of frequencies is permitted.
Notes	Cross-check interdependencies with UAS/ BVLOS requirements.

Ofcom	**UK Frequency Allocation Table**	**Issue No. 18, V1.1**							
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									

Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The UK Frequency Allocation Table (UKFAT) details the uses to which various frequency bands are put to the UK. It also shows the internationally agreed spectrum allocations of the International Telecommunication Union (ITU).
Key requirements	
Frequency allocation tables	The document besides other domains allocates spectrum bands for civil aviation domain
Notes	Cross-check when considering future EC requirements.

11.1.2 - ICAO

ICAO Annex 10, Vol. III			**Aeronautical Telecommunications - Communication Systems**				**2nd Edition, Amdt 91, March 2021**		
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	**UK**	**ICAO**	EC / EASA	FAA	**Critical**	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	Part I of the Annex provides international standards and recommended practices on Digital Data Communication Systems particularly for certain forms of equipment for communication systems.
Key requirements	
Part I, Chapter 3 Aeronautical Telecommunication Network	This chapter defines standard and recommended practices on the ATN which is specifically and exclusively intended to provide digital data communications services to air traffic service provider organizations and aircraft operating agencies.
Part I, Chapter 5 SSR Mode S Air-Ground Data Link	This section specifies Mode S characteristics and requirements. It describes functional elements of the Mode S subnetwork and its interfaces and processes. It defines requirements on the fields in Mode S packets.
Part I, Chapter 9 Aircraft Addressing System	The section specifies requirements on allocation of aircraft addressing 24 bit addresses for aircraft and also non-aircraft transponders.
Part I, Chapter 12 Universal Access Transceiver (UAT)	Defines requirements on UAT including UAT system characteristics (airborne and ground installation characteristics and physical layer characteristics). This chapter specifies requirements on: • Transmission frequency • Frequency stability • Transmit power • Polarization • Time and amplitude profile of UAT message transmission • Ground and aircraft installation system characteristics including transmitter power, receiving sensitivity and receiver selectivity

	• Receiver tolerance to pulsed interference • Modulation characteristics Section 12.5 provides also guidance materials on UAT including: • Transmitter power levels • UAT transmit spectrum • Standard UAT receiver rejection ratios • High-performance receiver rejection ratios.
Notes	Chapter 12 will need to be considered if UAT is recommended as future solution.

ICAO Annex 10, Vol. IV	**Aeronautical Telecommunications – Surveillance and Collision Avoidance Systems**						**Fifth Edition, Amdt 90, November 2018**		
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	**UK**	**ICAO**	EC / EASA	FAA	**Critical**	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	Part I of the Annex provides international standards and recommended practices on Surveillance and anti-collision systems.
Key requirements	
Chapter 2	This chapter provides general requirements on interrogation modes of Secondary surveillance radar (SSR)
Chapter 3	Chapter 3 specifies requirements on SSR system characteristics for all interrogation modes.
Chapter 4	This chapter is dedicated to airborne collision avoidance systems (ACAS). It defines general provisions and minimum characteristics requirements on ACAS I, ACAS II and ACAS III. It also provides requirements on ACAS protocols (surveillance, air to air coordination, ACAS communication with ground stations, definitions relating to the performance of the ACAS II collision avoidance logic, compatibility with ATM system. Additional to that, this section describes an ACAS use case of ACAS hybrid surveillance using extended squitter position data.
Chapter 5	**Chapter 5 defines requirements on Mode S extended squitter transmitting system characteristics (ADS-B out requirements, TIS-B out requirements) and Mode S extended squitter receiving system characteristics (ADS-B in and TIS-B in requirements).** It also provides requirements on interoperability.
Chapter 6	Requirements on multilateration systems are provided in Chapter 6. It provides functional and generic functional requirements.
Chapter 7	This chapter defines high level technical requirements for airborne surveillance applications based on aircraft receiving and using ADS-B message information transmitted by other aircraft/vehicles or ground stations. The capability of an aircraft to receive and use ADS-B/TIS-B (ADS-B/TIS-B In).
Notes	Requirements in Chapter 5 will need to be taken into account when considering TIS-B implementation.

ICAO Annex 11	Air Traffic Services								15th Edition, Amdt 52, November 2018	
Domain			**Applicability**				**Relevance for the study**			
Airborne	**Ground**	Policy	**UK**	**ICAO**	EC / EASA	FAA	Critical	**Essential**	Potentially applicable	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								
Description of the regulation / standard	This Annex defines requirements on provision of ATS (ATC services, FIS and Alerting service), ATS requirements on information and communication. It also describes ATS airspace classes and requirements on services provided and flight requirements.									
Key requirements										
Chapter 2	Chapter 2 determines the need for air traffic services and the portions of the airspace and controlled aerodromes where air traffic services will be provided. It defines also a framework for Performance based operations including Performance-based surveillance operations (PBS).									
Section 3.9	The section requires that radar and ADS-B ground systems shall provide for the display of safety-related alerts and warnings, including conflict alert, conflict prediction, minimum safe altitude warning and unintentionally duplicated SSR codes.									
Chapter 6.4	The section provides requirements on Automatic recording of surveillance data.									
Notes										

ICAO	Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization								Edition 3	
Domain			**Applicability**				**Relevance for the study**			
Airborne	**Ground**	Policy	UK	**ICAO**	EC / EASA	FAA	**Critical**	Essential	Potentially applicable	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								
Description of the regulation / standard	This document is intended to provide a framework and core capabilities of a "typical" UTM system to States that are considering the implementation of a UTM system. Any such UTM system must be able to interact with the air traffic management (ATM) system in the short term and integrate with the ATM system in the long term. The recommendations provided in this document cover communications systems, UTM-ATM Boundaries and Transition, essential Information exchange between ATM and UTM and UTM Service Providers (USP).									
Key requirements										
Appendix B	Communication systems This section describes potential means of information dissemination and coordination between entities providing UTM services. It also deals with the frequency spectrum requirements.									

Appendix D	ATM – UTM boundaries and transition This Appendix addresses practical issues and future implementation considerations of a UTM operational architecture in airspace where existing ATM services and protocols are generally provided for many volumes of airspace.
Appendix E	Essential information exchange between ATM and UTM systems This appendix aims to provide guidance to regulators and industry on specific elements that need to be considered for the exchange of essential information. Due to the uncertainty of how airspace will be organized and what the actual system requirements will be, the list of elements can neither be exhaustive nor will it be suitable for all possible scenarios. This section includes also ATM/UTM interoperability considerations, elements of information to be exchanged and also elements of aircraft user information.
Appendix G	Deconfliction and separation management This appendix describes considerations regarding three conflict management layers - strategic deconfliction, tactical deconfliction and collision avoidance.
Notes	The proposed solution should be in line with the Core principles for global harmonization described in this document.

Doc 9861			**Manual on the Universal Access Transceiver (UAT)**					**2nd edition, 2012**
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	**Policy**	UK	**ICAO**	EC / EASA	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The objective of Part I of the manual (in conjunction with the UAT SARPs of Annex 10, Volume III) is to define internationally agreed detailed technical specifications for the UAT system that accomplish establishment of a basis for RF compatibility of UAT with other systems operating in the 960 MHz to 1 215 MHz frequency band (ACAS, DME, SSR, TACAN, JTIDS/MIDS and GNSS E5/L5) and establishment of a common basis for UAT inter-system interoperability across implementations manufactured and certified in different regions of the world.
Key requirements	
Chapter 2	The chapter contains the specifications for the UAT ADS-B message data blocks, UAT ground uplink message data block and formats.
Chapter 3	This chapter contains the specifications for UAT aircraft and surface vehicles equipment and the **UAT ground transmitters (ground station)** including requirements for processing timing information.
Chapter 4	Chapter 4 contains the criteria for successful message reception, both UAT ADS-B messages and ground uplink messages.
Chapter 5	The chapter covers the interface requirements for aircraft equipment.
Notes	

ICAO Doc 4444	**PANS Air Traffic Management**	**16th Edition, Amdt 8**

		November 2020								
Domain			**Applicability**				**Relevance for the study**			
Airborne	**Ground**	Policy	UK	**ICAO**	EC / EASA	FAA	Critical	**Essential**	Potentially applicable	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								

Description of the regulation / standard	PANS 4444 complements ICAO SARPS contained in ICAO Annex 2 – Rules of the Air and ICAO Annex 11 Air Traffic Services. It specifies in greater detail the actual procedures which should be applied by air traffic service units in provision of the various air traffic services.
Key requirements	
Chapter 4	General provisions for air traffic services
Chapter 5	Separation methods and minima
Chapter 6	Separation in the vicinity of aerodromes
Chapter 8	ATS surveillance services including provision of ATS surveillance services and the usage of SSR transponders and ADS-B transmitters
Chapter 9	Flight information service and alerting service
Notes	

ICAO Doc 9871	**Technical Provisions Mode S Services Extended Squitter**	**2nd Edition 2012 Amdt 1, 2017**								
Domain			**Applicability**				**Relevance for the study**			
Airborne	**Ground**	Policy	UK	**ICAO**	EC / EASA	FAA	Critical	**Essential**	Potentially applicable	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								

Description of the regulation / standard	The manual specifies detailed technical provisions related to the implementation of the standards and recommended practices for surveillance systems using Mode S services and extended squitter (1 090 ES). The detailed technical provisions provided in the document supplement requirements that are contained in ICAO Annex 10 Vol. III and Vol. IV — Surveillance and Collision Avoidance Systems.
Key requirements	
Chapter 2	Overview of Mode S Services and Extended Squitter Version 0
Chapter 3	Overview of Extended Squitter Version 1
Chapter 4	Overview of Extended Squitter Version 2
Appendix B	Provisions for Extended Squitter Version 1
Appendix C	Provisions for Extended Squitter Version 2
Notes	

ICAO Doc 9924	Aeronautical Surveillance Manual									3rd Edition, 2020
Domain			**Applicability**				**Relevance for the study**			
Airborne	**Ground**	Policy	UK	**ICAO**	EC / EASA	FAA	**Critical**	Essential	Potentially applicable	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								

Description of the regulation / standard	The manual was produced by the Aeronautical Surveillance Panel (ASP) as a reference document consolidating the updated guidance material previously published in other manuals with new material covering more recent or emerging techniques. The chapters provide a basic understanding of various systems and how they are used for air traffic surveillance while the appendices contain detailed information on some specific systems and related topics
Key requirements	
Chapter 3	Application of air traffic surveillance
Chapter 4	Technical performance requirements for surveillance systems
Chapter 5	Air-ground surveillance systems
Chapter 6	Airborne surveillance
Appendix H	Mode S protocol considerations
Appendix I	Mode S specific services
Appendix J	Mode S implementation
Appendix K	1 090 MHz ES Appendix K provides a high-level overview of the 1 090 MHz ES. More detail may be found in Doc 9871. The description of 1 090 MHz ES is based primarily on the use of GNSS as the navigation source even though the message formats for ES permit the reporting of position based on other sources of navigation (e.g. inertial navigation system).
Notes	

11.1.3 - European Commission, EASA and Eurocontrol

EU Reg. 262/2009	Requirements for the coordinated allocation and use of Mode S interrogator codes for the single European sky									14 December 2016
Domain			**Applicability**				**Relevance for the study**			
Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								

Description of the regulation / standard	This regulation lays down requirements for the coordinated allocation and use of Mode S interrogator codes for the purposes of the safe and efficient operation of air traffic surveillance and civil-military coordination. It applies to eligible Mode S interrogators and related surveillance systems, their constituents and associated procedures, when supporting the coordinated allocation or use of eligible interrogator codes.

Key requirements	
Article 3	Specifies interoperability and performance requirements on Mode S operators. Detailed requirements are described in the Annex I (reference to ICAO Annex 10 Vol. III and IV) and Annex III.
Article 4	This article specifies procedures for Mode S operators. Detailed requirements are lin Annex II, Part A and Part B.
Article 8	The article defines requirements on civil-military coordination to avoid the uncoordinated use of any eligible interrogator code.
Notes	

EU Reg. 1207/2011	**Requirements for the performance and the interoperability of surveillance for the SES**								**30 April 2020**
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The regulation lays down requirements on the systems contributing to the provision of surveillance data, their constituents and associated procedures in order to ensure the harmonisation of performance, the interoperability and the efficiency of these systems within the EATMN and for the purpose of civil-military coordination.
Key requirements	
Article 4 and Annex I	Article 4 imposes performance requirements on surveillance systems for the separation of aircraft applied within the airspace under ANSP responsibility. The performance requirements on ground components are set out in Annex I which include surveillance data requirements and surveillance data performance requirements.
Article 5 Annex III	Article 5 defines interoperability requirements for exchange of the surveillance data. The article also requires that air navigation service providers shall ensure that the cooperative surveillance chain has the necessary capability to allow them to establish individual aircraft identification using downlinked aircraft identification.
Notes	

EU Reg. 923/2012	**Common rules of the air and operational provisions regarding services and procedures in air navigation (SERA)**								**29 June 2020**
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	**Policy**	UK	ICAO	**EC / EASA**	FAA	**Critical**	Essential	Potentially applicable
Controlled / Uncontrolled airspace									

Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The objective of the regulation is to establish the common rules of the air and operational provisions regarding services and procedures in air navigation that shall be applicable to general air traffic. It also applies to the competent authorities of the Member States, air navigation service providers, aerodrome operators and ground personnel engaged in aircraft operations.
Key requirements	
Annex	The Annex to the regulation defines Rules of the Air (replacement of ICAO Annex 2)
Notes	

