**NOTICE OF PROPOSED AMENDMENT: MAA/NPA/ 21/20**

<table>
<thead>
<tr>
<th>Title of Proposal</th>
<th>MAA/RN/2021/07 – DRAFT AEP-89 UNMANNED AERIAL VEHICLE (UAV) SYSTEMS AIRWORTHINESS REQUIREMENTS (USAR) FOR LIGHT VERTICAL TAKE-OFF AND LANDING (VTOL) AIRCRAFT INDUSTRY AND ACADEMIA COMMENT AND FEEDBACK</th>
</tr>
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<tbody>
<tr>
<td>RA(s) or Manual Chapter(s)</td>
<td>NATO Standard AEP-89: STANAG 4746 USAR</td>
</tr>
<tr>
<td>Stage of Development</td>
<td>Consultation</td>
</tr>
<tr>
<td>Organizations and/or business sectors affected</td>
<td>Industry and Academia and Regulated Community</td>
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<tr>
<th>RFC Serial No</th>
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<tr>
<th>Post</th>
<th>Rank/Name</th>
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<tbody>
<tr>
<td>MAA Author</td>
<td>DSA-MAA-Cert Struct1-FJ</td>
<td>Redacted</td>
</tr>
<tr>
<td>MAA Supervisor</td>
<td>DSA-MAA-Cert-S and ADS</td>
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<tr>
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<td>DSA-MAA-Cert-Struct2-TrgandRPAS</td>
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<td>MAA Legad (if required)</td>
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**Cross-references to Other Documents or Relevant Sources**

<table>
<thead>
<tr>
<th>Other MRP Amendments</th>
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<tr>
<td>Service Inquiry Recommendations</td>
<td>N/A</td>
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<td>AAIB Recommendations</td>
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<td>Other Investigation Recommendations</td>
<td>N/A</td>
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<tr>
<td>Any Other Document</td>
<td>Def Stan 00-970 Part 9 refers to STANAG 4746</td>
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**MAA Regulatory Publications Team Contact Details**

<table>
<thead>
<tr>
<th>Email</th>
<th><a href="mailto:DSA-MAA-MRPEnquiries@mod.gov.uk">DSA-MAA-MRPEnquiries@mod.gov.uk</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>GPTN</td>
<td>9679 Ext 84189 / 83914 / 82504</td>
</tr>
<tr>
<td>Civilian Telephone</td>
<td>030 679 84189 / 83914 / 82504</td>
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</tbody>
</table>
Feedback Notes for the Regulated Community

The Regulated Community are invited to offer feedback about the proposed amendment in the following areas:

- Air or Flight Safety impact
- Operational impact
- Errors or omissions
- Timescale for implementation
- Cost of implementation
- Amendment to internal processes/orders
- Resourcing the outcome of change
- (Contract amendments because of the change)

The format for feedback is available within a single Excel Template file on both internal (link) and external (link) MAA websites; it is important to use this format to ensure that your responses are considered and answered correctly.

Summary of Proposed Amendment

<table>
<thead>
<tr>
<th>Objective</th>
<th>STANAG 4746 contains the minimum set of technical Airworthiness requirements intended for the Airworthiness certification of VTOL Light UAS with maximum take-off weight of not greater than 150 kg and an impact energy greater than 66 J (49 ft-lb) that intend to regularly operate in non-segregated airspace. This consultation is open to all elements of the RC, but majority of focus is towards industry and academia. NSA requires response by 23 Aug 21. Consultation period to end 11 Aug 21, allowing time for subsequent collation and distribution to NSA.</th>
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<tbody>
<tr>
<td>Changes made</td>
<td>Numerous, throughout document.</td>
</tr>
<tr>
<td>Impact Assessment</td>
<td>MAA regulatory Impact minimum, feedback required from Industry and Academia to feedback to NATO Standardization Agency.</td>
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Courses of Action - Risk Evaluation

