Designation: F3442/F3442M – 23

Standard Specification for Detect and Avoid System Performance Requirements[1]

This standard is issued under the fixed designation F3442/F3442M; 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.

1. Scope

1.1 This specification applies to uncrewed aircraft (UA) with a maximum dimension (for example, wingspan, disc diameter) ≤25 ft, operating at airspeeds below 100 kts, and of any configuration or category. It is meant to be applied in a "lower risk" [low- and medium-risk airspace as described by Joint Authorities for Rulemaking on Unmanned Systems (JARUS)] airspace environment with assumed infrequent encounters with crewed aircraft; this is typically in classes G and E airspace [below about 1200 ft above ground level (AGL)], Class B, C, D (below approximately 400 ft to 500 ft AGL) below obstacle clearance surface (FAA Order 8260.3, as amended) or within low altitude authorization and notification capability (LAANC) designated areas below the altitude specified in the facility map.

1.1.1 Traffic encountered is expected to be mixed cooperative and non-cooperative traffic, instrument flight rules (IFR) and visual flight rules (VFR), and to mostly include low-altitude aircraft—including rotorcraft, small general aviation, crop dusters, ultralights, and light sport aircraft, but not transport category aircraft.

1.1.2 This includes, but is not limited to, airspace where nearly all aircraft are required[2] to be cooperative (for example, within the Mode C veil in the United States).

1.2 Ultimate determination of applicability will be governed by the appropriate civil aviation authority (CAA).

1.3 This specification assumes no air traffic control (ATC) separation services are provided to the UA.

1.4 While some architectures may have limitations due to external conditions, this specification applies to daytime and nighttime, as well as visual meteorological conditions (VMC) and instrument meteorological conditions (IMC). The system integrator shall document system limitation (that is, due to operating environments and/or minimum altitudes at which the air picture is no longer valid).

1.5 This specification is applicable to the avoidance of crewed aircraft by uncrewed aircraft systems (UAS), not UA-to-UA or terrain/obstacle/airspace avoidance (both to be addressed in future efforts). Likewise, birds or natural hazard (for example, weather, clouds) avoidance requirements are not addressed.

1.6 This specification does not define a specific detect and avoid (DAA) architecture[3] and is architecture agnostic. It will, however, define specific safety performance thresholds for a DAA system to meet in order to ensure safe operation.

1.7 This specification addresses the definitions and methods for demonstrating compliance to this specification, and the many considerations (for example, detection range, required timeline to meet well clear, and near mid-air collision (NMAC) safety targets) affecting DAA system integration.

1.8 The specification highlights how different aspects of the system are designed and interrelated, and how they affect the greater UAS system-of-systems to enable a developer to make informed decisions within the context of their specific UAS application(s).

1.9 It is expected this specification will be used by diverse contributors or actors including, but not limited to:

1.9.1 DAA system designers and integrators,
1.9.2 Sensor suppliers,
1.9.3 UA developers,
1.9.4 Control Station designers,
1.9.5 UAS service suppliers, and
1.9.6 Flight control designers.

1.10 Except for DAA system integrators for whom all the "shalls" in this specification apply, not all aspects of this specification are relevant to all actors/contributors. In some instances, the actor most likely to satisfy a requirement has been identified in brackets after the requirement; this is for informative purposes only and does not indicate that only that actor may fulfill that requirement. Where not specified, the system integrator/applicant is assumed to be the primary actor; in all cases, the system integrator/applicant is responsible for all requirements and may choose to delegate requirements as is suitable to the system design. Nonetheless, familiarity with the entire specification will inform all actors/contributors of how

[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.

Current edition approved Feb. 1, 2023. Published March 2023. Originally approved in 2020. Last previous edition approved in 2020 as F3442/F3442M–20. DOI: 10.1520/F3442_F3442-23.

[2] Refer to 14 CFR § 91.215 and 14 CFR § 91.225 in the United States, or to the international equivalent for exceptions.

[3] ACAS sXu is intended to serve as a reference architecture for this specification.

their contributions affect the overall DAA capability and is strongly recommended.

1.11 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.12 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.13 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 When external standards, documents, or studies are referenced by this specification, the latest revision applies unless otherwise stated herein. Standards referenced should not be considered normative unless explicitly stated.

