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Standard Specification for Design and Construction of a Small Unmanned Aircraft System (sUAS)[1]

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1. Scope

1.1 This specification defines the design, construction, and test requirements for a small unmanned aircraft system (sUAS).

1.2 *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.*

1.3 *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 *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
F2911 Practice for Production Acceptance of Small Unmanned Aircraft System (sUAS)
F3002 Specification for Design of the Command and Control System for Small Unmanned Aircraft Systems (sUAS)
F3003 Specification for Quality Assurance of a Small Unmanned Aircraft System (sUAS)
F3005 Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)
F3060 Terminology for Aircraft
F3341/F3341M Terminology for Unmanned Aircraft Systems

3. Terminology

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

3.1.1 *continued safe flight, n*—a condition whereby a UA is capable of continued safe flight, possibly using emergency procedures, without requiring exceptional pilot skill. Upon landing some UA damage may occur as a result of a failure condition.

3.1.2 *launch and recovery load, n*—those loads experienced during normal launch and recovery of the UA.

3.1.3 *limit load, n*—those loads experienced in the normal operation and maintenance of the UA.

3.1.4 *manufacturer, n*—entity responsible for assembly and integration of components and subsystems to create a safe operating sUAS.

3.1.5 *permanent deformation, n*—a condition whereby a UA structure is altered such that it does not return to the shape required for normal flight.

3.1.6 *propulsion system, n*—consists of one or more power plants (for example, a combustion engine or an electric motor and, if used, a propeller or rotor) together with the associated installation of fuel system, control and electrical power supply (for example, batteries, electronic speed controls, fuel cells, or other energy supply).

3.1.7 *small unmanned aircraft system, sUAS, n*—composed of the small unmanned aircraft (sUA) and all required on-board subsystems, payload, control station, other required off-board subsystems, any required launch and recovery equipment, and command and control (C2) links between the sUA and the control station. For purposes of this standard sUAS is synonymous with a small Remotely Piloted Aircraft System (sRPAS) and sUA is synonymous with a small Remotely Piloted Aircraft (sRPA).

3.1.8 *structural failure, n*—a condition whereby the structure is not able to carry normal operating loads.

[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] 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.

3.1.9 *supplier, n*—any entity engaged in the design and production of components (other than a payload which is not required for safe operation of the sUAS) used on a sUAS.

3.1.9.1 *Discussion*—Where the supplier is not the manufacturer, the supplier can only ensure that the components comply with accepted consensus standards.

3.2 *Shall versus Should versus May*—Use of the word "shall" implies that a procedure or statement is mandatory and must be followed to comply with this standard, "should" implies recommended, and "may" implies optional at the discretion of the supplier, manufacturer, or operator. Since "shall" statements are requirements, they include sufficient detail needed to define compliance (for example, threshold values, test methods, oversight, reference to other standards). "Should" statements are provided as guidance towards the overall goal of improving safety, and could include only subjective statements. "Should" statements also represent parameters that could be used in safety evaluations, and could lead to development of future requirements. "May" statements are provided to clarify acceptability of a specific item or practice, and offer options for satisfying requirements.

4. Applicability

4.1 This standard is written for all sUAS that are permitted to operate over a defined area and in airspace authorized by a nation's governing aviation authority (GAA). It is assumed that a visual observer(s) will provide for the sense-and-avoid requirement to prevent collisions with other aircraft and that the maximum range and altitude at which the sUAS can be flown at will be specified by the nation's GAA. Unless otherwise specified by a nation's GAA this standard applies only to UA that have a maximum takeoff gross weight of 55 lb/25 kg or less.

5. Requirements

5.1 *General:*

5.1.1 The sUAS shall be designed and constructed to meet sUAS limitations and performance capabilities required by the nation's GAA.

5.1.2 The sUA shall be designed and constructed so that the maximum level flight speed cannot exceed the maximum airspeed authorized by the nation's GAA. In addition, the maximum level flight airspeed should not exceed an airspeed that would prevent the sUA from remaining within the confines of the defined operational area without excessive maneuvering or exceptional pilot skill.

