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**Luft- und Raumfahrt –
Unbemannte Luftfahrzeugsysteme –
Teil 001: Anforderungen und Prüfverfahren;
Englische Fassung prEN 4709-001:2021**

Aerospace series –
Unmanned Aircraft Systems –
Part 001: Product requirements and verification;
English version prEN 4709-001:2021

Série aérospatiale –
Aéronefs télépilotés –
Partie 001: Exigences produit et méthodes de vérification;
Version anglaise prEN 4709-001:2021

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Gesamtumfang 135 Seiten

DIN-Normenausschuss Luft- und Raumfahrt (NL)

Nationales Vorwort

Der Verband der Europäischen Luft-, Raumfahrt- und Verteidigungsindustrie – Normung (ASD-STAN) ist vom Europäischen Komitee für Normung (CEN) für zuständig erklärt worden, Europäische Normen (EN) für das Gebiet der Luft- und Raumfahrt auszuarbeiten. Durch die Vereinbarung vom 3. Oktober 1986 wurde ASD Assoziierte Organisation (ASB) des CEN.

Das vorliegende Dokument (prEN 4709-001:2021) wurde von ASD-STAN, Fachbereich „Autonomes Fliegen“, unter Mitwirkung deutscher Experten des DIN-Normenausschusses Luft- und Raumfahrt (NL) erarbeitet.

Das zuständige deutsche Normungsgremium ist der Arbeitsausschuss NA 131-01-02 AA „Technische Systeme“ im DIN-Normenausschuss Luft- und Raumfahrt (NL).

Der vorliegende Norm-Entwurf enthält zur technischen Kommentierung einen Europäischen Norm-Entwurf (prEN) ausschließlich in Englischer Fassung aus der parallelen Umfrage von ASD-STAN und CEN.

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Aerospace series - Unmanned Aircraft Systems - Part 001:
Product requirements and verification

Série aéronautique - Aéronefs télépilotes - Partie 001 :
Exigences produit et méthodes de vérification

Luft- und Raumfahrt - Unbemannte
Luftfahrzeugsysteme - Teil 001: Anforderungen und
Prüfverfahren

This draft European Standard is submitted to CEN members for second enquiry. It has been drawn up by the Technical Committee ASD-STAN.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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COMITÉ EUROPÉEN DE NORMALISATION
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CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Contents

Page

European foreword	6
1 Scope.....	7
2 Normative references.....	7
3 Terms and definitions	8
4 Product Requirements and Compliance for Class 0 UAS	14
4.1 MTOM	14
4.1.1 Performance requirements.....	14
4.1.2 Verification method	15
4.1.3 Pass Criteria.....	15
4.2 Maximum Speed	16
4.2.1 Performance requirements.....	16
4.2.2 Verification method	16
4.2.3 Pass criteria	18
4.3 Maximum attainable height	18
4.4 Safely controllable	19
4.4.1 General.....	19
4.4.2 Pass Criteria.....	19
4.5 Minimize injury to people.....	19
4.5.1 Performance and design requirements.....	19
4.5.2 Verification methods	21
4.5.3 Pass criteria	25
4.6 Power	25
4.6.1 Performance and design requirements.....	25
4.6.2 Pass criteria	25
4.7 Follow-me mode.....	25
4.7.1 Performance and design requirements.....	25
4.7.2 Verification methods	25
4.7.3 Pass criteria	29
4.8 Manufacturer's instructions	29
4.8.1 Requirements.....	29
4.8.2 Verification method	29
4.8.3 Pass criteria	33
4.9 Information Notice	33
4.9.1 Design requirements	33
4.9.2 Verification method - Requirement (1) – Information notice	34
4.9.3 Pass criteria	34
5 Product Requirements and Compliance for Class 1 UAS	34
5.1 Ground impact	34
5.1.1 80 Joules	34
5.1.2 MTOM	39
5.2 Maximum speed	39
5.3 Maximum attainable height	39
5.3.1 Performance requirements.....	39

5.3.2	Verification method.....	40
5.3.3	Pass criteria.....	44
5.4	Safely controllable.....	45
5.4.1	General	45
5.4.2	Pass Criteria.....	45
5.5	Mechanical strength	45
5.5.1	Performance and design requirements.....	45
5.5.2	Verification methods.....	47
5.5.3	Pass Criteria.....	56
5.6	Minimize injury to people	56
5.7	Loss of data link.....	56
5.8	Sound power.....	56
5.8.1	General	56
5.8.2	Performance and design requirements.....	57
5.8.3	Verification method	57
5.8.4	Pass Criteria.....	59
5.9	Power	59
5.10	Unique physical serial number.....	59
5.11	Direct Remote Identification	59
5.12	Geo-awareness.....	59
5.13	Airspaces limitation function.....	59
5.14	Battery low level	59
5.15	Lights.....	59
5.16	Follow-me mode.....	59
5.17	Manufacturer's instructions	59
5.17.1	Requirements.....	59
5.17.2	Verification method.....	60
5.17.3	Pass criteria.....	65
5.18	Information notice	66
5.18.1	Design requirements.....	66
5.18.2	Verification method - Requirement (1) - Information notice.....	66
5.18.3	Pass criteria.....	66
6	Product Requirements and Compliance for Class 2 UAS.....	66
6.1	MTOM.....	66
6.1.1	General	66
6.1.2	Pass Criteria.....	66
6.2	Maximum attainable height.....	66
6.3	Safely controllable.....	67
6.3.1	Performance and design requirements.....	67
6.3.2	Verification method.....	69
6.3.3	Pass criteria.....	75
6.4	Mechanical strength	76
6.5	Tethered UA.....	76
6.6	Minimize injury to people	76
6.6.1	General	76
6.6.2	Performance and design requirements.....	76
6.6.3	Verification method - Requirement (6) - Speed limit	76
6.6.4	Pass Criteria.....	77
6.7	Command and Control (C2) link.....	77
6.7.1	Loss of C2 link	77
6.7.2	C2 link protection	80
6.8	Low speed mode.....	81

6.8.1	Performance requirements.....	81
6.8.2	Verification method - Requirement (1) - Low speed mode.....	82
6.8.3	Pass criteria	82
6.9	Sound power.....	82
6.10	Power	82
6.11	Direct Remote Identification	82
6.12	Geoawareness	82
6.13	Airspace limitation function	82
6.14	Battery low level	82
6.14.1	Performance requirements.....	82
6.14.2	Test methods	83
6.14.3	Pass criteria	84
6.15	Lights.....	84
6.16	Manufacturer's instructions	84
6.16.1	Requirements.....	84
6.16.2	Verification method	85
6.16.3	Pass criteria	90
6.17	Information Notice	91
6.17.1	Design requirements.....	91
6.17.2	Verification method - Requirement (1) - Information notice	91
6.17.3	Pass criteria	91
7	Product Requirements and Compliance for Class 3 UAS	91
7.1	MTOM	91
7.1.1	General.....	91
7.1.2	Pass Criteria.....	91
7.2	Maximum characteristic dimension	91
7.2.1	Design requirements	91
7.2.2	Verification methods	92
7.2.3	Pass Criteria.....	94
7.3	Maximum attainable height.....	94
7.4	Safely controllable	94
7.4.1	General.....	94
7.4.2	Pass Criteria.....	94
7.5	Tethered UA.....	95
7.5.1	Performance and design requirements.....	95
7.5.2	Verification methods	97
7.5.3	Pass Criteria.....	101
7.6	Loss of data link - Performance requirements.....	102
7.7	Sound power	102
7.8	Power	102
7.9	Unique physical serial number	102
7.10	Direct Remote Identification	102
7.11	Geoawareness	102
7.12	Airspace limitation function	102
7.13	Data link protection	102
7.14	Battery low level	102
7.15	Lights.....	102
7.16	Manufacturer's instructions	102
7.16.1	Requirements.....	102
7.16.2	Verification method	103
7.16.3	Pass criteria	108
7.17	Information Notice	109

7.17.1	Design requirements.....	109
7.17.2	Verification method - Requirement (1) – Information notice.....	109
7.17.3	Pass criteria.....	109
8	Product Requirements and Compliance for Class 4 UAS.....	109
8.1	MTOM.....	109
8.1.1	General.....	109
8.1.2	Pass Criteria.....	109
8.2	Safely controllable.....	110
8.2.1	Design and performance requirements.....	110
8.2.2	Verification method.....	110
8.2.3	Pass criteria.....	116
8.3	Automatic control modes conditions.....	116
8.3.1	Performance requirements.....	116
8.3.2	Verification method.....	116
8.3.3	Pass criteria.....	117
8.3.4	Test methods.....	118
8.4	Manufacturer's instructions.....	120
8.4.1	Requirements.....	120
8.4.2	Verification method.....	120
8.4.3	Pass criteria.....	125
8.5	Information Notice.....	126
8.5.1	Design requirements.....	126
8.5.2	Verification method - Requirement (1) – Information notice.....	126
8.5.3	Pass criteria.....	126
Annex A	(informative) Recommendations for the design to reduce the probability and effects of laceration by propellers.....	127
A.1	Mechanical Safeguards.....	127
A.2	Operational safeguards.....	127
A.2.1	Mechanical Shock Detection.....	127
A.2.2	Emergency Stop.....	127
Annex B	(informative) Verification method for distinguishing UA with different class marks.....	129
Annex ZA	(informative) Relationship between this document and the essential requirements of Delegated regulation (EU) 2019/945 of 12th March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems aimed to be covered.....	130
Bibliography		133

European foreword

This document (prEN 4709-001:2021) has been prepared by the Aerospace and Defence Industries Association of Europe — Standardization (ASD-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this document has received the approval of the National Associations and the Official Services of the member countries of ASD-STAN, prior to its presentation to CEN.

This document is currently submitted to the second Enquiry.

