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General requirements for tethered unmanned aircraft systems

Exigences générales relatives aux aéronefs sans pilote captifs

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 16, *Unmanned aircraft systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The purpose of this document is to describe a general technical architecture for tethered unmanned aircraft systems (*t*UAS). It addresses the general requirements for components and subsystems, functions and performance. The objective is to promote international trade, provide a technical basis for related industrial applications, a guidance for development and manufacturing, and to promote safe operations.

General requirements for tethered unmanned aircraft systems

1 Scope

This document specifies general and manufacturing requirements for tethered unmanned aircraft systems (*t*UAS), including heavier-than-air tethered unmanned aircraft (*t*UA), which are powered by equipment on the ground. The specifications are intended for *t*UAS where the purpose for the tether is to supply power to the *t*UA as well as to provide a mechanical restraint. Unmanned aircrafts (UAs) that are not receiving power from and only restrained by the tether are referred to ISO 21384-2; however, there are clauses in this document that apply to the tethering equipment (e.g. winches and cables).

This document is applicable to the development, manufacturing, industrial applications and delivery of *t*UAS.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 21384-2, *Unmanned aircraft systems — Part 2: UAS components*

ISO 21384-4, *Unmanned aircraft systems — Part 4: Vocabulary*

ISO 23629 (all parts), *UAS traffic management (UTM)*

IEC 60228, *Conductors of insulated cables*

IEC 60811, *Common test methods for insulating and sheathing materials of electric cables and optical cables*

IEC 60885-1, *Electrical test methods for electric cables — Part 1: Electrical tests for cables, cords and wires for voltages up to and including 450/750 V*

IEC 61076-1, *Connectors for electronic equipment — Product requirements — Part 1: Generic specification*

IEC 61076-2, *Connectors for electronic equipment — Product requirements — Part 2: Circular connectors*

IEC 62133, *Secondary cells and batteries containing alkaline or other non-acid electrolytes — Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications*

IEC 62197-1, *Connectors for electronic equipment — Product requirements — Part 1: Generic specification*

IEC 62197-2, *Connectors for electronic equipment — Product requirements — Part 2: Sectional specification for circular connectors*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21384-2, ISO 21384-4 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
winch
ground device which is able to automatically or manually coil and uncoil the cables

3.2
heavier-than-air tethered unmanned aircraft
heavier-than-air *t*UA
*t*UA (3.5), with a take-off weight that is more than the air it displaces

3.3
uninterruptible power supply
UPS
power supply system that provides emergency power to the unmanned aircraft system when the main power supply is disrupted

3.4
tethering cable
cable that provides power and a mechanical constraint to an unmanned aircraft, and may also be able to exchange data with the unmanned aircraft

3.5
tethered unmanned aircraft
***t*UA**
unmanned aircraft with range of movement limited by a *tethering cable* (3.4) and electrical power supplied by ground equipment conveyed through the tethering cable

3.6
tethered unmanned aircraft system
***t*UAS**
UAS comprised of a *t*UA (3.5) and associated components (e.g. *tethering cable* (3.4), *winches* (3.1), ground-based electrical system and with a potential for data exchange)

4 Abbreviated terms

GNSS	global navigation satellite system
RPS	remote pilot station
*t*UA	tethered unmanned aircraft
*t*UAS	tethered unmanned aircraft system
UA	unmanned aircraft
UPS	uninterruptible power supply
UTM	UAS traffic management

5 System general requirements

5.1 General requirements

General requirements for the *t*UAS shall be consistent with the general requirements for multirotor UAS given in ISO 21384-2, including but not limited to requirements for avionics, propulsion, navigation, flight control system, command and control link, RPS and mission payload interface. Additional requirements are specified in this document.