EU Reg. 2018/1139	**Regulation on common rules in the field of civil aviation and establishing EASA**							**5 July 2021**	
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	**Policy**	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	It is the basic regulation establishing essential requirements for civil aviation and establishing EASA. Besides other domains it applies to the provision of ATM/ANS in the SES airspace, and the design, production, maintenance and operation of systems and constituents used in the provision of those ATM/ANS.
Key requirements	
SECTION VII **Articles 55 - 58**	Unmanned aircraft The articles define essential requirements for unmanned aircraft, certification of unmanned aircraft and implementing acts regarding unmanned aircraft.
ANNEX VIII **2.6. Surveillance services**	Essential requirements for ATM/ANS and air traffic controllers, subsection 2.6. Surveillance services is a generic requirements that surveillance services shall determine the respective position of aircraft in the air and of other aircraft and ground vehicles on the aerodrome surface, with sufficient performance with regard to their accuracy, integrity, legitimacy of the source, continuity and probability of detection.
ANNEX IX Essential requirements for unmanned aircraft	The Annex defines essential requirements on airworthiness (2.1), operations (2.4), electromagnetic compatibility and radio spectrum (2.5). Specifically requires that the operator of an unmanned aircraft must ensure that the aircraft has the **necessary navigation, communication, surveillance, detect and avoid equipment**, as well as any other equipment deemed necessary for the safety of the intended flight, taking account of the nature of the operation, air traffic regulations and rules of the air applicable during any phase of the flight.
Notes	

GUID-147			EUROCONTROL Specification for ATM Surveillance System Performance					Edition 1.2 20 April 2021		
Domain			**Applicability**					**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA		**Critical**	Essential	Potentially applicable
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								

Description of the regulation / standard	The document provides performance requirements for ATM surveillance systems when supporting 3 and 5 NM horizontal separation applications. The specification was developed in parallel with the draft Surveillance Performance an Interoperability Implementing Rule (SPI IR).
Key requirements	
Section 3	The section defines standards and performance requirements for surveillance applications considering two families of elementary services - horizontal distance-based separation with a minimum of 5 NM and horizontal distance-based separation with a minimum of 3 NM. It defines mandatory and recommended performance requirements for each family.
Section 3.4.4	Mandatory and recommended performance requirements for 5 NM horizontal separation provided by ATCO including performance requirements on the surveillance system.
Section 3.4.5	Mandatory and recommended performance requirements for 3 NM horizontal separation provided by ATCO including performance requirements on the surveillance system.
Section 4	The section describes conformity assessment approach, procedures and criteria.
Annex D	The annex describes requirements on non-cooperative surveillance system legacy performance when supporting 3/5 nm separations. It also defines mandatory performance requirements for 3 and 5 NM horizontal separation provided by ATCO using non-cooperative surveillance system.
Appendix -I	Appendix -I provides justifications of the specified performance requirements.
Appendix - II	The appendix provides traceability, justification and links to equivalent requirement provisions.
Notes	The surveillance performance requirements should be considered for operation of UAS in controlled airspace where 3/5 NM separations are provided.

CORUS Eurocontrol			U-space Concept of Operations					Edition 01.01.03 4 September 2019		
Domain			**Applicability**					**Relevance for the study**		
Airborne	Ground	**Policy**	UK	ICAO	**EC / EASA**	FAA		Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								

Description of the regulation / standard	The document describes the characteristics for a proposed system from a user's perspective. It gives qualitative and quantitative details of how the system should be used and how it should behave. I also describes how very low-level (VLL) airspace should be organised and what rules and regulations should be put in place to enable the safe integration of UASs with other users of this airspace, and what U-space services should be available to help the UAS user achieve this
Key requirements	
Volume 1	The CONOPS describes: • The assumed steps of U-space implementation U1- U4 • **Operations of UASs in VLL and other airspace types** • **Access conditions into the different type of airspace** • **Estimated U-space services under different U-space phases** • **Separation and conflict resolution and** • Contingency and emergency.
Volume 2	Section 3: • Airspace volumes, provided services and UAS operations • Operational practice including rules of the air and flight Rules • Separations and conflict resolution Section 5 describes U-space services and high level architecture principles
Volume 3	Volume consists of annexes to main document: Use-cases B. Requirements Annex C. SORA Annex E. A list of threats and events Annex K. U-space architecture Annex L U-space usage model
Notes	

11.1.4 - EUROCAE

ED-142	**Technical Specifications for Wide Area Multilateration (WAM) Systems**							**2010 Edition, September 2010**	
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	Uncontrolled							
Description of the regulation / standard	This standard specifies the minimum performance requirements for a Wide Area Multilateration (WAM) System that is part of a system providing airspace situational awareness to air traffic controllers and other users within the European Air Navigation Region primarily intended for ATM, in both high and low density environments. The performance requirements are defined for 3 and 5 NM horizontal separations.								
Key requirements									

Chapter 3	Minimum WAM performance specifications under standard conditions: • Probability of position detection (PD) • Probability of long position gaps (PLG) • Probability of false detection (PFD) • Probability of code detection (PCD) • Probability of False Code Detection (PFCD) • Horizontal Position Accuracy
Notes	

ED-102A	**Minimum Operational Performance Standards for 1090 MHz Extended Squitter ADS-B and TIS-B**						**January 2012**		
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	Uncontrolled							

Description of the regulation / standard	ED-102A/DO-260B is a joint publication of EUROCAE and RTCA and is referenced as the basis for ADS-B version number 2. The standard contains Minimum Operational Performance Standards (MOPS) for airborne equipment for ADS-B and TIS-B utilizing 1090 MHz Mode-S Extended Squitter (1090ES).
Key requirements	
Section 2	The section defines on-board equipment requirements • ADS-B equipage classes - Interactive aircraft/vehicle participant systems (Class A, Table 2-3 and Table 2-5), Broadcast-only participant systems (Class B, Table 2-4) and Ground receive systems (Class C). • Minimum performance standards for each Class The following performance parameters are defined: • Navigation Accuracy Category for Position **(NACP), Table 2-70**: Navigation Accuracy Category for Position (NACP) Encoding - specifies the accuracy limits for each NACP (Navigation Accuracy Category for Position) value with regard to Estimated Position Uncertainty (EPU) • Navigation Accuracy Category for Velocity **(NACV), Table 2-22**: Determining NACV Based on Position Source Declared Horizontal Velocity Error • Source Integrity Level **(SIL) - Table 2-72**: "SIL" Subfield Encoding • Navigation Integrity Category **(NIC) Table 2-69**: Navigation Integrity Category (NIC) Encoding • Geometric Vertical Accuracy **(GVA), Table 2-71**: Encoding of the Geometric Vertical Accuracy (GVA) in Aircraft operational status messages
Section A.2	The section describes TIS-B formats and coding including TIS-B surveillance message definition and formats for 1090 MHz TIS-B message
Section D	1090 MHz ADS-B ground architecture example for ADS-B utilisation for ATC surveillance and TIS-B. The important sections for the study are: • D.2.6 Ground architecture for air-ground surveillance including Mode S SSR Ground station, extended squitter ground stations

	• D.2.7 Ground architecture for surface surveillance • D.3 Traffic information service broadcast (TIS-B) including Ground architecture
Section E	Air-to-Air range as limited by power of different avionics classes: • Table E-1: Summary of transmitter and receiver requirements • Table E-2: Air-to-air range as limited by power
Notes	This standard should be updated very soon as the B revision was planned February 2021. Even though this standard has not been mandate yet, the requirements defined by this document could be used to support selected final scenario.

11.1.5 - FAA

FAA			**UAS / UTM Concept of operations**					**Version 2.0** **2 March 2020**	
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	**Policy**	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	FAA UTM CONOPS documents do not prescribe solutions or specific implementation methods, unless for example purposes. Rather, they describe the essential conceptual and operational elements associated with UTM operations that will serve to inform development of solutions across the many actors and stakeholders involved in implementing UTM. The CONOPS focuses on UTM operations below 400 feet above ground level (AGL) and addresses increasingly complex UTM operations within and across both uncontrolled (Class G) and controlled airspace environments. It introduces scenarios that include beyond visual line of sight (BVLOS) operations in controlled airspace.
Key requirements	
Section 2.4.6	Responsibilities for maintaining separation from other aircraft, airspace, weather, terrain, and hazards, and avoiding unsafe conditions throughout an operation.
Section 2.7.1.2	The section describes principles of separation provision and conflict management.
Section 3	The scenarios presented in this section focus on different aspects of UTM operations. The scenarios present examples of processes, technologies, and techniques for accomplishing different operational needs – and should not be construed as final UTM implementation requirements or solutions. • Nominal UTM Operations in Uncontrolled and Controlled Airspace • UVRs and Associated Operational Impacts • Interactions between UAS and Manned Aircraft at Low Altitudes • Use of UTM to Remotely Identify UAS • Federal Public Safety Request for UTM Information
Appendix E	The appendix consists of the complete set of use cases developed to support NASA's TCL demonstrations and to serve as a basis for the concept narrative in the CONOPS. It covers the following use cases:

	• Two VLOS Operations with Voluntary Use of UTM for Coordination • One BVLOS Operation, One VLOS Operation with Voluntary UTM Participation for Coordination • Two BVLOS Operations near an Airport in Uncontrolled Airspace • One-Way BVLOS Flight, Separate Landing/Take-Off Locations • Negotiation versus Prioritization between Operators Due to Dynamic Restriction • UAS Interaction with Manned Aircraft in Low-Altitude Uncontrolled Airspace • BVLOS Operation Lost-Link Event • High Density UTM Operations in Uncontrolled Airspace • Last-Mile Rural Deliveries in Uncontrolled Airspace under the Mode C Veil • UAS Operator Loss of Performance Capabilities in Uncontrolled Airspace • BVLOS UTM Operation within UAS Facility Maps • Historical UTM Information Queries by Authorized Entities • UAS Urgency/Distress Condition with Alternate Landing and UTM Coordination • UAS Volume Reservation in Controlled Airspace • Report to FAA due to UAS Flight Incident.
Notes	

FAA AC 90-114B	**Automatic Dependent Surveillance-Broadcast Operations**								**30 December 2019**
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	**Policy**	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The circular requires ADS-B Out performance when operating in designated classes of airspace within the U.S. National Airspace System. It provides users of the NAS guidance regarding how to conduct ADS-B operations. The appendices provide guidance for additional operations enabled by ADS-B, including ADS-B In.
Key requirements	
Chapter 2	This chapter provides overview and ADS-B system description including system architecture, operating frequencies, avionics operating modes,
Chapter 4	Operating Procedures Section 4.3 defines requirements on ADS-B equipment operations including transmit requirements, equipment qualification requirements for different types of aircraft (type certified, Special light sport aircraft, experimental aircraft, etc). It also specifies how to handle aircraft with non-performing equipment.
Appendix B	The appendix describes **Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation (CAVS)** and provides guidance to operators seeking FAA authorization to conduct CAVS operations.
Appendix C	The appendix defines requirements on aircraft qualification and maintenance
Notes	

11.2 - Airborne regulations

This section gives some details on the regulations reviewed during this study. It centres on UK regulations, but also highlights requirements of interest from EASA, ICAO and the FAA.

Due to the global nature of aviation, there are often strong links between regulations. For example, a large proportion of EASA regulations were adopted into UK law following Brexit. For this reason, requirements that have already been covered are not duplicated.

11.2.1 - UK

11.2.1.1 - Framework legislation

CAP2038A00	**Air Navigation Order 2016**[65]								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	**Critical**	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	The Air Navigation Order is an overall framework for aviation in the UK, defining requirements for a wide range of topics from airworthiness, to operations, aircrew, prohibited behaviour, directives, rules, powers and penalties, etc.								
Key requirements									
Part 4	Airworthiness of Aircraft								
Part 5	Operations, including Equipment of aircraft								
SCHEDULE 5	Equipment For [Non-Part-21] Aircraft On Non-Commercial And Commercial Operations And Marking Of Break-In Areas								
SCHEDULE 6	Equipment Of [Non-Part-21] Aircraft On Public Transport Operations And Marking Of Break-In Areas								
Notes	Section 17 Transponder states that "where required by the notified airspace being flown, aircraft must be equipped with a secondary surveillance radar transponder."								

CAP 393	**Regulations made under powers in the Civil Aviation Act 1982 and the Air Navigation Order 2016**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	**Critical**	Essential	Potentially applicable
Controlled / Uncontrolled airspace									

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[65] *ANO 2016 is being amended by a Draft Statutory Instrument: The Air Navigation (Amendment) Order 2022, expected to enter into force in April 2022: "it makes changes which are consequential upon the repeal of Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation etc. and its replacement by Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation etc. ("the Basic Regulation")." These changes are not believed to have a material impact on this study -* https://www.gov.uk/government/publications/amendments-to-air-navigation-regulations?utm_medium=email&utm_campaign=govuk-notifications-topic&utm_source=5e521aba-1961-4645-bbee-7671010e15b5&utm_content=immediately

Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This work sets out various Regulations made under powers in the Civil Aviation Act 1982 and the Air Navigation Order 2016 namely: the Rules of the Air Regulations, the Air Navigation (General) Regulations, the Air Navigation (Cosmic Radiation) Regulations, the Air Navigation (Dangerous Goods) Regulations, various Permanent Air Navigation (Restriction of Flying) Regulations, and the Civil Aviation Authority Regulations.
Key requirements	
Part 6 Navigation performance and equipment	• Mode S transponder: References which ICAO Annex to refer to when consulting CAP 393 Air Navigation: The Order and Regulations
Notes	Part 6 directly references Extended Squitter Functionality "which, for this purpose, means functionality that supports Mode S Elementary Surveillance and Mode S Enhanced Surveillance to provide Automatic Dependant Surveillance–Broadcast, using unsolicited transponder broadcasts"

11.2.1.2 - Airworthiness

CAP2020A00	**Law 2018-1139 Basic Regulation (Unamended since 1 January 2021)**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The principal objective of this Regulation is to establish and maintain a high uniform level of civil aviation safety.
Key requirements	
Chapter I	Principles, covering the objectives and scope of the regulation
Chapter II	Aviation safety management
Chapter III	• Section I on airworthiness and environmental protection • Section III on air operations • Section IV on ATM/ANS • Section VII on unmanned aircraft
Annexes	Laying down the Essential Requirements for all domains
Notes	

CAP 747	**Mandatory Requirements for Airworthiness**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This CAP is the means by which airworthiness requirements made mandatory by the CAA are notified. It also identifies the sources for other requirements made

	mandatory for UK-registered aircraft included in the scope of Regulation (EU) 2018/1139 (as in "retained EU law"). It includes requirements based on certain SARPs contained in Annexes to the Chicago Convention. It applies to both Part 21 and non-Part 21 aircraft.
Key requirements	
Section 2	• Part 1 defines airworthiness directives and mandatory information applicable to aircraft, engines, propellers and equipment. This includes specific requirements on RAF Radio Equipment • Part 4 GR No. 18 specifies Electrical Power Supplies for Aircraft Radio Systems for non-Part 21 aircraft
Notes	There is no mention of minimum equipment/performance required for entering different types of airspace.