This document was originally reviewed by the Domain Technical Coordinator of ASD-STAN's Autonomous flying Domain.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

1 Scope

This document provides technical specification and verification method to support compliance with Commission Delegated Regulation (EU) 2019/945 of 12 March 2019 on unmanned aircraft systems and on third-country operators of unmanned aircraft systems.

This includes compliance with product requirements for all UAS authorized to operate in the ‘open’ category (class C0, C1, C2, C3 and C4 UAS).

This document does not cover “Specific” or “Certified” categories of UAS as well not UAS lighter than air (e.g. airships and balloons).

Compliance with this document assists in complying with CE marking technical requirements.

This document is only applicable for UA with energy sources based on electro-chemical technologies.

Additional hazards that occur from the characteristics of the payload are excluded and are under the responsibility of the manufacturer and operator.

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.

EN 71-1:2014+A1:2018, *Safety of toys - Part 1: Mechanical and physical properties*

prEN 4709-002:2020, *Aerospace series — Unmanned Aircraft Systems — Part 002: Direct Remote Identification*

prEN 4709-003:2020, *Aerospace series — Unmanned Aircraft Systems — Part 003: Geo-awareness requirements*

prEN 4709-004:2020, *Aerospace series — Unmanned Aircraft Systems — Part 004: Lighting requirements*

EN IEC 62368-1:2020, *Audio/video, information and communication technology equipment - Part 1: Safety requirements*

EN ISO 2307:2019, *Fibre ropes - Determination of certain physical and mechanical properties (ISO 2307:2019)*

EN ISO 3744:2010, *Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering methods for an essentially free field over a reflecting plane (ISO 3744:2010)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

- ISO Online browsing platform: available at <http://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

automatic flight

flight following pre-programmed instructions, loaded in the unmanned aircraft (UA) flight control system that the UA executes

3.2

open category

category of UAS operation that, considering the risks involved, does not require a prior authorisation by the competent authority nor a declaration by the UAS operator before the operation takes place

3.3

specific category

category of UAS operation that, considering the risks involved, requires an authorization by the competent authority before the operation takes place and takes into account the mitigation measures identified in an operational risk assessment, except for certain standard scenarios where a declaration by the operator is sufficient

3.4

certified category

category of UAS operation that, considering the risks involved, requires the certification of the UA, a licensed remote pilot and an operator approved by the competent authority, in order to ensure an appropriate level of safety

3.5

competent authority

authority responsible for the certification, authorization and oversight of UAS air operations in the Member State where the UAS operator has its principal place of business or place of residence

3.6

direct remote electronic identification

function for broadcasting the identity of the UA so that it can be directly received by existing mobile devices within the broadcasting range

3.7

follow-me mode

means a mode of operation of a UAS where the unmanned aircraft constantly follows the remote pilot within a predetermined radius

3.8

geo-awareness

means a function that, based on the data provided by Member States, detects a potential breach of airspace limitations and alerts the remote pilots so that they can take immediate and effective action to prevent that breach

3.9

hazard

condition or an object with the potential to cause injuries, damage, loss of material or a reduction of the ability to perform a prescribed function

3.10

Maximum Take-Off Mass

MTOM

maximum take-off mass of the UA in the heaviest combination with accessories, payloads and batteries, as defined by the manufacturer when placing the product on the market, at which the UA can be safely operated

Note 1 to entry: As opposed to classical manned aircraft, small unmanned aircraft can have removable or adaptable items that are neither the payload nor the batteries, but are considered as part of the UA itself. When applying the MTOM definition to the UA, the term UA is to be understood as including all accessories that are neither payloads nor batteries but that relate directly to the UA and can be attached to it.

3.11

unmanned aircraft system operator

legal or natural person who operates or intends to operate one or more UAS

3.12

remote pilot

natural person responsible for safely conducting the flight of a UA by operating its flight controls, either manually or, when the UA flies automatically, by monitoring its course and remaining able to intervene and change its course at any time

3.13

return home

fail safe function that upon loss of data link will direct the UA back to predefined home position

3.14

standard scenario

description of a type of operation included in a certification specification issued by EASA, for which a specific operations risk assessment (SORA) has been conducted

3.15

Unmanned Aircraft

UA

aircraft operating or designed to operate autonomously or to be piloted remotely without a pilot on board

3.16

Unmanned Aircraft System

UAS

unmanned aircraft and its associated elements which are operated with no pilot on board

Note 1 to entry: ISO/CD 21384-2.

3.17

Visual Line Of Sight

VLOS

type of operation in which the remote pilot maintains continuous unobstructed and unaided visual contact with the UA, allowing the remote pilot to monitor the flight path of the UA in relation to other aircraft, persons, and obstacles, for the purpose of maintaining separation from them and avoiding collisions

3.18

equipment to control unmanned aircraft remotely

instrument, equipment, mechanism, apparatus, appurtenance, software or accessory that is necessary for the safe operation of a UA, other than a part, and which is not carried on board that UA

3.19

payload

means instrument, mechanism, equipment, part, apparatus, appurtenance, or accessory, including communications equipment, that is installed in or attached to the aircraft and is not used or intended to be used in operating or controlling an aircraft in flight, and is not part of an airframe, engine, or propeller

3.20

configuration

basic design arrangement of the UA: fixed-wing, rotary wing or multicopter

3.21

list of items

list provided with the description of the UA in the technical documentation that identifies the UA and all removable and adaptable items that can be attached to the main structure of the UA and are provided in any packaging configurations in which the UAS is placed on the market

Note 1 to entry: The list includes all payloads and batteries but not spare parts. The list identifies the items by part number and mass.

3.22

non-configurable UA

UA with a single combination that cannot be combined with other *payloads* (if any) or removable batteries (if removable)

Note 1 to entry: A non-configurable UA is the UA itself and its list of items contains only the UA.

3.23

primary structural elements

primary structural elements are those parts of the structure of the UA the failure of which would lead to a hazardous or more serious failure condition, e.g. primary UA structure bearing aerodynamic, inertial and propulsion forces; control surface and control system structural elements, control surface hinges; structural elements of systems used in launching and recovery phases ([8])

3.24 tether

a tether in the sense of this standard is a mechanical device for the purpose of effectively restraining the UA within the range permitted by the length of the tether as its primary function

Note 1 to entry: A tether in the sense of this standard is not any cable linking the UA to the ground e.g. an electric cable powering the UA, even if it was the only source of power and a loss of connection would inevitably lead to a loss of flight. However, the tether may be used to transmit electrical power to the UA as a secondary function.

3.25 mode of control

mode of control is used to distinguish between different methods of exercising control over the direction of flight of the UA

Note 1 to entry: This includes but is not limited to attitude, heading, track, speed, altitude, rate of climb. All flight modes are clearly defined in the flight manual explaining how pilot input (e.g. sticks) are associated to air vehicle degrees of freedom. Necessary conditions for each flight mode is also defined (e.g. GPS coverage is necessary for ground velocity or position control mode)

3.26 control operational modes

the UA can be operated in the following operational modes, according to STANAG4703 UL47.1 definition here rephrased. The expression “control operational modes” is used to address safety relevant control categories

Note 1 to entry: Several flight control modes can be used for each category

3.27 automatic mode

control operational mode where UA attitude, speed and flight path are fully controlled by the flight control system

Note 1 to entry: No pilot input is needed to address flight controls and vehicle steering, other than to change the operational mode, load or modify the required flight plan or waypoint parameters. Examples of automatic modes are waypoint path navigation, waypoint holding (hovering/loitering), automatic take-off, automatic landing, follow-me mode, return to home, etc.

3.28 semi-automatic mode

control operational mode where the remote pilot commands outer loop parameters such as altitude, heading and air speed

Note 1 to entry: The flight control system operates the UA controls to achieve the commanded outer loop parameter value. Envelope flight protection and/or control decoupling functions should be in place in this control operational mode. The flight manual clearly specifies, for any possible/available control mode that is classified as semi-automatic, for each degree of freedom, the level of involvement of the pilot to address control stability.

Note 2 to entry: A wide range of flight control modes are semi-automatic, from low level attitude/rate control, autopilot heading/speed/altitude control, velocity control; position control may be considered semi-automatic if pilot input is transformed into position commands continuously (or an automatic mode if pilot inputs only modify waypoint coordinates in on-board autopilot)

3.29

manual direct piloting mode

control operational mode where the remote pilot directly commands UA controls (e.g., aerodynamic surfaces through servo-actuators and engine through electronic speed control)

Note 1 to entry: This control operational mode does not benefit from autopilot aiding action (e.g. flight envelope protection FEP) in excess of stability augmentation.

3.30

manual mode

refers to all Control operational modes where the pilot is using manipulators or similar inceptors to change the trajectory of flight in real-time, such as in manual direct piloting mode and semi-automatic mode, as opposed to automatic mode where high level commands (such as setting waypoints or actuating an RTH button) are used to change the trajectory

3.31

automated mode

refers to Automatic mode and Semi-automatic mode (as opposed to Manual direct piloting mode) which depend on automation in excess of stability augmentation to control the trajectory of flight

3.32

holding

hovering for hovering capable aircraft, i.e., maintaining altitude and position; for fixed wing aircraft holding corresponds to loitering, i.e., flying a minimum distance orbit around current position, at low speed and holding altitude

Note 1 to entry: holding is used to address a flight condition where aircraft minimizes risks of flight path deviation (to reduce the risk of collisions) and loss of control.

