Detect and Avoid Policy Concept Consultation Document

CAP 3015

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CHAPTER 1
Introduction

Background

1.1 There is currently a strong industry demand for Beyond Visual Line of Sight (BVLOS) operation of Remotely Piloted Air Systems (RPAS) within the UK, and while forecast estimates vary, they consistently show a large increase in the sector over the next 10+ years. Perhaps the most significant barrier to the growth of this sector is the mid-air collision risk associated with Beyond Visual Line of Sight (BVLOS) operations.

Aviation Conflict Management and BVLOS Scalability

1.2 Conflict management within the existing global aviation system is premised on cockpit-based pilot see-and-avoid supporting elements of both layer two and three of the following three-layer system [1]:

- **Layer 1: Strategic conflict management** – Airspace design, demand & capacity balancing, traffic synchronisation. Strategic is used here to mean ‘in advance of tactical’. The objective of this layer is to minimise the need to apply the second layer.
- **Layer 2: Separation provision** – This is the tactical (in-flight) process of keeping aircraft away from hazards by at least the appropriate separation minima. A pre-determined separator is required, which is typically the airspace user via cockpit based see-and-avoid, unless an ATM separation provision service is required.
- **Layer 3: Collision avoidance** – Required when the separation mode has been compromised. This layer is predominately based on cockpit view pilot ‘see-and-avoid’, although for some categories of aircraft this may be augmented by systems such as Traffic Collision Avoidance System (ACAS).

1.3 For RPAS operations that are BVLOS of the remote pilot and outside of segregated airspace a DAA capability is therefore required to replace the pilot see-and-avoid responsibilities. DAA is defined within the ICAO RPAS Manual [2] as providing “*the capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action*”. The DAA system therefore enables the Remote Pilot (RP) to exercise their responsibilities with regard to other aircraft, as required within the standardised rules of the air [3].

1.4 Within their RPAS CONOP for International IFR [4], ICAO also define the following:

- **Accommodation** – Where RPAS can operate along with some level of adaptation or support that compensates for its inability to comply within existing operational constructs.
- **Integration** – Where RPAS enter airspace system routinely without requiring special provisions.

1.5 DAA, as defined above, is therefore a critical enabler for BVLOS RPAS operations and the safe *integration* of RPAS into the wider airspace environment. Where the DAA system is not able to fully replicate the pilot cockpit see-and-avoid capability then *accommodation* is still possible, with the required ruleset and procedures dependent on the capability of the DAA system.

1.6 The *scalability* of the BVLOS solution can then be defined by the restrictions imposed on other air users for the *accommodation* of RPAS operations. Such restrictions may include:

- **Loss of airspace access**, e.g., segregation of RPAS from all other air users.
- **Mandatory equipment carriage**, e.g., Electronic Conspicuity (EC) or enhanced visual or radar conspicuity.
- **Traffic control procedures**, e.g., a separation or deconfliction service to structure traffic within the airspace.
- **Traffic density restrictions**, e.g., to enable large separation distances.
- **Traffic speed / size restrictions**, e.g., low speed light aircraft only.

1.7 The requirement for such restrictions, and hence the scalability of the BVLOS solution, is determined largely by the assured performance capability of the RPAS DAA system.

Objective

1.8 The CAA's vision for the BVLOS RPAS operation within the UK is set out in the Airspace Modernisation Strategy (AMS) [5,6], which describes a transition from the use of segregated airspace to integrated operations, supported by the use of Transponder Mandatory Zones (TMZs). In support of this vision, and the above discussion of BVLOS scalability, *the objective of this paper is to set out a policy concept for the assurance of DAA systems*. Once agreed, this DAA policy concept will be published, allowing industry feedback and testing via sandbox and innovation type projects, ahead of formal policy adoption which will subsequently enable scaled up BVLOS operations.

Structure of this Paper

1.9 The remainder of this paper is structured as follows:

- Chapter 2 defines the scope and assumptions that underpin the DAA policy concept.
- Chapter 3 defines the DAA intended function, interaction with standardised rules of the air, and examples levels of automation and autonomy.
- Chapter 4 presents a range of metrics and discusses the assessment of DAA system performance.
- Chapter 5 then presents a range of requirements regarding the implementation of the DAA intended function, categorised via i) performance, ii) system reliability / availability, iii) data integrity and iv) oversight and assurance.
- Finally, next steps, nomenclature, definitions, point of contact and references are provided in Chapters 6 to 9 respectively.

CHAPTER 2
Scope

Scope

2.1 This policy concept applies to all classes of airspace and categories of RPAS, with crewed aircraft as the only hazard considered. RPAS to RPAS encounters and other airborne hazards such as birds, weather and other obstacles will be considered in a later version of the policy. Additionally, no distinction is made between the use of onboard and offboard equipment within the DAA system. For example, a DAA capability may exploit ground-based surveillance rather than onboard sensors if available and preferred.

2.2 The context within which this DAA policy sits is the UK Specific Operating Risk Assessment (SORA) Air Risk Model [7]. The initial version of the Air Risk Model does not in itself enable new RPAS BVLOS operations within the UK. Rather, it embeds current CAA policies for approval of RPAS operations within the SORA structure and terminology, creating a framework within which new policies that are currently in progress will sit, including:

- Atypical air environment.
- Electronic conspicuity.
- Detect and Avoid (DAA) – *This document.*
- Unmanned aircraft systems Traffic Management (UTM).
- Airspace requirements for integration of BVLOS in unmanned aircraft in UK airspace [8].

2.3 Two distinct types of flight operations are considered:

- **Type-1**: Operations primarily conducted under self-separation and see-and-avoid (*primarily* uncontrolled airspace).
- **Type-2**: Operations that occur with separation provided by an Air Navigation Service Provider (*primarily* controlled airspace).

2.4 Encounters between RPAS and both type-1 and type-2 traffic are considered, where an encounter is defined as an event associated with the presence of an intruder aircraft. An Encounter is simply a measure of when the proximity of two aircraft becomes relevant, or where a simulation or timeline may start. An encounter must be ‘big enough to include all things which may influence the tactical mitigations of the aircraft, but not so big that the actions of aircraft 300 miles away are also counted' [9].

2.5 The air risk model [7] provides a structured process for determining the Air Risk Class (ARC) of an RPAS BVLOS operation, which is then used to determine a proportionate level of capability and oversight. Broad descriptions of each of the four ARCs are as follows:

- **Residual ARC-a**: Encounter rate with other crewed air traffic demonstrated to be negligible, therefore DAA based tactical mitigation of the air risk is not required.
- **Residual ARC-b**: Encounter rate with other crewed air traffic demonstrated to be low and exclusively Type-1, but not negligible. DAA based tactical mitigation is therefore required but must be supported by one or more additional mitigation layers.
- **Residual ARC-c**: Predominately Type-1 traffic and negligible commercial air transport aircraft, with either an encounter rate that cannot be demonstrated to be low enough for ARC-b, or additional supporting strategic mitigations are not available. DAA based tactical mitigation is therefore required and expected to be used routinely rather than occasionally.
- **Residual ARC-d**: Predominately Type-2 traffic, therefore subject to the highest level of tactical mitigation due to highest severity consequence (e.g., risk to life) and highest safety standard airspace. Specific category operations likely to be exceptions (e.g., via certified DAA system) rather than the normal for this ARC.

2.6 This DAA policy concept defines the proportionate requirement for tactical DAA based mitigation for ARC-b, ARC-c and ARC-d. The derivation of each ARC is provided in the UK SORA Air Risk Model [7].

Consultation Questions

Which of the Residual ARCs do you expect to operate in?

- Residual ARC-a
- Residual ARC-b
- Residual ARC-c
- Residual ARC-d

How strongly do agree with proposed scope of the Detect and Avoid Policy Concept?

- Strongly Agree
- Agree
- No strong feelings either way
- Disagree
- Strongly Disagree
- No view/don’t know

Please explain your answer and provide any other general comments.

Is there anything missing from the scope of the Detect and Avoid Policy?

CHAPTER 3
DAA Intended Function

Overview

3.1 The fundamental objective of a DAA system is to enable the RP to exercise their responsibilities with regard to the collision risk with other aircraft as defined within the standardised rules of the air [3] (e.g., vigilance, proximity and right of way as discussed further in Chapter 3, Interaction with SERA). The top-level generic functions of a DAA system are defined within the JARUS SORA [9] as:

- **Detect** – Surveillance for other local aircraft and tracking of any potential threats.
- **Decide** – Evaluation and selection of manoeuvre if necessary to avoid any threats.
- **Command** – Trigger the selected avoidance manoeuvre.
- **Execute** – Implement the triggered avoidance manoeuvre.
- **Feedback** – Continually[1] re-evaluate the encounter during any manoeuvre to see if the collision risk has changed.

3.2 The above functions can be implemented in many different ways, with examples provided within various technical standards [10,12,13,14,15,16], covering both performance level requirements and architecture and algorithm design. Within these options there are some minor differences in terminology and functionality, in particular for different classes of RPAS and classes of airspace. However, the core intended DAA functionality within these standards is comprised of the following:

- **Traffic surveillance function** – This may include onboard and/or offboard sensing for the detection of both cooperative and / or non-cooperative aircraft (see Chapter 4, Definitions).
- **Track processing function** – Using both own aircraft and surveillance data to generate and maintain intruder aircraft tracks for use by the display, alerting and guidance functions.

[1] Note that ACAS algorithms for coordinated manoeuvres usually only allow one resolution advisory reversal, for the case where one of the conflicting aircraft either doesn't follow the RA or follows it incorrectly.

- **Traffic display function**– Providing the RP with an awareness of the relative position of local air traffic.
- **Remain Well Clear (RWC) function** – Providing alerting and guidance to maintain any intruder aircraft outside of a pre-defined DAA Well Clear (DWC) volume.
- **Collision Avoidance (CA) function**[2] – Providing alerting and guidance to maintain any intruder aircraft outside of a pre-defined Near Mid Air Collision (NMAC) volume.

3.3 An example of DWC and NMAC boundaries is provided in Figure 1. In this case the definitions are purely spatial, but in many types of operations a temporal element is also included to account for high closure rates. As example of this is provided in Figure 2 where the protected volume depends on the speed and heading of the aircraft involved in the encounter. The applied definition of NMAC and DWC volumes is dependent on RPAS category and the phase of flight, as defined within Chapter 5, DAA requirements.

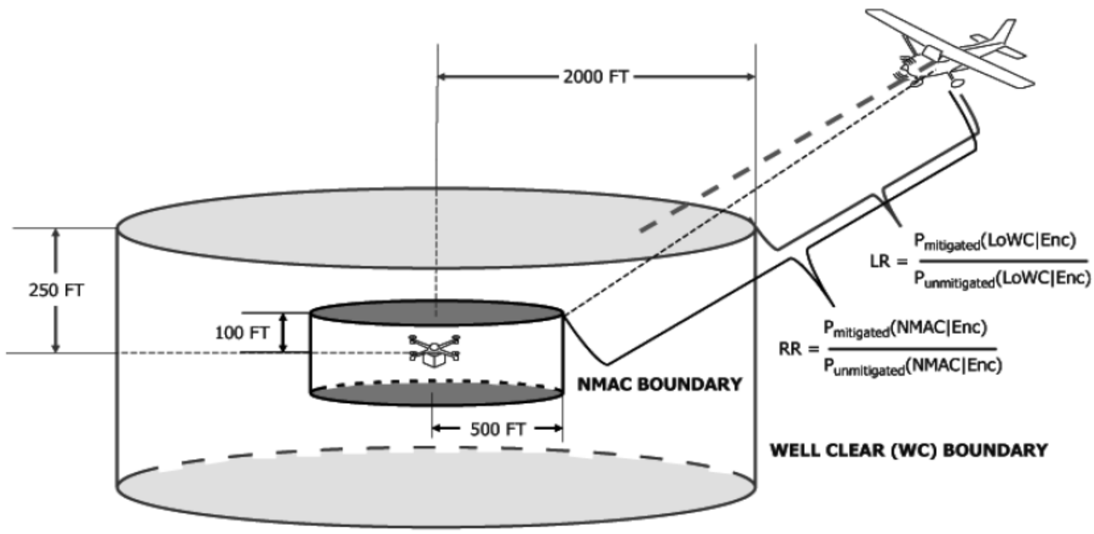

Figure 1 – NMAC and Well Clear Boundary example [16]

[2] Note that DO-365 [13] requires a maintain and regain RWC function and not a CA function. A CA function is allowed within the standard but is not required.

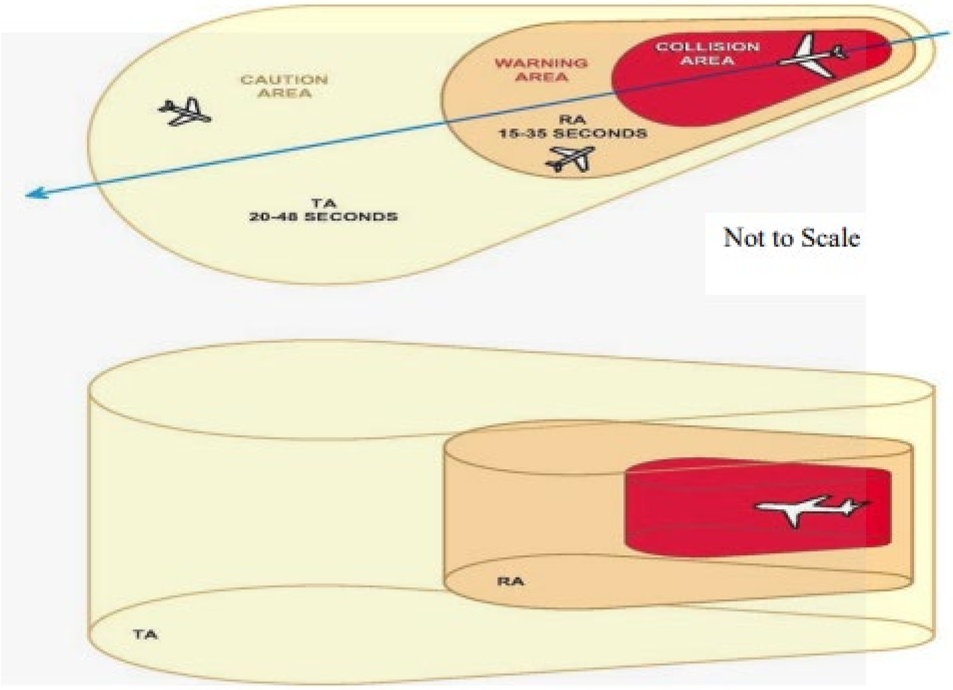

Figure 2 – TCAS protection Volumes [39]

Interaction with Standardised European Rules of the Air (SERA)

3.4 The UK CAA is currently conducting a review of the rules-of-the-air with regard to BVLOS RPAS operations. Until that review is complete this chapter provides initial guidance in line with the existing rules of the air and ICAO documentation.

3.5 Focussing only on the collision hazard with other aircraft the relevant rules from SERA [3] are:

(a) **SERA.3201**, which states that nothing within SERA relieves the pilot-in-command of an aircraft from the responsibility to take collision avoidance action. The GM also requires "… vigilance [on-board an aircraft] for the purpose of detecting potential collisions…".

(b) **SERA 3205**, which requires to not operate an aircraft in such proximity to other aircraft as to create a collision hazard.

(c) **SERA 3210**, which defines the right-of-way rules between certain types of aircraft, and manoeuvres that must be taken to avoid collisions.

3.6 The DAA system enables the RP to exercise their responsibilities with regard to the above rules and hence other aircraft.

3.7 The ICAO DAA Manual [12] states that DAA *Remain Well Clear* manoeuvres are intended to respect the right-of-way rules of SERA. However, DAA *Collision Avoidance* manoeuvres allow the RP to 'take any action necessary to best avoid a collision', which is 'similar to Airborne Collision Avoidance System (ACAS)'. If operating under a separation service, then RWC alerting must provide sufficient time to coordinate a required manoeuvre with ATC. Collision Avoidance manoeuvres do not require coordination with ATC.

3.8 The ICAO RPAS Manual [40] states the following:

(a) Para 1.3.5 *The rules of the air apply to all aircraft, manned or unmanned*. Furthermore, they oblige Contracting States to maintain national regulations uniform with ICAO Standards, to the greatest possible extent, and to prosecute all persons violating them. This is the basis for international harmonization and interoperability, which is as essential for unmanned as manned operations to be conducted safely.