2.2 *ASTM Standards:*[4]

F3060 Terminology for Aircraft

F3341/F3341M Terminology for Unmanned Aircraft Systems

ASTM TR1-EB Autonomy Design and Operations in Aviation: Terminology and Requirements Framework

2.3 *Other Documents:*

14 CFR § 1.1 General definitions[5]

14 CFR § 91.111 Operating near other aircraft[5]

14 CFR § 91.113 Right-of-way rules: Except water operations[5]

14 CFR § 91.119(c) Minimum safe altitudes. General.[5]

14 CFR § 91.215 ATC transponder and altitude reporting equipment and use[5]

14 CFR § 91.225 Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment and use[5]

14 CFR § 107.37 Operation near aircraft; right-of-way rules[5]

FAA AC (Advisory Circular) 23.1309-1E System Safety Analysis and Assessment for Part 23 Airplanes

FAA AC 25.1322-1 Flightcrew Alerting[6]

FAA Order 8260.3 United States Standard for Terminal Instrument Procedures (TERPS)[6]

JARUS Specific Operations Risk Assessment (SORA) (package) V2.0[7]

RTCA DO-365C Minimum Operational Performance Standards (MOPS) for Detect and Avoid (DAA) Systems[8]

RTCA DO-381 MOPS for Ground-based Surveillance System (GBSS) for Traffic Surveillance[8]

SERA Standardised European Rules of the Air[9]

3. Terminology

3.1 *Unique and Common Terminology*—Terminology used in multiple standards is defined in Terminologies F3341/F3341M and F3060 and UAS Terminology Standard. Terminology that is unique to this specification is defined in this section.

3.2 *Use of Shall, Should, and May*—The use of *shall* indicates a requirement, *should* indicates a recommendation, and *may* is used to indicate that something is permitted.

3.3 *Definitions:*

3.3.1 *alert function, A1F, n*—function within the DAA system tasked with notifying the avoid function (whether human or automated system, or both) of the presence of an intruder.

3.3.2 *avoid function, A2F, n*—function within the DAA system tasked with providing the flight guidance necessary to maneuver away from the potential hazard posed by detected intruder(s). Avoidance may be executed automatically by a flight controller or manually by a pilot.

3.3.3 *beyond visual line of sight, BVLOS, n*—operation when the UA cannot be seen by the individuals responsible for see-and-avoid with unaided (other than corrective lenses or sunglasses, or both) vision, but where the location of the UA is known through technological means without exceeding the performance capabilities of the command and control (C2) link. See Terminology F3341/F3341M.

3.3.4 *collision avoidance, n*—avoidance maneuver with the objective of preventing the predicted penetration of the near-midair collision volume (NMAC).

3.3.5 *controlled airspace, n*—an airspace of defined dimensions within which air traffic control service is provided in accordance with the airspace classification.

3.3.5.1 *Discussion*—For example, in the United States, Classes A, B, C, D, and E airspace.

3.3.5.2 *Discussion*—Controlled airspace does not automatically imply separation services, or that the location of all traffic is known.

3.3.6 *cooperative intruder, n*—those intruders using a Mode C/S transponder or ADS-B, or both, that operate with like equipment used on other aircraft or ground-based services to establish the intruder's position.

[4] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[5] Available from U.S. Government Publishing Office (GPO), 732 N. Capitol St., NW, Washington, DC 20401, http://www.govinfo.gov.

[6] Available from Federal Aviation Administration (FAA), 800 Independence Ave., SW, Washington, DC 20591, http://www.faa.gov.

[7] Available from Joint Authorities for Rulemaking on Unmanned Systems (JARUS), http://jarus-rpas.org/content/jar-doc-06-sora-package.

[8] Available from RTCA, Inc., 1828 L St., NW, Suite 805, Washington, DC 20036. 6

[9] Available from European Union Aviation Safety Agency (EASA), Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, https://www.easa.europa.eu.

