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Standard Specification for Verification of Lightweight Unmanned Aircraft Systems (UAS)¹

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1. Scope

1.1 This specification covers the airworthiness requirements for the design of light unmanned aircraft systems. This specification defines the baseline verification requirements for an unmanned aircraft system (UAS).

1.2 As a minimum, a UAS is defined as a system composed of the unmanned aircraft and all required on-board subsystems, payload, control station, other required off-board subsystems, any required launch and recovery equipment, all required crew members, and command and control (C2) links between UA and the control station.

1.3 The intent is for this standard of practice for CAA, self- or third-party determinations of airworthiness for UAS. This specification provides the core requirements for airworthiness certification of lightweight (UAS) for certain CAA operational approvals using risk-based categories. Additional requirements are envisioned to address the requirements for expanded operations and characteristics not addressed by this specification.

1.4 This specification is intended to support UAS operations. It is assumed that the risk of UAS will vary based on concept of operations, environment, and other variables. The fact that there are no human beings onboard the UAS may reduce or eliminate some hazards and risks. However, at the discretion of the CAA, this specification may be applied to other UAS operations.

1.5 *Units*—The values in Imperial units are to be regarded as the standard. The values in SI are for information only.

1.6 *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.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standard-*

ization 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 ASTM Standards:²

F2908 Specification for Unmanned Aircraft Flight Manual (UFM) for an Unmanned Aircraft System (UAS)

F2909 Specification for Continued Airworthiness of Lightweight Unmanned Aircraft Systems

F3002 Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems (sUAS)

F3060 Terminology for Aircraft

F3120/F3120M Specification for Ice Protection for General Aviation Aircraft

F3201 Practice for Ensuring Dependability of Software Used in Unmanned Aircraft Systems (UAS)

F3298 Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS)

F3341/F3341M Terminology for Unmanned Aircraft Systems

F3478 Practice for Development of a Durability and Reliability Flight Demonstration Program for Low-Risk Unmanned Aircraft Systems (UAS) under FAA Oversight

2.2 ANSI Standard:³

ANSI Z535.1-1998 American National Standard for Safety Colors

2.3 FAA Standard:⁴

Order 8130.34D Airworthiness Certification of Unmanned Aircraft Systems and Optionally Piloted Aircraft

2.4 Federal Standard:⁵

14 CFR Part 107 Small Unmanned Aircraft Systems

² 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.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁴ Available from Federal Aviation Administration (FAA), 800 Independence Ave., SW, Washington, DC 20591, <http://www.faa.gov>.

⁵ Available from U. S. Government Accountability Office (GAO), 441 G St., NW, Washington, DC 20548, <http://www.gao.gov>.

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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- 2.5 *Joint Authorities for Rulemaking of Unmanned Systems*:⁶
CS-LURS Certification Specification for Light Unmanned Rotorcraft Systems
CS-LUAS Recommendations for Certification Specification for Light Unmanned Aeroplane Systems
- 2.6 *Unmanned Systems Canada Best Practices*:⁷
Small Remotely Piloted Aircraft System (UAS) Best Practices for BVLOS Operations

3. Terminology

3.1 *Unique and Common Terminology*—Terminology used in multiple standards is defined in Terminology **F3341/F3341M** and Terminology **F3060**.

3.2 Terminology that is unique to this specification is defined in this section.

3.3 This specification uses terminology contained within Specification **F3298**. These terms are not duplicated within this document.

3.4 Abbreviations:

- 3.4.1 *ADS-B*—automatic dependent surveillance broadcast
 3.4.2 *AR*—aspect ratio
 3.4.3 *AFCS*—automated flight control system

4. Significance and Use/Applicability

4.1 This specification is intended for lightweight UAS permitted to operate over a defined area and in airspace authorized by a nation's civil aviation authority (CAA) with a fully interactive off-board person as "Remote Pilot in Command."

4.2 The baseline covered by this specification should not require an authorization by a civil aviation authority for the flight but stay within defined boundaries for the operation (for example, distance from airports, from people, maximum weight, altitude, airspeed and operational envelope). However, unless otherwise allowed by a nation's CAA or subject to voluntarily compliance by an applicant, this specification applies to UA that are remotely piloted (that is, flown without the possibility of direct human intervention from within or on the aircraft), and conduct expanded operations that typically require authorization from the CAA (for example, Operations Authorization for Specific Category UAS or Part 107 Certificate of Waiver/Authorization) with specific limitations adapted to the operation.