Note 2 to entry: Besides the general minimum speed and minimum displacement requirement, radius/turn rate/bank angle/load factor and speed are specifically selected for each aircraft in order to provide a safe and stable flight condition (e.g. proper margins with respect to stall speed and load factors)

3.33

link loss control mode

control mode that the UA reverts to in the event of a C2 link loss. Typical link loss control modes are:

- holding
- return to home (RTH)
- automatic landing

3.34

return to home

automatic mode intended for returning to a pre-defined, safe landing position (“home”) such as the take-off position; does not necessarily entail commence to land; typically includes climb or descent to a safe height, following a predefined route, approaching the landing position

3.35

automatic landing,

automatic mode where the UA attempts an automatic landing or an emergency landing at the current position

3.36

safely controllable

general ability of the remote pilot to exercise control over the UA at any time to change the position of the UA as far as required to avoid hazards to other persons using the airspace and persons on the ground

Note 1 to entry: As long as the UA is controlled manually (see manual mode) this includes manoeuvrability and handling qualities, unless functions are automated (see automated mode)

3.37

nominal mode

nominal mode is the basic modes of operation encountered in normal operation in the absence of any loss of features, functions or capabilities, or degradation of performance

3.38

degraded mode

degraded mode is any temporary, persistent, or permanent reduction in features, functions, and capabilities, including the ability to cope with adverse environmental conditions outside of the limitations of the service envelope defined by the manufacturer likely to occur when operating close to or at those limitations

Note 1 to entry: such limitations are (but not limited to): GNSS reception due to satellite constellation, ionospheric disturbances, jamming, etc.; magnetic deviation and disturbance affecting the compass (magnetometer); data link quality, in terms of latency, bandwidth, availability and integrity.

Note 2 to entry: Failures of one or, if applicable, more systems relevant for stability, controllability and pilot workload, such as (if required) accelerometers, gyroscopes, airspeed sensors, engine speed sensors, electrical power supply systems (batteries), power distribution systems (harnesses, connectors, voltage converters, fuses, etc.), and systems relevant for health monitoring such as internal temperatures and battery status, that are likely to occur during the life of the product are taken into account.

Note 3 to entry: If the number of possible combinations of failure condition can be represented by a smaller number of failure effects, then the manufacturer provides an FMEA showing that the failure effects subject to test are representing the failure conditions likely to occur during the life of the product. Failure of systems relevant for health monitoring without impact on stability and controllability, or pilot workload, may not be considered.

3.39

level flight

quasi-stationary flight condition with straight path, no bank angle nor turn rate

Note 1 to entry: Remark that straight path is also applicable in steady wind condition (constant speed and direction) because wind drift only affects a difference between airspeed and groundspeed with course over ground being different about vehicle heading

3.40

low-level battery warning

alert that indicates a critical status of the battery of the UA or its equipment to control the UA remotely that requires immediate landing of the UA

Note 1 to entry: Under the precondition of ensuring flight safety, UA manufacturer normally will define a minimum safety energy threshold e.g. 10 % on top of the critical status of the battery and may initiate pre-warnings of the low-level battery warning to the remote pilot. Such kind of pre-warnings are optional and not part of the defined low-level battery warning required by EN 4709-001.

3.41

mitigated failures

most designs are normally not able to provide a mitigation for certain kinds of single or multiple failures, such as a quadcopter configuration is unable to mitigate the failure of a single motor or propeller, a fixed wing configuration is unable to mitigate the failure of the wing structure, a lighter-than-air aircraft is unable to mitigate a breach of the hull, etc

Note 1 to entry: The consequences of failures modes that cannot be mitigated by design would be considered as escalation of failure effects.

Note 2 to entry: For these cases, the manufacturer may substantiate by testing supported by analysis that the likelihood of such failures during the expected life of the product is remote, or that such failures can be detected and prevented by regular inspections, maintenance, and replacement of parts. In the latter case the manufacturer may provide instructions

3.42

pusher propeller

arrangement in which the propeller or the airscrew is behind the engine, and it pushes the airplane rather than pulling it

Note 1 to entry: the advantage of this arrangement is that the absence of an engine nacelle forward of the wing permits unrestricted airflow over the wing. The opposite version is a tractor propeller

4 Product Requirements and Compliance for Class 0 UAS

4.1 MTOM

4.1.1 Performance requirements

- (1) The MTOM declared in the manufacturer's instructions shall be less than the maximum allowed mass for the corresponding class.
- (2) The maximum mass of the UA used to demonstrate compliance to a requirement in the technical documentation shall not exceed the MTOM declared.
- (3) The mass of any combination of the UA with payloads and batteries made available on the market together with the UAS shall not exceed the MTOM declared in the manufacturer's instructions.
- (4) If the manufacturer's instructions define the maximum mass of accessories, payloads and batteries that can be fitted to the UA, then this mass shall be compatible with the MTOM declared in the manufacturer's instructions.
- (5) The manufacturer's instructions shall include either
 - a. a statement clearly forbidding to fit any accessory or payload; or
 - b. a warning clearly reminding the Remote pilot of his/her responsibility to verify that the mass of the UA shall not exceed the MTOM declared in the manufacturer's instructions whenever it is fitted with an accessory or a payload not included in the original packaging of the UA.

4.1.2 Verification method

4.1.2.1 Requirement (1) – MTOM declared

- Identify the MTOM declared in the manufacturer's instruction.

4.1.2.2 Requirement (2) – MTOM in technical documentation

- Review the technical documentation and identify all the occurrences where the maximum mass of the UA shall be used to demonstrate compliance to a requirement.

4.1.2.3 Requirement (3) – Weighing procedure

- Review the technical documentation and identify the declared masses within the list of items.
- Determine the masses of all items in the list of items according to the weighing procedure described below.
- Determine the mass of the heaviest combination of the UA and its items in the list of items.

Weighing procedure:

1. Weigh the item
2. Record the mass

The weighing device should meet at least the requirements for an EN 45501:2015 class III high accuracy device. The accuracy shall be verified and proof of accuracy shall be provided in the technical documentation.

4.1.2.4 Requirement (4) – manufacturer statement or warning

Determine by review of the manufacturer's instructions that either:

- a. a statement is provided clearly forbidding to fit any accessory or payload not included in the original packaging of the UA; or
- b. a warning is included clearly reminding the Remote pilot of his/her responsibility to verify that the mass of the UA shall not exceed the MTOM declared in the manufacturer's instructions whenever it is fitted with an accessory, payload or battery not included in the original packaging of the UA.

4.1.3 Pass Criteria

- (1) The MTOM declared in the manufacturer's instruction is less than 250 g.
- (2) The maximum UA mass used to demonstrate compliance in the technical documentation to requirements is less or equal to the MTOM declared by the manufacturer's instructions.
- (3) The mass of the heaviest combination of the UA is not exceeding the MTOM declared with a $\pm 3\%$ margin
- (4) Compliance with manufacturer statement or warning requirement.

4.2 Maximum Speed

4.2.1 Performance requirements

- (1) The manufacturer shall declare the maximum speed in the manufacturer's instructions.
- (2) The declared maximum speed shall not exceed 19 m/s.
- (3) The maximum speed of the UA shall not exceed the declared maximum speed
 - a. for hover-capable UA, as ground speed in horizontal flight in all directions;
 - b. otherwise, as airspeed in horizontal straight and level flight.

4.2.2 Verification method

4.2.2.1 Requirement (2) - Maximum speed

4.2.2.1.1 General

- Determine the maximum speed of the UA by any of the tests described below.
- Repeat the selected test 3 times and consider the maximum value as the maximum speed.
- Verify that the maximum speed was determined in all possible flight modes, including follow-me mode, and in any possible direction of flight.

At the beginning of the tests the UA needs to be fully charged and configured for maximum speed.

Flight stabilization options will be set to default according to manufacturer's instructions.

Before the start of the test fly the UA to a stable hover for multirotor UA or loiter for fixed-wing UA in a height suitable for the selected test setup.

4.2.2.1.2 Array Fly-by

The measurement relies on calibrated devices to measure speed, e.g. speed radars, laser speed meter.

It is necessary to install within the test area at least two devices to measure speed at 20 meters from each other.

The pilot will progressively increase demanded speed to the maximum speed.

The UA will pass in front of the three speed devices taking care to keep a trajectory parallel to the line linking the speed devices.

If the speed measured from the devices is progressive and showing that the speed during the pass by was increasing, then repeat the test from a larger distance until the speed measured is within $\pm 0,5$ m/s.

Repeat the test for the adjusted distance 3 times.

Record the maximum value of the speed as maximum speed.



Figure 1 — Array Fly-by field test setup (top view with 3 devices)

4.2.2.1.3 Frame Count

Define a centerline of length D of 30 m to 90 m and setup four landmarks, A, A', and B, B', marking the vertices of a path of length D and width $W = D/10 \pm 10\%$ along the centreline (Figure 3). Measure the distance D between the landmarks A and B with an accuracy of 2 %.

Setup 2 video cameras with a frame rate of not less than 25 frames per second (FPS) and recording with a time stamp of a resolution of not less than 1 second. Ensure that both cameras are set to the same date and time with an accuracy of ± 1 minute.

Place Camera 1 on a line perpendicular to the centerline between both landmarks A and B such that all landmarks, as well as the area 5 m above the centerline, in which the UA is supposed to pass by, are in the field-of-view (FOV) of the camera (Figure 3).

Place Camera 2 on the extension of the centerline such that all landmarks and the area 5m above at landmark B are in the FOV (Figure 3).

1. Start recording on both cameras. The cameras do not need to be started at the same time.
2. The pilot will progressively increase demanded speed to the maximum speed such as to pass over the centreline from between A and A' to B and B' at 5m height above ground.
3. Retrieve the videos from both cameras.

From Camera 2:

- Note the date and time of the recording.
- Verify that the UA did not deviate from the path marked by the landmarks.