5.2 Composition of *t*UAS

A system shall be considered as a *t*UAS when consisting of a minimum of the following components:

a) *t*UA, including the airframe, avionics, propulsion, and electrical, navigation and flight control systems;

b) command and control link, using either wireless or wired (tether-based) technology;

c) communication system, via voice or datalink

d) mission payloads;

e) RPS;

f) ground support equipment, including ground-based electrical power supply, tethering cable and winches.

5.3 Design for long-duration reliability

The corresponding technical measures are considered in the design and manufacturing process to improve long-duration reliability. Technical measures shall:

a) apply proven technology using mature design solutions and components;

b) simplify the design by reducing the complexity of the equipment;

c) meet the functional requirements of the product with as few components as possible;

d) minimize the power requirements to reduce the failure rate of components;

e) include fault-tolerant circuits and software in the design to avoid effects due to transient processes and accidental errors or faults;

f) design with components with a long lifetime or known failure lifetimes specified by manufacturers or suppliers.

In order to improve the long-duration flight reliability of the *t*UAS, a high precision positioning system (e.g. GNSS) tracking function and signal quality alerting function shall be included.

6 Operator's manual requirements

6.1 System performance

The following characteristics and performance parameters of the *t*UAS shall be published in the operator's manual:

a) maximum climb speed;

b) maximum descent speed;

c) maximum hovering height;

d) maximum operational height;

e) maximum flight time;

f) take-off and landing speeds;

g) take-off and landing wind limits;

h) hovering accuracy (altitude and horizontal control accuracies);

i) hovering wind limits;

j) glide distance;

k) winch uncoiling time;

l) winch coiling time;

m) *t*UA folded dimension;

n) *t*UA unfolded dimension.

6.2 Weight limits

The following weight limits of the *t*UAS shall be published in the operator's manual:

a) tethering cable;

b) maximum payload for the maximum operational height;

c) UA maximum take-off weight for the maximum operational height;

d) UA empty weight.

6.3 Electrical characteristics

The following electrical characteristics of the *t*UAS shall be published in the operator's manual:

a) system total rated power;

b) system maximum power;

c) onboard input voltage;

d) onboard input current;

e) onboard emergency power duration for the main power system;

f) onboard emergency power duration for the flight control system;

g) RPS power requirement.

6.4 Environmental characteristics

Environmental conditions that affect the storage, transportation and ground handling of the *t*UAS shall be listed in the operator's manual.

For the *t*UAS, data links and mission equipment shall be designed to withstand a variety of natural and induced conditions under launch, flight and recovery conditions. As a minimum, limitations incurred by the following operating conditions within the specified flight envelope that can affect *t*UAS components shall be addressed in the operator's manual:

a) temperature;

b) atmospheric pressure;

c) humidity;

d) impact;

e) vibration;

f) lightning;

g) rain;

h) icing;

i) mildew;

j) salt spray;

k) sand and dust;

l) sheltered from wind;

m) sound noise level.

NOTE The test methods for humidity, vibration, salt spray are recommended to refer to IEC 60068[2].

6.5 Fatigue endurance and life characteristics

Requirements for fatigue endurance and life characteristics of the *t*UAS shall ensure:

a) the fatigue life of the system meets the requirements given in ISO 21384-2;

b) the fatigue life of tether components is defined in the design document.

6.6 Paintings and markings for *t*UAS safety

The following requirements apply:

a) The tethering cable shall be painted with either a high-visibility pattern or fluorescent colours, or both.

b) The propellers/rotor blades shall be marked with high-visibility colours on the tip.

c) The high-voltage power supplies and transporting sub-systems shall be made highly visible on the outer casing.

6.7 Lighting

The following requirements apply:

a) The *t*UAS shall be equipped with a flashing white or red anti-collision strobe light.

b) The tethering cable shall be equipped with lighting devices if the system is to be operated at night.

6.8 Others

Maintainability, testability, interchangeability, package, storage and transportation, ground support and maintenance shall meet the requirements given in ISO 21384-2.