4.3 These requirements apply to unmanned aircraft systems that are:

- 4.3.1 *Fixed-Wing*—Heavier than air and supported in flight by the dynamic reaction of the air against its wings. The UA may be powered or unpowered; the UA may have rigid, semi-rigid, or flexible wings.
 4.3.2 *VTOL*—Heavier than air and capable of vertical or near-vertical takeoffs and landings. The rotor system may be

powered or unpowered; rotors may be either fixed collective pitch or collective pitch control that are not adjustable in flight. Reference 3.1.52 for characteristics by category of vertical flight aircraft.

4.3.3 Hybrid UAS (that is, incorporating gyrodyne or powered-lift flight modes) are recommended to follow the most restrictive aspects of this specification.

5. Flight

5.1 Proof of Compliance:

5.1.1 Each applicant who claims compliance to this specification shall be able to show compliance with the applicable requirements of this specification.

6. Operating Limitations and Information

6.1 During the verification process, the applicant shall determine and document in the aircraft flight manual appropriate operating limitations and other information necessary for safe operation of the system. This shall include any wind limitations as well as features of the control station and the C2 link functions of the system.

6.2 Weight and Center of Gravity:

6.2.1 During the verification process, the applicant shall determine and document weight and loading distribution, including the maximum certificated weights and the center of gravity (CG) range.

6.2.2 The applicant shall determine the location of the reference datum used in balance computations.

6.3 Propulsion System Limitations:

6.3.1 The propulsion limitations portion describes operating limitations on an aircraft's reciprocating or electric engine(s).

6.3.2 These include limitations for takeoff power, maximum continuous power, and maximum normal operating power, which is the maximum power the engine can produce without any restrictions, and any other limitations specified in the OEM engine/motor installation manual.

6.4 Electromagnetic Environmental Effects:

6.4.1 The UAS should be verified with an operational envelope that contains a specific external High Intensity Radio Frequency (HIRF) environment.

7. Documentation

7.1 Verification Control:

7.1.1 The documentation of an unmanned aircraft consists of at least the following:

7.1.1.1 The drawings and specifications, and a listing of those drawings and specifications necessary to define the configuration of the UA shown to comply with this specification.

7.1.1.2 Information on dimensions, materials, and processes necessary to define the structural strength of the UA.

7.1.1.3 Any other data necessary to allow, by comparison, the determination that later UA of the same or similar design meet the requirements of this specification.

7.1.2 The manufacturer shall retain documentation of appropriate verification results including data showing compliance with this specification.

⁶ Available from Joint Authorities for Rulemaking of Unmanned Systems (JARUS), <http://www.jarus-rpas.org>.

⁷ Available from Unmanned Systems Canada, PO Box 81055, Ottawa, Ontario, K1P 1B1, <https://www.unmannedsystems.ca>.

7.1.3 All verification documentation may be developed in the manufacturer's format or using best available documentation practices (for example, engineering notebook format).

7.1.4 *Performance Records:*

7.1.4.1 All verification shall be recorded and available at the applicant's location for future reference for UAS that will receive type certification by a CAA, or (as appropriate) self or third-party determinations of airworthiness for UAS.

7.1.4.2 At a minimum, flight demonstrations or testing should be logged using aviation best practices. An example is as follows: "I certify that the prescribed flight test hours have been completed and the aircraft is controllable throughout its normal range of speeds and throughout all maneuvers to be executed, has no hazardous operating characteristics or design features, and is safe for operation. The following aircraft operating data has been demonstrated during the flight testing; speeds V_{SO} , V_X , and V_Y , and the weight and CG location at which they were obtained." For multiengine aircraft, add V_{XSE} , V_{YSE} , and V_{MC} .

7.2 *Unmanned Aircraft Flight Manual (UFM):*

7.2.1 The applicant shall adhere to Specification **F2908** for the unmanned aircraft flight manual.

7.2.2 The applicant shall determine and document in the unmanned aircraft flight manual appropriate operating limitations and other information necessary for safe operation of the system. This shall include any wind limitations as well as features of the control station and the CNPC link functions of the system.