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<tr>
<th>Courses of Action</th>
<th>Do Nothing</th>
<th>Partial Amendment</th>
<th>Full Amendment</th>
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<tbody>
<tr>
<td>Do Nothing</td>
<td>Reputational Damage, by not performing this National Level review to return to NATO.</td>
<td>N/A</td>
<td>Improved safety standards, and guidance provided for new certification requirements for VTOL UAS.</td>
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</table>

Consultation Period Ends

11 August 2021

The consultation period for this proposed amendment ends on the stated date. Please send your feedback, using the Response Form, via email to DSA-MAA-MRPEnquiries@mod.gov.uk
<table>
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<th>Approval</th>
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NATO STANDARD

DRAFT AEP-89

Unmanned Aerial Vehicle (UAV) Systems Airworthiness Requirements (USAR) for Light Vertical Take-Off and Landing (VTOL) Aircraft

Edition A

MONTH YEAR

NORTH ATLANTIC TREATY ORGANIZATION

ALLIED AIR TRAFFIC MANAGEMENT PUBLICATION

Published by the
NATO STANDARDIZATION AGENCY (NSA)
© NATO/OTAN

NATO UNCLASSIFIED
# RECORD OF RESERVATIONS

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<th>CHAPTER</th>
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Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Database for the complete list of existing reservations.
# RECORD OF SPECIFIC RESERVATIONS

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1. **Scope**

This document contains the minimum set of technical airworthiness requirements intended for the airworthiness certification of VTOL Light UAS with a maximum take-off weight not greater than 150 kg and an impact energy\(^1\) greater than 66 J (49 ft-lb) that intend to regularly operate in non-segregated airspace.

The lower limit is established according to available blunt trauma studies showing that below this level it is reasonably expected that a fatal injury should not occur if the UA strikes an unprotected person. It is recognized that 66 J is a conservative value based on current research that will be reviewed after further investigation.

For UA below the 66J impact energy threshold, it is reasonable that a number of requirements can be relaxed. Specific airworthiness requirements must be approved by the Certifying Authority on a case-by-case basis. Annex J of this document provides applicable guidelines that are not limited to VTOL aspects.

This document is limited to vertical take-off and landing (VTOL) aircraft that can hover, take-off, land vertically and do not rely on dedicated or primary wing structures for lift in forward flight. The VTOL classification for the purposes of this document excludes Autogyros and fixed-wing aircraft variants such as but not limited to tilt-rotor or blown lift fixed wing aircraft.

Cybersecurity is outside of the scope of the USAR. It is recognized that Cybersecurity may introduce unique safety risks to the UAS and it should therefore be considered.

These requirements represent the minimum acceptable airworthiness requirements for design and construction of military VTOL UAS intended to operate in non-segregated airspace. It may be augmented by additional Special Conditions (i.e. additional airworthiness requirements) required by Certifying Authorities. This STANAG is intended for application by Certifying Authorities within each country's relevant national regulatory framework.

The most recent version of any referenced document in effect shall apply unless otherwise specified or agreed with the certifying authority. In case of conflicting requirements between a referenced document and the STANAG 4746, STANAG 4746 shall take precedence. In case of a conflict between a referenced document and this document, it should be reported to the custodian of this document.

2. **Introduction**

Due to the large variety of possible configurations and technology in this category of UAS and the fact that many of these systems are architecturally simple, this STANAG has been developed with the following objectives.

- require no more than the minimum amount of certification evidence that is needed to substantiate an acceptable level of airworthiness;
- address all design attributes which may endanger safety;
- be flexible by being non-prescriptive, in order not to limit the design solutions (i.e., address issues instead of prescribing solutions).

\(^1\) The impact energy must be calculated using the worst case terminal velocity based on the foreseeable failure conditions, as agreed by the Certifying Authority.
It has been considered that a pure complete traditional prescriptive set of airworthiness codes (e.g. CSs, FARs) could not fulfil this objective, and it could not be derived from existing civil or military regulations applicable to manned aircraft. Therefore, a hybrid approach has been established, which combines a set of conventional airworthiness code requirements with other types of qualitative criteria aimed to achieve a high level of confidence that the type design is airworthy (e.g. through process evidence or design criteria).