5.1.3 The sUAS shall be designed using appropriate and reasonable engineering design and verification techniques. Test shall be conducted in accordance with section 5.11 to verify that the design requirements have been satisfied and the results of the tests recorded and available for future reference.

5.1.4 The sUAS shall be designed and constructed to initialize in a known, safe state when power is applied.

5.1.5 The sUA should be designed and constructed to minimize the likelihood of fire, explosion, or the release of hazardous chemicals, materials, and flammable liquids or gasses, or a combination thereof, in flight or in the event of a crash, hard landing, or ground handling mishap. This includes, but is not limited to: containing the fire if the sUA crashes; protecting first responders from hazards at the crash site; use of flame resistant materials; suppression of in-flight fires; and protection against battery-induced fires.

5.1.6 During the design process, the manufacturer shall determine the permissible range of weight and positions of the center of gravity of the sUA. The sUA shall then be designed and constructed to ensure that the center of gravity remains within this permissible weight and range for all intended payloads, fuel, batteries, and other onboard items. If removing/adding ballast is permitted, the sUAS 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. The aircraft flight manual shall have a method to verify or calculate CG location.

5.1.7 During the design process, the manufacturer shall determine the maximum takeoff gross weight and minimum operational empty weight for the sUA.

5.1.8 The sUAS should be designed and constructed to minimize injury to persons or damage to property during operation.

5.1.8.1 Designs that use exposed, rigid sharp structural objects should be minimized. For those systems that might have components capable of causing injury due to misuse or mishandling, a warning/caution statement should be added to the aircraft flight manual alerting the crew to the risk.

5.1.8.2 The sUA shall be designed so that the sUA will remain controllable and predictable or capable of performing a safe recovery maneuver in the event of asymmetric deployment of any single, normal control surface as well as high-lift/drag devices (trailing edge flaps, leading edge flaps or slats, spoilers, flaperons, and the like).

5.1.9 The sUA shall be designed and constructed so that all fasteners will remain secure over the operational and environmental range of flight conditions.

5.1.10 The sUA should be designed and constructed so that it is possible to determine quickly that all doors, panels, and hatches that can be opened are secured before takeoff.

5.1.11 *Construction*—In addition to construction requirements specified above:

5.1.11.1 The sUAS should incorporate materials that have the strength, corrosion resistance, and durability characteristics appropriate to the application in the design.

5.1.11.2 Energy absorbing structure should be used wherever possible.

5.1.11.3 Material strength design properties should be based on analysis or testing, or both, determined by the manufacturer/supplier that confirms these material strength design properties have been achieved. Documentation of this analysis or testing, or both, should be recorded and available at either the manufacturer's or supplier's location (as appropriate) for future reference.

5.2 *Structure:*

5.2.1 The sUA structure shall be designed and constructed so that:

5.2.1.1 The structure will not fail at 1.5 times the limit loads. This shall be verified either through analysis or testing as determined by the manufacturer/supplier.

5.2.1.2 Binding, chafing, or jamming of controls do not occur at 1.5 times the limit load threshhold. This shall be verified by test.

5.2.1.3 The structure can withstand limit loads and launch and recovery loads without permanent deformation.

5.2.2 The sUA and systems required for continued safe flight shall be designed and constructed to be capable of supporting flight loads predicted by analysis or flight test to be encountered throughout the proposed flight envelope to include atmospheric gusts or evasive maneuvering loads, or both.

5.2.3 The sUA and systems required for continued safe flight shall be designed and constructed to withstand normal landing impact loads without damage that would affect safety of flight of subsequent flights unless it can be maintained, repaired, and inspected as per procedures that will ensure continued safe operation.

5.2.4 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 aircraft flight manual but may be included in other instructions as deemed necessary by the manufacturer.