CAP 562	**Civil Aircraft Airworthiness Information and Procedures**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	Civil Aircraft Airworthiness Information and Procedures (CAAIP) (aka Leaflets) are published by the CAA. The Leaflets give information on a variety of matters concerned with civil aircraft during manufacture, overhaul, repair, maintenance, operation and procedures. Leaflets may assist and increase the knowledge of the reader on subjects for which there is a shortage of information from other sources. The information is essentially of a general nature which does not include detail on specific types of aircraft and engines, specialised equipment and component parts fitted to civil aircraft.
Key requirements	
Chapter B Airworthiness Information	• Leaflet B-180 APPENDIX 34-2 MODE "S" Transponder ICAO 24-bit Aircraft Addresses • APPENDIX 34-3 ATC Transponders and Traffic Alert and Collision Avoidance Systems (TCAS) Ground Testing
Chapter C	• Leaflet C-50 UK Certification of Aircraft which are Eligible for the Issue of an EASA or UK National Certificate of Airworthiness - Radio Licence and Installation Approval
Chapter 24 Electrical Power	• Leaflet 24-10 Charging Rooms for Aircraft Batteries • Leaflet 24-20 Nickel Cadmium Batteries
Chapter 34 Navigation	• Leaflet 34-40 Certification and Installation of ACAS 1 Equipment and Other Similar Non-Mandatory Aircraft Collision Avoidance Systems
Chapter 39 Electrical-Electronic Components and Multifunction Units	• Leaflet 39-10 The Selection and Procurement of Electronic Components • Leaflet 39-20 Antistatic Protection • Leaflet 39-30 Protection from the Effects of HIRF (High Intensity Radiated Fields) associated with Aircraft Modifications
Notes	Some of the requirements defining the airworthiness of radio equipment might be relevant to EC devices (eg antenna installation).

CAP 472	**BCAR Section R - Radio**

Domain			Applicability				Relevance for the study		
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	CAP 472 comprises minimum requirements applicable to the design and testing of radio apparatus, and the design and testing of aircraft radio communication and radio navigation installations.
Key requirements	
	• Sub-section R2 Aircraft radio systems • Sub-section R3 Radio apparatus: Approval category unrestricted and restricted • Sub-section R4 Aircraft radio installation: Installation, Aerial systems, Appendix #8 Test of air traffic control transponder systems
Notes	Provides requirements on radio system and antenna installation.

11.2.1.3 - Air operations

CAP2025A00	**Air Operations Regulation 965/2012**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	**Critical**	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							

Description of the regulation / standard	This Regulation lays down detailed rules for air operations with aeroplanes and helicopters, including ramp inspections of aircraft of operators under the safety oversight of another State when landed at aerodromes located in the United Kingdom. It describes the surveillance requirements on operators for the purpose of commercial air transport and non-commercial operations. It also covers commercial and non-commercial specialised operations.
Key requirements	
Annex IV COMMERCIAL AIR TRANSPORT OPERATIONS	• Navigation equipment • SSR transponder equipage where required by the airspace being flown • Communication, navigation and surveillance equipment for operations under IFR or under VFR over routes not navigated by reference to visual landmarks • RVSM equipment requirements Portable electronic devices
Annex VII NON-COMMERCIAL AIR OPERATIONS WITH OTHER-THAN COMPLEX MOTOR-POWERED AIRCRAF	• Equipment loading and securing • Reporting of acts of unlawful interference • Restriction on the use a portable electronic device (PED) that could adversely affect the performance of the aircraft systems and equipment or the ability of the flight crew member to operate the aircraft • Operational procedures and training when ACAS II is in use • Operation of the aircraft if the performance is adequate to comply with the applicable rules of the air and any other restrictions applicable to the flight, the airspace or the aerodromes or operating sites used • Approval of instruments and equipment in accordance with the applicable airworthiness requirements

	• Readily operation and access to instruments and equipment from the station where the flight crew member that needs to use it is seated • Requirements on the commencement of a flight when any of the aeroplane instruments, items of equipment or functions required for the intended flight are inoperative or missing • SSR transponder equipage where required by the airspace being flown
Notes	CAP2025A00 stipulates that "aeroplanes / helicopters shall be equipped with surveillance equipment in accordance with the applicable airspace requirements." This would enable the introduction by the CAA of additional EC requirements for different classes of airspace.

923-2012	**Standardised European Rules of the Air**									
Domain			**Applicability**				**Relevance for the study**			
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	Essential	**Potentially applicable**	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								
Description of the regulation / standard	The objective of this Regulation is to establish the common rules of the air and operational provisions regarding services and procedures in air navigation that shall be applicable to general air traffic.									
Key requirements										
Annex I RULES OF THE AIR > Annex part6 Airspace classification	*Annex subpart SERA6005* *Requirements for communications and SSR transponder* • Radio Mandatory Zones (RMZ) • Transponder Mandatory Zones (TMZ) • Promulgation in the aeronautical information publications									
Annex I RULES OF THE AIR > Annex part13 SSR Transponder	Annex subpart SERA13001 Operation of an SSR transponder • Transponder operation for aircraft without sufficient power									
Notes	These requirements allow some flexibility on the type of EC devices carried as it allows "alternative provisions prescribed for that particular airspace by the ANSP".									

11.2.1.4 - Surveillance

CAP 670	**Air Traffic Services Safety Requirements**						**Third Issue, Amendment 1/2019, 1 August 2019**		
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This CAP is addressed to ATS providers who are expected to demonstrate compliance with applicable ATS Safety requirements. The document highlights the requirements to be met by providers of civil air traffic services and other services in the UK in order to ensure that those services are safe for use by aircraft. SUR 07 describes the requirements for ADS-B Systems, including the airborne component.
Key requirements	
SUR 07	Requirements for ADS-B Systems • ADS-B Receiver Requirements • ADS-B based surveillance services • Position Accuracy and Integrity Requirements (NIC, NACp, NUC, and SIL) • ADS-B Ground Processing System Requirements • Quality Indicators
Notes	

CAP 1391	**Electronic conspicuity devices**									
Domain			**Applicability**				**Relevance for the study**			
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	**Critical**	Essential	Potentially applicable	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	**Uncontrolled**								

Description of the regulation / standard	Industry standard for a low-cost EC device for use on light aircraft relying on ADS-B messages transmitted on 1090MHz. This CAP focuses on EC devices intended for voluntary carriage on registered and non-registered UK Annex II aircraft; non-complex EASA aircraft of <5700kg MTOM and for gliders and balloons (including those covered under ELA 1 and ELA 2) within uncontrolled UK airspace. This CAP fulfils two key requirements: • producing Technical Specification Requirements (and associated AMC) for EC devices • providing assurance that EC devices manufactured to these specifications will not compromise the performance of air to air or air to ground safety nets. • It also summarises the licensing requirements for aircraft owners/ operators wishing to purchase such EC devices.
Key requirements	
Chapter 6	• ADS-B messages to be transmitted • Equipment approval • Transmitter requirements for portable EC devices • Quality Indicator reporting • Recommendations for all portable EC devices • Recommended considerations for EC device receivers, traffic displays and alerting functions • Recommended EC device tests • Requirements for the EC device operating manual
Annex A	Acceptable means of compliance
Notes	Tiered capability for EC devices: • Basic–a transmit-only device with no alerts to the carrier: using a commercial off-the-shelf (COTS), non-qualified GPS/GNSS receiver and ADS-B transmitter conforming to the specification set out in Chapter 6 of this publication. No visual or audible alerts would be available to the user.

	• Intermediate–a transmit/receive device with minimal interoperability and audible only alerts: an ADS-B transmitter/receiver using a COTS, non-qualified GPS/GNSS receiver offering interoperability with air and ground safety nets as detailed in Chapter 6 of this publication and providing audible and, possibly, visual alerts. • Full–a transmit/receive device interoperable with other air and ground safety nets with visual and audible alerts: such a device is currently limited to secondary surveillance radar (SSR) technology and is considered outside of the scope of Chapter 6 of this publication.

11.2.1.5 - UASs

CAP 722	**Unmanned Aircraft System Operations in UK Airspace – Guidance**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	CAP 722 is intended to assist those who are involved with the development, manufacture or operation of UAS to obtain appropriate operational authorisation(s) and to ensure that the required standards and practices are met. Its content is primarily intended for non-recreational UAS operators, but much of this guidance is also directly relevant to recreational uses. Furthermore, CAP 722 highlights the safety requirements that must be met, in terms of airworthiness and/or operational standards, before a UAS is allowed to operate in the UK.
Key requirements	
Chapter 3.5	• 3.5.1 details the rules UAS have to follow for operating in non-segregated airspace • 3.5.2 summarises the surveillance technologies available to for UAS • 3.5.3 explains the licensing obligation and responsibilities of both manufacturers and UAS regarding ICAO 24-bit Aircraft Address for EC devices • 3.5.4 considers Special purpose transponder codes
Chapter 3.6	• Detect and Avoid (DAA) capabilities
Chapter 3.9	• 3.9.8 Safe Operation with Other Airspace Users • 3.9.8 Compliance with Air Traffic Management Requirements
Notes	The radar and surveillance technologies requirements are applicable to all civil UAS operating BVLOS within non-segregated UK airspace, regardless of origin. UAS must be able to interact with all other airspace users, regardless of the airspace or aircraft's flight profile, in a manner that is transparent to all other airspace users and Air Navigation Service Providers (ANSPs), when compared to manned aircraft. Special equipment (e.g. Secondary Surveillance Radar (SSR) Transponder) mandated for manned aircraft in certain classifications of airspace must also be considered a minimum requirement for UAS intending to fly in the same airspace. In order to be authorised as 'EC compatible' a piece of equipment, device or service will first have to satisfy certain minimum performance, reliability, safety, interoperability and efficiency standards. UAS Operations in Non-Segregated Airspace - Special equipment (e.g. Secondary Surveillance Radar (SSR) Transponder) mandated for manned aircraft in certain classifications of airspace must also be considered a minimum requirement for UAS intending to fly in the same airspace. BVLOS UAS operations in a non-segregated airspace will not normally be permitted without an acceptable DAA capability.

	If a UAS is equipped with a transponder and operating in an area where use of the transponder is necessary, the capability to change SSR code whilst in flight must be included. ICAO has issued a letter to States prohibiting the use of 1090 MHz below 500 feet.

CAP 722C	**UAS Airspace Restrictions Guidance and Policy**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	**Uncontrolled**							
Description of the regulation / standard	This CAP describes the guidance and policy on the use of airspace restrictions to either facilitate, or restrict, UAS operations. It provides initial guidance, and signposts readers to other policy documents and processes where necessary.								
Key requirements									
Chapter 1	1.2.1 Purpose of a UAS Geographical Zone								
Notes	References the concept UAS access to airspace could be facilitated by equipping with EC devices. "For example, a condition of entry to the airspace would include meeting the equipage level defined for the area, such as EC. In this example permission would not be required to enter the airspace providing the conditions of entry (including level of equipage) were met (and there are no other restrictions on flying)." The requirements of controlled airspace are currently not applied to UAS below 20 Kg and will continue to not apply to UAS being operated within the Open and Specific category, under the UAS Implementing Regulation.								

11.2.2 - ICAO

11.2.2.1 - Airworthiness

Annex 8	**Airworthiness of Aircraft**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	**ICAO**	EC / EASA	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							
Description of the regulation / standard	Annex 8 includes broad standards which define the minimum basis for the recognition by States of Certificates of Airworthiness for the purpose of flight of aircraft of other States into and over their territories. It is recognized that ICAO Standards would not replace national regulations and that national codes of airworthiness containing the full scope and extent of detail considered necessary by individual States would be required as the basis for the certification of individual aircraft.								
Key requirements									
Part V. Small Aeroplanes	Aeroplanes Over 750 Kg but Not Exceeding 5 700 Kg for which Application for Certification was Submitted on or After 13 December 2007 • Chapter 6: Systems and equipment, including installation,								

Notes	

11.2.2.2 - Air operations

Annex 6	**Operation of Aircraft**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	**ICAO**	EC / EASA	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This Annex contains SARPs adopted by ICAO as the minimum Standards applicable to the operation of: • Part I: aeroplanes by operators authorized to conduct international commercial air transport operations. These international commercial air transport operations include scheduled international air services and non-scheduled international air transport operations for remuneration or hire; • Part II: international general aviation operations with aeroplanes; • Part III: helicopter operations.
Key requirements	
Part I International Commercial Air Transport	• Chapter 3: General, including compliance with laws, regulations and procedures • Chapter 4: Flight Operations including operational certification and supervision • Chapter 6: Aeroplane instruments, equipment and flight documents, including Aeroplanes required to be equipped with an airborne collision avoidance system (ACAS II) • Chapter 7: Aeroplane communication, navigation and surveillance equipment, including Surveillance equipment and installation
Part II International General Aviation aeroplanes	Similar to Part I • Appendix 2.4: General aviation specific approvals
Part III International Operations — Helicopters	Similar to Part I and II • Chapter 2: Flight operations, including Helicopter airworthiness and safety precautions
Notes	Requirement Part I 7.3.1 indicates that "An aeroplane shall be provided with surveillance equipment which will enable it to operate in accordance with the requirements of air traffic services", laying the legal basis for airspace access based on EC capabilities. This requirement is replicated in Part II 2.5.3.1 and Part III 5.3.1. Appendix 2.4 General aviation specific approvals provides a template.