7.2.3 The applicant should provide a Pilot Operating Handbook/Checklist containing system descriptions, operating procedures and limitations, engine and aircraft performance, critical airspeeds and altitudes, emergency procedures, pre-flight inspections, and any other information critical to safe operation of the unmanned aircraft.

7.2.4 *General Information:*

7.2.4.1 The General section provides the basic descriptive information on the airframe and propulsion system(s). The POH should include a three-dimensional drawing of the aircraft that provides dimensions of various components. Included are such items as wingspan, maximum height, overall length, wheelbase length, main landing gear track width, diameter of the rotor system, maximum propeller diameter, propeller ground clearance, minimum turning radius, and wing area.

7.2.4.2 This section serves as a quick reference and helps a remote pilot become familiar with the aircraft.

7.2.5 *Operating Limitations:*

7.2.5.1 The Limitations section contains only those limitations required by regulation or that are necessary for the safe operation of the aircraft, powerplant, systems, and equipment. It includes operating limitations, instrument markings, color-coding, and basic placards.

7.2.5.2 Some of the limitation areas are airspeed, propulsion system, weight and loading distribution, and flight.

7.2.5.3 For those systems that might have components capable of causing injury, the UA shall have a warning/caution statement added to the unmanned aircraft flight manual alerting the crew to the risk.

7.2.5.4 If removing/adding ballast is permitted, the unmanned aircraft flight manual shall include instructions with respect to loading, marking, and securing of removable ballast and ensuring the center of gravity remains within limits that can be controlled by the control system and ensures adequate aerodynamic stability.

7.2.5.5 The aircraft flight manual shall have a method to verify or calculate CG location.

7.2.5.6 The manufacturer shall develop and provide instructions to ensure any damage caused by shipping or handling are identified prior to flight. These instructions should normally be part of the pre-flight inspection procedures in the unmanned aircraft flight manual but may be included in other instructions as deemed necessary by the manufacturer.

7.2.6 *HIRF:*

7.2.6.1 The Unmanned Aircraft Flight Manual (UFM) shall include the specific external HIRF environments for the UAS intended operational envelope.

7.2.6.2 If the UAS design did not consider a specific HIRF, or did not verify the HIRF protection of the UAS, the UFM shall include a caution statement.

7.2.7 *Emergency Procedures:*

7.2.7.1 The emergency procedures section shall include checklists describing the recommended procedures and airspeeds for coping with various types of emergencies or critical situations. Some of the emergencies covered include: engine failure, fire, and system failure.

7.2.7.2 Applicant should first show an emergency checklist in an abbreviated form with the order of items reflecting the sequence of action. Amplified checklists that provide additional information on the procedures follow the abbreviated checklist.

7.2.8 *Normal Procedures and Checklists:*

7.2.8.1 This section should begin with a list of the airspeeds for normal operations.

7.2.8.2 The section shall include several checklists that may include preflight inspection, before starting procedures, starting engine, before taxiing, taxiing, before takeoff, climb, cruise, descent, before landing, balked landing, after landing, and post flight procedures. An Amplified Procedures area follows the checklists to provide more detailed information about the various previously mentioned procedures.

7.2.8.3 All specializations and limitations shall be those determined from the preceding relative design criteria.

7.2.9 *Navigational Databases:*

7.2.9.1 The POH should describe procedures for updating the navigational database in accordance with the appropriate data revision cycle. This includes a contract with a database supplier and the inclusion, in the appropriate company manuals, of the person responsible for installing the updates in the UA.

7.2.9.2 The POH should describe procedures for remote pilots to report database errors and for information on database errors to be passed on to other pilots, the avionics manufacturer and other appropriate individuals.

7.3 *Maintenance Manual:*

7.3.1 The applicant should provide a maintenance manual containing routine, inspection, and repair maintenance procedures for the UA and engine.

7.3.2 The maintenance manual shall include maximum damage and wear limits for the propellers.

7.3.3 The maintenance manual shall provide instructions for continued airworthiness that are in compliance with Practice **F2909**.