From Camera 1:

- Verify that the recording is taken at the same date and time.
- Determine the number of frames per second FPS recorded by the camera by counting the frames in any 1 second interval in the recording.
- Determine the number N of frames that it took the UA to pass between the landmarks.
- Calculate the maximum speed of the UA:

$$V_{max} = \frac{D \cdot FPS}{N}$$

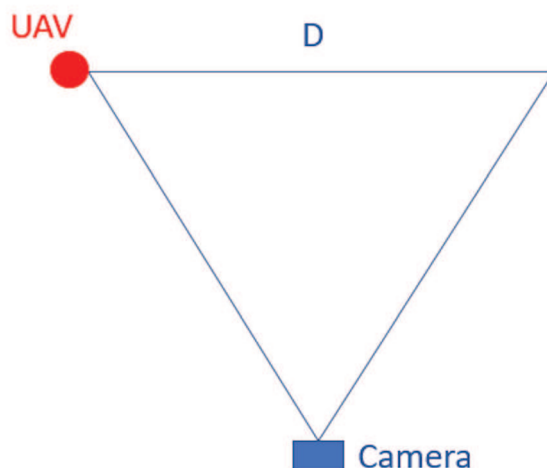


Figure 2 — Frame Count field test setup (top view)

EXAMPLE Distance $D = 90\text{ m}$ covered in 5 seconds with 150 frames, $\text{FPS} = 30$, $N = 150$:

$$V_{\max} = \frac{D \cdot \text{FPS}}{N} = \frac{90\text{ m} \cdot 30\text{ s}^{-1}}{150} = 18\text{ m s}^{-1}$$

4.2.2.1.4 Wind tunnel

Wind tunnel testing is a possible alternative test if the following conditions are met:

- The UA is hover capable.
- Maximum declared airspeed of UA is less than 19 m/s (check flight manual).
- Maximum allowed wind speed is far less than 19 m/s (check flight manual).
 1. Perform wind tunnel tests with hovering UA at increasing airspeed.
 2. Record the maximum speed up until which the UA was able to maintain its position.

4.2.3 Pass criteria

- (1) Verify by review of the manufacturer's instructions that the maximum speed is declared.
- (2) Verify that the declared maximum speed does not exceed 19 m/s.
- (3) Verify that the measured speed does not exceed the declared maximum.

4.3 Maximum attainable height

To show compliance with this requirement manufacturers of UA shall apply 5.3.1, requirement (1), the associated verification method in 5.3.2.1, and pass criteria given in 5.3.3 (1).

NOTE All subclauses referring to selectable height are irrelevant for this subclause.

4.4 Safely controllable

4.4.1 General

To show compliance with this requirement manufacturers of UA shall apply the requirements and verification methodology given in 6.3.1 and 6.3.2.

4.4.2 Pass Criteria

The pass criteria (1) to (7) given in 6.3.3 apply. Instead of (8) given in 6.3.3, the following pass criterion applies:

(8) Compliance with handling quality requirement. Verify that operations:

- a. in nominal automatic mode have an HQR of 3.
- b. in nominal semi-automatic mode have an HQR of at least 3.
- c. in nominal manual direct piloting mode have an HQR at least 3.
- d. in any degraded or mitigated single failure case in any mode have an HQR of at least 2.

4.5 Minimize injury to people

4.5.1 Performance and design requirements

4.5.1.1 Introduction

The injuries considered are those induced on third parties by laceration by sharp edges or corners or by the crash of the UA.

In this section the term “sharp edge” will be used for “sharp edge and corner with a pathway for exposure”.

The definitions for sharpness of edges as defined in EN 71-1:2014+A1:2018, 4.7 (edges), along with A.8, and 8.11 (sharpness of edges), applies. Similarly, the definition of sharp points as defined in EN 71-1:2014+A1:2018, 4.8 (points and metallic wires), along with A.9, and 8.12 (sharpness of points) shall be used.

Leading and trailing edges of propellers are unavoidable for the intended function and shall be considered as sharp functional edges in the sense of EN 71-1:2014+A1:2018, 4.7d, and the potential danger shall be drawn to the attention of the user.

4.5.1.2 Sharp edges on parts other than propellers

- (1) There shall be no sharp edges and points with a pathway for exposure on parts of the UA other than the propellers in any flight configuration taking into account all accessories and payloads placed on the market together with the UAS.

4.5.1.3 Propellers

- (2) Propellers shall be designed without sharp corners and sharp points, in particular at the propeller tip, which could cause injury by puncture and laceration when the propeller is at stand-still, as well as by laceration when spinning, by possibly repetitive contact with the tip or by contact with the leading edge. Propeller blades shall not be made from metal. To this end:

- a. an asymmetrical propeller shall not have a leading-edge radius $R_{\text{leading-edge}}$ of less than 1 mm (Figure 3, left);

- b. a rounded propeller tip shall not have a radius R_{tip} of less than 1 mm (Figure 3, middle);
- c. a square propeller tip shall have a tip chord c_{tip} of more than 2 mm or $\frac{c_{tip}}{c_{max}} > 30\%$ of the maximum blade chord c_{max} whichever is larger (Figure 3, right);
- d. foldable propellers of any tip shape other than having protrusions in the direction of rotation shall be designed to fold back in the event of a contact;

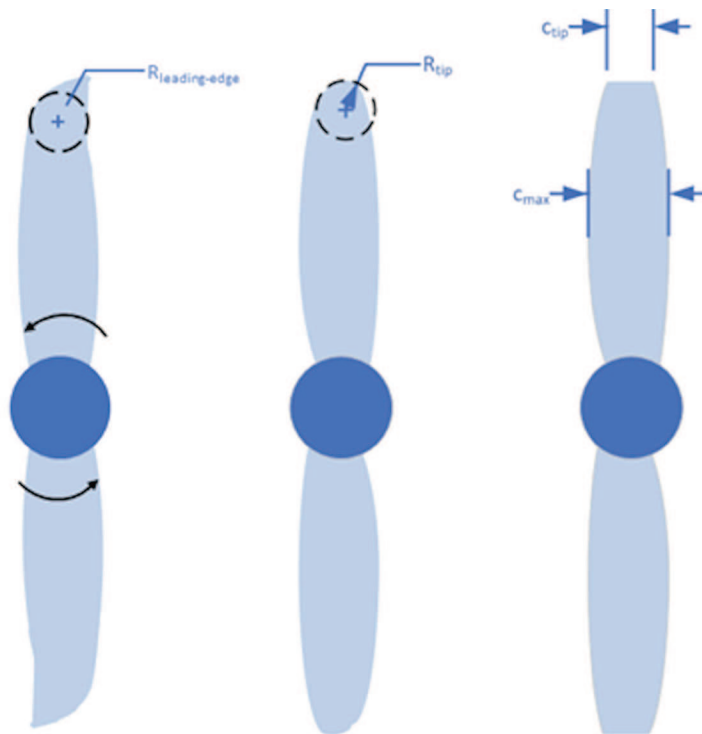


Figure 3 — Propeller geometry

- e. for fixed-wing UA only, the propeller shall be located at the rear to protect third parties from laceration by the crash of the UA (pusher propeller design).



Figure 4 — FW pusher propeller design

4.5.1.4 Crashworthiness

- (3) Any damage to the UA during operation including possible crash shall not lead to a fire or explosion.

4.5.2 Verification methods

4.5.2.1 Requirement (1) - Sharp edges on parts other than propellers

- Describe precisely in the technical documentation all configurations of the UA in flight mode taking into account all accessories and payloads placed on the market together with the UAS (removable safeguards should be taken into account if they present potential sharp edges/points).
- Identify all possible sharp edges and points and demonstrate that they are not sharp or not with a pathway for exposure. To this end, the following applies:
 - o the definitions for sharpness of edges provided in EN 71-1:2014+A1:2018, 4.7 (edges) along with A.8, and 8.11 (sharpness of edges)
 - o the definition of sharp points as defined in EN 71-1:2014+A1:2018, 4.8 (points and metallic wires), along with A.9, and 8.12 (sharpness of points)
 - o the demonstration that sharp edges or points are not in the pathway for exposure shall be based on EN 71-1:2014+A1:2018, 8.10)

4.5.2.2 Requirement (2) – Propeller Geometry – Design of Propeller Tip

4.5.2.2.1 General

- Compliance of the propeller design is verified by review of documentation (manufacturing drawings)

Alternatively:

- Verify that when the UA is operated, spinning propellers in the event of a crash do not create an injury using the test or the analysis described below.

4.5.2.2.2 Impact test method

4.5.2.2.2.1 General

The purpose of this test is to observe the propeller and cage interaction during dynamic impacts to determine if the structure or the propellers pose a cutting hazard during impacts.

The test is designed to represent the UA's maximum horizontal velocity with maximum take-off mass MTOM taking into account the implemented safeguards as specified in the manufacturer's instructions.

High speed cameras recording at 960 frames-per-second should be positioned to capture a top-down and side view of the impacts.

The impact block shall be made of 30 g/L EPP to see if the propeller impacts are capable of cutting the surface.

Verify that the impact block does not show cuts from the propellers.

4.5.2.2.2.2 Linear impact test method for fixed wing UA

This test may be conducted as a flight test.

Linear impact tests shall be conducted with the UA oriented at angle of attack/test about the centre of gravity between the forward axis of the UA and the direction of travel determined based on manufacturer assessment of the most probable angle in case of crash. For the purpose of this test the forward axis of the UA should be aligned with the axis of rotation of the propeller.

If mounted on a sledge or dolly the UA shall be fixed in such a way that it may break away from the fixture in upwards direction. Alternatively, it may break away from the rail together with the sledge or dolly provided the assembled mass of UA and sledge or dolly have a mass equal to the MTOM.

This test shall be completed 2 times.

4.5.2.2.2.3 Linear impact test method for hovercapable UA

This test may be conducted as a flight test.

This test shall be completed 1 time in each of the 4 orientations (front, back, left and right).