(b) Para 6.9.6 The RPAS operator is responsible for designating the remote PIC. This individual *is responsible for the operation of the RPA in accordance with the rules of the air* laws, regulations and procedures of those States in which operations are conducted, except that the remote PIC may depart from these in circumstances that render such departure absolutely necessary in the interests of safety.

(c) Para 8.1.1 Remote pilots are fundamental to the safe operation of RPAS. They have the same basic responsibilities as pilots of manned aircraft for the operation of the aircraft in accordance with the rules of the air, and the laws, regulations and procedures of those States in which operations are conducted.

(d) Para 10.3.2 The detectability and conspicuity of RPA will have to be sufficient to ensure timely identification by other airspace users and ATC in all phases of flight (including ground operations). *Timely detection (by visual or electronic means) will ensure that the rules of the air can be applied safely*.

(e) Para 10.3.3 If a very small RPA is to be integrated into non-segregated airspace, it is doubtful that it will be visible to manned aircraft. Even if the RPA has a transponder or ADS-B, not all manned aircraft will have the capability to detect it. As a result, it may be difficult to integrate such non-conspicuous RPA into non-segregated airspace *unless they can be made visible to pilots of manned aircraft*.

(f) Para 10.11.1 During an encounter between an aircraft without ACAS and an RPA, the RPA’s DAA system should propose a resolution advisory that will be *consistent with the rules of the air*. In case the RPA is not equipped with a DAA system, the pilot will take action and *follow the rules of the air*.

Levels of Automation

3.9 A range of levels of automation are feasible for the DAA system. This can vary from fully manual where the RP is presented with data and then decides how best to respond, to fully automated where the system determines and executes any necessary manoeuvres without requiring pilot intervention. The following distinct options are discussed within several different DAA technical standards [13, 14, 16]:

- **Information only Display** – This approach enables a digital form of self-separation and can be considered as analogous to a digital equivalent to Visual Flight Rules (VFR), where a minimum set of intruder information is displayed to the pilot (e.g., call sign, range, location, heading, bearing, relative and absolute altitude, vertical trend, and ground speed) but no manoeuvre guidance is provided.
- **Suggestive piloted** – In addition to the information only display, guidance is also provided to the pilot on 'a range of advantageous or disadvantageous' [13] manoeuvres relating to conflicting traffic. However, it is left to the pilot to choose the appropriate course of action.
- **Directive piloted** – This approach provides a single recommended avoidance manoeuvre but relies on a human pilot to execute it.
- **Automated control** - Systems that are capable of identifying conflicts and manoeuvring to resolve them with no intervention by a human pilot.

3.10 In addition to the above functional capabilities the following JARUS levels of autonomy [17] enable the level of human oversight for individual DAA system functions to be specified:

- **Level 0 – Manual Operation**: The human fully responsible for function execution, with no machine support.
- **Level 1 – Assisted Operation**: The machine operates in an out-of-the-loop supporting role to the human in executing the function, e.g., provision of relevant information.
- **Level 2 – Task Reduction**: The machine operates in an in-the-loop management role in reducing human workload to accomplish the task, e.g., conflict alert and resolution advisory based on predicted flight paths.
- **Level 3 – Supervised Automation**: The machine executes the function under the supervision of the human who is expected to monitor and intervene as required, e.g., an automatic traffic collision and avoidance (TCAS) system tied to an autopilot which can automatically perform a manoeuvre when a Resolution Advisory is alerted.
- **Level 4 – Manage by Exception**: The machine executes the function alerting the human in the event of an issue. The human is not required to monitor the function in real time and is able to intervene at any time after being alerted by the machine to an issue.

- **Level 5 – Full Automation**: The machine is fully responsible for function execution. The human is unable to intervene in real-time either due to practical limitations or deliberate exclusion within the ODD.

3.11 Use of the above framework enables clear definition of the division of responsibility between the system and the pilot, which subsequently helps to direct assurance and oversight to both human and machine elements of the functional system. Legal and liability issues surrounding different levels of automation are currently being reviewed by the Law Commission on behalf of the UK CAA.

3.12 Finally it must be noted that any DAA function that relies on the remote pilot is also dependent on the performance and status of the command and control (C2) link. DAA assessment therefore needs to consider normal C2 link latency, integrity, availability and continuity, ensuring suitable mitigation of the MAC risk in the event of a lost C2 link.

Consultation Questions

How strongly do agree with the overall intended function for Detect and Avoid?

- Strongly Agree
- Agree
- No strong feelings either way
- Disagree
- Strongly Disagree
- No view/don’t know

Please explain your answer and provide any other general comments.

How strongly do agree with the levels of automation included in the Detect and Avoid Policy Concepts Intended function?

- Strongly Agree
- Agree
- No strong feelings either way
- Disagree
- Strongly Disagree
- No view/don’t know

Please explain your answer and provide any other general comments.

Do you expect to have difficulties identifying which of the levels of automation you operations will fit in to?

- Yes
- No
- No view/don't know

Please provide your reasoning

CHAPTER 4

DAA Terminology, Metrics and Performance Assessment

Definitions

4.1 Commonly used terminology for discussing and evaluating DAA systems is as follows:

- **Ownship** (or own aircraft) – The aircraft on which the ACAS or DAA system referred to is installed / functions [16].
- **Intruder** – An aircraft within the surveillance volume for which a track has been established [10] – ALTERNATIVE – A aircraft external to ownship within or projected to be in the ownship's vicinity soon [16].
- **Near Threat** – An intruder deserving special attention because it is close to becoming a potential threat, based on separate tests on measurements meeting specific criteria [10].
- **Potential threat** – An intruder deserving special attention either because of its close proximity to own aircraft (ownship) or because successive measurements indicate that it could be on a collision or near-collision course with own aircraft (ownship). The alerting time provided against a potential threat is sufficiently small such that a caution level alert is justified but not so small that a resolution advisory (RA) would be justified [10].
- **Threat** – An intruder whose position is independently tracked or subject to a validation function and that requires special attention, either because of its close proximity to own aircraft or because successive measurements indicate that it is on a collision or near-collision course with the own aircraft. The warning time provided against a threat is sufficiently small such that a resolution advisory is justified using warning-level alerting. [10]).
- **Cooperative aircraft** – Aircraft that transmit surveillance data that can be received by ownship [10].
- **Non-cooperative aircraft** – Aircraft that do not transmit surveillance data that can be received by ownship [10].
- **Encounter** – An event associated with the presence of an intruder aircraft. An Encounter is simply a measure of when the proximity of two aircraft becomes relevant, or where a simulation may start. An encounter must be 'big enough to include all things which may influence the tactical mitigations of the aircraft, but not so big that the actions of aircraft 300 miles away are also counted' [9].

- **Encounter set** – The complete set of encounters that are used to assess the performance of a DAA system.
- **Encounter Models** – Statistical models of encounters that are representative of what actually occurs in the required air environment. Can be used to sample individual encounter sets to be used to evaluate DAA system performance, e.g., in Monte Carlo simulation.
- **DAA well clear (DWC**) – A temporal and/or spatial boundary around the aircraft intended to be used in a DAA system as an electronic means of avoiding conflicting traffic [10].
- **Near mid-air collision (NMAC) –** Two aircraft simultaneously coming within 100 ft vertically and 500 ft horizontally [10].
- **Caution level alert** – An alert that requires immediate pilot awareness and subsequent response [10]. Also see [31] for guidance on implementation.
- **Warning level alert** – An alert that requires immediate pilot awareness and immediate pilot response [10]. Also see [31] for guidance on implementation.
- **Suggestive guidance** – A range of potential manoeuvres provided in order to avoid a hazard with manual execution. An algorithm provides a remote pilot with a range of advantageous or disadvantageous manoeuvres [14].
- **Directive guidance** – A specific recommended resolution to avoid a hazard with manual or automated execution. An algorithm informs the pilot when and how to perform a recommended manoeuvre [14].
- **Explicit coordination** – Coordination in which each aircraft in an encounter uses real-time exchange of information to ensure compatible RAs [10].
- **Implicit coordination** – Coordination in which each aircraft in an encounter uses a shared set of rules without real-time exchange of information to ensure compatible manoeuvre guidance [10].
- **Surveillance volume** – The volume of airspace where the DAA sensors can detect and track intruders. The surveillance volume may be different for each sensor [10].