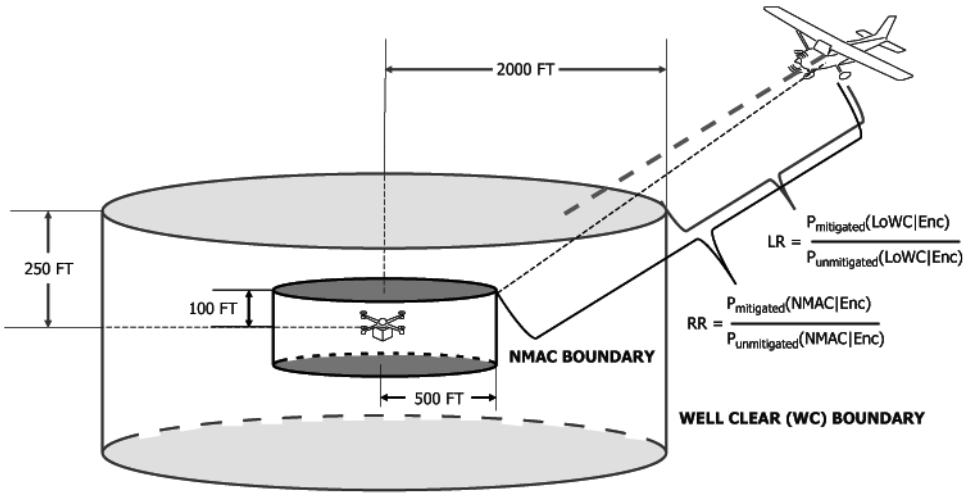

FIG. 1 RR and LR Illustration

3.3.7 *detect and avoid, DAA, n*—subsystem within the UAS providing the situation awareness, alerting, and avoidance necessary to maintain safe operation of the ownship in the presence of intruders.

3.3.8 *DAA cycle, n*—maximum time from the detection of the intruder's presence to the initiation of an avoidance maneuver

3.3.9 *DAA system integrator, n*—person/organization/entity who integrates the parts of a DAA system, and then shows that the risk ratios required by this standard are met.

3.3.10 *detect function, DF, n*—function within the DAA system tasked with maintaining temporal and spatial awareness of intruders.

3.3.11 *encounter, n*—event associated with the presence of an intruder.

3.3.12 *encounter rate, n*—number of encounters per unit of time.

3.3.13 *false alert, n*—an incorrect alert caused by a non-aircraft track or by a failure of the alerting system, including the sensor.

3.3.14 *intruder, n*—a crewed aircraft external to ownship within or projected to be in the ownship's vicinity in the near future.

3.3.14.1 *Discussion*—This definition is deliberately equivocal since the DAA system architecture and technologies employed, as well as ownship maneuvering capabilities, will shape the specific definitions of "vicinity" and "near future." The term "traffic" is often used synonymously with intruder.

3.3.15 *loss of well clear, loWC, n*—two aircraft coming within the well clear boundary of each other while in flight.

3.3.16 *loss of well clear risk ratio (LR) measurement, n*—LR is the quotient of the probability of a loss of well clear (LoWC) given an encounter with a DAA system, and the probability of loss of well clear given an encounter without a DAA system. The lower the LR, the better the DAA system is at preventing a loss of well clear. The LR is a measurement to ensure that a portion of the mitigation happens before loss of well clear as opposed to after. See Fig. 1 for depictions and formulae. See also Ref (**1**).[10]

3.3.17 *mid-air collision, MAC, n*—two aircraft colliding with each other while in flight.

3.3.18 *maintain well clear, n*—the act of maneuvering an aircraft with the objective of preventing the predicted erosion of the well clear margin of safety.

3.3.19 *near mid-air collision, NMAC, n*—two aircraft coming within 100 ft vertically and 500 ft horizontally of each other while in flight.

3.3.20 *NMAC risk ratio (RR) measurement, n*—RR is the quotient of the probability of an NMAC given an encounter with the DAA system and the probability of an NMAC given an encounter without the DAA system. The lower the RR, the better the DAA system is at preventing an NMAC.

3.3.20.1 *Discussion*—The RR used in this assessment is not a measurement of the collision avoidance function alone. The RR is a measurement from an encounter to an NMAC, and it is a measurement of all UAS DAA systems components used in mitigating NMAC. See Fig. 1 for depictions and formulae.

3.3.21 *non-cooperative intruder, n*—any aircraft not meeting the definition of cooperative in 3.3.6.

3.3.22 *nuisance alert, n*—alert generated by a system that is functioning as designed, but which is inappropriate or unnecessary for the particular condition.

3.3.23 *operational volume, n*—volume of airspace in which the UA operation intends, or is authorized, to take place.

3.3.23.1 *Discussion*—The term *operational volume* in this specification is aligned with the JARUS use of the term in Annex C of the Specific Operations Risk Assessment (SORA) and is different from the UAS traffic management (UTM)/U-space communities' use of the term. "Area of operation," or the intersection of acceptable air and ground risk in accordance

[10] The boldface numbers in parentheses refer to the list of references at the end of this standard.