PANS OPS Doc 8168	**Aircraft Operations – Volume III – Aircraft Operating Procedures**	
Domain	**Applicability**	**Relevance for the study**

Airborne	Ground	Policy	UK	ICAO	EC / EASA	FAA	Critical	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The Procedures for Air Navigation Services – Aircraft Operation s (PANS-OPS) consists of three volumes as follows: • Volume I – Flight Procedures • Volume II – Construction of Visual and Instrument Flight Procedures • Volume III – Aircraft Operating Procedures Previously part of Doc 8168, Volume I, this new volume focuses exclusively on aircraft operation procedure topics that can assist crews in ensuring the highest level of safety during flight.
Key requirements	
Section 4	Secondary surveillance radar (SSR) transponder operating procedures, including operation of transponders, phraseology, and operation of airborne collision avoidance system (ACAS) equipment
Section 8	Airborne surveillance, covering the operation of ADS-B IN traffic display
Notes	

11.2.2.3 - Surveillance

Doc 9861	**Manual on the Universal Access Transceiver (UAT)**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	FAA	Critical	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The universal access transceiver (UAT) is a wideband broadcast data link operating on 978 MHz. By design, UAT supports multiple broadcast services: automatic dependent surveillance — broadcast (ADS-B), as well as flight information services (FIS-B) and traffic information services (TIS-B) (see section 4.4.3 - for more information). There are two basic types of broadcast transmissions — or messages — on the UAT channel: the UAT ADS-B message and the UAT ground uplink message. The UAT ADS-B message is broadcast by an aircraft to convey its state vector and other information. The UAT ground uplink message is used by UAT ground stations to uplink flight information, such as text and graphical weather data, advisories and other aeronautical information, to UAT-equipped aircraft that are in the service volume of the UAT ground station.
Key requirements	
Part I Detailed technical specifications	• Chapter 2: UAT message data blocks (including NIC, SIL, NACp, NACv encoding) • Chapter 3: System timing and message transmission procedures • Chapter 4. Criteria for successful message reception • Chapter 5. Interface requirements for the aircraft equipment

Part II Implementation aspects	• Chapter 2 Operating concepts • Chapter 3. Scheduling of UAT ADS-B messages • Chapter 4. UAT aircraft/vehicle ADS-B transmitting subsystem input requirements • Chapter 5. UAT aircraft installation guidance • Chapter 6. UAT ground infrastructure • Chapter 7. UAT frequency planning criteria • Chapter 8. Guidance on UAT spurious emissions • Chapter 9. Potential future services of UAT
Notes	Inter-system interoperability as well as RF compatibility of UAT with other systems operating in the 960 MHz to 1 215 MHz frequency band (ACAS, DME, SSR, TACAN, JTIDS/MIDS and GNSS E5/L5) is defined in PART I DETAILED TECHNICAL SPECIFICATIONS Part II provide information and guidance related to the implementation of the UAT system.

Annex 10	**Aeronautical Telecommunications – Volume IV – Surveillance and Collision Avoidance Systems**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	**ICAO**	EC / EASA	FAA	**Critical**	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							
Description of the regulation / standard	Volume IV of Annex 10 contains Standards and Recommended Practices and guidance material for secondary surveillance radar (SSR) and airborne collision avoidance systems (ACAS), including SARPs for SSR Mode A, Mode C and Mode S; and the technical characteristics of ACAS.								
Key requirements									
Chapter 2	General, including Secondary surveillance radar (SSR)								
Chapter 3	Surveillance systems, including SSR system characteristics								
Chapter 4	Airborne Collision avoidance system								
Chapter 5	• Mode S extended squitter, including transmitting system characteristics and receiving system characteristics (ADS-B in and TIS-B in) • ADS-B Class A equipment characteristics • ADS-B Class B equipment characteristics • Reception performance for airborne receiving systems • Mode S extended squitter airborne receiving system reporting requirements								
Chapter 6	• Technical requirements for airborne surveillance applications								
Notes	The provisions presented within Chapter 5 are focused on requirements applicable to specific classes of airborne and ground transmitting systems that are supporting the applications of ADS-B and TIS-B. Many of the requirements associated with the transmission of Mode S extended squitter are included in Chapter 2 and Chapter 3 for Mode S transponder and non-transponder devices using the message formats defined in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871). It provides details including the transmission requirements (Class A to Class C), in particular for Class A equipment: • A0-to-A0 nominal air-to-air range is 10 NM; • A1-to-A1 nominal air-to-air range is 20 NM;								

	• A2-to-A2 nominal air-to-air range is 40 NM; and • d) A3-to-A3 nominal air-to-air range is 90 NM.

11.2.2.4 - RPAS

	Remotely Piloted Aircraft System (RPAS) Concept Of Operations (Conops) for International IFR Operations									
Domain			**Applicability**				**Relevance for the study**			
Airborne	Ground	Policy	UK	**ICAO**	EC / EASA	FAA	Critical	**Essential**	Potentially applicable	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								
Description of the regulation / standard	This concept of operations aims to describe the operational environment of manned and unmanned aircraft thereby ensuring a common understanding of the challenges and how the subset that are remotely piloted can be expected to be accommodated and ultimately integrated into the airspace for international instrument flight rules (IFR) operations. This CONOPS describes UAS operations, system descriptions, operating environments, control methods, and interfaces with ANSPs and other aircraft. The scope is currently limited to certificated UAS operating internationally within controlled airspace1 under instrument flight rules (IFR) in non-segregated airspace and at aerodromes in the 2031 onward timeframe.									
Key requirements										
1 Introduction	• 1.3.3 Airspace aspects • 1.4.1.1 Accommodation from present to 2025									
2 System overview	• 2.4.1 Detect and Avoid Capability • 2.5 System interfaces									
3 Airworthiness	• 3.1 General provisions, referencing ICAO Annex 8 – Airworthiness of Aircraft • 3.2.3 Airworthiness approval and oversight									
4 UAS operations	• 4.5.2 Delegated separation									
6 Operating environments	• 6.1 International airspace rules and procedures • 6.2 Airspace requirements and UAS capabilities									
Notes	Section 2.5 highlights that architectures for relaying information between surveillance systems may involve terrestrial, satellite, and airborne links. These system interfaces must be interoperable, in terms of performance and functionality. Section 6.2 states that UAS must be able to comply with the requirements of the class of airspace in which they are operating. This requirement is inclusive of both equipage and operational parameters (e.g. transponder, two-way communications with ATC, etc.). UAS will need to be equipped and have the required operational approvals in terms of required surveillance performance (RSP) as required by the airspace within which they plan to operate.									

	Unmanned Aircraft Systems Traffic Management (UTM) – A Common Framework with Core Principles for Global Harmonization

Domain			Applicability				Relevance for the study		
Airborne	Ground	Policy	UK	**ICAO**	EC / EASA	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This document is intended to provide a framework and core capabilities of a "typical" UTM system to States that are considering the implementation of a UTM system. Any such UTM system must be able to interact with the air traffic management (ATM) system in the short term and integrate with the ATM system in the long term. A common framework is needed to facilitate the harmonization between UTM systems globally and provide a stepped approach towards integration into the ATM system. This would enable industry, including manufacturers, service providers and end users, to grow safely and efficiently without disrupting the existing manned aviation system.
Key requirements	
Gaps, Issues and Challenges	• Airspace classification • Airspace access • Rules of the Air • Data standards • Positional references
Appendix E	Essential information exchange between UTM and ATM systems
Notes	This document recognises that policies, rules and priorities required to support equitable access to airspace must be developed. Also commonality for positional references for manned and unmanned operations is needed such as common altitude, navigation and temporal references. Requirements for operations in controlled airspace are provided in AC 922-001 (section 6.1 Operations in controlled airspace). A key recognised challenge is the separation of aircraft participating in the UTM system, with particular reference to methodologies to allow improved or enhanced detectability and conspicuity of UA by manned aviation.

Part 101 and 102	**ICAO Model UAS regulations, and associated Advisory circulars (101-1 & 102-1)**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	**ICAO**	EC / EASA	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This document is an example that member States may consider for implementation to regulate the operation of Unmanned Aircraft Systems (UAS).
Key requirements	
Subpart B	Operating Rules covering controlled airspace
Notes	

11.2.3 - European Commission

11.2.3.1 - Airworthiness

CS-23	Normal, Utility, Aerobatic and Commuter Category Aeroplanes								
Domain			Applicability				Relevance for the study		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This Certification Specification prescribes airworthiness standards for the issuance of type certificates, and changes to those certificates, for aeroplanes in the normal category.								
Key requirements									
SUBPART F	• SYSTEMS AND EQUIPMENT								
SUBPART G	• FLIGHT CREW INTERFACE AND OTHER INFORMATION								
Flight Test Guide - CHAPTER 5	• Equipment								
Notes									

CS-25	Large Aeroplanes								
Domain			Applicability				Relevance for the study		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	These Certification Specifications are applicable to turbine powered Large Aeroplanes.								
Key requirements									
Subpart F	Systems and Equipment								
Notes									

CS-27	Small Rotorcraft								
Domain			Applicability				Relevance for the study		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	These Certification Specifications are applicable to small rotorcraft with maximum weights of 3175 kg (7000 lbs) or less and nine or less passenger seats.								

Key requirements	
SUBPART F	EQUIPMENT
Notes	

748/2012			**Airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations**						
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	Technical requirements and administrative procedures to ensure the airworthiness and environmental compatibility of aeronautical products, parts and appliances. Such requirements and procedures specify the conditions to issue, maintain, amend, suspend or revoke the appropriate certificates. This regulation also defines ELA1 and ELA2 aircraft.								
Key requirements									
Annex I – Part 21	Covers the certification of aircraft and related products, parts and appliances, and of design and production organisations.								
Notes									

Annex to Decision 2014/029/R			**AMC and GM to Part-CAT–Issue 2, Amendment 1 - Transmitting portable, electronic devices (T-PEDs)**						
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This AMC describes the technical prerequisites under which any kind of portable electronic device (PED) may be used on board the aircraft without adversely affecting the performance of the aircraft's systems and equipment.								
Key requirements									
AMC1 CAT.GEN.MPA.140 - TECHNICAL PREREQUISITES FOR THE USE OF PEDS	• Prerequisites concerning the aircraft configuration • Scenarios for permitting the use of PEDs • Demonstration of electromagnetic compatibility • Operational conditions of C-PEDs and cargo tracking devices • Batteries in C-PEDs and cargo tracking devices								
AMC2 CAT.GEN.MPA.140 Portable electronic devices	• Hazard identification and risk assessment • Use of PEDs in the passenger compartment • Use of PEDs in the flight crew compartment • PEDs not accessible during the flight								

GM1CAT.GEN.MPA.140 Portable electronic devices	• Definition and categories of PEDs • Controlled PEDs (C-PEDs)
Notes	CAP 1391 identifies portable low power EC devices as T-PEDs A controlled PED (C-PED) is a PED subject to administrative control by the operator using it. This will include, inter alia, tracking the allocation of the devices to specific aircraft or persons and ensuring that no unauthorised changes are made to the hardware, software or databases. C-PEDs can be assigned to the category of non-intentional transmitters or (T-PEDs). Guidance to follow in case of fire caused by PEDs is provided by the International Civil Aviation Organisation, 'Emergency response guidance for aircraft incidents involving dangerous goods', ICAO Doc 9481-AN/928.

Annex to Decision 2014/030/R	**AMC and GM to Part-NCC – Amendment 1 (September 2014)**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	Commission Regulation (EU) No 965/2012 and its amendments, Commission Regulations (EU) No 2013/800 and 2014/379 make it the operators' responsibility to demonstrate that any PED use on-board is safe and does not affect adversely the performance of the aircraft systems and equipment. This Decision enables the expanded use of any kind of PEDs by amending the provisions (AMC and GM) related to the PED policy. This includes both, non-intentional transmitters and T-PEDs. Thereby, emphasis is given to aircraft technical aspects as well as to cabin safety elements.								
Key requirements									
NCC.GEN.130 - Portable electronic devices	• AMC1 - TECHNICAL PREREQUISITES FOR THE USE OF PEDS, including Prerequisites concerning the aircraft configuration • AMC2 - PROCEDURES FOR THE USE OF PEDS, including Hazard identification and risk assessment, Use of PEDs in the flight crew compartment • GM1 - Definition and categories of PEDs								
CAT.GEN.MPA.140 Portable electronic devices	• GM2 - CREW REST COMPARTMENT, NAVIGATION, TEST ENTITIES AND FIRE CAUSED BY PEDS								
Notes	This document provides definition of PEDs and considerations relating to their use onboard an aircraft.								

11.2.3.2 - Air operations

No 2021/666	**Requirements for manned aviation operating in U-space airspace**	
Domain	**Applicability**	**Relevance for the study**

Airborne	Ground	Policy	UK	ICAO	EC / EASA	FAA	Critical	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This is an amendment to SERA (Regulation 923/2012) which places requirements for communications, SSR transponder and electronic conspicuity in U-space airspace. To allow manned aircraft which are not provided with an air traffic control service to safely operate alongside unmanned aircraft in U-space airspace, it is important that the position of manned aircraft is communicated to U-space service providers. This should be achieved by making manned aircraft electronically conspicuous, effectively signalling their presence by means of surveillance technologies.
Key requirements	
SECTION 6 Airspace classification - SERA.6005	U-space airspace
Notes	This EU requirement is not currently replicated into UK law. SERA.6005(c) is to be implemented by January 2023.

11.2.3.3 - Surveillance

No 1207/2011	**Performance and the interoperability of surveillance for the single European sky (SPI IR) + amendments**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This Regulation lays down requirements on the systems contributing to the provision of surveillance data, their constituents and associated procedures in order to ensure the harmonisation of performance, the interoperability and the efficiency of these systems within the European air traffic management network (EATMN) and for the purpose of civil-military coordination.
Key requirements	
Article 5	• Interoperability requirements (on operators)
Article 6	• Spectrum protection (on Member States)
Article 7	• Associated procedures (on Member States and operators) in relation the assignment of 24-bit ICAO aircraft addresses to aircraft equipped with a Mode S transponder
Article 12	• Additional requirements on operators to ensure that the personnel operating and maintaining surveillance equipment are made duly aware of the relevant provisions of this Regulation
Annex II	• Secondary Surveillance Radar transponder capabilities • Surveillance data exchange requirements
Notes	This EU Implementing Regulation has been adopted in UK law.