The standard referred in this document will have a normal evolution with the publication of later editions. This document will not be updated every time a new standard will be available. The applicant should therefore refer to the latest published standard unless expressly specified.

The following areas are not covered by this airworthiness code:

a. Control station security;
b. Security of the command and control data link from wilful interference;
c. Airspace integration and segregation of aircraft (including "sense and avoid");
d. The competence, training and licensing of UAS crew, maintenance and other staff;
e. Approval of operating, maintenance and design organizations;
f. Frequency spectrum allocation;
g. Noise, emission and other environmental certification;
h. Launch/landing equipment that is not safety critical and which does not form part of the Type Certification Basis;
i. Operation of the payload (other than its potential hazard to the aircraft);
j. Carriage or release of weapons, pyrotechnics and other functioning or non-functioning stores designed for release during normal operations;
k. Sea-basing.

It is expected that these areas will be subject to other forms of approval by Certifying Authority in order to ensure a total aviation safety approach. Where such approval requires technical assessment, the Certifying Authority may supplement these requirements with suitable additional conditions as appropriate.

Creating this hybrid approach, the top-level starting point is the set of the Military Essential Requirements for Airworthiness which have been transferred into the STANAG to the greatest extent possible in their original wording and have only been modified where necessary to accomplish the specific characteristics of these type of UAS. This STANAG also establishes detailed arguments to comply with each of these mandatory minimum essential requirements in order to obtain a UAS Type Certificate (or equivalent document) for UAS with Maximum Take-Off Weight of 150 kg, or less, for flight in non-segregated airspace.

The Certifying Authority will issue a Military Type Certificate or equivalent national document containing as minimum:

a. System Identification;
b. System Configuration description;
c. Requested operating frequencies;
d. Statement of compliance (including, if applicable, additional conditions exemptions and deviation);
e. List of approved publications (operating and maintenance instructions);
f. Issuing Agency;
g. Date of Issue.

Throughout this document, the term ‘Type Certificate’ refers to any document issued by a National Certifying Authority that, within the regulatory framework of that Nation, certifies compliance as determined
by the National Certifying Authority with this STANAG.

It is recognized that 'sense and avoid' is a key enabling issue for UA operations. The derivation and definition of 'sense and avoid' requirements is primarily an operational issue and hence outside the scope of this STANAG. However, once these requirements are clarified, any system designed and installed to achieve these objectives shall be considered as an item of installed equipment within a UAS.

3. Type design airworthiness evidence

The Applicant must provide to the Certifying Authority any type of verifiable evidence that the system is designed to be airworthy for its intended purpose through its lifetime.

The Applicant should create comprehensive arguments, supported by a body of evidence, to demonstrate how the mandatory Essential Requirements for Airworthiness have been met and to provide confidence in the airworthiness of the UA type design. The evidence could consist of one or more forms of the following types as agreed with the certifying authority:

- direct evidence from analysis;
- direct evidence from demonstration (laboratory testing, rig testing, simulation, representative prototype ground, aircraft inspection, equipment qualification, and flight operation, operational experience);
- direct quantitative safety evidence;
- direct qualitative safety evidence;
- direct evidence from hazard risk management;
- direct evidence extracted from the design review process;
- direct technical description of design features and system functions;
- direct qualitative evidence of good design (e.g. design criteria and practices);
- process evidence (e.g. Design Assurance Levels allocation as per ARP-4754; Safety Management System processes) showing good UA life-cycle safety issues management;
- any other quantitative and/or qualitative compelling argument provided to the Certifying Authority in order to demonstrate compliance with mandatory Essential Requirements for Airworthiness.