The Yaw axis of the UA shall be chosen by the manufacturer to impact the target with the propellers of front UA arms. Propellers should be the first UA zone contact with the impact block.

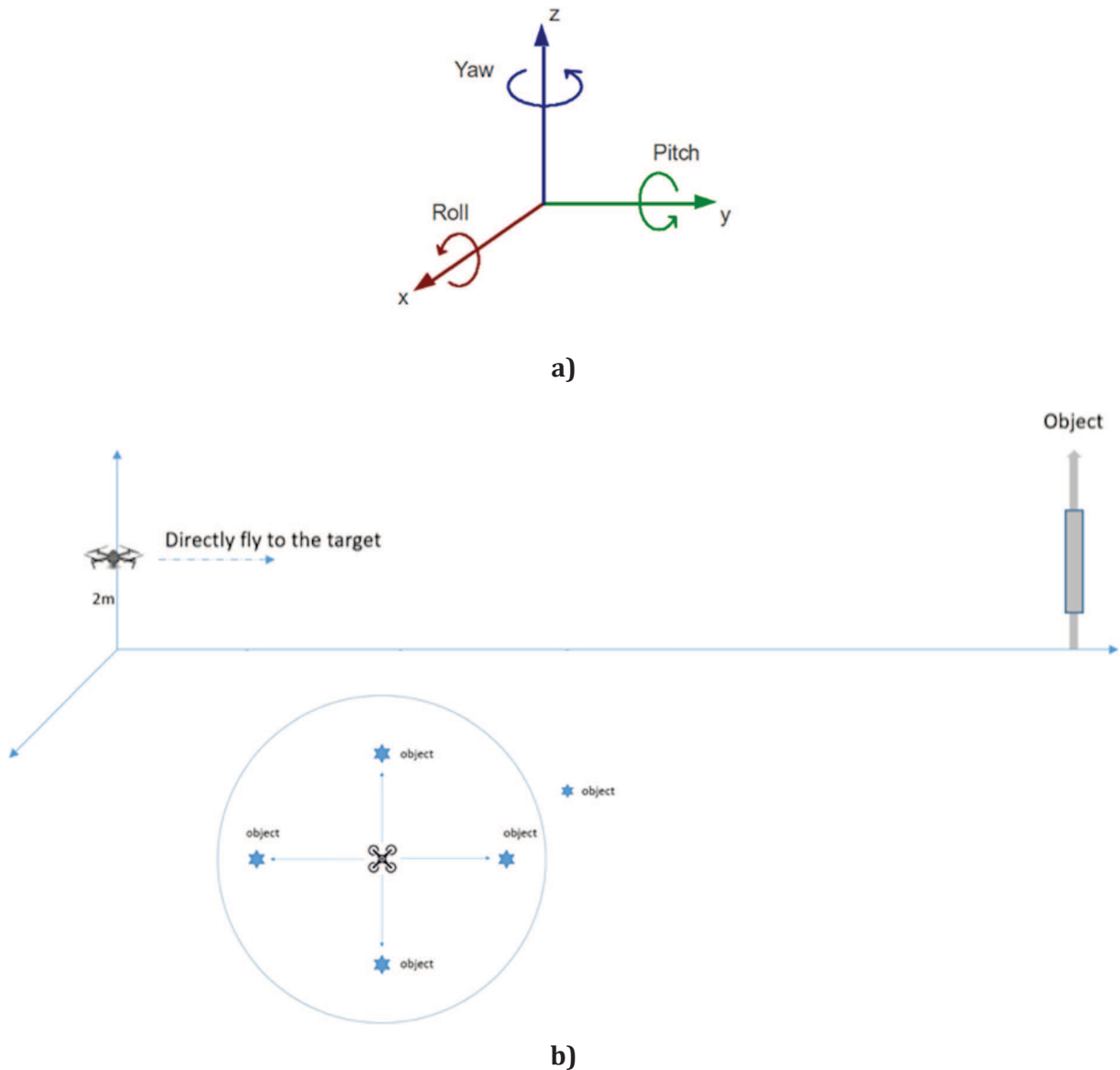


Figure 5 — Impact test setup for Multicopter UA

4.5.2.2.3 Analytical method - Injury index based on fans

- Determine the category of mechanical energy source according to EN IEC 62368-1:2020, Clause 8.
- This method is for plastic fan blades only.
- The injury index as calculated lower shall be equal or lower than 1:

$$\text{Injury index} = N/44\,000 + K/7\,200$$

With:

- N is the rotation speed of the propeller set in round per minutes
- K is a rotation energy factor calculated as $K = 6,10^{-7} \cdot m \cdot r^2 \cdot N^2$. The calculation of the K factor should take into account the design of the propeller:
- m is the mass (kg) of the moving part of the fan assembly (blade, shaft and rotor)
- for foldable propellers: m is the mass in kg of one single blade
 - o r is the radius in mm between the axis of rotation and the tip of the propeller blade, which could be referenced to technical documents of manufacturer.
 - o N is the rotation speed of the propeller set in round per minutes, referring to N_{max} (see paragraph 5.5.1.1)

NOTE This method is more conservative than the other methods outlined above.

4.5.2.3 Requirement (3) - Crashworthiness

- Verify the absence of explosion or fire in case of a UA crash according to the procedure below.

The test shall be performed according to EN IEC 62368-1:2020, 4.8.4.4, M.4.4, along with T.7, with the drop the height given below. The test may be combined with other drop tests.

The drop height shall be sufficient to ensure that the UA reaches its terminal velocity as per 5.1.1.2.1.1, or 19 m/s, whichever is less.

Without analysis, a drop height of 20 m is acceptable¹⁾. When the UA reaches its terminal velocity, which may be less than 19 m/s, from a height of less than 20m, then the lesser height will be sufficient.

The crash test shall be conducted with the maximum mass achievable with the maximum amount of batteries installed. This mass may be below MTOM.

The drop condition shall be representative for all possible abnormal conditions that may occur during use. If more than one drop condition is possible then the most critical shall be selected. If the results are inconclusive or cannot be combined in a single test case, then individual crash tests for each test case shall be conducted. It is acceptable to use a special firmware to perform the crash test.

The test specimen does not need to be newly manufactured and may be repaired provided the repair was conducted according to repair instructions provided by the manufacturer. A UA or a battery that was already subject to test required by 4.5.2.2.2, 4.5.2.2.1.1, 4.5.2.2.1.2 or 4.5.2.3, or drop tests as per EN IEC 62368-1:2020, shall not be re-used for the crash test.

The configuration of the test specimen including the firmware identification shall be recorded.

It is recommended to use high speed cameras recording at least at 60 frames-per-second positioned to capture a side view of the impact.

The batteries shall be fully charged. The test shall be conducted immediately after removal of the batteries from their charger unless the manufacturer has specified a minimum time interval between end of charging and commission to flight.

The UA shall be flown to the drop position on its own power. The drop test shall be initiated within 10 seconds upon arrival at the designated drop position.

¹⁾ Without consideration of aerodynamic drag the potential energy at the drop height equals the kinetic energy at ground impact, hence $h = V^2/2g \sim 20$ m.

4.5.3 Pass criteria

- (1) No sharp edge/point with a pathway for exposure exists for the UA in any flight configuration taking into account all accessories and payloads with which it is placed on the market.
- (2) Propeller design complies with the design requirements for propeller tips. or alternatively it is shown by test or analysis that the spinning propellers in the event of a crash do not create an injury.
- (3) No explosion or fire occurred during crashworthiness test.

4.6 Power

4.6.1 Performance and design requirements

- (1) The UA shall be powered by electricity without using fossil energy sources onboard.

4.6.2 Pass criteria

- (1) Verify by design inspection of the UA that the UA is powered by electricity only.

4.7 Follow-me mode

4.7.1 Performance and design requirements

- (1) The UA shall follow the remote pilot in a distance not exceeding 50 m or stop to follow and maintained its last position.
- (2) In excess of a distance of 50 m between UA and remote pilot the UA shall stop and maintain its last position.
- (3) In excess of a distance of 50 m between UA and remote pilot the UA shall not resume follow-me mode.
- (4) The remote pilot shall be able to regain control of the UA.

4.7.2 Verification methods

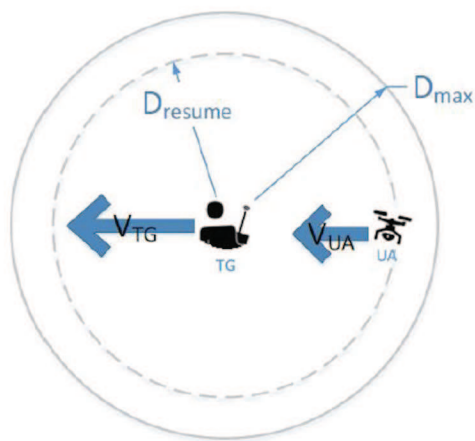
4.7.2.1 Introduction

The UA system shall be set up in such a way that the pilot can easily accelerate to and maintain a velocity V_{TG} in excess of the maximum ground speed of the UA as specified by the manufacturer for follow-me mode $V_{UA,max}$ by 10 km/h.

The test shall be conducted on a road or similarly paved way without obstacles obstructing radio transmission and line of sight, that allows to safely accelerate to and maintain a velocity specified by the manufacturer for follow-me mode plus 10 km/h – typically 80 km/h – for more than 0,5 minutes. Suitability shall be evaluated before committing to test.

Use of a trombone or circular shaped racetrack is recommended (Figure 7). If using a circular shaped racetrack, the diameter should be in excess of $3 \times D_{max}$.

The test shall be recorded on video. The distance between UA and pilot shall be determined by post-processing the positions of UA and pilot from the log files.



