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Standard Specification for Design and Performance of an Airborne Sense-and-Avoid System¹

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1. Scope

1.1 This specification covers requirements for the design and performance of airborne sense-and-avoid (S&A) systems. This specification includes requirements to support detection of, and safe separation from, airborne objects such as manned or unmanned aircraft and air vehicles.

1.2 This specification applies to the manufacturer of an appliance seeking civil aviation authority approval, in the form of flight certificates, flight permits, or other like documentation, as providing an equivalent level of safety to the see-and-avoid capability of a human pilot.

1.3 This specification is not intended to apply to the design and performance of cooperative S&A systems. Existing standards and guidance should be referenced for specifications describing these transponder or broadcast-based systems (examples of existing guidance and standards for cooperative S&A systems include FAA 20-131A, RTCA DO-289, and TSO-C119B).

1.4 This specification does not apply to appliances on-board one or more airborne objects flying in formation flight.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *Code of Federal Regulations (CFR):*²

14 CFR 91.1 General Operating and Flight Rules—Applicability

14 CFR 91.113 General Operating and Flight Rules—Right-of-Way Rules: Except Water Operations

¹ This specification is under the jurisdiction of ASTM Committee F38 on Unmanned Aircraft Systems and is the direct responsibility of Subcommittee F38.01 on Airworthiness.

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² Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, <http://www.access.gpo.gov>.

14 CFR 91.123 General Operating and Flight Rules—Compliance with ATC Clearances and Instructions

2.2 *Federal Aviation Administration (FAA) Publications:*³

FAA 8700.1 General Aviation Operations Inspector's Handbook

FAA P-8740-51 How to Avoid a Midair Collision

FAA 90.48C Advisory Circular—Pilots' Role in Collision Avoidance

FAA 20-131A Advisory Circular—Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders

TSO-C119B Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment

TSO-C153 Integrated Modular Avionics Hardware Elements

AC 21-33 Quality Assurance of Software used in Aircraft of Related Products

AC 20-145 Guidance for Integrated Modular Avionics (IMA) that Implement TSO-C153 Authorized Hardware Elements

2.3 *ICAO Publications:*⁴

ICAO Rules of the Air—Annex 2

2.4 *RTCA Publications:*⁵

DO-289 Minimum Aviation System Performance Standards (MASPS) for Aircraft Surveillance Applications (ASA)

3. Terminology

3.1 *Definitions:*

3.1.1 *airborne object, n*—any object that is operating in the airspace to include manned or unmanned aircraft or air vehicles.

3.1.2 *airspace of operations, n*—all classes of airspace in which a system is intended to operate.

3.1.3 *closing velocity, n*—rate of change of the decreasing distance between two objects.

³ Available from Federal Aviation Administration (FAA), 800 Independence Ave., SW, Washington, DC 20591, <http://www.faa.gov>.

⁴ Available from International Civil Aviation Organization (ICAO), 999 University St., Montreal, Quebec H3C 5H7, Canada.

⁵ Available from RTCA, Inc., 1828 L Street, NW, Suite 805, Washington, DC 20036.

3.1.4 *collision threat*, *n*—hazard consisting of a manned or unmanned aircraft, air vehicle, or other airborne object.

3.1.5 *cooperative S&A system*, *n*—system capable of communicating with systems on-board other airborne objects in order to facilitate detection or coordinate resolution maneuvers, or both.

3.1.6 *detection distance*, *n*—distance at which an S&A system can perceive a potential collision threat.

3.1.7 *field of regard (FOR)*, *n*—area capable of being perceived or monitored by a sensor, or both, specified in terms of azimuth and elevation from the fixed body reference frame of the S&A platform.

3.1.8 *miss distance*, *n*—distance between two airborne objects at their closest point of approach.

3.1.9 *non-cooperative S&A system*, *n*— system capable of detecting other airborne objects that do not have a cooperative S&A system.

3.1.10 *platform*, *n*—manned or unmanned aircraft, air vehicle, or other airborne object on which the S&A system is intended to operate.

3.1.11 *resolution maneuver*, *n*—intentional change in an airborne object’s flight path, velocity, or altitude, or a combination thereof, to avoid a collision threat.

3.1.12 *S&A system infrastructure*, *n*— system of systems consisting of the S&A system, pilot(s), or related systems, or a combination thereof, combined with the air traffic control infrastructure in place on the ground and in orbit, that is intended to provide safe separation of two or more airborne objects.

3.1.13 *scan rate*, *n*—time between successive surveys of the entire field of regard for potential collision threats.

3.1.14 *sense and avoid (S&A)*, *v*—process of determining the presence of potential collision threats, and maneuvering clear of them; the automated equivalent to the phrase “see and avoid” for the pilot of a manned aircraft.

3.1.15 *sense-and-avoid system*, *n*—appliance which fulfills the requirements of 14 CFR 91.113.

3.1.15.1 *Class 1*—Pilot-in-the-loop: Declares collision threat to the human pilot for action by that pilot.

3.1.15.2 *Class 2*—Automated Air: Initiates avoidance maneuver upon declaring a collision threat while in the air; interfaces with the autopilot.

3.1.15.3 *Class 3*—Automated Air and Surface: Initiates avoidance maneuver upon declaring a collision threat while operating in the air or on the ground; interfaces with the autopilot, throttles, and brakes.

4. Performance Requirements

4.1 *General Performance*—All performance requirements apply in and shall be corrected to International Civil Aviation Organization (ICAO) defined standard atmosphere. Speeds shall be given in true airspeed (TAS) in nautical miles per hour (knots).

4.2 Sensing:

4.2.1 *Detection Distance*—Detection of the collision threat shall be at a range to allow a resolution maneuver that results in a required miss distance of 500 ft or greater (see FAA 8700.1).

4.2.2 *Field of Regard*:

4.2.2.1 *Azimuth*—It shall be demonstrated that the S&A system can search from $\pm 110^\circ$ referenced from the S&A platform’s body frame of reference.⁶

4.2.2.2 *Elevation*—It shall be demonstrated that the S&A system can search from $\pm 15^\circ$ referenced from the S&A platform’s body frame of reference.⁷

4.2.3 *Latency*—It shall be demonstrated that the time between detection of a collision threat and initiation of a resolution maneuver does not compromise the required miss distance specification. This time latency may include, but is not limited to:

4.2.3.1 Communication delays,

4.2.3.2 Scan rates,

4.2.3.3 Pilot-in-the-loop reaction times,

4.2.3.4 Coordination with air traffic control authorities, and

4.2.3.5 On-board or ground-based processing time for collision avoidance or flight control algorithms.

4.3 Avoidance:

4.3.1 *Traffic*—Resolution maneuvers shall achieve the required miss distance from all aircraft, air vehicles, and other airborne objects that are:

4.3.1.1 Equipped with cooperative S&A systems (a cooperative flight environment), and

4.3.1.2 Not equipped with cooperative S&A systems (a non-cooperative flight environment).

4.3.2 Resolution maneuvers may include one or more of the following changes in flight profile:

4.3.2.1 Altitude,

4.3.2.2 Heading, and

4.3.2.3 Airspeed.

4.3.3 If any resolution maneuver deviates from an air traffic control clearance or instruction, air traffic control shall be notified of the deviation as soon as possible (see 14 CFR 91.123).

4.3.4 When the potential for multiple collision threats exists, the resolution maneuver to avoid one collision threat shall be planned and executed to reduce the occurrence of subsequent or more hazardous conditions, or both.

4.3.5 *Maneuvering*—For straight flight and turns in either direction during climb, cruise, and descent, it shall be shown that:

4.3.5.1 All resolution maneuvers are within the structural and aerodynamic performance limitations of the S&A system and platform at all flight conditions and profiles.

4.3.5.2 The S&A platform is safely controllable and maneuverable during all phases of the resolution maneuver from initiation to its return to an original or newly assigned flight path and altitude.

⁶ FAA P-8740-51 suggests that azimuth FOR be $\pm 60^\circ$ off the aircraft nose; ICAO Annex 2 specifies $\pm 110^\circ$ off the aircraft nose.

⁷ FAA P-8740-51 suggests that elevation FOR be $\pm 10^\circ$ from the aircraft’s body frame of reference; Department of Defense and NASA studies indicate $\pm 15^\circ$ is an appropriate threshold.