Consideration of design criteria and airworthiness management processes is as important as compliance with detailed codes, where applicable, and may constitute a certification credit giving the Certifying Authority the necessary confidence and level of trust that the result of the design activity is an airworthy UA. In other words, behind this STANAG is the firm belief that the verification of design criteria, safety management plans, and technical qualitative arguments constitute an additional means in order to demonstrate compliance with high-level Essential Requirements for Airworthiness, which are general and qualitative in nature. Therefore, consideration of additional evidence, other than conventional quantitative arguments, is an effective strategy that may be used by the Authority to certify the airworthiness of a Light UA for which the variety of possible configurations and technical design solutions may sometimes compromise compliance with a detailed set of airworthiness codes.
4. **Source documents**

The following rules and standards have been used as source material to derive this STANAG:

- STANAG 4671 (UAV Systems Airworthiness Requirements for North Atlantic Treaty Organization Military UAV Systems),
- Draft STANAG 4702 (Rotary Wing UAV Airworthiness Requirements)
- STANAG 4703 (Light UAV Systems Airworthiness Requirements for North Atlantic Treaty Organization (NATO) Military UAV Systems)
- CS 27 (Certification Specifications for Small Rotorcraft)
- CS VLR (Certification Specifications for Very Light Rotorcraft)
- DEF STAN 00-56 (Safety Management Requirements for Defence Systems).

5. **Restricted Certification**

Non-segregated airspace contains regions of densely populated areas and sparsely populated areas. It is therefore possible that UAS not meeting all the objectives in this STANAG will be airworthy to fly in sparsely populated areas of non-segregated airspace as determined by the Certifying Authority.

Non-compliance with some requirements of this STANAG may be negotiated on a case-by-case basis depending on particular UA design and envisaged operating restrictions in the framework of a Restricted Type Certification.

Any non-compliance or operating restriction must be approved by the Certifying Authority, tracked and identified in the Certificate Data Sheet (or equivalent).

6. **Requirements**

The following section provides the Certification Basis requirements for Light UAS in the form of a three column table in which:

I. the first column expresses the mandatory Essential Requirements for Airworthiness;

II. the second column presents the means to comply with the Essential Requirements in the first column into an Airworthiness Basis for a specific type of UA;

III. the third column presents an acceptable set of evidence that may be provided to the Certifying Authority in order to demonstrate that the means of compliance have been met.

The Applicant shall comply with the second column as a means of compliance with the Airworthiness essential requirements, which are either:

I. “Must” statements, which are mandatory, or

II. “Should” statements, which are an acceptable means of compliance but not the only means. The applicant may propose an alternate means of compliance with a rational demonstration that a comparable level of safety is assured, which must be agreed with the Certifying Authority.

Unless stated as a requirement (i.e. "must" statements), the detailed arguments may be interpreted as Applicable Means of Compliance with the Airworthiness Essential Requirements. The Applicant should follow these requested arguments. Nevertheless, if it is difficult for a particular application to comply with the detailed request, the Applicant may propose to the Certifying Authority compelling alternative
arguments with a rational demonstration that a comparable level of safety is assured. Where within the detailed argument there is a requirement to have an agreement with the Certifying Authority, the airworthiness implication of such agreement shall be documented by the applicant and provided to the Certifying Authority.

7. Special Conditions and Special Military Airworthiness Requirements

In addition to the requirements of this STANAG, it is expected that national certifying authorities may impose extra airworthiness requirements (for instance cold soak). Where these are of a nature similar to Special Conditions usually imposed by civilian certifying authorities and potentially applicable to both civil and military applications, these will be known as Special Conditions.

It is also expected that UAS certified or assessed using this STANAG will be employed in a variety of military roles and/or modes, all or some of which may involve manoeuvres or use of special equipment or payloads that fall outside the scope of these requirements. It is expected that national authorities will address these modes by the use of special military airworthiness requirements. Special military airworthiness requirements recognize the unique nature of military operations, and are analogous to Special Conditions or similar terminology used by a civilian Certifying Authority. They are to be applied and assessed in a similar manner to Special Conditions.

It is expected that any special military airworthiness requirements that result in an actual or potential hazard condition that reduces the margin of safety below the levels required by ER.1.3.3 “Safety Requirements”, everything under UL.30 and UL.31, whether temporary or permanent, will be addressed by suitable operational
restrictions. Where this is not possible, the condition is to be clearly identified in the Type Certificate as resulting in the system operating at a level of safety below that required by this STANAG. The resulting technical and/or operational risk associated with the special military airworthiness requirements are expected to be assessed and accepted using relevant national procedures.
NOTE

**DETAILED ARGUMENTS:** Compliance with the Essential Requirements may be shown by the Applicant through these detailed arguments or by any other argument which meets the intent behind them with a comparable level of safety, to be as agreed by the Certifying Authority, wherever a “should” statement appears.