UA	Unmanned aircraft
TG	Pilot ("target")
D_{max}	maximum distance between UA and target to stop follow-me mode, not to exceed 50 m
D_{resume}	maximum distance between UA and target to resume follow-me mode
V_{TG}	ground speed of target
V_{UA}	ground speed of UA $\leq V_{UA,max}$
$V_{UA,max}$	maximum ground speed of the UA in follow-me mode, not to exceed 19 m/s

Figure 6 — Definitions

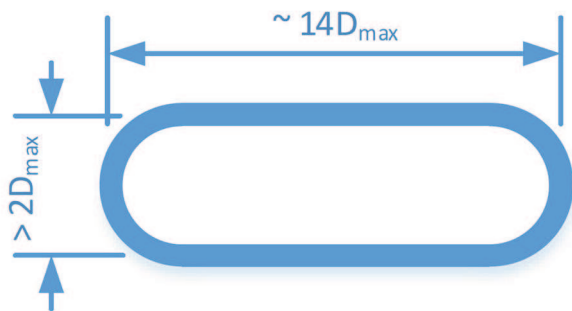


Figure 7 — Trombone-shaped racetrack

NOTE Values given in rounded brackets { } are provided as guidance under the assumption $V_{UA,max} = 19$ m/s.

4.7.2.2 Requirement (1) – Follow the Remote Pilot

- Verify that as the remote pilot moves away from the stable UA at a rate within the limits defined by the manufacturer, the UA will keep a distance D not exceeding $D_{max} \leq 50$ m from the remote pilot, or stop to follow and maintain its last position, using test described below.

The test begins from still-stand of the remote pilot with the UA at still-stand in a position in a distance as close to the pilot as allowed by the manufacturer with a minimum height of $2\text{ m} \pm 0,5\text{ m}$ in the direction opposite to the intended direction of the test (Figure 8).

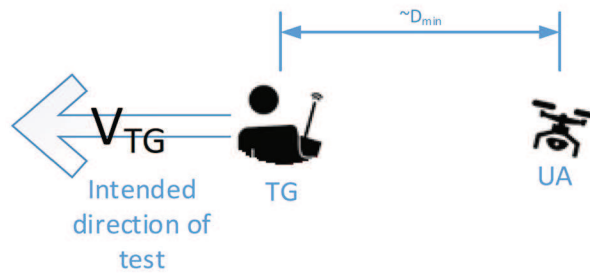


Figure 8 — Constellation at begin of test

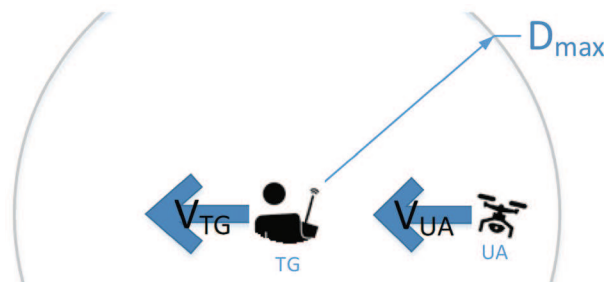


Figure 9 — Follow the remote pilot test

1. Pilot (TG) to accelerate to a velocity of not more than $V_{UA,max}$ {40 km/h to 50 km/h}.
2. Pilot (TG) to maintain the velocity for at least 2 min.
3. Decelerate to stop.

Repeat the test with a lower speed down to $\frac{1}{2}V_{UA,max}$ if the UA is not able to follow.

4.7.2.3 Requirement (2) – Stop to Follow the Remote Pilot

- Verify that as the remote pilot moves away from the UA at a rate in excess of the limits defined by the manufacturer, the UA will stop at a distance D exceeding $D_{max} \leq 50$ m from the remote pilot and remain at its last position, using test described below.

The test begins from still-stand of the remote pilot with the UA at still-stand in a position in a distance as close to the pilot as allowed by the manufacturer with a minimum height of $2 \text{ m} \pm 0,5 \text{ m}$ in the direction opposite to the intended direction of the test (Figure 8).

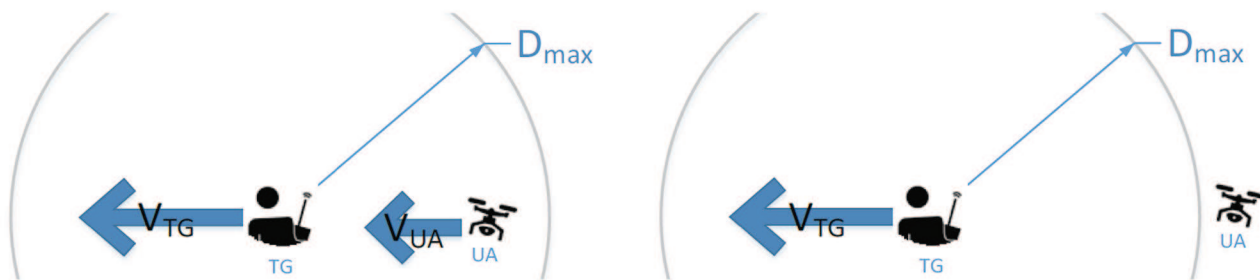


Figure 10 — Follow-me mode escape test

1. Accelerate to a velocity in excess of $V_{UA,max} + 10 \text{ km/h}$ {80 km/h}.
2. Maintain velocity until UA stops to follow.
3. Record the distance D between UA and remote pilot.
4. Decelerate to stop.

4.7.2.4 Requirement (3) – Resume to Follow the Remote Pilot

- Verify that at a distance D exceeding $D_{max} \leq 50 \text{ m}$ between UA and remote pilot the UA does not resume follow-me mode, using test described below.

The test begins from still-stand of the remote pilot with the UA at still-stand in a position in a distance D exceeding $D_{max} \leq 50 \text{ m}$ between UA and remote pilot with a minimum height of $2 \text{ m} \pm 0,5 \text{ m}$ in the intended direction of the test (Figure 11).

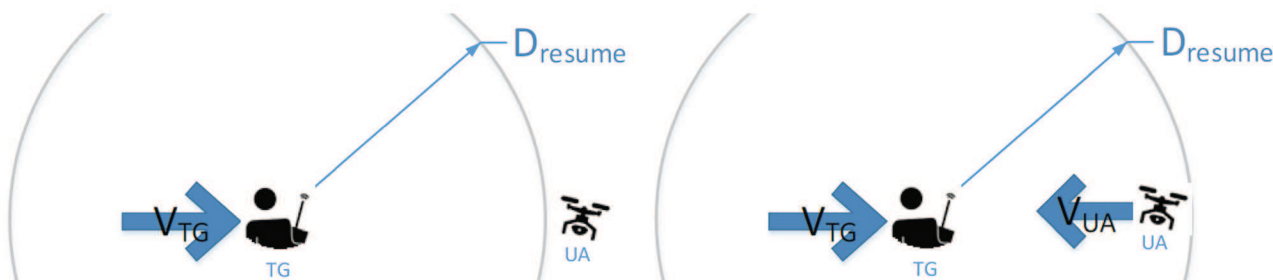


Figure 11 — Follow-me mode: Reacquisition test

1. Accelerate to a velocity of less than $\frac{1}{3} V_{UA,max}$ {20 km/h to 25 km/h} in the direction of the UA.
2. Maintain velocity until the distance between UA and remote pilot is less than D_{max} .
3. Decelerate to stop.

4.7.2.5 Requirement (4) – Regain control

— Verify that the remote pilot can regain control of the UA using the test described below.

With the UA at a distance D not exceeding $D_{max} \leq 50$ m from the remote pilot:

1. turn off the follow-me mode and switch to manual mode;
2. perform a full turn;
3. fly towards the remote pilot and stop to hover in a distance as close to the pilot as allowed by the manufacturer.

4.7.3 Pass criteria

- (1) UA followed the pilot in less than 50 m distance or stopped to follow and maintained its last position.
- (2) At a distance between UA and remote pilot of more than 50 m the UA stopped to follow and maintained its last position.
- (3) At a distance between UA and remote pilot of more than 50 m the UA did not resume to follow.
- (4) The pilot was able to regain and exercise control over the UA after switching from follow-me mode to manual mode.

4.8 Manufacturer's instructions

4.8.1 Requirements

- (1) The manufacturer shall provide a description of the characteristics of the UA in the manufacturer's instructions.
- (2) The manufacturer shall provide clear operational instructions in the manufacturer's instructions.
- (3) The manufacturer shall provide operational limitations of the UAS in the manufacturer's instructions.
- (4) The manufacturer shall provide an appropriate description of all the risk related to UAS operations in the manufacturer's instructions.

4.8.2 Verification method

4.8.2.1 Requirement (1) – Part A: UAS characteristics

— Verify by review of the manufacturer's instructions that all items given below are addressed.

1. Generalities
 - a. UAS class;
 - b. maximum take-off mass (MTOM);
 - c. maximum propeller speed;

- d. list of UA configurations;
- e. list of items;
- f. list of UAS combinations;
- g. instructions on how to distinguish similar products with different class identifiers.

2. Payload

- a. list of payloads approved to be combined with the UAS, identified by Manufacturer and Part Number, with description of:
 - i. maximum dimensions and weight,
 - ii. integration instructions,
 - iii. functional compatibility with UAS;
- b. maximum mass of accessories, payloads and batteries not included in the original packaging of the UA that can be fitted to the UA;
- c. MTOM warning or statement (cf. paragraph 4.1.3 (4)).

3. Equipment to control the UA remotely

- a. accurate description of the flight commands;
- b. list of equipment to control UA remotely approved to be combined with the UAS, identified by Manufacturer and Part Number with related SW versioning identifiers;
- c. list of applications for mobile devices, including their compatibility with mobile device specifications, operating system, and software versioning;
- d. an accurate description of the flight commands;
- e. the risks of control interference and misuse of controls to be minimized, with consideration for the information layout and information readability in all the external lighting conditions;
- f. all warnings or alerts to the remote pilot with their cues, instructions and procedures how to manage;
- g. additional devices like virtual reality headsets or similar auxiliary equipment that provide supplementary information to the remote pilot.

4. Loss of command and control link

- a. a description of the behaviour of the UAS in case of loss of data link: This description shall include the visual, aural, haptic warnings to the pilot to inform of a data link loss;
- b. in case a method for recovery the UA in this condition is provided and it is selectable by the remote pilot, a description of the selectable behaviour shall be provided and how the remote pilot would be able to select the method for recovery; the manufacturer shall

clearly describe under which conditions the method for recovery can be selected and triggered;

- c. if the control of the UA relies on GNSS or other external means of radio navigation then the manufacturer shall provide all necessary information about the conditions for a loss of C2 link in conjunction with loss or degradation of such means of navigation below minimum performance level, the lapse of time (time-out), warnings and alerts, and the behaviour of the UAS under such conditions;
- d. if installed, the manufacturer shall provide all necessary information about the conditions for a C2 link reacquisition, the associated lapse of time (time-out), warnings and alerts, and the behaviour of the UAS in the Manufacturer's Instructions.

4.8.2.2 Requirement (2) – Part B: Operational instructions

— Verify by review of the manufacturer's instructions that all items given below are addressed.

1. Crew health precautions – relevant mandatory regulations and guidance instructions concerning health requirements for the remote pilot related to UAS operations
2. Ground Handling – relevant guidance instructions on carefully handling the UA and the equipment to control the UA remotely before and after flight operations, including safe handling of energy storages (batteries), cleaning and refurbishment, pre-flight calibrations, protective caps, plugs and covers, if foreseen.
3. Pre-flight Operations
 - a. instructions for UA Operation preparation, including:
 - i. limits for allowed height,
 - ii. flight path definition related to density of population,
 - iii. caution on other additional local limitations, if existing;
 - b. guidance for check list, including:
 - i. UA, visual and functional checks,
 - ii. Equipment to control the UA remotely, visual and functional checks.
4. Flight Operations – Flight Operation Instructions prescribing actions to avoid accidental operations or misuse. This section shall
 - a. define flight operations in standard conditions;
 - b. define emergency operations, including fail safe default operations;
 - c. instruct on changes in case of SW Updates, including training on new/upgraded UAS features, if any.
5. Operating Conditions – Operating Conditions Instructions indicating the usage of UAS within design limits for:

- a. typical flight in manual or automated modes;
- b. take-off and landing;
- c. transportation and storage of the UA, the equipment to control the UA remotely and the batteries.

4.8.2.3 Requirement (3) – Part F: Operational limitations

— Verify by review of the manufacturer's instructions that all items given below are addressed.

1. Speed and height limitations (cf. 4.2 and 4.3)
2. Type of approved operations
 - a. lighting and visibility conditions (day, night, dawn, dusk, fog, dust);
 - b. specific flying limitation such as:
 - i. ground elevation,
 - ii. proximity of high voltage electro duct,
 - iii. proximity of High Intensity Radiation Field e.g. high power radar or TV Broadcasting antennae emitters,
 - iv. horizontal distance to buildings.
3. Wind limits
4. Performance limitations (where applicable)
 - a. battery performance variation at different ambient temperatures, charging cycles, shelf life, age, misuse;
 - b. change of endurance due to installation of accessories or payloads;
 - c. change of flight behaviour in the presence of external payloads.
5. Environmental limitations
 - a. altitude: operation, transport and storage;
 - b. temperature: operation, transport and storage, including battery specific protections for low temperature;
 - c. humidity: operation, transport and storage;
 - d. precipitation (rain, ice, hail, fog): operation;
 - e. operation - other: thunderstorm, bird flocks, sandstorm.

4.8.2.4 Requirement (4) – Part G: Description of risks

— Verify by review of the manufacturer's instructions that all items given below are addressed.

1. Risk categories

- a. List of the major risk related to UA open category operations, and mandatory instructions for safety of operations during:
 - i. pre-flight and post flight operations
 - ii. flight operations
 - iii. maintenance operations
 - iv. transportation
 - v. shelf storage
- b. Security instructions for SW integrity, potentially at-risk during data exchange operations on external devices to download videos pictures and SW updates via internet using external devices
- c. Information related to Privacy rights, for people involuntarily under video filming or cameras pictures made by the UAS.
- d. Requirement for registration of the UAS operator if the UA is or can be equipped with sensors able to detect personal data.

2. Safeguards

- a. List of all safeguards,
- b. Instructions how to install safeguards and to verify proper functioning.

4.8.3 Pass criteria

- (1) Compliance with UAS characteristics requirement.
- (2) Compliance with operational instructions requirement.
- (3) Compliance with operational limitations requirement.
- (4) Compliance with description of risks requirement.

4.9 Information Notice

4.9.1 Design requirements

- (1) The UAS manufacturer shall include the information notice published by the European Union Aviation Agency (EASA) and available on the EASA website providing applicable limitation and obligations, in accordance with implementing regulation.²⁾

²⁾ EU regulation (EU) 2019/947

4.9.2 Verification method - Requirement (1) – Information notice

- Verify by review of the package content including the manufacturer's instructions that the information notice published by the European Union Aviation Agency (EASA) providing applicable limitation and obligations, in accordance with implementing regulation ²⁾, is provided.

4.9.3 Pass criteria

- (1) The EASA information notice is provided.

5 Product Requirements and Compliance for Class 1 UAS

5.1 Ground impact

5.1.1 80 Joules

5.1.1.1 Performance and design requirements

5.1.1.1.1 Introduction

This paragraph is of relevance for UA with a MTOM in excess of 900 g but less than 25 kg to be operated in subcategory A1, class C1.

NOTE The use of explosives to perform in-flight total destruction of the UA is not an acceptable means of compliance (cf. STANAG 4703, U1412 (e)). However, in-flight controlled disassembly of the UA into more than one subassembly that by themselves have masses less than the MTOM of the UA itself is a viable solution to reduce the kinetic energy at impact.

5.1.1.1.2 Requirements

- (1) The energy transmitted to the human head in the event of an impact of the UA at terminal velocity shall not exceed 80 J.
- (2) A parachute recovery system shall not be considered when showing compliance with this requirement.
- (3) The manufacturer shall provide the value of the terminal velocity and the energy transmitted to the human head in the manufacturer's instructions along with the method applied, the combination and configuration, if applicable, and the mass for which it was determined.

5.1.1.2 Verification Method

5.1.1.2.1 Requirement (1) – Energy transmitted

5.1.1.2.1.1 General

- Determine the terminal velocity by application of one of the tests described in 5.1.1.2.1.2 below.
- Determine the energy transmitted in the event of an impact of the UA at terminal velocity by application of one of the tests described in 5.1.1.2.1.3 below.

If the UA is configurable then the determination shall be conducted for each combination of UA with accessories, payloads, and batteries in which the UA is placed on the market, and the maximum kinetic energy value shall be selected.

Without validation a safety factor of 1,23 shall be applied to the terminal velocity³⁾.

5.1.1.2.1.2 Determination of terminal velocity

Determination of terminal velocity by test

Carry out the tests out under calm wind conditions.

Determine the terminal velocity for a loss of control scenario - Single engine or servo actuator cut-off for the UA to enter into a descent (“tumbling drop” for a hover capable configuration: The UA may be equipped with means to stabilize a “tumbling drop” into a “flat drop” provided the engine or servo actuator cut-off initially is not re-engaged).

The UA shall be equipped with instrumentation to record or transmit height above take-off place, either from GNSS or barometric altitude, and vertical speed, either from GNSS, variometer or by in-flight or post-flight differentiation of barometric altitude. When using variometer or barometer, those have to be calibrated with GNSS raw vertical (“downwards”) speed. The test may be conducted with instrumentation that is part of the regular equipment of the UA in the combination in which it is placed on the market (cf. 4.3).

Calibration of instrumentation shall be conducted by flight test prior to test. If the instrumentation is not part of the regular equipment of the UA then calibration may be accomplished using a UA of a similar design or make.

It is not necessary to record height and vertical speed with a time stamp.

1. Fly UA up to maximum height H_{max} (see 4.3). If equipped with selectable height limit then the UA shall be flown to the maximum height selectable following the instructions and limitations provided in the manufacturer’s instructions, but not more than 200 m above take-off place, otherwise up to the maximum height possible.
2. Stabilize the UA:
 - a. with no forward speed (hover capable configurations), or
 - b. in horizontal flight (height $H_{max} \pm 5$ m) at cruise speed V_C as provided in the manufacturer’s instructions.
3. Trigger the drop
4. Determine the terminal velocity from the recorded data as the averaged value over the last 10 m at the end of the descent.

The UA may be pulled out of the descent to avoid ground impact. If the vertical velocity has not stabilized by then, then the terminal velocity shall be determined from the recorded data by cubic spline extrapolation over the last 30 m.

The tests shall be repeated 3 times for each test case. If the results are consistent and reproducible within ± 3 m/s then the average value shall be used.

The maximum value shall be used.

³⁾ Obtained from a safety factor of 1,5 for the resulting energy; when applied to terminal velocity then $\sqrt{1,5} \cong 1,23$.

Determination of terminal velocity by rational analysis

For the calculation of kinetic energy at impact for the loss of control case the mass to consider, is the maximum take-off mass and the velocity used is the probable terminal velocity, i.e.

$$V_t = \sqrt{\frac{2mg}{\rho_0 S \cdot C_D}}$$

with

m = Maximum Take-Off Mass (MTOM), as provided in the manufacturer's instructions,

g = gravity constant 9,80665 m/s²,

ρ_0 = ambient density of air at S.L. 1,225 kg/m³,

S = reference area (e.g. wing area as provided in the manufacturer's instructions, or cross section of the body),

C_D = drag coefficient, which depends of the body geometry

- For Fixed-wing: minimum drag coefficient in enroute configuration;
- For Rotorcraft: of body with rotor(s) stationary.
- For Multicopter: of body and motor arms, propellers may be wind-milling.
- For Airships/Balloons: with the envelope ruptured/deflated to the extent that no lifting medium remains.