5.3 *Propulsion:*

5.3.1 The propulsion system (including batteries for electric power plants) shall be designed and constructed to:

5.3.1.1 Operate throughout the flight envelope,

5.3.1.2 Conform to the installation instructions provided by the propulsion system supplier, and

5.3.1.3 Have a positive means to cut off ignition or fuel flow both in-flight and on the ground.

5.3.2 Propulsion system controls and displays at the control station shall be designed and constructed to be adequate to control the propulsion system safely under all operating conditions as determined by the manufacturer or the engine supplier, or both. Examples include:

5.3.2.1 Ability to be able to observe whether engine is on or off (corroborated by multiple sensors).

5.3.2.2 Ability to command the engine off quickly.

5.3.2.3 Ability to have a multi-step safeguard in turning the engine on or off.

5.3.2.4 Vital engine instruments as determined by the manufacturer or engine supplier/manufacturer, or both, as necessary to properly control the engine such as: fuel flow and pressure, RPM, manifold pressure, carburetor icing detector, exhaust temperature, and cylinder head temperature for combustion engines and current, temperature, etc for electric propulsion (or other parameters applicable to the propulsion system design).

NOTE 1—May not be applicable for rotorcraft or manually controlled sUAS using simple model aircraft radio control equipment.

5.3.3 *Propellers:*

5.3.3.1 All propellers should be non-metallic.

5.3.3.2 Propellers (both fixed and variable pitch) should be designed to have adequate structural strength.

5.3.3.3 Provisions shall be made to ensure that the propulsion system shaft and propeller rotational speed do not exceed the value specified by the supplier.

5.3.4 The propulsion system should be designed to minimize failure for reasons other than insufficient fuel or electrical power and to support normal operations throughout the anticipated lifecycle of the system or until reaching the manufacturer/supplier-determined inspection or replacement interval.

5.3.5 *Fuel and Oil Systems*—For sUA using a combustion propulsion system:

5.3.5.1 The fuel and oil systems shall be designed and constructed to be capable of supplying fuel and oil to the power plant throughout the entire flight envelope at the required rate and pressure specified by the propulsion system supplier;

5.3.5.2 The fuel and oil systems shall be designed so that there is a means of determining the amount of fuel and oil on board when the UA is on the ground, whether via internal sUA systems or external means;

5.3.5.3 Piping, fittings, valves, O-rings, and gaskets used shall be resistant to deterioration caused by fuel, oil, and lubricating grease;

5.3.5.4 Each fuel system and oil system shall be designed to be able to withstand 1.5 limit loads; and

5.3.5.5 Each fuel system (excluding bladder type systems) shall be designed so that it is vented to the atmosphere and can be drained when the aircraft is on the ground.

5.3.6 *Cooling*—Not all sUA require a cooling system. However, if one is necessary the following requirements apply:

5.3.6.1 The cooling system shall be designed and constructed to ensure adequate cooling of the power plant at the highest ambient temperatures expected during maximum climb rate and cruise operations of the sUA.

5.3.6.2 The cooling system should be designed and constructed so that any air induction system filters can be inspected, serviced, or replaced, or a combination thereof, as part of routine maintenance as specified by the manufacturer.

5.3.6.3 Where necessary to maintain a safe operating temperature, naturally aspirated cooling shall be supplemented by an appropriate cooling method.

5.3.7 The exhaust system shall be designed and constructed to ensure that hot exhaust gases do not impinge directly on nearby unprotected surfaces.

5.3.8 For combustion engine power plants, the system shall include:

5.3.8.1 An ignition switch incorporated into the controls available at the control station, and

5.3.8.2 A means of interrupting engine ignition on the aircraft to permit external operation to shut down the engine when the aircraft is on the ground.

5.3.9 For aircraft using electric power plants, the system shall include:

5.3.9.1 A master switch or other means (for example, removing battery) mounted on the aircraft to permit external operation to shut down the power plant when the aircraft is on the ground and

5.3.9.2 A means to permit the operator to determine the capacity remaining in the batteries.

5.3.10 *Batteries*—Refer to Specification F3005 for design requirements.

5.4 *Command and Control (C2) Link*—Refer to Specification F3002 for design requirements.

5.5 *Data Link*—Reserved.

5.6 *Systems and Equipment:*

5.6.1 All system components shall be designed and constructed to:

5.6.1.1 Be appropriate to their intended function and

5.6.1.2 Function properly when installed.

5.6.2 The sUAS design may include an air data system based upon a pitot-static system installed on the aircraft. If a pitot-static system is installed it should be calibrated at an interval defined by the manufacturer.

NOTE 2—May not be applicable for rotorcraft or manually controlled sUAS using simple model aircraft radio control equipment.