<table>
<thead>
<tr>
<th>AIRWORTHINESS ESSENTIAL REQUIREMENTS</th>
<th>MEANS OF COMPLIANCE</th>
<th>MEANS OF EVIDENCE</th>
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</table>
| ER.1  System integrity               | UL.0 The Applicant must identify the design usage spectrum as the set of all the foreseen operational conditions of the UAS:  
- typical design missions;  
- in-flight operation conditions;  
- on-ground operation conditions;  
- operational modes (automatic, speed-hold, altitude hold, direct manual, etc.);  
- take-off / launch / ramp conditions;  
- landing / recovery conditions;  
- locations and platforms (e.g. land vehicle, water vessel, aircraft, building, etc.) from which launch, command and control, and recovery operations will be performed (e.g., land, littoral/maritime, air);  
- number of air vehicles to be operated simultaneously;  
- transport conditions (define the transportation and storage environment of the UAS e.g. bag, package, truck or whatever is required);  
- operating environmental conditions:  
  - natural climate (altitude, temperature, pressure, humidity, wind, rainfall rate, lightning, ice, salt fog, fungus, hail, bird strike, sand and dust, etc.);  
  - electromagnetic environmental effects (electromagnetic environment among all sub-systems and equipment, electromagnetic effects caused by external environment, electromagnetic interference among more than one UAS operated in proximity);  
  - lighting conditions (e.g., day, night, dawn, dusk, mixed, etc.);  
- identify all the possible mass configurations (minimum and maximum flying weight, empty CG, most forward CG, most rearward CG must be identified). | ME0 Description of the design usage spectrum |
<table>
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<th>AIRWORTHINESS ESSENTIAL REQUIREMENTS</th>
<th>MEANS OF COMPLIANCE</th>
<th>MEANS OF EVIDENCE</th>
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<tbody>
<tr>
<td>UL. 1 The Applicant must identify design criteria, standards and practices used to design UA. This may include but not limited to the following: drive system, structure, engine, rotor blades, shrouded rotor blades, ducted fan, propeller, and vertical lifting element(s).</td>
<td>ME1 A description of the design criteria to be used must be submitted to the Certifying Authority, in order to gather a sufficient level of trust</td>
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<tr>
<td>UL.1.1 Where practicable, the UA should be designed without sharp edges that may constitute a danger to third parties on the ground. Rotor blades, shrouded rotor blades, ducted fan, propellers, or vertical lifting elements should be designed in a way to limit any injury that may be inflicted by the blades.</td>
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<tr>
<td>ER.1.1 Structures and materials</td>
<td>UL. 2 Loads. The Applicant must define and justify with a rationale; a positive margin beyond the maximum operating envelope, in order to establish the design loads. This margin must take into account all the possible uncertainties related to: operator usage (e.g. loads may be exceeded due to operator demands in manual direct piloting conditions), material properties variation, and design method approximation. Strength Requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads. The following margins should be taken into account, unless more rational means agreed by the Certifying Authority:</td>