7 Airborne monitoring system

7.1 System functions

The airborne monitoring system shall:

a) detect conditions that are outside acceptable ranges or other faults;

b) automatically trigger to alarm thresholds (from user or manufacturer pre-sets);

c) send warning information to the remote pilot;

d) store data (logs) in real time;

e) continuously store data for the planned duration of the flight;

f) provide an external log reading interface;

g) communicate flight and route information to the UTM provider, as outlined in the ISO 23629 series, when interaction with other aircraft is predicted;

h) be able to send the following status parameters to the monitoring software at the RPS:

   1) airborne electrical system input and output voltage and current;

   2) propulsion system temperature (if applicable);

   3) battery temperature;

   4) temperature of other internal components of the *t*UAS.

7.2 Monitoring software

The *t*UAS monitoring software shall be able to:

a) manage airborne monitoring system parameters;

b) display the monitoring parameters and protection status given in 7.1;

c) prevent the *t*UA from infringing in airspace with geo-limitations.

7.3 Wireless data transmission module

The wireless data transmission module, if applicable, shall meet the following requirements:

a) The power available for maximum data transmission range shall be greater than the distance between the connecting devices.

b) The data transmission bandwidth shall be sufficient.

c) The module shall have efficient error-detection and error-correction mechanisms.

d) The module shall have electromagnetic compatibility and shall not interfere with other electronic equipment.

e) Delays or latencies and other requirements in the *t*UA control data shall meet ISO 21384-2.

8 Propulsion and electrical system

8.1 Propulsion system

The following operational limitations should be included in the operator's manual to define the overall performance limits of the *t*UAS:

a) current;

b) voltage (normal, high or ultra-high);

c) propulsion system temperature;

d) torque;

e) steering;

f) efficiency;

g) temperature performance;

h) environmental adaptability;

i) electromagnetic compatibility;

j) noise level.

8.2 Electrical system

8.2.1 General

The electrical system consists of two parts: the airborne electrical system and the ground electrical system. The general requirements for the electrical system are as follows:

a) The electrical system shall have protective measures, e.g. over-voltage, over-current, under-voltage, short-circuit, over-temperature protections.

b) The electrical system shall have aviation plugs for all cable connections which meet IEC 61076-1 and IEC 61076-2 requirements.

c) Associated quality assessment requirements for connectors shall refer to IEC 62197-1 and IEC 62197-2.

8.2.2 Airborne electrical system

8.2.2.1 Composition and function

The airborne electrical system includes airborne main power and airborne UPS power.

The main function of the airborne electrical system is to supply power to the propulsion system and airborne equipment, by converting the high-voltage power provided by the ground power or using the airborne UPS power.

8.2.2.2 Airborne main power sub-system

The airborne main power sub-system shall:

a) include DC transformers;

b) either display a warning at the RPS or initiate a self-protection measure, or both, when triggered by conditions that are outside acceptable ranges or other faults.

8.2.2.3 Uninterruptible power supply

The UPS, either onboard the *t*UA or at the RPS, or both, shall have:

a) sufficient emergency power to enable the *t*UA to land at a designated location;

b) an automatic switching time that ensures the attitude and altitude of the *t*UA are not affected;

c) passed the safety test and life test specified in IEC 62133;

d) the product identification on the surface of battery pack;

e) the positive and negative poles clearly marked for easy connection;

e) a battery connector with anti-loose and anti-error functions.

8.2.3 Ground electrical system

The ground electrical system includes generators (optional) and the ground power converter.

The main function of the ground electrical system is to convert the alternating current into high-voltage direct current to supply the power through the tethering cable. The remote voltage compensation shall be considered for power transmission efficiency. The ground electrical system should protect against:

a) over-voltage;

b) over-current;

c) over-load;

d) under-voltage;

e) short circuit;

f) over-temperature.

When the operating conditions trigger the protections, the system should issue a warning message to the RPS or protect itself automatically, or both.

9 Power transportation system

9.1 Tethering cables

The design, manufacture and application processes for the tethering cables, consisting of insulated cables and/or optical fibre cables, shall take account of optical and electrical performance requirements, mechanical properties and environment adaptability.