ACID/ELS/02	EUROCONTROL Mode S Elementary Surveillance (ELS) Operations Manual								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The guidance on operational procedures contained in this Manual is primarily aimed at facilitating ATC operations with respect to civil and military Mode S and Mode A/C ground and airborne systems as the European Mode S infrastructure is being established and extended. States should consider the contents of this Operations Manual when developing procedures to facilitate the inter-operation of their Mode S network with remaining Mode A/C facilities.
Key requirements	
Chapter 2	• Airborne systems, covering compliance, ICAO 24-Bit Aircraft Address, backwards compatibility, transponder interrogator code supportability, Antenna diversity and aircraft identification feature
Chapter 5	• Civil / Military interface, covering interoperability issues, airborne air defence operations
Annex A	• Airborne Equipment Requirements for Mode S Elementary Surveillance
Notes	

No 262/2009	Requirements for the coordinated allocation and use of Mode S interrogator codes for the single European sky								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This Regulation lays down requirements for the coordinated allocation and use of Mode S interrogator codes (hereinafter interrogator codes) for the purposes of the safe and efficient operation of air traffic surveillance and civil-military coordination
Key requirements	
Article 5	Associated procedures for Member States
Article 8	Civil-military coordination
Article 9	Safety requirements
Notes	

TSO-C199	Traffic Awareness Beacon System (TABS)	21 February 2018
Domain	Applicability	Relevance for the study

Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA	**Critical**	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							

Description of the regulation / standard	The Technical Standard Order defines applicability of TABS as TABS devices are distinctly different from other transponders. TABS devices are intended for voluntary equipage on aircraft exempted from carrying a transponder or automatic dependent surveillance-broadcast (ADS-B) equipment, such as gliders, balloons and aircraft without electrical systems. TABS devices do not meet the transponder or ADS-B requirements defined in EU IR 1207/2011 but shall enable an aircraft to be visible to other aircraft equipped with Traffic Advisory System (TAS), a Traffic Alert and Collision Avoidance System I (TCAS I) , a Traffic Alert and Collision Avoidance System II (TCAS II) and aircraft with ADS-B IN capability.
Key requirements	
Section 3	• The section defines requirements on class A and Class B TABS and also minimum performance standards. • TABS requirements are derived from existing transponder and ADS-B requirements. Equipment meeting only the minimum TABS requirements will provide the capability to be seen by other aircraft equipped with traffic advisory systems but may not support detection by ground surveillance systems relying on full transponder functionality.
Notes	

CS-ACNS	**Certification Specifications and Acceptable Means of Compliance for Airborne Communications, Navigation and Surveillance, Issue 3 (May 2021)**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	These certification specifications are intended to be applicable to aircraft for the purpose of complying with the communications, navigation and surveillance carriage requirements. Compliance with the relevant sections of CS-ACNS ensures compliance with the following European regulations: (a) Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council; (b) Commission Implementing Regulation (EU) No 1207/2011 of 22 November 2011 laying down requirements for the performance and the interoperability for surveillance for the single European sky; (c) Commission Implementing Regulation (EU) No 1206/2011 of 22 November 2011 laying down requirements on aircraft identification for surveillance for the single European sky;

	(d) Commission Regulation (EC) No 29/2009 of 16 January 2009 laying down requirements on data link services for the single European sky; (e) Commission Implementing Regulation (EU) No 1079/2012 of 16 November 2012 laying down requirements for voice channels spacing for the single European sky.
Key requirements	
Subpart D - Surveillance (SUR)	Section 1 – Mode A/C only surveillance
	Section 2 – Mode S elementary surveillance
	Section 3 – Mode S Enhanced Surveillance
	Section 4 – 1090 MHz Extended Squitter ADS-B
Notes	This document gives detailed specifications on transponder characteristics, data transmission, integrity, etc.

<table>
<tr><td colspan="2">CS-STAN</td><td colspan="8">Certification Specifications for Standard Changes and Standard Repairs, Issue 3 (April 2019)</td></tr>
<tr><td colspan="3">Domain</td><td colspan="4">Applicability</td><td colspan="3">Relevance for the study</td></tr>
<tr><td>Airborne</td><td>Ground</td><td>Policy</td><td>UK</td><td>ICAO</td><td>EC / EASA</td><td>FAA</td><td>Critical</td><td>Essential</td><td>Potentially applicable</td></tr>
<tr><td colspan="3">Controlled / Uncontrolled airspace</td><td colspan="4"></td><td colspan="3"></td></tr>
<tr><td>Controlled</td><td>Uncontrolled with FIS</td><td>Uncontrolled</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Description of the regulation / standard</td><td colspan="8">This document provides guidance on how to install and repair certain equipment, including transponders.
These certification specifications for SCs/SRs contain design data with acceptable methods, techniques, and practices for carrying out and identifying SCs/SRs. SCs/SRs, designed in compliance with these certification specifications, are not subject to an approval process, and, therefore, can be embodied in an aircraft when the conditions set out in the relevant paragraphs of Part-213 for SCs/SRs, i.e. 21.A.90B or 21.A.431B, are met.</td></tr>
<tr><td colspan="10">Key requirements</td></tr>
<tr><td colspan="2">Subpart B – Standard Changes – Communi-cation</td><td colspan="8">• CS-SC002c — Installation of Mode S elementary surveillance equipment
• CS-SC004a — Installation of antennas
• CS-SC005a — Installation of an ADS-B OUT system combined with a transponder system</td></tr>
<tr><td colspan="2">Subpart B – Standard Changes – Avionics/ NAV/ Instruments</td><td colspan="8">• CS-SC051c — Installation of ‘FLARM’ equipment
• CS-SC058a — Installation of traffic awareness beacon system (TABS) equipment</td></tr>
<tr><td colspan="2">Subpart B – Standard Changes – Cabin</td><td colspan="8">• CS-SC102a — Installation of DC power supply systems (PSS) for portable electronic devices (PED)
• CS-SC105a — Installation of mounting systems to hold equipment</td></tr>
<tr><td colspan="2">Notes</td><td colspan="8"></td></tr>
</table>

AMC 20-24	Certification Considerations for the Enhanced ATS in Non-Radar Areas using ADS-B Surveillance (ADS-B-NRA) Application via 1090 MHZ Extended Squitter (May 2008)									
Domain			Applicability				Relevance for the study			
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								
Description of the regulation / standard	This AMC is for operators seeking to operate in airspace classifications A to E where ADS-B-NRA services have been implemented by the Air Navigation Service Provider. It provides the basis for approval of aircraft systems and identifies operational considerations. It may also assist other stakeholders by alerting them to aircraft requirements, operator procedures and related assumptions. These other stakeholders could include airspace planners, air traffic service providers, ATS system manufacturers, surveillance data processing system manufacturers, communication service providers, aircraft and avionics equipment manufacturers and ATS regulatory authorities.									
Key requirements										
Section 7	Functional criteria									
Section 8	Airworthiness considerations									
Section 10	Operational considerations									
Notes	This document provides integrity requirements, continuity requirements, latency requirements, etc.									

11.2.3.4 - UASs

EU Reg. 2019/945	Regulation on unmanned aircraft systems and on third-country operators of unmanned aircraft systems						20 July 2020			
Domain			Applicability				Relevance for the study			
Airborne	Ground	**Policy**	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								
Description of the regulation / standard	The regulation lays down the requirements for the design and manufacture of UAS intended to be operated under the rules and conditions defined in Implementing Regulation (EU) 2019/947 and of remote identification add-ons. It also defines the type of UAS whose design, production and maintenance shall be subject to certification.									
Key requirements										
Chapter 2	• Section 3 Conformity of the product: Presumption of conformity, EU declaration of conformity • Section 4 Notification of conformity assessment bodies: Notification, Notifying authorities, Information obligation on notifying authorities, Requirements relating to notified bodies									

Chapter 3	Requirements for UAS operated in the 'certified' the 'specific' categories except when conducted under a declaration
Chapter 4	Third-country UAS operators
Annex Part 1	Requirements for a class C0 Unmanned aircraft system
Annex Part 2	Requirements for a class C1 Unmanned aircraft system
Annex Part 3	Requirements for a class C2 Unmanned aircraft system
Annex Part 4	Requirements for a class C3 Unmanned aircraft system
Annex Part 5	Requirements for a class C4 Unmanned aircraft system
Annex Part 6	Requirements for a direct remote identification add-on
Annex Part 16	Requirements for a class C5 unmanned aircraft system
Annex Part 17	Requirements for a class C6 unmanned aircraft system
Notes	Reflection on whether conformity procedures could / should include requirements on EC device, and whether notifying authorities could carry that task if needed Chapter 4 applies to UK operators

No 2019/947	**Rules and procedures for the operation of unmanned aircraft**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							
Description of the regulation / standard	This Regulation lays down detailed provisions for the operation of unmanned aircraft systems as well as for personnel, including remote pilots and organisations involved in those operations.								
Key requirements									
Article 12	Authorising operations in the 'specific' category								
Article 18	Tasks of the competent authority, which includes (d) issuing, amending, suspending, limiting or revoking operational authorisations and LUCs and verifying completeness of declarations, which are required to carry out UAS operations in the 'specific' category of UAS operations, and (m) establishing and maintaining registration systems for UAS whose design is subject to certification and for UAS operators whose operation may present a risk to safety, security, privacy, and protection of personal data or the environment.								
Notes	Reflection on whether the authorisation delivered by Competent Authority under article 12 could / should include requirements on EC device. This could be supported by Article 18(d).								

11.2.4 - FAA

11.2.4.1 - Airworthiness

AC 25-1302-1	**Installed Systems and Equipment for Use by the Flightcrew**

Domain			Applicability				Relevance for the study		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This advisory circular (AC) provides guidance for the design and methods of compliance for installed equipment on transport airplanes intended for use by the flightcrew. The guidance provided by this AC is intended to minimize the occurrence of design-related errors by the flightcrew and to enable the flightcrew to detect and manage errors that do occur. This AC provides recommendations for the design and evaluation of controls, displays, system behavior, and system integration that are all part of human factors considerations.								
Key requirements									
Chapter 4	• Certification Planning								
Chapter 5	• Design considerations and Guidance								
Notes									

AC 25-11B	**Electronic Flight Displays**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This advisory circular (AC) provides guidance for showing compliance with certain requirements of Title 14, Code of Federal Regulations part 25 for the design, installation, integration, and approval of electronic flight deck displays, components, and systems installed in transport category airplanes.								
Key requirements									
Chapter 2	• Electronic Flight Display System Overview, including Addressing Intended Function in the Certification Plan and Non-Interference with Flying Duties								
Chapter 3	• Electronic Display Hardware, including Display hardware characteristics, Visual display characteristics and Installation								
Chapter 7	• Electronic Display System Control Devices								
Chapter 8	• Showing Compliance for Approval of Electronic Display Systems								
Notes									

AC 23.1311-lC	**Installation of Electronic Display in Part 23 Airplanes**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This advisory circular (AC) provides guidance for showing compliance with certain requirements of Title 14, Code of Federal Regulations (CFR), part 23, as well as general guidance for the design, installation, integration, and approval of electronic flight deck displays, components, and systems installed in part 23 category airplanes. The guidance provided in this document is directed to airplane and avionics manufacturers, modifiers, and operators of part 23 category airplanes.								
Key requirements									

7	• Display Description, including display configuration
8	• Flight Displays
10	• Electronic Displays for Navigation Information
13	• General Human Factors Considerations for Design of Electronic Displays
14	• Location and Configuration of Displays
15	• Pilot Field-of-View Considerations
19	• Lag Time and Data Update
Notes	

AC 120-76C	**Guidelines for the Certification, Airworthiness, and Operational Use of Electronic Flight Bags (May 2014)**									
Domain			**Applicability**				**Relevance for the study**			
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**	
Controlled / Uncontrolled airspace										
Controlled	**Uncontrolled with FIS**	**Uncontrolled**								
Description of the regulation / standard	This joint Flight Standards Service (AFS) and Aircraft Certification Service (AIR) advisory circular (AC) contains guidance on the operational use of Electronic Flight Bags (EFBs). It is intended for all operators conducting flight operations under Title 14 of the Code of Federal Regulations (14 CFR) part 121, 125, 135, or 91 subpart F (part 91F) and part 91 subpart K (part 91K) who want to replace required paper information or utilize other select functions of an EFB. Part 91 operators can find additional EFB information in the current edition of AC 91-78, Use of Class 1 or Class 2 Electronic Flight Bag (EFB). For guidance on the installation of EFB components, refer to the current edition of AC 20-173, Installation of Electronic Flight Bag Components.									
Key requirements										
10	• Display of own-ship position									
11	• EFB classifications for airworthiness certification and authorization for use									
12	• Portable EFB hardware considerations									
13	• EFB system design considerations									
14	• Authorization process									
Notes										

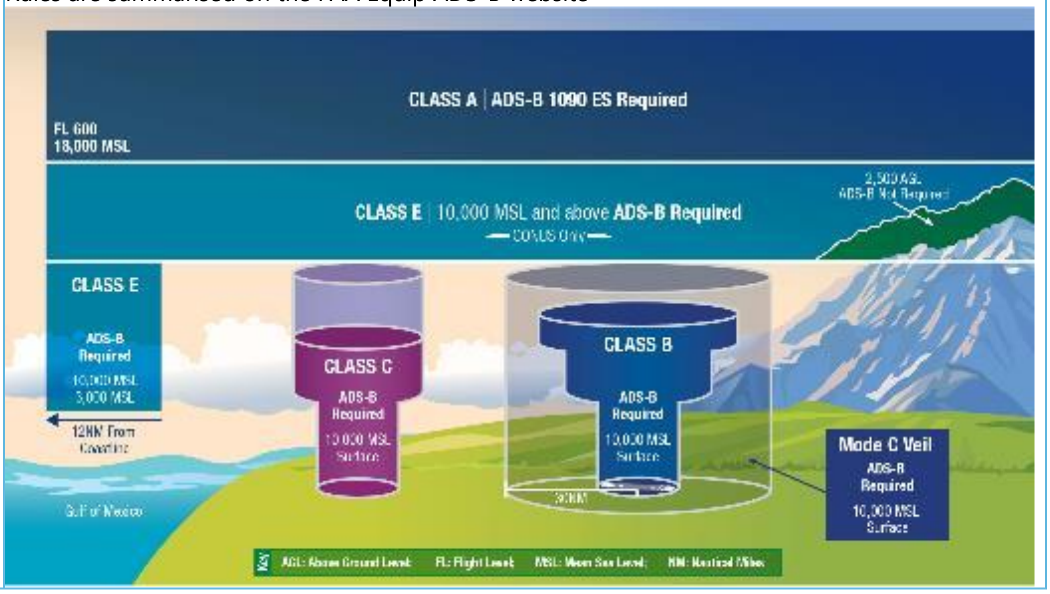
AC 20-164A	**Designing and Demonstrating Aircraft Tolerance to Portable Electronic Devices (September 2017)**									
Domain			**Applicability**				**Relevance for the study**			
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**	
Controlled / Uncontrolled airspace										
Controlled	**Uncontrolled with FIS**	**Uncontrolled**								
Description of the regulation / standard	This advisory circular (AC) identifies RTCA, Inc., document DO-307A, Aircraft Design and Certification for Portable Electronic Device (PED) Tolerance, dated December 15, 2016, as an acceptable means for designing and demonstrating aircraft tolerance to potential electromagnetic interference from portable electronic devices (PEDs). This AC is not mandatory and does not constitute a regulation. This AC has been written for aircraft manufacturers and modifiers who want to design and demonstrate that their aircraft can tolerate passengers and flightcrew using PEDs without adverse electromagnetic interference to aircraft systems.									