<td>ME2 A description of the rationale for the design loads margins to be included in Design Criteria in ME1</td>
</tr>
<tr>
<td>The integrity of the structure must be ensured throughout, and by a defined margin beyond, the operational envelope for the VTOL UA, including its propulsion system, and maintained for the operational life of the VTOL UA.</td>
<td>UL.2.1 A positive margin between the maximum design speed (v_d) and the maximum operating speed (v_{\text{max}}) (the maximum operating speed should be no more than 0.9 the maximum design speed);</td>
<td></td>
</tr>
<tr>
<td>UL.2.2 NOT USED</td>
<td>UL.2.3 an ultimate load factor of safety (\geq 1.5) (for structure whose failure would lead to a Hazardous or more serious failure condition) or (\geq 1.25) (for other structure).</td>
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<tr>
<td>UL.2.4 Factor of Safety</td>
<td>UL.2.4 Factor of Safety The factor of safety of UL2.3 should be multiplied by a further special factor in the following cases:</td>
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<td>- (\geq 2.0) on castings,</td>
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<td>- (\geq 1.15) on fittings,</td>
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<tr>
<td>AIRWORTHINESS ESSENTIAL REQUIREMENTS</td>
<td>MEANS OF COMPLIANCE</td>
<td>MEANS OF EVIDENCE</td>
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| - ≥2.0 on bearings at bolted or pinned joints subject to rotation,  
- ≥4.45 on control surface hinge-bearing loads except ball and roller bearing hinges,  
- ≥2.2 on push-pull control system joints,  
- in composite structures, if A or B allowables for hot and wet conditions are not statistically justified (as per UL9.2 and UL9.3), the following special factors should be used: ≥1.2 for moisture conditioned specimen tested at maximum service temperature, providing that a well-established manufacturing and quality control procedure is used; or ≥1.5 for specimen tested with no specific allowance for moisture and temperature;  
- ≥1.5 for attachments in frequently assembled and disassembled structural parts, to cover potential deterioration in service; alternatively, this factor is not needed if a test reproducing the required number of assemble/disassemble operations demonstrates no degradation of structural integrity;  
- in certain circumstances the Certifying Authority may choose to use a further justified special factor >1 to cover any uncertainty not previously mentioned. | **UL2.5** Loads VTOL  
(a) **NOT USED**  
(b) Unless otherwise provided, the specified air, ground, and water loads must be placed in equilibrium with inertia forces, considering each item of mass in the UA. These loads must be distributed to closely approximate or conservatively represent actual conditions.  
(c) If deflection under load would significantly change the distribution of external or internal loads, this redistribution must be taken into account. | **UL2.6** Proof of Structure  
(a) Compliance with the strength and deformation requirements of this paragraph must be shown for each critical loading condition accounting for the environment to which the structure will be exposed in operation. Structural analysis (static or fatigue) may be used only if the structure conforms to those structures for which experience has shown this method to be reliable. In other cases, substantiating tests must be made. (See Annex F)  
(b) Proof of compliance with the strength requirements of this paragraph must include - |
## AIRWORTHINESS ESSENTIAL REQUIREMENTS