The tethering cable shall be constructed with multiple layers, including but not limited to the conductor, the insulation and the outer sheath.

The following characteristics shall be specified in the detailed specification for tethering cables, including but not limited to:

a) the cable structure;

b) length;

c) external diameter;

d) linear density;

e) tensile strength;

f) bending radius;

g) operating voltage;

h) breakdown voltage;

i) current rating;

j) direct current resistance;

k) insulation resistance;

l) operating temperature;

m) storage temperature and humidity.

The test of the insulated cable shall be consistent with IEC 60885-1 and IEC 60811. The conductor of the insulated cables shall be consistent with IEC 60228.

The dielectric withstand voltage of the tethering cables shall be no less than 2,5 times the maximum working voltage.

The tensile strength of the tethering cables shall not be less than four times the maximum *t*UA take-off weight or maximum vertical thrust, whichever is greater.

The onboard mooring point should be beneath the *t*UA centre of gravity vertically and the connector shall have a positive locking design.

The safety factor for means of attachment to the *t*UA and the mooring points (both onboard and ground) shall withstand the maximum tensile strength of tethering sub-systems.

The generic specification for the tethering cable connectors shall be consistent with IEC 61076-1. The product details shall follow IEC 61076-2. The associated quality assessment requirements should refer to IEC 62197-1 and IEC 62197-2.

The tethering cables and the associated elements shall meet the environmental adaptability requirements given in 6.4.

If the tether cable also contains optical cables, the following optical performance requirements shall also be considered:

— optical fibre type;

— operating wavelength;

— insertion loss (including the connectors).

The optical fibres should be consistent with IEC 60793-1[2] and IEC 60793-2[3]. The optical fibre cables should be consistent with IEC 60794-1-1[4], IEC 60794-4[5] and IEC 60794-3-20[6].

The optical fibre cables in practical application shall meet the requirements for high-speed data transmission.

9.2 Winches

9.2.1 Characteristics

The following characteristics for winches shall be provided by manufacturers:

a) dimensions;

b) weight;

c) maximum cable storing length;

d) maximum tension maintained through braking;

e) tension range maintained through automatic operations;

f) maximum coiling and uncoiling speeds matching with the descent and climb speeds of the *t*UA.

9.2.2 Environment adaptability, protection and connectors

The environment adaptability, protection and connectors requirements for the winches shall include:

a) lightning protection and grounding device, to ensure the lightning protection ability of the winches;

b) safety warning signs, including but not limited to, high-voltage, lightning protection, grounding and electric shock protection;

c) leakage current meeting the requirements of safe use;

d) the connectors in accordance with IEC 61076-1 and IEC 61076-2, and that the associated quality assessment requirements are in accordance with IEC 62197-1 and IEC 62197-2;

e) good waterproof, vibration-proof, abrasive resistance, anti-UV aging properties in accordance with the environmental adaptability requirements given in 6.4.

9.2.3 Functional elements

The functional elements for winches should include:

a) automatic and manual coiling, and uncoiling;

b) operating condition indication;

c) cable meter counting, display and alarm;

d) transport locking mechanism;

e) automatic braking mechanism when jammed;

f) power transmission and data communication;

g) protecting the bending of the tethered cable from damage;

h) outlet protective design for the cable;

i) isolation strategies for the accessible mechanical transmission parts;

j) transportation protection design.

10 Remote pilot station

The RPS shall meet the requirements given in ISO 21384-2 and include the following functions, at a minimum:

a) ground electrical system switch;

b) automatic winch controls;

c) airborne monitoring system control and its data acquisition and processing;

d) fault alarm;

e) relevant emergency protections.

11 Test verification

11.1 General

A ground test and a flight test should be carried out according to the requirements of different mission purposes, to verify whether the performance of the *t*UAS meets the requirements of the user and Clauses 4 to 8.