5.6.3 *Flight, Navigation, and Power Plant Displays*—The sUAS should be capable of down linking data concerning flight, power plant, and navigation parameters as identified in 5.6.4.

NOTE 3—May not be applicable for manually controlled sUAS using simple model aircraft radio control equipment.

5.6.4 The control station shall provide the pilot with all information required for accurate control of the sUAS. Refer to Specification F3002 for design requirements.

NOTE 4—May not be applicable for manually controlled sUAS using simple model aircraft radio control equipment.

5.6.5 *Equipment, Systems, and Installation*—Each item of equipment, each system, and each installation shall be designed and constructed so that when performing its intended function, it does not adversely affect the response, operation, or accuracy (as specified by the manufacturer) of any equipment required for the safe operation of the sUAS.

5.6.6 The system should be designed and constructed so that the aircraft remains controllable or automatically initiates a predictable and safe maneuver in the event of the failure of any flight critical component or system.

5.6.7 *Automatic Pilot*—Any automatic pilot shall be designed and constructed so that it is possible for the operator to assume manual control of the trajectory of the aircraft at any time during the flight or ground handling.

NOTE 5—This is not to be interpreted as mandating that the pilot shall be able to engage true stick to surface control at any time.

5.6.8 *Electrical System:*

5.6.8.1 An electrical load analysis shall be performed to ensure that electrical bus loads and capacity are adequate to power all aircraft systems and installed payloads.

5.6.8.2 The electrical system shall be designed and constructed so that:

(1) There is a means to enable the operator to determine the correct operation of the electrical system, including correct operation of any generator;

(2) Circuit protective devices are incorporated where necessary to ensure that wiring is not overloaded;

(3) Electrical wiring and cables have adequate capacity;

(4) Loosening of connections over the range of vibrations expected is prevented; and

(5) If there is provision for applying external electrical power to the aircraft when on the ground, connection points are adequately labeled with respect to current and voltage and polarity limitations.

5.6.9 *Anti-Collision Lights*—Anti-collision lights shall be installed and functional for night operations.

5.6.10 *Landing Gear:*

5.6.10.1 For sUA that use conventional landing, the landing gear shall be designed and constructed to accommodate normal landing impact loads without damage to the structure.

5.6.10.2 If the landing gear is retractable and its status cannot be confirmed visually, there shall be an indicator or display at the control station to advise the operator that the landing gear is:

(1) Securely locked down before landing and

(2) Stowed securely in the correct position for flight when landing gear is selected up.

5.7 *Payloads*—All payloads shall be designed and constructed so that the safe operation of the sUAS is not prevented by electronic emissions, weight/location, or other characteristics of the payload. This is the responsibility of the manufacturer if the payload is provided as part of the delivered system. If the manufacturer allows additional supplier provided payloads to be installed in the field by the operator then the manufacturer shall provide guidance to the operator as to how to verify that this requirement has been met.

5.8 *Control Station*—Refer to Specification F3002 for design requirements.

5.9 *Launch and Recovery System*—Any required launch and recovery system shall be designed, constructed, and tested in accordance with an appropriate consensus standard.

5.10 *System Level:*

5.10.1 *Stalls (aerodynamic departure from controlled flight):*

NOTE 6—Not applicable for rotorcraft or sUAS manually controlled using simple model aircraft radio control equipment.

5.10.1.1 For sUA that are not equipped with automatic stall protection, a means shall be provided to warn the pilot when the aircraft is approaching the stall. The warning shall be available to the pilot and be an audible or distinctive tone or a flashing visual indicator, or a combination thereof, and shall be initiated when the aircraft is no less than 10 % above the stall speed/angle of attack.

5.10.1.2 The manufacturer shall design the sUAS so that recovery from any departure from safe flight can be accomplished with a single specific action that positively returns the aircraft to controlled flight.

5.10.2 If the sUAS is equipped with an automatic departure prevention capability, that subsystem shall be shown to have appropriate reliability even to the extent of having battery power independent of the primary power system or to the extent of protecting the power to the departure-prevention subsystem such that failures in other subsystems do not cut power to the departure-prevention subsystem. The minimum