Key requirements	
6	• How to obtain FAA approval of a PED-tolerant aircraft design
Notes	

11.2.4.2 - Air operations

Title 14 CFR	**General Operating and Flight Rules**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							

Description of the regulation / standard	Subpart C defines Equipment, Instrument, and Certificate Requirements, which includes requirements on transponder carriage for accessing different classes of airspace.
Key requirements	
91.225	• Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment and use.
91.227	• Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment performance requirements, including 1090 MHz ES and UAT Broadcast Links and Power Requirements, ADS-B Out Performance Requirements for NACP, NACV, NIC, SDA , and SIL, Minimum Broadcast Message Element Set for ADS-B Out, ADS-B Latency Requirements
Notes	The performance requirements prescribed by Title 14 refer to TSO-C166b for ADS-B and TSO-C514c for UAT. Aircraft operating at and above Flight Level 180 must be equipped with 1090ES. Aircraft operating below 18,000 feet mean sea level (MSL) and within U.S. ADS-B-required airspace must be equipped with either 1090ES or UAT equipment. The FAA recommends a WAAS GPS that is compliant with the latest version of TSO-C145 or TSO-C146. These requirements have entered into force in January 2020. Rules are summarised on the FAA Equip ADS-B website[66]



[66] https://www.faa.gov/nextgen/equipadsb/

11.2.4.3 - Surveillance

AC 91-50	Importance of Transponder Operation and Altitude Reporting (August 1977)								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This advisory circular provides information and guidance concerning the importance of transponder operation and altitude reporting in the National Airspace System (NAS).								
Key requirements									
3	• Transponder and altitude reporting requirements								
4	• Airworthiness requirement								
Notes	Sets the basis for transponder usage in the US								

AC 20-149B	Installation Guidance for Domestic Flight Information Service-Broadcast (December 2015)								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This advisory circular (AC) supports the use of Flight Information Services-Broadcast (FIS-B) weather and other aeronautical data link products for enhanced situation awareness of flight conditions. In this AC, the FAA recommends one way to gain airworthiness approval for the installation of FIS-B avionics equipment. We identify safety and installation requirements for continued airworthiness of aircraft FIS-B avionics equipment, systems, and applications. This AC is not mandatory and does not constitute a regulation.								
Key requirements									
5	• Background, including Equipment Classes for FIS-B								
8	• Design Considerations								
11	• Additional installation considerations								
Notes	The FAA SBS FIS-B provider broadcasts a basic set of free weather and aeronautical products for use by UAT-equipped aircraft. FIS-B value-added services for Class 2 equipment are provider-unique products for paid subscribers. These services may include: […]• Special Use Airspace (SUA) depictions. Portable display systems do not require design approval and are outside the scope of this AC. Contains a useful list of "Related publications" in Chapter 3.								

AC 20-165B	Airworthiness Approval of Automatic Dependent Surveillance - Broadcast OUT Systems (December 2015)								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**

Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This advisory circular (AC) provides guidance for the installation and airworthiness approval of Automatic Dependent Surveillance - Broadcast (ADS-B) OUT systems in aircraft.								
Key requirements									
Chapter 1	• General Information, including ADS-B OUT System Approval Process								
Chapter 3	• ADS_B OUT System Installation Guidance								
Chapter 4	• Test and Evaluation								
Notes									

AC 20-172B	**Airworthiness Approval for ADS-B In Systems and Applications (May 2015)**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This advisory circular (AC) provides guidance for the initial and follow-on installations of Automatic Dependent Surveillance – Broadcast (ADS-B) In systems supporting ground and airborne traffic applications. These applications are defined in TSO-C195b, Avionics Supporting Automatic Dependent Surveillance – Broadcast (ADS-B) Aircraft Surveillance Applications (ASA).								
Key requirements									
Chapter 2	• ADS-B In System Installation Guidance								
Chapter 3	• Test and Evaluation								
Appendix B	• Symbol Requirements for the CDTI (Cockpit Display of Traffic Information)								
Appendix C	• ATAS Integration with existing Traffic Alerting Avionics, giving examples of acceptable configuration of TAS/TCAS I/TCAS II and ATAS								
Notes	This AC does not cover the reception of Flight Information Service – Broadcast (FIS-B) messages. Installation guidance for FIS-B applications that make use of the Surveillance and Broadcast Services (SBS) ground system as well as third-party providers can be found in AC 20-149, Installation Guidance for Domestic Flight Information Services – Broadcast. The latency analysis provided in appendix A points to RTCA/DO-317B MOPS for Aircraft Surveillance Applications (ASA) System								

TSO-C154c	**UAT ADS-B equipment operating on frequency of 978 MHz**							**2 December 2009**	
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	**UK**	ICAO	EC / EASA	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							
Description of the regulation / standard	The TSO's standards apply to equipment intended to transmit and receive broadcast messages about an aircraft's position, velocity, integrity, and other parameters. Similarly-equipped operators will share these messages with one another and with								

	ground-based facilities such as air traffic services. These message parameters form the basis for various ADS-B, ADS-R and TIS-B reports. The TSO supports two major classes of UAT ADS-B equipment - Class A and Class B.
Key requirements	
Section 3	The TSO provides Class A and Class be equipment definitions and requirements on: • Functionality (reference to RTCA/DO-282B, Section 2.1) • Failure condition classifications • Functional qualification (reference to RTCA/DO-282B, Section 2.4) • Environmental qualification (reference to RTCA/DO-282B, Section 2.3) • Software qualification (reference to RTCA/DO-178B) • Electronic hardware qualification (reference to RTCA/DO-254 Design Assurance Guidance for Airborne Electronic Hardware)
Notes	

AC 20.131A	**Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders (March 1993)**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This AC provides guidance material for the airworthiness and operational approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S transponders.								
Key requirements									
3	• Airworthiness considerations, including Equipment installation, Software Verification and Validation								
Appendix 3	• Transponder tests								
Notes	Old document								

AFS-360_2016-03-02	**Installation Approval for ADS-B Out Systems (March 2016)**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	The purpose of this memorandum is to explain the FAA's policy regarding installation of ADS-B Out systems into civil aircraft certificated under Title 14, Code of Federal Regulations (14 CFR) Parts 23, 25, 27, 29, and their predecessor regulations, for compliance of section 91.225 and section 91.227.								
Key requirements									
N/A	How can the ADS-B OUT system obtain initial approval?								
	After initial approval, can applicable ADS-B OUT systems be installed on aircraft not covered by that approval?								

	Can ADS-B OUT system that do not meet the requirements for installation without further data approval be installed?
	Does installation of an ADS-B OUT system require revision of the Aircraft Flight Manual?
	Can a TC holder modify their aircraft design for ADS-B OUT under a minor change in type design?
Attachment 1	ADS-B Alteration Flow Chart
Notes	

AFS-360-2017-1	**Installation of ADS-B OUT Equipment (September 2017)**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	The purpose of this Technical Paper is to explain the Federal Aviation Administration's (FAA) policy regarding alterations to aircraft for the installation of Automatic Dependent Surveillance-Broadcast (ADS-B) equipment. This policy applies to aircraft certificated under Title 14, Code of Federal Regulations (14 CFR) § 23, 25, 27, 29, and their predecessor regulations. This Technical Paper provides policy pursuant to compliance with 14 CFR § 91.225 and § 91.227.								
Key requirements									
7	• Is it possible to upgrade components in an existing ADS-B OUT system installation?								
11	• System Performance Verification and Methods								
12	• Documenting ADS-B OUT System Performance Verification								
15	• What are the installation and approval requirements for ADS-B IN equipment?								
Notes									

Docket No. FAA-2019-0539	**Statement of Policy on Performance Requirements for Operators of Aircraft That are Equipped With Automatic Dependent Surveillance-Broadcast (ADS-B) Out**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	After January 1, 2020, unless otherwise authorized by ATC, all aircraft operating in the airspace identified in § 91.225 must comply with the ADS-B Out performance requirements in § 91.227. However, there are circumstances outside of an operator's control that may result in a temporary degradation of GPS performance and an apparent violation of § 91.227. An operator may exercise due diligence in performing a preflight availability prediction for its intended route of flight but experience rerouting by ATC after obtaining an initial ATC route clearance, which may cause an unanticipated degradation of performance. Additionally, an operator may encounter actual GPS interference on its intended path of flight, which would affect the ability of an aircraft to meet the performance requirements of § 91.227. Lastly, an operator may not be able to complete a preflight availability prediction for its intended route of flight due to the FAA's SAPT being out of service. As previously explained, the FAA recognizes that these situations are outside of the operator's control. Therefore, the FAA will not consider these events to constitute noncompliance with § 91.227 due to the circumstances discussed in this document to the extent such an application would impose a standard of conduct wholly outside the operator's control.								
Key requirements									
	• ADS-B Position Sources								
	• FAA ADS-B Service Availability Prediction Tool (SAPT)								

	• Exemption No. 12555 for an exemption from the Navigation Accuracy Category for Position (NACp) and Navigation Integrity Category (NIC) requirements of the rule
	• GPS Interference
Notes	

Docket No. FAA-2019-0239	**Statement of Policy for Authorizations to Operators of Aircraft That are Not Equipped With Automatic Dependent Surveillance-Broadcast (ADS-B) Out Equipment (April 2019)**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	To operate in ADS-B airspace, an operator who has chosen not to equip with ADS-B Out equipment must obtain a preflight authorization in accordance with § 91.225(g). The operator has the responsibility to obtain a preflight authorization from ATC for all ADS-B Out airspace on the planned flight path. The FAA will however be very unlikely to issue routine and regular authorizations to scheduled operators seeking to operate non-equipped aircraft in rule airspace. Likewise, although unscheduled operators may request authorizations for airspace at capacity constrained airports, issuance of an authorization may prove difficult to obtain.								
Key requirements									
A	• General Policy								
B	• Policy for Scheduled Operations in ADS-B Out Airspace								
C	• Policy for Operations Other Than Scheduled Operations in ADS-B Out Airspace								
D	• Continued Provision of ATC Services to Non-Equipped Aircraft								
Notes	This document provides some explanations on how the FAA chose to manage non-compliant aircraft.								

Docket No.: FAA-2017-1194	**Change to Automatic Dependent Surveillance Broadcast Services**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This action announces changes in ADS-B services, including Traffic Information Service—Broadcast (TIS-B), for a small number of aircraft. The FAA is implementing a filter for certain ADS-B equipped aircraft broadcasting erroneous or improper information when the broadcast information could affect the safe provision of air traffic services. Any aircraft subject to the filter will not have its ADS-B information sent to an air traffic control (ATC) facility nor will the aircraft be a client for TIS-B services. Affected aircraft will continue to receive ATC services within radar coverage using secondary radar information.								
Key requirements									
Action	Mentions that the FAA will filter the ADS-B information from any aircraft transmitting a non-compliant address code (eg "000000" and "FFFFFF") from the FAA's operational ATC systems. Aircraft broadcasting these incorrect ICAO address codes will be unable to receive TIS-B services								

Notes	Footnote mentions "TIS-B uses secondary surveillance radars and multilateration systems to provide proximate traffic situational awareness, including position reports from aircraft not equipped with ADS-B Out. TIS-B data may not provide as much information as could be received directly from an aircraft's ADS-B Out broadcast, because of the required data processing. The TIS-B signal is an advisory service that is not designed for aircraft sur veillance or separation, and cannot be used for either purpose.

Docket No.: FAA-2018-0914	**Changes to Surveillance and Broadcast Services (November 2018)**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	**Uncontrolled**							
Description of the regulation / standard	This action announces changes to the following surveillance and broadcast services after January 1, 2020: Automatic Dependent Surveillance—Broadcast (ADS-B); Traffic Information Service—Broadcast (TIS-B); Automatic Dependent Surveillance—Rebroadcast (ADS-R); and Automatic Dependent Surveillance—Same Link Rebroadcast (ADS-SLR). These service changes will affect aircraft equipped with older ADS-B avionics that do not meet the requirements of 14 CFR 91.225. That is equipment that do not meet the performance requirements of TSO-C166b or TSO-C154c (aka Pre-2020 Equipment).								
Key requirements									
NAS-Wide Service Changes	FAA will no longer use ADS-B data from Pre-2020 Equipment to provide ATC surveillance services after January 1, 2020. As such, the FAA will discontinue TIS-B and ADS-R client services NAS-wide for aircraft equipped with Pre-2020 Equipment after January 1, 2020								
Notes	The FAA funded a project to upgrade Pre-2020 Equipment in certain regions (eg Alaska).								