Metrics

4.2 Initial attempts to quantify safety requirements for DAA systems were based on achieving equivalence to crewed aircraft ‘see-and-avoid’ performance – *known as an Equivalent Level of Safety (ELS)*. This approach has proven to be challenging, primarily due to known variation between pilots and difficulties quantifying human performance [35]. As a result, the primary internationally accepted DAA safety metric, in common with that used for Airborne Collision

Avoidance System (ACAS) / Traffic Collision Avoidance System (TCAS), is a risk ratio defined as follows:

$$Risk\ Ratio\ (RR) = \frac{\text{Probability of an event occuring WITH the mitigation in place}}{\text{Probability of the same event occuring WITHOUT the mitigation in place}}$$

Equation. 1

4.3 A RR is a dimensionless quantity that captures as a percentage the relative benefit of a mitigation. A smaller value denotes improved performance, e.g., a RR of 0.1 indicates that 90% of events have successfully been mitigated. Two types of RRs are typically quoted:

- **Logic RR,** which is the net benefit of the mitigation assuming nominal performance (incl. sensors, comms, human, manoeuvring, etc.). Logic RRs are quoted by ICAO for TCAS performance [11], ASTM small RPAS DAA Minimum Operational Performance Standards (MOPS) [16] and will also be used for ICAO DAA performance [10].
- **System RR,** which includes failure conditions (e.g., hardware, software, human). System RRs are quoted within JARUS SORA V2.5 (Annex D) [9].

4.4 Based on the DAA intended functions of Remain Well Clear (RWC) and Collision Avoidance (CA) described in Chapter 3, DAA system performance can then be measured by two distinct RRs:

$$RR\ (LWC|Enc) = \frac{P_{Mitigated}(LWC|Encounter)}{P_{Unmitigated}(LWC|Encounter)}$$ **Equation. 2**

$$RR\ (NMAC|Enc) = \frac{P_{Mitigated}(NMAC|Encounter)}{P_{Unmitigated}(NMAC|Encounter)}$$ **Equation. 3**

Where:

- P(X|Y) is the conditional probability of event X given that event Y has occurred.
- CA = Collision Avoidance
- LWC = Loss of Well Clear
- NMAC = Near Mid- Air Collision
- Encounter is an incursion by another aircraft into a volume defined as appropriate to capture the possible dynamics between the two aircraft.

4.5 The use in the RR definition of conditional probabilities rather than standalone probabilities ensures that performance is comparable for each encounter, rather than being dependent on the number of encounters predicted across an operation. Additionally, the use of a ratio ensures that the result is not dependent on the definition of an encounter.

4.6 Secondary safety metrics that are commonly used include:

- **Probability (or number of) induced NMACs or Loss of Well Clear (LWC)** – An induced NMAC or LWC is one that happened only in the mitigated scenario where the DAA system was active.
- **Probability (or number of) unresolved NMACs / LWC** – It is important to note that achieving a RR performance does NOT mean that NMAC or LWC will not occur. The RR is simply a comparative measure of the improvement in safety when the DAA system is added. Therefore, the CAA may also want to review the probability or number of NMACs or LWCs that occurred during acceptance testing.
- **Severity of LWC** – This can be reported as a percentage of penetration into the WC volume [10].
- **Horizontal & vertical miss distances** – To avoid having to consider different aircraft shapes, penetration into the NMAC volume can be considered as a collision [12] and therefore miss distance is measured from the NMAC volume boundary. This is also often referred to as the Closest Point of Approach (CPA).

4.7 In addition to the primary safety metrics a range of operational suitability metrics must also be considered, with key ones as follows:

- **Alert rate / frequency** – The percentage of encounters where an alert was issued [15]. Note this may also consider nuisances, where alerts are issued in otherwise safe situations [12], e.g., other traffic also under a separation service (ATC / UTM).
- **Reversal rate** – The percentage of encounters where direction reversing guidance is provided [15].
- **Split rate** – The percentage of encounters where a second alert is issued after notifying clear of conflict [15].
- **Flight path deviations** – Noting that it may be desirable to minimise the deviation from a planned flight path in response to DAA guidance [12].
- **Alert timings** – Where sufficient time may be required to react to the situation, coordinate with ATC and execute the manoeuvre [12].

Encounter Sets

4.8 An encounter set defines the complete set of air-to-air conflict encounters that are used to assess the performance of a DAA system within the expected operating environment. The ICAO DAA Manual [12] requires that encounter sets have the following properties:

- **Relevance** – To expected intruder types[3], equipment carriage and operating rules.
- **Realism** – Approach geometries should be physically possible and distributed / weighted by likelihood. For example, DO-365C DAA MOPS [13] defines test vectors that cover the following conflict scenarios: *Head-on, Converging, Overtaking, Manoeuvring, Designer / stressor cases, terminal area*, etc. Additionally, the ICAO DAA Manual requires that multi-intruder conflicts are also considered.
- **Range** – Spanning the defined variables of interest, including timeline (early and late detection), approach geometries (including variance in horizontal and vertical miss distances), sensor performance, intruder types, pilot response, ownship manoeuvrability, environmental conditions, etc.
- **Resolution** – Proportionately discretising the range of the encounter set variables to ensure that the results are statistically significant.

4.9 Evaluation of a DAA system performance is sensitive to the chosen encounter sets. DAA system metrics provide a relative measure of performance against a specific encounter set; therefore, *it is critical that authority agreement is obtained on the encounter set ahead of final performance evaluation*. Encounter sets can be generated via some form of airspace characterisation, potentially ranging from qualitative local area surveys to quantitative ANSP surveillance informed measurement.

4.10 The impact of encounter set selection on DAA system performance is analogous to measuring the performance of a football team against different levels of opponents, e.g., a school team, a semi-professional team, or the English Premier League champions. While the same metrics can be calculated for each match (e.g., final score, possession, pass completion, corners, etc.), understanding the absolute performance of the team is not possible just from the performance metrics, it is also necessary to understand the standard of the opposition. Similarly, a DAA system can be found to perform well against some encounters, but poorly against other more challenging cases.

4.11 The final encounter set must therefore represent a range of encounter geometries, including stress test cases, for example due to poor surveillance or tracking performance. Encounters involving a single intruder aircraft are

[3] Potentially include intruders that may be challenging to detect, e.g., due to low radar cross section.

expected to be the most common scenario. However, multiple intruders must also be considered.

Alerting Thresholds and Timeline Analysis

4.12 Two levels of alerts are discussed by the various DAA standards [13,14,15,16]:

- **Caution level alerts** – Those which require *immediate* remote pilot awareness and *subsequent* response.
- **Warning level alerts** – Those that require *immediate* remote pilot awareness and *immediate* remote pilot response.

4.13 Alerting thresholds need to be defined to ensure that avoidance manoeuvres can be conducted in time to prevent a loss of either DWC or NMAC, as required by the RR performance targets. However, consideration of nuisance alerts is also required to meet operational suitability metrics.

4.14 Specific examples of alerting levels and scenarios are provided in the technical standards [13, 15, 16]. For example, the ASTM DAA standard [16] requires the following:

- Use of a *warning* level alert if an intruder is predicted to breach either the DWC or NMAC volumes.
- Use of a *caution* level alert if an intruder is not currently predicted to breach the DWC volume but may do so if either the ownship or intruder manoeuvres abruptly.

4.15 Definition of alerting thresholds is informed by a timeline analysis which includes intruder closure rates, DAA system processing delays, pilot response delays & ownship performance. This timing analysis can also be used to define the required detection volume such that the alerting thresholds and required avoidance manoeuvres are feasible. Annex X2 to the ASTM DAA Performance Standard [16] presents an example timing analysis, where the following elements are considered:

- **Detection function** – Including surveillance sensor scan rate, sensor fusion and track processing rate, and output publishing rate.
- **Alert function** – Processing delays involved with evaluating tracks and alerting the avoid function.
- **Avoid function** – Manoeuvre option evaluation delay, command and manoeuvre execution delays.

4.16 Decomposing overall DAA system delays into these elements enables timing budgets for different functional elements to be determined, against which a design can be validated. For example, fusion of multiple surveillance sources into a single track-picture requires significantly more processing capacity (and / or time) for complex high-density airspace than for environments where only occasional intruders can be expected.