7.3.4 Applicants shall provide the CAA with a written, self-certifying statement that they have an established inspection and maintenance program for the continued airworthiness of the aircraft.

8. Verification

8.1 General:

8.1.1 *System Verification*—This specification requires the manufacturer to complete functional verification prior to achieving compliance.

8.1.2 Verification techniques may include the use of hardware in the loop simulation, ground/flight testing, and other techniques. If sufficient operational reliability is not demonstrated, the manufacturer shall levy initial operational restrictions until an acceptable level of demonstrated reliability is reached.

8.1.3 UAS design and construction requirements shall be verified with a combination of analysis, inspections, demonstrations or tests.

8.1.3.1 The applicant will conduct any necessary inspections, flight, or ground tests required to verify the appropriate flight test requirements based on the type of aircraft, intended use, and CONOPS.

8.1.3.2 UAS demonstrations, testing, analysis, or simulations, or combinations thereof, shall be conducted to verify that the design requirements have been satisfied and the results recorded and available for future reference.

8.1.3.3 Software and hardware development assurance are not in the scope of this specification and this specification should not be used if a development assurance process is required. Refer to Practice **F3201** for software used in UAS. Refer to the standards listed in **2.1** for hardware used in UAS.

8.1.3.4 This verification process specifically addresses definition, identification, and verification of system functions. Processes conducted under this specification may not satisfy all applicable external requirements; additional review on the part of the system developer, integrator, or installer may be required to meet specific requirements or the specified mission of the aircraft, or both.

8.2 Methods of Verification:

8.2.1 The applicant shall verify the proper completion of each ready-to-fly UAS by conducting a final system test in accordance with the requirements below.

8.2.2 The following ground check and flight test procedures shall be conducted and documented for each ready-to-fly UAS using one or more of the following methods:

8.2.2.1 Analysis:

(1) Mainly used where testing to realistic conditions cannot be achieved or is not cost-effective.

8.2.2.2 Inspection:

(1) Inspection is used to check properties or characteristics best determined by observation (for example, paint color, weight, documentation, listing of code, etc.).

(2) The control station and other associated elements required for remote operations shall be inspected during the onsite inspection. During the inspection, the applicant should demonstrate control link and control station functionality by performing procedures such as turning on/off the aircraft lights, deflecting flight controls, or conducting an engine run, or combinations thereof.

8.2.2.3 Demonstration:

(1) Demonstration may be appropriate when requirements or specification are given in statistical terms (for example, mean time to repair, average power consumption, etc.).

(a) The objective is to demonstrate the aircraft's controllability throughout all the maneuvers and to detect any hazardous operating characteristics or design features.

(b) The applicant shall complete a minimum of 25 h of flight time for UAS, to demonstrate that the aircraft and all required on-board subsystems, payload, control station, other required off-board subsystems, any required launch and recovery equipment, all required crew members, and command and control (C2) links between UA and the control station perform as designed in the intended configuration. This demonstration is for design type and specific configuration, not each individual aircraft.

(c) The applicant should complete a minimum of 40 h of flight time for the UA.

8.2.2.4 Test:

(1) Testing is performed onto the submitted element by which functional, measurable characteristics, operability, supportability, or performance capability is quantitatively verified when subjected to controlled conditions that are real or simulated.

(2) Testing should use special test equipment or instrumentation to obtain accurate quantitative data to be analyzed.

8.3 Organizational Requirements:

8.3.1 An organization complying with this specification shall manage under configuration control all life cycle data which are generated by applying this specification.

8.3.2 The organization shall keep a record of the documentation used to show compliance of each approved system configuration produced to all applicable consensus specifications and regulatory requirements in effect at the time of manufacture or major change.

8.4 Product Definition Process:

8.4.1 *Function Identification*—Document the intended function(s) of the system.

8.4.2 Function Classification:

8.4.2.1 For each function identified under Specification **F3298** 15.4.1, determine and document whether it is to be verified under this specification or by other means.

8.4.2.2 Other means of verification may be proprietary or may be based on other standards, as best suits the applicant's objectives with regard to safety, marketability, and compliance concerns.

8.4.3 Function Specification: