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# Standard Specification for Design and Performance of an Airborne Sense-and-Avoid System<sup>1</sup>

This standard is issued under the fixed designation F 2411; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

<sup>e1</sup> NOTE—Section 7 was updated editorially in July 2005.

## 1. Scope

1.1 The following requirements cover 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 manned aircraft.

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 is not intended to apply to multiple 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):*<sup>2</sup>

[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

[14 CFR 91.123](#) General Operating and Flight Rules—Compliance with ATC Clearances and Instructions

2.2 *Federal Aviation Administration (FAA) Publications:*<sup>3</sup>

[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

2.3 *ICAO Publications:*<sup>4</sup>

[ICAO Rules of the Air—Annex 2](#)

2.4 *RTCA Publications:*<sup>5</sup>

[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.

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.

3.1.4 *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 aircraft, air vehicles, or airborne objects in order to facilitate detection or coordinate resolution maneuvers, or both.

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

<sup>3</sup> Available from Federal Aviation Administration (FAA), 800 Independence Ave., SW, Washington, DC 20591.

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

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

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 or more aircraft, air vehicles, or airborne objects at their closest point of approach.

3.1.9 *non-cooperative S&A system, n*—system that is capable of detecting aircraft, air vehicles, or 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 aircraft, air vehicle, or other 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 mechanical 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](#).

## 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.<sup>6</sup>

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.<sup>7</sup>

<sup>6</sup> 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.

<sup>7</sup> 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.

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.

4.3.5.3 All maneuvers to return to an original or newly assigned flight path and altitude comply with current right-of-way rules for aircraft, air vehicles, and other airborne objects in accordance with [14 CFR 91.113](#). This applies to both autonomous and pilot-initiated maneuvers.

4.3.5.4 Non-emergency maneuvers for course or altitude changes, or both, do not compromise the performance of the S&A system.

### 4.4 Proof of Compliance:

4.4.1 These requirements shall be met at the most critical (for example, highest) closing velocities and most unfavorable (for example, climbing, descending) flight profiles. To the extent that the S&A system may operate in all-weather conditions, it will be evaluated in the least favorable flight