4.17 *Avoid* function delays are dependent on the level of automation used in the DAA system, as well as the C2 link latency and ownship performance. For example, for pilot response delays the ASTM DAA MOPS for small UAS [16] define the following assumed response times for different levels of DAA system automation (as defined within Chapter 3, Levels of Automation):

- **Suggestive piloted** – It is assumed that the pilot monitors the display for approximately 10 seconds, and there is a 5 second delay between the last surveillance data used in decision-making and the execution of the manoeuvre.
- **Directive piloted** – It is assumed that approximately 5 seconds elapse between the surveillance that generates the conflict warning and the execution of the manoeuvre.
- **Automatic** – It is assumed that this system will react immediately.

4.18 An example DAA timeline can be illustrated by an encounter where an intruder is on course for a head-on collision with a closure rate of 200kts and the preferred avoidance manoeuvre is vertical only. Assuming that the ownship climb-rate is 500ft/min, this requires a minimum of 30s to achieve the 250ft DWC volume vertical boundary. Different options can be considered from here:

- **Suggestive piloted** level of DAA automation results in an additional 15s delay for remote pilot situation awareness and decision making, which results in a latest alert threshold for DWC being 45s. For the given closure rate of 200kts this requires a warning alerting (for this particular encounter) at a minimum range of 15,165ft (or 4,622m). Note that the previously discussed DAA system processing delays will add to this value.
- For an **automated** system where remote pilot delays are not required the latest warning alert threshold for loss of DWC is 30s. For the given closure rate of 200kts this requires a warning alert (for this particular encounter) at a minimum range of 10,110ft (or 3,081m). Note that the previously discussed DAA system processing delays will add to this value.

4.19 The above example may also be used to illustrate the dependency between closure rate, surveillance volume (or detection range) and ownship performance. For an automated system where the closure rate has increased from 200kts to 400kts the minimum detection range doubles from 3,081m to 6,172m. If the ownship climb performance improves from 500ft / min to 750ft/min than the detection range for the 400kt closure rate case can be reduced from 6,172m to 4115m.

Evaluation of Avoidance Alerting and Guidance

4.20 Evaluation of avoidance functionality may be based on a combination of different testing approaches, including:

- fast-time simulation
- real-time simulation
- live-virtual constructive
- bench test
- field tests
- 'as-built' full system trials

4.21 The use of, and rigour associated with, each of these approaches is dependent on the overall level of operational risk as discussed further in Chapter 5 (DAA assurance and oversight requirements) of this document.

4.22 Industry best practice for evaluation of DAA guidance or automated avoidance algorithms is fast time Monte Carlo simulation of a large number of realistic encounters (typically millions). Monte Carlo simulation is a computational approach that uses repeated random sampling to obtain the likelihood of a range of results occurring. It is therefore well suited to the probabilistic nature of air-to-air encounters, allowing the DAA system to be assessed against the agreed encounter set with a probabilistic spread of parameters that performance is dependent on, e.g., sensor performance, reaction and manoeuvre performance, etc.

4.23 To enable simulation testing all elements of the end-to-end system must be modelled, including aircraft dynamics, surveillance and tracking, alerting and guidance and pilot response. Chapter 5 requires an applicant to evidence expected nominal performance levels of certain key parameters that impact DAA system performance, C2 link latency (Chapter 5, Reliability and Availability), detection volume and Ownship / intruder state uncertainty (Chapter 5, Data Integrity). The sensitivity of DAA system performance against off-nominal data should also be investigated to ensure that operating procedures are appropriate, e.g., reduced detectability intruders.

4.24 In addition (or as a potential alternative) to system specific performance models, *standard error models* may also be appropriate for certain sensors. For example, ICAO ACAS SARPS [11] define standard error range models for air-to-air transponder interrogation as:

- **Standard bearing error model** = Normal distribution with mean 0.0 degrees and standard deviation 10.0 degrees.
- **Standard range error model** = Normal distribution with mean 0 ft and standard deviation 50 ft.

4.25 The ICAO ACAS SARPS [11] also provide standard models for remote pilot and ATC controller response.

4.26 Real-time Human-In-The-Loop (HITL) simulation may also be used to evaluate a limited number of encounters. This would usually focus on validating expected remote pilot response to DAA alerts, suggestive and directive guidance. Interaction with Air Traffic Control can also be validated using this approach.

4.27 Simulation testing (fast time and / or real-time) is then usually followed by a range of live trials such as bench-testing, field trials and 'as-built' final tests. These additional tests enable spot point validation of results from simulation assessment.

4.28 Finally, ASTM Committee F38 is currently finalising a Standard DAA Test Method as a companion to their DAA performance standard [16]. This standard is expected to provide a range of requirements across different testing modalities, including Monte Carlo, real-time HITL, bench tests field trials and 'as built' final system tests.

Consultation Questions

How strongly do agree with the metrics we are including in the Detect and Avoid Policy Concept?

- Strongly Agree
- Agree
- No strong feelings either way
- Disagree
- Strongly Disagree
- No view/don't know

Please explain your answer and provide any other general comments.

Are there additional metrics or performance criteria you believe should be included in the Detect and Avoid Policy Concept?

CHAPTER 5

DAA Requirements

Overview

5.1 This chapter defines a range of requirements for the assurance of DAA systems as appropriate for different ARCs. The requirements are structured around the following categories:

- **Performance** – DAA Metrics which define the functional effectiveness of the system within nominal operating conditions.
- **Reliability** – The probability that a system or item will perform a required function under specified conditions, without failure, for a specified period of time [20]. Reliability is often measured by the expected Mean Time Between Failures (MTBF), or system *availability* (see below), with requirements applied individually to software and hardware elements of the system.
- **Availability** – Qualitative or quantitative attribute that a system or item is in a functioning state at a given point in time [20]. Availability can be measured by an expected uptime percentage, and, as with reliability, availability accounts for 'loss of function' which is not captured in the performance metrics.
- **Data Integrity** – The quality or trustworthiness of the data that the system acts upon.
- **Assurance** – The planned and systematic actions necessary to provide adequate confidence and evidence that a product or process satisfies given requirements [21].
- **Oversight** – Activities by the Authority / CAA relating to approvals, safety surveillance and investigation of aviation activities.

Performance

5.2 The required DAA system performance is dependent on the Air Risk Class of the proposed RPAS BVLOS operation, as identified by the UK SORA Air Risk Model [7]. The DAA System (i.e., equipment & remote pilot) are designed to be no worse than systems and pilots in an equivalent manned-aircraft situation. Performance requirements are provided below:

DAA Performance requirements

Residual ARC-a

- DAA capability is not required.

Residual ARC-b and ARC-c

- DAA performance requirements as defined for LOW air risk environments within ASTM, F3442/F3442M – 23 [16] (**Note-1**).
- The applicant must also consider the use of secondary safety and operational suitability metrics discussed in Chapter 4 (Metrics), providing suitable justification if they are not used in the DAA system performance assessment.
- A Human Factors evaluation is required to demonstrate that the Human Machine Interface (HMI) is appropriate for the DAA function (**Note-2**).

Residual ARC-d

- ICAO DAA SARPS [10] / DO-365C [13] / Comparable EUROCAE performance requirements.

5.3 **Note-1**: A summary of the NMAC and LWC risk ratio requirements above is provided in Table 2, with additional guidance provided below:

- The required RR values are 'logic RRs' rather than 'system RRs' and are therefore based on expected nominal performance of sensors, C2 link, vehicle and human reaction. The required performance is based on many years of ACAS / TCAS experience and are assessed against all expected intruders whether within a sensor Field of View (FoV) or not. Justification of the values is provided within [23], with required performance defined to be both achievable and as good as or better than pilots and systems would perform in the same encounter.
- It can be seen that the required performance of the DAA system is dependent on the equipment fit of the intruder aircraft, therefore performance is expected to be poorer for non-cooperative or non-coordinating aircraft than it is for cooperative coordinating aircraft. This follows the same principle applied in [24] for deriving the JARUS SORA Target Level of Safety (TLS), where carriage of certain equipment impacts the accepted collision risk and may therefore act as an incentive for use.
- The above RRs are defined for the NMAC and LWC volumes provided below, which are again dependent on the category of intruder and phase of flight:
  - **NMAC RPAS <-> Crewed aircraft encounters –** A standard spatial volume definition of 500ft horizontal and 100ft vertical is used for all classes of RPAS/Crewed aircraft encounters. This is the same volume that has been established for crewed aircraft ACAS system for over 40 years [18] and is used by all referenced technical standard within this document. This volume is illustrated by ASTM [16] in Figure 1.

- **RWC small RPAS <-> Crewed aircraft encounters –** For encounters between 'smaller' RPAS[4] and crewed aircraft ASTM [16] define RWC as a spatial volume of 2,000ft horizontal and +/-250ft vertical. This value was proposed by MIT [22] based on simulation studies to provide a 10% probability of NMAC given a DWC volume breach. Within this work sensitivity to crewed aircraft performance and a temporal component within the RWC volume definition was evaluated but found not to be required. This volume is illustrated by ASTM [16] in Figure 1.
- **RWC RPAS <-> crewed aircraft –** For larger[5] RPAS operating within higher risk areas, e.g., integrated IFR, different RWC are proposed depending on the flight phase and equipment fit, e.g., En route versus terminal and cooperative versus non-cooperative. The values include a temporal element and are used within the ICAO DAA manual [12], RTCA DAA MOPS [13] and ACAS Xu MOPS [14], as shown in Figure 2, Figure 3 & Figure 4. These values have been derived using extensive simulation to provide a defined probability of NMAC given a LWC event, as well as a consideration of interaction with TCAS as discussed in detail within Annex C of DO-365C [13]. The significantly larger RWC volume for cooperative intruders was driven primarily by operational suitability rather than safety, ensuring that DAA RWC manoeuvres can be conducted ahead of any TCAS alerts [13].
- Additional detail and guidance on the temporal definition of RWC and the derivation of the required values is provided within the technical standards referenced above. It should also be noted that the NMAC and DWC volumes used for DAA are distinct from Air Traffic Control (ATC) separation standards, which are significantly larger.

5.4 **Note-2**: SORA Annex E [9] provides some additional guidance on HF analysis. The traffic display should be consistent with existing aviation traffic and DAA standards, e.g., Eurocontrol ACAS Guide [34] DO-365C [13]. Some guidance on display iconography is provided in ASTM DAA, DO-365C [13] and other DAA standards referenced. Traffic displayed shall include ID, horizontal position, altitude, direction (ground track), vertical and horizontal speed and associated uncertainty, including information latency, track coasting status. Further supporting information from ICAO may also be found in [38, 37].

[4] Ref [16] applies to unmanned aircraft with a maximum dimension of <25ft operating at airspeeds below 100kts.

[5] Unmanned aircraft that do not meet the definition of 'smaller' as discussed in Footnote 4.

Intruder equipage description	NMAC RR	LWC RR
Cooperative, with coordinating and responding Collision Avoidance, e.g., TCAS II, ACAS sXu.	≤ 0.04	≤ 0.4
Cooperative	≤ 0.18	≤ 0.4
Non-cooperative	≤ 0.3	≤ 0.5

Table 1 – Logic RR performance requirement summary

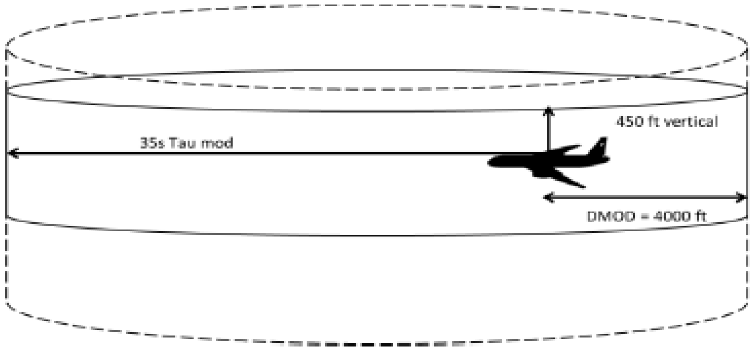

Figure 3 – En route RWC for cooperative intruders [12]

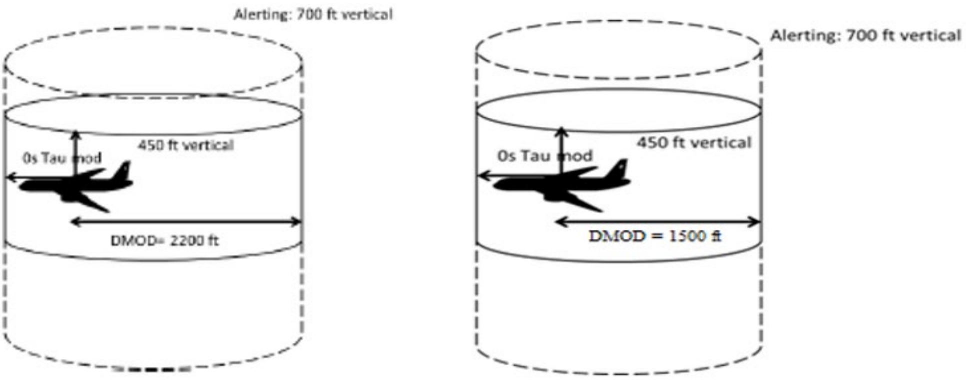

Figure 4 – (LEFT) En route RWC for non-cooperative intruders & (RIGHT) terminal area [12]

Reliability / Availability

5.5 DAA system reliability / availability requirements cover all functions required for nominal DAA operation, failures of which are not captured within the DAA performance requirements. The requirements are dependent on the Air Risk Class of the proposed RPAS BVLOS operation, as identified by the UK SORA Air Risk Model [7], and are provided below:

DAA Reliability / Availability requirements

Residual ARC-a

- DAA capability is not required.

Residual ARC-b

- Allowable loss of function shall be less than $1x10^{-2}$ per flight hour (Note-3).
- Hazardously misleading information or malfunction without warning shall occur less than $1x10^{-3}$ per flight hour (Note-4).
- The nominal performance of the C2 link must be defined (including at a minimum latency and availability) and used within the DAA system performance assessment. The applicant shall provide evidence to support the defined C2 link performance, e.g., via analysis or live test (Note-5).
- DAA systems that are not capable of fully automated avoidance manoeuvres must have suitable contingency mitigation for MAC in the event of lost C2 link, unless the C2 link can be demonstrated to be suitably reliable (Note 5a).
- The Remote Pilot (RP) must be alerted within an appropriate timeframe of any in-flight degraded or lost function that impacts DAA performance or requires contingency actions.
- DAA system failures where degraded performance cannot be detected in-flight must be identified in advance.
- A maintenance plan is required for the DAA system, including the ability to detect pre-flight failures.

Residual ARC-c

All requirements of ARC-b, with the following exception relating to loss of function and hazardously misleading information:

- Allowable loss of function and hazardously misleading information without warning shall be derived from a ‘1309 like’ approach, based on the agreed loss of DAA function severity and the applicable probability of a conflicting aircraft with another aircraft (Note-5c).

Residual ARC-d

All requirements of ARC-b, with the following exception relating to loss of function and hazardously misleading information:

- In line with a CS.25 AMC.1309 [29] approach, using a functional hazard analysis to identify failure conditions and associated severities (Note-6).

5.6 **Note-3:** This value is in line with both ASTM [16] and JARUS SORA Annex D TMPRs [9]. Both of these documents provide the following additional guidance on meeting these requirements:

- ASTM Section 5.5.2 [16] states that “loss of function includes failures such as sensor failures, C2 link failures, and DAA equipment failures, which are not captured in the RR and LR performance requirements”.
- JARUS SORA Annex D (Sect 5.4) [9] states that an allowable loss of function of $1x10^{-2}$ per flight hour is “*considered to be met by commercially available products. No quantitative analysis is required*.”
- ASTM Section 5.5.2.4 [16] state that the above requirements may be met by either redundancy or using simple conventional architecture “*appropriately qualified for the installed environment and the individual failure rates of its components are below the objective of 1E-2 for Class 1 Equipment or 1E-3 for Class 2 Equipment.*”
- Referring to [20] as long recognised standards JARUS [26] states that a Development Assurance Level (DAL) D ‘*gives confidence that the manifestation of a possible remaining error is at least compliant with the Probable probability class defined as $1x10^{-3}$ per flight hour ≤ P > $1x10^{-5}$ per flight hour*’.

The applicant is also free to propose alternative means to demonstrate suitable reliability / availability.

5.7 **Note-4**: This value is in line with ASTM [16], where hazardously misleading information is defined as being “introduced by undetected software and hardware faults, which are not captured in the RR and LR performance requirements.”. See also Note-3 comments on development process.