11.3 - Industry standards

11.3.1 - Ground

11.3.1.1 - EUROCAE

ED-129B	**Technical specifications for a 1090 MHz extended squitter ADS-B ground systems**						**B Issue** **March 2016**		
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA	**Critical**	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							
Description of the regulation / standard	The standard defines the minimum technical specification for a 1090 MHz Extended Squitter ADS-B Ground System. The ADS-B System is the "SUR Sensor" element of an infrastructure supporting ATS Surveillance Service(s), such as the Approach Control and Area Control Services within the European Air Navigation Region.								
Key requirements									
Chapter 2	Chapter 2 contains general design requirements.								

Chapter 3	The requirements specified in chapter 3 are the minimum surveillance performance specifications for an ADS-B System to support the applications for different types of airspace and separations defined in Chapter 1. The requirements listed in this chapter specify: • Functionality of the system (Section 3.2) • **Surveillance data processing performance (Section 3.3)** • Data formats to interface with other systems (Section 3.4) • Control and monitoring functionality (Section 3.5) These requirements are to be met in standard operational conditions.
Notes	ADS-B performance requirements, specified in Section 3.3 will need to be considered when considering the controlled airspace. Different requirements might be needed for FIS and deconfliction service.

ED-142			**Technical Specifications for Wide Area Multilateration (WAM) Systems**				**2010 Edition, September 2010**	
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	Uncontrolled							
Description of the regulation / standard	This standard specifies the minimum performance requirements for a Wide Area Multilateration (WAM) System that is part of a system providing airspace situational awareness to air traffic controllers and other users within the European Air Navigation Region primarily intended for ATM, in both high and low density environments. The performance requirements are defined for 3 and 5 NM horizontal separations.								
Key requirements									
Chapter 3	Minimum WAM performance specifications under standard conditions: • Probability of position detection (PD) • Probability of long position gaps (PLG) • Probability of false detection (PFD) • Probability of code detection (PCD) • Probability of False Code Detection (PFCD) • Horizontal Position Accuracy								
Notes									

ED-109A			**Software Integrity Assurance Considerations for Communication and Navigation and Surveillance and Air Traffic Management (CNS/ATM) systems**				**Corr 1** **15 Feb 2021**		
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									

Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This document deals with aspects of approval that pertain to the production of software for CNS/ATM systems. A complete description of the system life cycle processes, including the system safety assessment and validation processes, or the approval process is not intended. This document assumes that during the system definition, functions have been allocated to either software or hardware. Other documents exist that provide guidance for development assurance for functions that are allocated to implementation in hardware. This document provides guidance for functions that are allocated to software. This standard is also a strong guideline comprising both recommendations and assessable objectives. It is intended for use in developing ground-based systems (containing software) which are involved with aircraft operations. These ground-based systems almost always make heavy use of Commercial Off The Shelf (COTS) technologies including hardware and software. The ground-based systems governed by ED-109A often have much larger, and more diverse, software components than their airborne avionic counterparts.
Key requirements	
Section 9	Approval liaison process
Section 10	Overview of CNS / ATM system approval process This section is an overview of the approval process with respect to software aspects of the CNS/ATM systems equipment.
Section 12.4	Commercial off-the-shelf software verification and validation processes
Notes	Jointly developed with RTCA DO-278

ED-153			**Guidelines for ANS Software Safety Assurance**						**August 2009**
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This document applies to software that forms part of an ANS system. The scope of this extends to the overall lifecycle of software within an ANS system, however this document considers aircraft software out of scope and is therefore limited to the "ground" segment of ANS. This document assumes that a risk assessment and mitigation process has been undertaken along with an a priori system (where system includes people, procedure and equipment) safety assessment with the results forming an input to this document. This document is limited to software safety assurance and any references to software lifecycle data are made solely within the context of software safety assurance. Documentation not related to software lifecycle data is therefore out of scope. This document covers: • Guidance for an ANSP to establish a software safety assurance system;

	• Guidance for software suppliers on the necessary software safety assurance regarding products and processes; • A reference against which stakeholders can assess their own practices for software safety assurance of: specification, design, development, operation, maintenance, and decommissioning; • A software assurance process that will promote interoperability through its common application to ANS software development.
Key requirements	
Notes	This standard will need to be applied if there is a need to develop new ANS software for processing EC-based surveillance information.

ED 126			**Safety, performance and interoperability requirements for ADS-B NRA application**						
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This document addresses the operational concept and minimum requirements for the use of ADS-B Surveillance for ATS services in Non-Radar Areas (ADS-B-NRA). This ED defines and allocates the set of minimum requirements for the end-to-end operational, safety, performance and interoperability aspects for implementations of the ADS-B-NRA application. These requirements can be used for approval processes including aircraft type design approval, and operational approvals for aircraft operators and ATS providers.
Key requirements	
Section 3	Section 3 of the main body specifies the minimum operational safety and performance requirements for both, the airborne and the ground domain. Subsection 3.4 provides the performance requirements to aircraft domain which are divided into those on the surveillance data (e.g. data accuracy and integrity), and requirements on the overall system which collects, processes and transmits the data (e.g. airborne system reliability, timing, and functional integrity). Subsection 3.5 covers the ground functional requirements and ground performance requirements.
Section 4	Interoperability requirements specifying the needed transfer of data between transmitting aircraft and ground domains is provided in section 4. This interoperability specification is presented at a link-neutral (i.e. MASPS) level. Annex H provides traceability of Section 4 to specific 1090MHz Extended Squitter interoperability requirements.
Annexes E	Surveillance risk and quality consideration for ADS-B.
Annex D	Summary of the recommendations for ground systems
Annex F	Mapping between NUCp and NIC/NACp for ATC separation service
Annex H	ADS-B-NRA interoperability requirements for 1090 MHz extended squitter

Notes	This ED was developed jointly with RTCA 303.

11.3.1.2 - RTCA

DO-358A	**Minimum Operational Performance Standards (MOPS) for Flight Information Services - Broadcast (FIS-B) with Universal Access Transceiver (UAT)**								**Revision B,** **March 2021**	
Domain			**Applicability**				**Relevance for the study**			
Airborne	**Ground**	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								
Description of the regulation / standard	This document contains MOPS for Flight Information Services – Broadcast (FIS-B) system with UAT. These standards specify system characteristics that should be useful to designers, manufacturers, installers and users of the equipment. Compliance with these standards is recommended as one means of assuring that the equipment will perform its intended function(s) satisfactorily under all conditions normally encountered in routine aeronautical operation. This document considers an equipment configuration consisting of the airborne processing and cockpit display of aeronautical and meteorological data known as FIS-B provided by the Federal Aviation Administration. Functions or components that refer to equipment capabilities that exceed the stated minimum requirements are identified as optional features.									
Key requirements										
Section 1	The section provides information needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment operations and operation goals and establishes the basis for the standards stated in Section 2. Definitions and assumptions essential to proper understanding of this document are also provided in this section.									
Section 2	Section 2 contains the minimum performance standards for the equipment. These standards specify the required performance under standard environmental conditions. Also included are recommended bench test procedures necessary to demonstrate equipment compliance with the stated minimum requirements.									
Notes										

DO-303	**Safety, Performance and Interoperability Requirements Document for the ADS-B Non-Radar Airspace Application**								**2006 Edition** **December 2006**
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									

Controlled	Uncontrolled with FIS	Uncontrolled						

Description of the regulation / standard	This standard addresses the operational concept and minimum requirements for the use of ADS-B Surveillance for ATS services in Non-Radar Areas (ADS-B-NRA).
Key requirements	
Section 3	The results of these assessments have been compiled into Section 3 of the main body which specifies the minimum operational safety and performance requirements (SPR)
Section 4	Interoperability requirements specifying the needed transfer of data between transmitting aircraft and ground domains is provided in this section.
Annexes	Annexes of the document contain the Operational Services and Environment Definition (OSED), a comparative operational performance assessment, an operational safety assessment, and a summary of a published comparative risk assessment.
Notes	DO 303 was developed jointly with EUROCAE ED 126.

DO-286B	**MASPS for Traffic Information Service – Broadcast (TIS-B)**							**Revision B, October 2007**	
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	This document contains MOPS for airborne equipment for ADS-B and TIS-B utilizing 1090 MHz Mode-S Extended Squitter. The supporting hardware can be incorporated within other on-board equipment, or alternatively, the ADS-B equipment may be a separate avionics unit. Revision B to DO-286A separates Automatic Dependent Surveillance - Rebroadcast (ADS-R) from the TIS-B MASPS. The basic TIS-B services described in DO-286A remain fundamentally unchanged.
Key requirements	
Section 1	This section provides information and assumptions needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment applications and operational goals and, along with RTCA DO-242A, Minimum Aviation System Performance Standards for ADS-B, forms the basis for the standards stated in Sections 2 and 3.
Section 2	Section 2 contains the minimum operational performance standards for the equipment. These standards define required performance under standard operating conditions and stressed physical environmental conditions. Also included are recommended bench test
Notes	Developed jointly with EUROCAE ED-102.

DO-282B	**Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast**	

Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The document contains Minimum Operational Performance Standards for airborne equipment to support Automatic Dependent Surveillance - Broadcast utilizing the Universal Access Transceiver (UAT). UAT is a multi-purpose aeronautical data link intended to support not only ADS-B, but also Flight Information Service - Broadcast (FIS-B), Traffic Information Service - Broadcast (TIS-B) and, if required in the future, supplementary ranging and positioning capabilities.
Key requirements	
Section 2	Section 2 summarises equipment performance requirements and test procedures
Section 3	This section provides equipment performance characteristics and defines performance requirements.
Section 4	Section 4 contains required operational performance characteristics of the equipment
Annex D	The annex describes the UAT ground infrastructure and guidance for its deployment
Notes	The standard was developed in parallel with DO-260B.

DO-365B	**MOPS for Detect and Avoid (DAA) Systems UAS**	**Revision B** **March 2021**

Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	The DAA system was specified to assist the remote pilot with operating an aircraft safely. The DAA equipment may also be used to comply with the duties in International Civil Aviation Organization (ICAO) Annex 2 to the Convention on International Civil Aviation, specifically Chapter 2, Paragraph 2.3.1. This document contains MOPS for DAA systems used in aircraft transiting and performing extended operations in Class D, E, and G airspace along with transiting Class B and C airspace. It includes equipment to enable UAS operations near Terminal Areas during approach and departure in Class C, D, E, and G airspace, and off-airport locations, but not operating in the visual traffic pattern or on the surface. It does not apply to small UAS (under 55 pounds (lbs)) operating in low-level environments (below 400') or other segmented areas.
Key requirements	
Section 2	Section 2 defines DAA equipment performance requirements and test procedures

Section 4	This section provides Aircraft operational performance characteristics
Annex A	The annex describes DAA OSED
Notes	

DO-381	**MOPS for Ground-based Surveillance System (GBSS) for Traffic Surveillance implemented with UAS**								**March 2020**	
Domain			**Applicability**				**Relevance for the study**			
Airborne	**Ground**	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**	
Controlled / Uncontrolled airspace										
Controlled	Uncontrolled with FIS	Uncontrolled								
Description of the regulation / standard	This document contains MOPS for the Ground Based Surveillance System for Traffic Surveillance systems implemented with Unmanned Aircraft Systems (UAS) transiting and performing extended operations in Class D, E and G airspace, along with transiting Class B and C airspace. It includes equipment to enable UAS operations near terminal areas during approach and departure in Class C, D, E and G airspace and off-airport locations. It does not apply to small UASs. Likewise, it does not apply to operations in the Visual Flight Rules (VFR) traffic pattern of an airport, nor to surface operations. Compliance with these standards is recommended as one means of assuring that the equipment will perform its intended function(s) satisfactorily under the conditions specified herein. Any regulatory application of this document is the sole responsibility of appropriate governmental agencies.									
Key requirements										
	Full standard was not available for review.									
Notes										

11.3.2 - irborne

11.3.2.1 - EUROCAE

ED-102A	**Minimum Operational Performance Standards for 1090 MHz Extended Squitter ADS-B and TIS-B**								**January 2012**
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	**Uncontrolled with FIS**	Uncontrolled							
Description of the regulation / standard	ED-102A/DO-260B is a joint publication of EUROCAE and RTCA and is referenced as the basis for ADS-B version number 2. The standard contains Minimum Operational Performance Standards (MOPS) for airborne equipment for ADS-B and TIS-B utilizing 1090 MHz Mode-S Extended Squitter (1090ES).								

Key requirements	
Section 2	The section defines on-board equipment requirements • ADS-B equipage classes - Interactive aircraft/vehicle participant systems (Class A, Table 2-3 and Table 2-5), Broadcast-only participant systems (Class B, Table 2-4) and Ground receive systems (Class C). • Minimum performance standards for each Class The following performance parameters are defined: • Navigation Accuracy Category for Position **(NACP), Table 2-70:** Navigation Accuracy Category for Position (NACP) Encoding - specifies the accuracy limits for each NACP (Navigation Accuracy Category for Position) value with regard to Estimated Position Uncertainty (EPU) • Navigation Accuracy Category for Velocity **(NACV), Table 2-22**: Determining NACV Based on Position Source Declared Horizontal Velocity Error • Source Integrity Level **(SIL) - Table 2-72:** “SIL” Subfield Encoding • Navigation Integrity Category **(NIC) Table 2-69:** Navigation Integrity Category (NIC) Encoding • Geometric Vertical Accuracy **(GVA), Table 2-71:** Encoding of the Geometric Vertical Accuracy (GVA) in Aircraft operational status messages
Section A.2	The section describes TIS-B formats and coding including TIS-B surveillance message definition and formats for 1090 MHz TIS-B message
Section D	1090 MHz ADS-B ground architecture example for ADS-B utilisation for ATC surveillance and TIS-B. The important sections for the study are: • D.2.6 Ground architecture for air-ground surveillance including Mode S SSR Ground station, extended squitter ground stations • D.2.7 Ground architecture for surface surveillance • D.3 Traffic information service broadcast (TIS-B) including Ground architecture
Section E	Air-to-Air range as limited by power of different avionics classes: • Table E-1: Summary of transmitter and receiver requirements • Table E-2: Air-to-air range as limited by power
Notes	Section D will be important for the TIS-B scenario.