Values shall be accurate within ± 10 %.

Values obtained from experiments with the UA itself do not require further validation.

Values obtained from experiments with similar UA require an analysis to address the effects of the differences between the UA itself and the similar UA used to obtain the experimental values.

Values obtained from calculation or literature, and explicitly not obtained from tests on the UA itself (or similar), shall be conservative and should be validated by experiments.

Determination of terminal velocity from statistical data

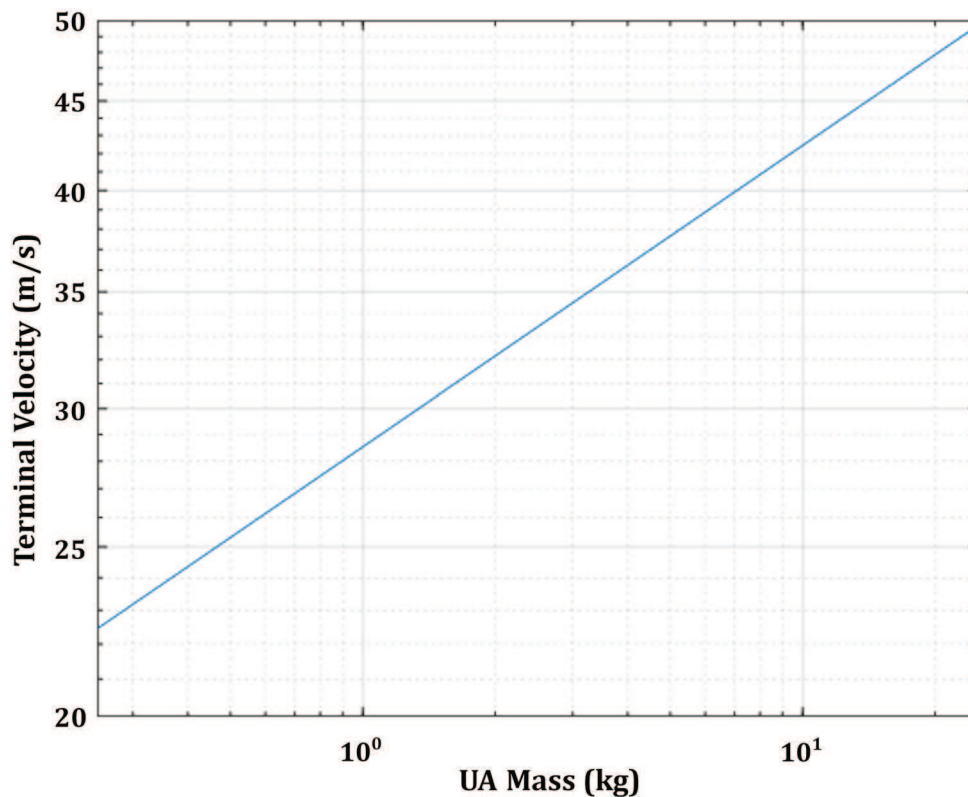


Figure 12 — Terminal velocity for UA departing controlled flight from 400 ft AGL ([10] Figure 6)

Determine the terminal velocity from Figure 12 for the respective mass of the UA, Maximum Take-Off Mass (MTOM), or for configurable UA the mass that results in the maximum terminal velocity, as provided in the manufacturer's instructions.

5.1.1.2.1.3 Energy transmitted to the human head

The transmission factor can be determined by test, or by simulation or rational analysis as given in 5.1.1.2.1.2.3 based on tests with models of similar design and make.

In the absence of substantiating evidence, a transmission factor of $f = 100 \%$ shall be assumed.

Determination of energy transmitted from terminal velocity

Determine the maximum kinetic energy from:

$$E_{K,max} = \frac{1}{2} \cdot f \cdot m \cdot V_t^2$$

with

$$f = \text{transmission factor} = \frac{\text{energy transmitted to head}}{\text{total energy}} \leq 100 \%$$

m = Maximum Take-Off Mass (MTOM), or for configurable UA the mass that results in the maximum kinetic energy, as provided in the manufacturer's instructions,

V_t = terminal velocity.

The velocity of concern is the maximum velocity that the UA may reach at a drop from maximum height above ground (may not exceed 120 m). Due to aerodynamic drag the velocity will eventually stabilize at terminal velocity V_t .

The terminal velocity may not take wind into account except for airships and balloons, for which the maximum wind specified by the manufacturer in the manufacturer's instructions shall be added to the terminal velocity determined for no wind conditions.

Determination of energy transmitted from statistical data

This method is not applicable for airships and balloons.

Determine the kinetic energy from Figure 13 for the respective mass of the UA, Maximum Take-Off Mass (MTOM), or for configurable UA the mass that results in the maximum kinetic energy, as provided in the manufacturer's instructions, and multiply with the transmission factor:

$$E_{K,max} = f \cdot \text{Terminal Kinetic Energy from Figure 13}$$

with

$$f = \text{transmission factor} = \frac{\text{energy transmitted to head}}{\text{total energy}} \leq 100 \%$$

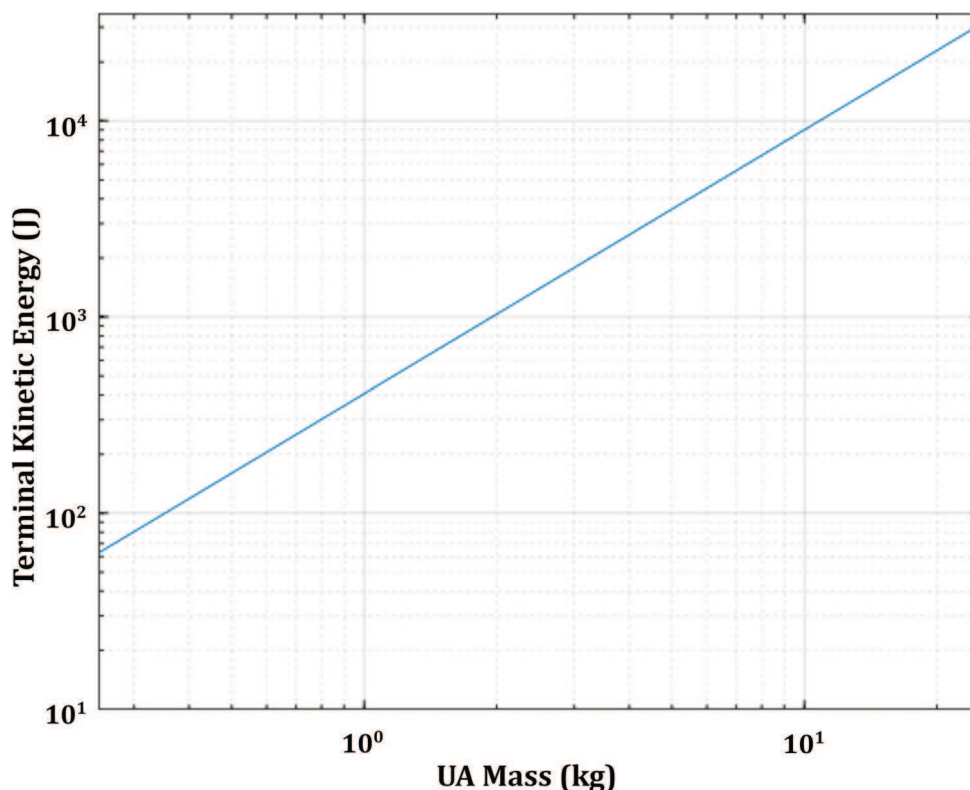


Figure 13 — Kinetic energy for UA departing controlled flight from 400 ft AGL ([10] Figure 7)

Impact simulation method

Determine the value of kinetic energy transmitted to the head in the event of an impact of the UA at terminal velocity as obtained from 5.1.1.2.2 by simulation with the UA fully equipped with accessories, payloads and batteries as provided in the manufacturer's instructions.

Impact simulation methods may be based on finite element analysis (FEA) calculations or on statistical methods.

Such calculations shall be validated by values obtained from experiments with similar UA or be shown to be conservative in nature.

5.1.1.3 Pass criteria

- (1) Verify that the maximum energy transmitted to the head is less than 80 J.
- (2) Verify that the determination does not take a parachute into account.
- (3) Verify by review of the manufacturer's instructions that the terminal velocity and the energy transmitted to the human head are provided along with the method applied, the combination and configuration, if applicable, and the mass for which it was determined.

5.1.2 MTOM

5.1.2.1 General

To show compliance with this requirement manufacturers of UA shall apply the requirements and verification methodology given in 4.1.1 and 4.1.2.

5.1.2.2 Pass Criteria

- (1) The MTOM declared in the manufacturer's instruction is less than 900 g.

In addition the pass criteria (2) to (4) given in 4.1.3 apply.

5.2 Maximum speed

To show compliance with this requirement manufacturers of UA shall apply the methodology given in 4.2.

5.3 Maximum attainable height

5.3.1 Performance requirements

- (1) The UAS shall have inherent performance limitations to limit the maximum attainable height of the UA to 120 m above the surface or take-off point.
- (2) If installed, the UAS shall be equipped with a function limiting the height above the surface or take-off point to a value in excess of 120m selectable by the remote pilot.
 - a. The altitude information shall be clearly and continually indicated to the remote pilot.
 - b. The manufacturer's instructions shall clearly state that the function is implemented, and procedures how the function can be activated, selected height modified, and deactivated.