5.8 **Note-5**: JARUS SORA Annex D TMPRs [9] require a maximum C2 link latency of 5s for ARC-b and 3s for ARC-c. Rather than directly requiring similar values the approach taken here follows that of ASTM [16] where the defined C2 link performance must be reflected in the timing and performance analysis, and be suitable to support the required risk ratios and other chosen metrics.

5.9 **Note-5a**: As defined by the severity of the loss of DAA function (see Note 5c).

5.10 **Note-5c**: The CAA is currently undertaking a due diligence exercise on the JARUS air risk MAC TLOS values of $1x10^{-7}$pfh for type-1 encounters and $1x10^{-9}$pfh for type-2 encounters. For example, assuming a TLOS of $1x10^{-7}$ and an applicable unmitigated probability of a conflicting aircraft of $1x10^{-3}$pfh, then the maximum allowable loss of DAA function would be $1x10^{-4}$pfh, and hazardously misleading information shall occur less than $1x10^{-5}$pfh.

5.11 **Note-6:** Both the FAA [27] and JARUS [28] conclude that although a MAC is considered as catastrophic, it cannot occur as the consequence of a loss of DAA function alone. There must also be another aircraft on a conflicting trajectory that fails to separate, which results in a reliability / availability requirement lower than catastrophic.

Data Integrity

5.12 Key data of interest to a DAA system includes:

- **Intruder state** – Including position (relative to the ownship or absolute), altitude, airspeed, heading and possibly intent as derived from either cooperative or non-cooperative surveillance.
- **Ownship state** – Including position, altitude, airspeed and heading as derived from ownship onboard navigation system.
- **Geospatial awareness** – Including weather, airspace constraints and terrain elevation (if operating at low level).

5.13 DAA data integrity requirements are dependent on the Air Risk Class of the proposed RPAS BVLOS operation, as identified by the UK SORA Air Risk Model [7], and are provided below:

Data integrity requirements

Residual ARC-a

- DAA capability is not required.

Residual ARC-b

- Ownship and Intruder EC equipment to be in line with CAA recommendations (Note-7).
- A common altitude reference shall be used between all traffic (Note-8).
- The nominal detection volume for intruder aircraft must be defined and used by the DAA system performance assessment. The applicant shall provide evidence to support the defined values, e.g., via analysis or live test (Note-9).
- The nominal range of accuracy / uncertainty of intruder tracks and ownship states (horizontal position, altitude, ground track and ground speed) must be defined and used by the DAA system performance assessment. The applicant shall provide evidence to support the defined values, e.g., via analysis or live test (Note-9 and Note 9a).
- The DAA system must monitor and report any degradation of the detection volume, intruder tracks or ownship state (beyond the nominal range) to the remote pilot and alerting and guidance functions (if implemented) (Note-10).

- Independent validation[6] of EC tracks is not required unless GNSS jamming, spoofing, and / or intruder track spoofing is identified as a specific risk for the operating area.
- The expected accuracy / uncertainty of any other required data (e.g., terrain elevation, feature location or weather) must be defined and used by the DAA system performance assessment. The applicant shall provide evidence to support the defined values.

Residual ARC-c

All requirements of ARC-b, with the following exception:

- Independent validation of EC is required, and the DAA system (and ownship position, navigation and timing) must be resilient to GNSS jamming and spoofing by design, unless the operating environment is such that this risk is agreed as acceptable by the CAA.

Residual ARC-d

ICAO DAA SARPS [10] / DO-365C [13] / Comparable EUROCAE performance requirements. Including:

- Validation of passive intruder tracks ahead of manoeuvring.
- EC data quality & ownship navigation accuracy requirements (e.g., ownship position uncertainty / integrity, NACp, NACv, Surveillance Integrity Level).

5.14 **Note-7**: In December 2022, the Department for Transport (DfT) and CAA published a joint statement [29] detailing their support for the recommended adoption of Automatic Dependent Surveillance -Broadcast (ADS-B) operating on 1090 MHz for piloted aircraft and 978 MHz for UA respectively, utilising existing global standards. The DfT and CAA are currently undertaking a programme of work to deliver this Electronic Conspicuity (EC) specification, aligned to the aims of the Airspace Modernisation Strategy, to support the rapidly evolving needs of new airspace users and to provide additional safety benefits to airspace users in Class G airspace in the UK. Further information of EC can be found in [30].

5.15 **Note-8**: Crewed aircraft commonly use pressure altitude, whereas RPAS commonly use GNSS based vertical distance either Above Mean Sea Level (AMSL) or Above Ground Level (AGL) at the take-off location.

5.16 **Note-9**: Rather that directly requiring minimum performance values the approach taken here follows that of ASTM [16] where the defined performance must be

[6] In this context ‘validation’ refers to confirming that the source of an EC signal aligns with the reported position. This is achieved by the use of a secondary sensor, such as radar, EO, active interrogation or ground based multilateration.

reflected in the performance analysis, and be suitable to support the required risk ratios and other chosen metrics.

5.17 **Note-9a**: Surveillance and navigation sources can broadly be categorised as i) those intended to cue a pilot for visual acquisition, and ii) those sufficient for collision avoidance without visual confirmation. Examples of the former category include TIS-B (e.g., FAA TSO-C166c) and CAP1391 [41] where information is provided as an enhancement to the visual scan, supporting visual acquisition followed by see-and-avoid as required. A higher level of integrity may be required for the latter category, with an example being TSO-C145e compliant GNSS equipment.

5.18 **Note-10**: ADS-B includes several data quality metrics which may be used to estimate real-time position reporting accuracy, including Navigation Accuracy Category position (NACp) and Navigation Accuracy Category velocity (NACv). These values are typically based on GNSS Horizontal and Vertical figures of merit (HFOM and VFOM). If such values are not available, then [36] discusses an approach for estimating uncertainty based on the GNSS provided Horizontal Dilution of Precision (HDOP). The applicant is free to propose other methods for measuring intruder / ownship position accuracy in-flight if preferred (e.g., for non-GNSS derived data). If such real-time accuracy monitoring is not available, then an appropriate increase to NMAC and RWC volumes may be considered as an alternative.

Assurance and Oversight

5.19 The principle of *proportionality* is fundamental to the UK SORA Air Risk Model, and manifests via both the assigned ARC for the RPAS operation, and the expected level of assurance and oversight against each of the previously defined requirements.

5.20 A summary of DAA data assurance and oversight requirements are provided below.

DAA assurance and oversight requirements

Residual ARC-a

- DAA capability is not required.

Residual ARC-b & ARC-c

- The applicant shall evidence a proportionate (Note-11) level of algorithmic rigour (Note-12) for any DAA alerting and guidance functions (if implemented).

- The applicant shall agree with the CAA and evidence a proportionate (Note-11) level of software and hardware implementation rigour (Note-13) for all DAA functions.

- The DAA capability shall include an Incident log (Note-14).

Residual ARC-d

- Certification of the DAA system against ICAO DAA SARPS [10] / DO-365C [13] / Comparable EUROCAE performance requirements (Note-15).

5.21 **Note-11**: Regarding 'proportionality', DAA systems for ARC-c operations can expect a comparable level of assurance and oversight to certified equipment (based on agreed failure severity and expected traffic encounter types). Oversight and assurance requirements for ARC-b DAA systems can expect to be proportionately reduced due to the operating environment and additional air risk mitigation required for this ARC. However, detailed requirements / expectations for the level of evidence provision and authority oversight / monitoring are not provided at the policy concept stage defined within this document. The level of effort and evidence required will depend on the particular DAA system implementation and this will be explored and agreed with applicants during the policy concept stage via sandbox / innovation projects. In addition to the requirements within this policy concept the ASTM DAA performance standard [16] also provides additional detail and requirements that should be considered good practice and implemented where deemed suitable.

5.22 **Note-12**: Algorithmic rigour is provided by the extent of testing of the alerting and guidance algorithms, including the breadth of the encounter set and the depth of the probabilistic testing against all of the associated variables. Algorithmic rigour is expensive and time consuming to provide but can be obtained by implementing one of the RTCA ACAS standards where this level of testing has already been conducted. Correct implementation of these standards can be verified via the provided test suite. If not implementing an ACAS standard, then the applicant shall agree the with the CAA:

- Encounter set for the DAA system to be tested against (See Chapter 4, Encounter Sets).

- Performance targets for any proposed secondary safety and operational suitability metrics.