ED-115	**MOPS for Light Aviation SSR**							**August 2002**	
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							
Description of the regulation / standard	This MOPS is designed to ensure that Light Aviation Secondary Surveillance Radar (SSR) Transponder (LAST)equipment compliance with the MOPS, will be compatible with ICAO Annex 10, Volume IV, as to Amendment 77. This MOPS also includes requirements and tests for a dedicated LAST power source (e.g. battery), a dedicated altitude coder and antenna subsystem which may also be part of the LAST. This Minimum Operational Performance Specification does not include detailed descriptions of Mode S coding formats, protocols and interfaces; these can be found in ICAO Annex 10, Volume IV.								

Key requirements	
Chapter 1	This chapter provides information necessary to understand the need for the equipment requirements and tests defined in the remaining chapters. It describes typical equipment applications and operational objectives and is the basis for the performance criteria stated in Chapter 2 to Chapter 4. Definitions essential to proper understanding of this document are also provided in Chapter 1.
Chapter 2	Chapter 2 contains general design specifications.
Chapter 3	Chapter 3 contains the minimum performance specification for the equipment, defining performance under standard operating conditions.
Chapter 6	Chapter 6 specifies the performance requirements of the installed equipment. It also includes ground and flight tests of the installed equipment that may be required when performance cannot be adequately determined through testing under standard test conditions
Notes	

ED-73E	**MOPS for SSR Mode S Transponders**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	These minimum operational performance specifications are designed to ensure that aircraft Mode S transponder equipment certificated to them will be compatible with ICAO Annex 10, Volume IV, Part I and ICAO Document 9871 Technical Provisions for Mode S Services and Extended Squitter. In addition, it contains new requirements that are proposed to be added in a future version of ICAO Annex 10, Volume IV. These minimum operational performance specifications do not include detailed descriptions of Mode S coding formats, protocols and interfaces; these can be found in ICAO Annex 10, Volume IV.
Key requirements	
Chapter 1	Chapter 1 provides information necessary to understand the need for the equipment requirements and tests defined in the remaining chapters. It describes typical equipment applications and operational objectives and is the basis for the performance criteria stated in Chapter 2 to Chapter 4. Definitions essential to proper understanding of this document are also provided in Chapter 1.
Chapter 2	The chapter contains general design specifications.
Chapter 3	This chapter contains the minimum performance specification for the equipment, defining performance under standard operating conditions.
Chapter 6	Chapter 6 specifies the performance demanded of the installed equipment. It also includes ground and flight tests of the installed equipment which may be required when performance cannot be adequately determined through testing under standard test conditions.
Notes	

EUROCAE ED-161	Safety Performance and Interoperability Requirements for ADS-B in Radar Airspace (ADS-B RAD)								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	**EC / EASA**	FAA	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							
Description of the regulation / standard	This standard includes the definition of the services and environmental conditions relevant to the implementation of the ADS-B-RAD application and the operational, safety, performance and interoperability requirements for using the application. This document defines and allocates the set of minimum requirements for the end-to-end operational, safety, performance and interoperability aspects for implementations of the ADS-B-RAD application. Requirements are allocated to the necessary domains of the CNS/ATM system, i.e., at Aircraft and Ground Domain level. This document also provides guidance to determine the levels of design assurance and performance that are needed for each element (aircraft, operator, and Air Navigation Service Provider (ANSP)) to support the ADS-B-RAD application. The ADS-B-RAD SPR and interoperability standards are envisioned to be used along with SPR and interoperability standards from other surveillance applications based on ADS-B to develop minimum standards for avionics systems to assure that all subsystems perform their intended functions adequately for ADS-B applications. This document defines ADS-B requirements applicable to dense airspaces such as those that will be found in Europe and the USA. The requirements in this document have been developed from a necessarily conservative comparative analysis of ADS-B performance to radar performance. Local implementers may pursue further studies and analyses, such as target level-of-safety (TLS) studies in relation to the ADS-BRAD operational performance assessment, to confirm minimum performance standards. If these studies indicate that a different set of requirements can be supported, the relevant standards may be updated accordingly.								
Key requirements									
Section 3	This section contains the outcome of the Safety and Performance Requirements (SPR) assessment for the ADS-B-RAD application. The safety and performance requirements detailed in this section are the requirements that resulted from retaining the most stringent values from the operational performance assessment (Annex B) and the operational safety assessment (Annex C).								
Section 4	Section 4 specifies the minimum set of interoperability requirements to provide assurance that the elements of the CNS/ATM system are compatible with each other and will perform their intended function for ADS-B-RAD. The CNS/ATM system relevant to ADS-B-RAD is divided into the aircraft and ground domains.								
Notes	Developed jointly with RTCA DO-318								

EUROCAE ED-164	Safety Performance and Interoperability Requirements for ATSAW during flight operations (ATSAW AIRB).	
Domain	**Applicability**	**Relevance for the study**

Airborne	Ground	Policy	UK	ICAO	EC / EASA	FAA	Critical	Essential	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	ED 164 includes the definition of the services and the environmental conditions relevant to the implementation of the ATSA-AIRB application and the operational, safety, performance and interoperability requirements for using the application. The document defines and allocates the set of minimum requirements for the end-to-end operational, safety, performance and interoperability aspects for implementations of the ATSA-AIRB application. Allocation of these requirements is done by this SPR/interoperability to the necessary domains of the CNS/ATM system, i.e. at aircraft and ground domain level. These requirements can be used as a component for approval processes including aircraft type design approval, aircraft operator operational approval and Air Traffic Services (ATS) provider operational approval. In addition, this document provides guidance to determine the levels of design assurance and performance that are needed for each element (aircraft, operator and ANSP - Air Navigation Service Provider) to support the ATSA-AIRB application.
Key requirements	
Chapter 3	Safety and performance requirements (SPR) Chapter 3 contains the outcome of the SPR assessment for the ATSA-AIRB application. The SPRs detailed in this section are the requirements that resulted from retaining the most stringent values from the operational performance assessment (Annex B) and the operational safety assessment (Annex C).
Chapter 4	Interoperability requirements This chapter specifies the minimum set of interoperability requirements and allocations necessary to provide assurance that the elements of the CNS/ATM system are compatible with each other and will perform their intended function for ATSAAIRB. The interoperability requirements found in this chapter specify technical exchange of data between all relevant domains for the ATSA-AIRB application. This exchange of data focuses on the ADS-B surveillance data and therefore does not include data that is communicated over voice or other surveillance data such as TIS-B or ADS-R. Chapter 4 provides the minimum interoperability requirements needed to satisfy the SPRs stated in Chapter 3. It also included are recommendations for further requirements or means on how requirements are best met.
Annex A	OSED
Notes	Developed jointly with RTCA DO-319

11.3.2.2 - RTCA

DO-307A			**Aircraft Design and Certification for Portable Electronic Device (PED) Tolerance**					**December 2016**	
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**

Controlled / Uncontrolled airspace								
Controlled	Uncontrolled with FIS	Uncontrolled						

Description of the regulation / standard	This standard defines design guidance and certification recommendations for aircraft tolerance to interference from portable electronic devices. The aircraft design guidance and certification recommendations address all portable electronic devices, including transmitting portable electronic devices. The document recommends specific interference path loss targets for aircraft to mitigate the effects of PED spurious emissions on aircraft radio receivers. The report recommends specific RF immunity requirements for aircraft systems that are exposed to PED intentional RF transmissions. The recommendations are independent of class of aircraft; they can be applied to small and large airplanes, and small and large rotorcraft.
Key requirements	
Notes	This standard was not available for a full review.

DO-294C	**Guidance on Allowing Transmitting Portable Electronic Devices (T-PEDs) on Aircraft**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							

Description of the regulation / standard	DO-294C addresses near-term T-PED technologies such as existing devices enabled with cellular technologies, wireless local area networks (WLANS), and wireless personal area networks (WPANS) as well as emerging PED technologies, for example active RF Identification (RFID) tags, transmitting medical devices, and picocells for devices enabled by cellular technologies for use on board aircraft. The document defines and recommends a process by which aircraft operators and/or manufacturers may assess the risk if interference due to a specific T-PED technology within any aircraft type and model It also provides a means for aviation authorities and others to determine acceptable and enforceable policies and processes for passenger and crew use of T-PEDs.
Key requirements	
Notes	This standard was not available for a full review.

DO-385	**Minimum Operational Performance Standards for Airborne Collision Avoidance System X (ACAS X) (ACAS Xa and ACAS Xo**								
Domain			**Applicability**				**Relevance for the study**		
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									

Controlled	Uncontrolled with FIS	Uncontrolled						

Description of the regulation / standard	his document sets forth minimum operational performance standards for the Airborne Collision Avoidance System X (ACAS X) equipment, including both Active surveillance (Xa) and special Operations (Xo) functions. ACAS X is intended to improve air safety by acting as a last-resort method of preventing mid-air collisions or near mid-air collisions between aircraft. By utilizing surveillance information from Secondary Surveillance Radar (SSR) and ADS-B technology, ACAS X equipment operates independently of ground-based aids and air traffic control (ATC). Aircraft equipped with ACAS X have the ability to interrogate airborne transponders and receive ADS-B Messages to determine the location of other aircraft in the vicinity and assess the risk of collision. ACAS Xa/Xo equipment is not required to detect non-cooperative aircraft. ACAS X provides Traffic Advisories (TAs) and Resolution Advisories (RAs) in the vertical plane. RAs are indications given to the flight crew recommending manoeuvres intended to avoid collisions with all threats, or restrict manoeuvres to maintain existing separation. RA information is provided by ACAS X to Mode S SSRs and ADS-B ground radios, but typically is not presented to controllers. Some alerts (e.g. wind shear warnings, stall warnings, and Ground Proximity Warning System warnings) have higher priority than ACAS RAs. Incorporated within these standards are system characteristics that should be of value to users, designers, manufacturers, and installers. These characteristics are intended to accommodate the requirements of various users. This standard is published in two volumes. Both Volumes I and II contain certain standards and performance requirements that ensure that ACAS X is fully interoperable with other airspace elements and equipment. It is mandatory that these interoperability provisions be met without exception or deviation. Other technical and performance requirements stated herein that were derived from the particular implementation approach that formed the basis for the development of this MOPS may be waived if the manufacturer or installer provides evidence of equivalent system performance for an alternative method of implementation and if the alternative implementation does not violate interoperability provisions.
Key requirements	
Section 1	Section 1 Volume I is intended to provide information needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical equipment applications and operational goals and is the basis for the standards stated in the document. Definitions essential to proper understanding of this document are also provided in Section 1.
Section 2	Section 2 of Volume I contains the minimum performance standards for the equipment. These standards define the required performance under standard operating conditions and stressed physical environmental conditions. It also details bench test procedures that demonstrate compliance, including specific bench tests for the collision avoidance logic performance.
Section 3	Section 3 of Volume I describes the performance required of the installed equipment. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing.
Notes	

DO-242	**Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS- B)**									**Revision A** **December 2006**	
Domain			**Applicability**				**Relevance for the study**				
Airborne	Ground	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	Essential	**Potentially applicable**		
Controlled / Uncontrolled airspace											
Controlled	Uncontrolled with FIS	Uncontrolled									
Description of the regulation / standard	This document supersedes DO-242 and provides an up-to-date view of the system-wide operational use of ADS-B. This revised ADS-B MASPS concentrates on four major areas of development: 1) Separating the accuracy and integrity components of the Navigation Uncertainty Category (NUC) into the new fields Navigation Accuracy (NAC) and Navigation Integrity Category (NIC); 2) Reorganization of the State Vector, Mode-Status, and On-condition reports; 3) Restructuring the content and manner in which intent information is broadcast; and 4) Clarification that system requirements at the MASPS level are based on operational ranges and not particular applications.										
Key requirements											
Section 2	Section 2 defines ADS-B operational requirements and system performance requirements										
Section 3	This section describes ADS-B System and also ADS-B functional level requirements										
Notes											

DO-338	**Minimum Aviation System Performance Standards (MASPS) for ADS-B Traffic Surveillance Systems and Applications (ATSSA)**								**June 2012**
Domain			**Applicability**				**Relevance for the study**		
Airborne	**Ground**	Policy	UK	ICAO	EC / EASA	**FAA**	Critical	**Essential**	Potentially applicable
Controlled / Uncontrolled airspace									
Controlled	Uncontrolled with FIS	Uncontrolled							
Description of the regulation / standard	This document contains information previously provided in other MASPS: the MASPS for Aircraft Surveillance Applications (RTCA DO-289), the MASPS for ADS-B (RTCA DO-242A); and the MASPS for TIS-B (RTCA DO-286B). The document combines those MASPS and updates requirements consistent with ADS-B Version 2. Requirements have been added and revised as necessary from ADS-B Version 1 and are reflected in this document to support the operational applications. ADS-B Version 2 is also the basis for ADS-B equipage requirements in the United States and other parts of the world to support ATC separation services. The document specifies requirements for and describes assumptions for all subsystems supporting the operational application of ATSSA, e.g., Automatic Dependent Surveillance - Broadcast (ADS-B), Traffic Information Service - Broadcast (TIS-B), Automatic Dependent Surveillance - Rebroadcast (ADS-R), Airborne Surveillance and Separation Assurance Processing (ASSAP) and Cockpit Display of Traffic Information (CDTI).								
Key requirements									

Notes	This standard was not available for a full review.

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