Whether implementing an ACAS standard or not, an appropriate testing strategy will need to be agreed with the CAA, defining the appropriate balance and depth of different test modes (e.g., simulation, bench, 'as-built' – See Chapter 4, Evaluation of Avoidance Alerting and Guidance).

5.23 **Note-13**: Software and hardware implementation rigour is provided by suitable development assurance and testing, e.g., DO-178 [21] and DO-254 [42] which provides guidance for the production of software and hardware with a level of confidence appropriate for associated failure condition severity. Such implementation rigour is expensive and time consuming to provide, and little guidance is currently available for specific category RPAS systems. However, EUROCAE have recently created a new working group (WG-127 / Lower Risk Aviation Applications) to create a software development standard for EASA Specific Category RPAS operations. The applicant is free to propose a different software development and testing process if these standards are considered as not proportionate for the application.

5.24 **Note-14**: In addition to the usual Mandatory Occurrence Reporting (MOR) the CAA will conduct a monitoring programme on any approved DAA enabled operations. This will ensure that the build-up of operational experience is monitored, and any unexpected consequences are identified. Amongst other parameters the CAA will monitor the following:

- BVLOS flight-time accumulated.
- Encounter rate against intruder aircraft.
- Rate of intruder aircraft within the operating area that did not meet the encounter criteria, e.g., due to UA not being airborne, or at a sufficiently large distance.
- Triggering of DWC or NMAC alerting or guidance.
- Loss of DWC or NMAC, or other degradation of the agreed DAA performance and operational suitability metrics.
- Technical or operational issues, e.g., loss of C2 link or DAA function in-flight, implementation of abnormal or emergency procedures.

The applicant shall log appropriate information to enable the above and is referred to ASTM DAA standard [16] for further requirements on the DAA system incident log function, including sufficient data recording, timestamping, incident ID and data recovery.

5.25 **Note-15**: The highest level of rigour and oversight is required, matching the very high level of rigour (algorithmic and implementation) that is associated with Traffic Collision Avoidance System (TCAS), potentially within a fully certified RPAS. ACAS Xu provides a reference implementation of the defined standards for ARC-d.

5.26 Additional guidance on all of the above is expected to become available after initial testing of this policy concept.

5.27 Finally, it should be noted that in addition to defining the TMPRs / DAA Policy the agreed ARC also influences the overall SORA approval process via the Specific Assurance and Integrity Level (SAIL) score for the RPAS BVLOS operation. The SAIL score defines the level of robustness or rigour that is required across a set of Operational Safety Objectives (OSOs) with which the applicant must show compliance to. The OSOs address several factors including the following:

- Operator competence (OSO#1).
- UAS Manufacturing (OSO#2) and Maintenance (OSO#3).
- C3 link characteristics (OSO#6).
- Operational procedures suitable for normal, abnormal and emergency situations (OSO#8).
- Remote crew training and currency (OSO#9).
- HF evaluation and HMI suitability (OSO#20).

5.28 Although this policy concept document focusses only on the DAA system and the OSOs address the entire RPAS operation it is likely that there will be a degree of overlap with some of the requirements.

Consultation Questions

How strongly do you agree that the requirements provided in the DAA policy concept are sufficient enough to ensure safe BVLOS reliance of DAA capabilities?

- Strongly Agree
- Agree
- No strong feelings either way
- Disagree
- Strongly Disagree
- No view/don’t know

Please explain your answer and provide any other general comments.

Are there any specific requirements that you expect to have difficulty meeting in current, or future operations?

Please explain your answer and provide any other general comments.

Are there any specific requirements that you believe need further clarification or adjustment?

CHAPTER 6

How to respond and next steps

How to respond to this consultation

6.1 We have sought to make this consultation as accessible as possible by presenting the key points on our dedicated consultation website. The longer document you are reading is for stakeholders wanting more detail. The questions in each case are the same.

6.2 The consultation will close at 23.59 on 19 September 2024 and we cannot commit to taking into account comments received after this date. Please let us have your comments by answering the questions online: https://consultations.caa.co.uk/future-safety/detect-and-avoid-policy-concept-consultation

6.3 Our strong preference is that you complete the online consultation. We understand that some stakeholders prefer not to be constrained by the questions alone and will want to send a self-contained response. While we will accept these submissions, we ask that they are structured around our questions. Otherwise we will not be able to analyse the submissions in the same way that we analyse the online responses.

6.4 We will assume that all responses can be published on our website. When you complete the online consultation, there will be an option for you to hide your identity or refuse publication. (In any event, your email address will not be published.) In the interests of transparency, we hope people will not refuse publication. If you do send us a separate submission and it includes any material that you do not want us to publish, please also send us a redacted version that we can publish. You should be aware that information sent to and therefore held by the CAA is subject to legislation that may require us to disclose it, even if you have asked us not to (such as the Freedom of Information Act and Environmental Information Regulations). Therefore, if you do decide to send information to the CAA but ask that this be withheld from publication via redacted material, please explain why, as this will help us to consider our obligations to disclose or withhold this information should the need arise.

6.5 If you would like to discuss anything about how to respond to the consultation please email airspacemodernisationdelivery@caa.co.uk.

Next steps

6.6 Once the deadline for consultation responses has passed, we will assess all the responses we have received and, in the light of these, make any amendments to our proposals which seem justified. We will publish a summary of the responses we receive.

6.7 If the amendments to our proposals are significant, we may feel we need to reconsult on our revised proposals. Otherwise, we will publish a policy document confirming the new policy on Detect and Avoid and the date that it will come into force. We intend to have undertaken these steps by early 2026.

6.8 Publication of this DAA Policy concept signals the beginning of a DAA test and feedback phase, the objective of which is to ensure completeness and suitability of the requirements, considering safety, technical and commercial feasibility, as well as market supply of appropriate equipment. Testing will be conducted via the TRA Sandbox projects, where applicants and CAA Subject Matter Experts (SMEs) are able to assess the application of the policy in detail, generating agreement on acceptable means of compliance with the policy requirements. This consultation enables feedback from industry outside of the Sandbox process. Initial CAA expectation is that the test and feedback phase will last 12 to 18 months, during which time the CAA will update the DAA policy, generate guidance material and train CAA staff in preparation for DAA policy adoption and scaled routine operations, i.e., business as usual. A formal public consultation is also expected to be conducted prior to adoption of the DAA policy.

CHAPTER 7

Nomenclature

- ACAS Airborne Collision Avoidance Systems
- AIP Aeronautical Information Publications
- ALARP As Low As Reasonably Practicable
- ANSP Air Navigation Service provider
- AMS Airspace Modernisation Strategy
- ARC Air Risk Class
- ARM Air Risk Model
- ATC Air Traffic Control
- BVLOS Beyond Visual Line of Sight
- CANP Civil Aviation Notification Procedure
- DA Danger Area
- DAA Detect and Avoid
- DAL Development Assurance Level
- DWC DAA Well Clear
- FISO Flight Information Service Officer
- GA General Aviation
- GRC Ground Risk Class
- HDOP Horizontal Dilution of Precision
- HEMS Helicopter Emergency Medical Service
- HFOM Horizontal Figure of Merit
- IFR Instrument Flight Rules
- JARUS Joint Authorities for Rulemaking on Unmanned Systems
- MAC Mid Air Collision
- MOPS Minimum Operational Performance Standards

- NACp Navigation Accuracy Category position
- NACv Navigation Accuracy Category velocity
- NMAC Near Mid Air Collision
- OSO Operational Safety Objectives
- RMZ Radio Mandatory Zone
- RPAS Remotely Piloted Air Systems
- RR Risk Ratio
- SAIL Specific Assurance and Integrity Level
- SARP Standards and Recommended Practices
- SORA Specific Operating Risk Assessment
- SIL Surveillance Integrity Level
- TLS Target Level of Safety
- TMPR Tactical Mitigation Performance Requirements
- TMZ Transponder Mandatory Zone
- TRA Temporary Reserved Area
- TSA Temporary Segregated Area
- UA Unmanned Aircraft
- UTM Unmanned aircraft systems Traffic Management
- SAIL Specific Assurance Integrity Level
- SUA Special Use Airspace
- VFR Visual Flight Rules
- VHF Very High Frequency

CHAPTER 8
Point of Contact

8.1 Any queries or further guidance required on the content of this consultation should be sent to airspacemodernisationdelivery@caa.co.uk.

CHAPTER 9

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