### MEANS OF COMPLIANCE

| (1) Dynamic and endurance tests of vertical lifting element(s), vertical lifting element(s) drives, and vertical lifting element(s) controls; |
| (2) Limit load tests of the control system, including control surfaces; |
| (3) Operation tests of control system; |
| (4) Flight stress measurement tests; |
| (5) Landing gear drop tests; and |
| (6) Any additional tests required for new or unusual design features; |

### UL2.7 Design limitations

The following values and limitations must be established to show compliance with the structural requirements of this paragraph:

- (a) The design maximum weight.
- (b) The main vertical lift element rpm ranges power-on and (where applicable) power-off. For rotorcraft designed VTOL see Annex K.
- (c) The maximum forward speeds for each main vertical lifting element rpm within the ranges determined in sub-paragraph (b).
- (d) The maximum rearward and sideward flight speeds.
- (e) The center of gravity limits corresponding to the limitations determined in sub-paragraphs (b), (c), and (d).
- (f) The rotational speed ratios between powerplant and each connected rotating component.
- (g) The positive and negative manoeuvring load factors.

### ER.1.1.1 All parts of the UA, the failure of which could reduce

### UL.3 The Applicant must identify Primary Structural Elements (PSEs) for which failure would lead to hazardous or more serious effects (e.g. primary UA structure bearing aerodynamic, inertial and

### ME3 Description of the PSEs

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| the structural integrity, must comply with the following conditions without detrimental deformation or failure. This includes all items of significant mass and their means of restraint. | propulsion forces; control surface and control system structural elements, control surface hinges; structural elements of systems used in launching and recovery phases. | UL 4  For each PSE identified in UL.3 and for all on-board equipment, the structure must be proven according to the following criteria:  
- no detrimental deformation against the Limit Loads, and  
- no rupture against the Ultimate Loads obtained by multiplying the loads identified under UL.5 to UL.6 by the ultimate load factors of safety in UL.2;  
- the control system is free from interference, jamming, excessive friction and excessive deflection when the control system loads are applied to the controls and the surfaces; additionally the control system stops must withstand those loads.  
For non-PSEs, the structure must be proven according to the following criterion:  
- no rupture against the Ultimate Loads obtained by multiplying the loads identified under UL.5 to UL.6 by the ultimate load factors of safety in UL.2. | ME4  Static strength should be demonstrated through ultimate load test in the appropriate environment or by using the appropriate knockdown factors. Alternatively, proof by analysis may be accepted provided it is supported by the appropriate extent of lower testing to validate the method used. |
| ER.1.1.1.1 All combinations of load reasonably expected to occur within, and by a defined margin beyond, the weights, centre of gravity range, operational envelope and life of the UA must be considered. This includes loads due to gusts, manoeuvres, pressurisation, movable surfaces, control, and propulsion systems both in flight and on the ground. | UL.5  Flight loads  
The Applicant must identify all of the loads that PSEs must withstand in flight, at each critical combination of altitude, speed and UA configurations (including weight, centre of gravity, landing gear configurations, fuel distribution, aerodynamic configurations, etc.).  
UL5.1. The manoeuvres which need to be considered in the load establishment are those resulting from all reasonable combinations of possible control surface deflections and power or thrust settings, taking into account the UAS design peculiarities.  
If convenient, conservative manoeuvre conditions may be used, providing there is compelling rationale to justify the degree of conservatism.  
The resulting load conditions (with all forces acting on the UA placed in equilibrium with inertial forces) must be established in a rational or conservative manner and must consider: | ME5  Assumptions and analysis of the design loads in-flight |

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<td>- the UAS nominal modes of control,</td>
<td>- the UAS failure modes where probability of occurrence is higher than extremely remote,</td>
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<tr>
<td>- the UAS failure modes where probability of occurrence is higher than extremely remote,</td>
<td>- Non-symmetrical loads due to engine failure (for multi-engine configurations).</td>
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<tr>
<td>UL.5.2  Maneuvering Load Factors</td>
<td>(a) The UA should be designed for a maneuvering load factor ≥ 3.5. A negative maneuvering load factor ≤1.0 should be established.</td>
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<td>(b) Maneuvering load factors lower than the above may be used if the UA has design features that make it impossible to intentionally exceed these values in flight.</td>
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<td>(c) There should be means to avoid maximum load factor exceedance in all operational modes, including manual direct mode where applicable (e.g. warning systems to the operator or load envelope protections as per UL.57 and UL.58). If such design features are not provided, an adequate proof factor of safety &gt;1.0 should be agreed by the Certifying Authority, and applied to all PSEs to prove that detrimental deformation will not occur.</td>
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<td>UL.5.3  Gust loads</td>
<td>The UA must be designed to withstand loads at each critical airspeed including hovering.</td>
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<td>Gust values should be determined by rational analysis of the intended use of the UA, considering the design operational altitude level and the cruise speed (consistent with the design usage spectrum defined in UL.0). In absence of an alternative compelling rationale, the following should be used; the loads resulting from a vertical gust of 9.1 m/s (30 ft/s)</td>
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<td>Potential limitations may be established, where applicable, and documented in operating manuals, taking due account of the design usage spectrum as per UL.0.</td>
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<td>UL.5.4  Recovery with parachute (for applications with normal parachute landing operations)</td>
<td>- The loads during recovery phase due to deployment of the parachute and consequent aerodynamic and inertial loads from the worst operational condition of weight and flight envelope must be determined.</td>
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<tr>
<td><strong>UL5.5.</strong> Recovery with parachute (for applications in which parachute recovery is an emergency condition only) – The loads due to deployment of the parachute and consequent aerodynamic and inertial loads from the worst operational condition of weight and flight envelope must be determined as an ultimate condition only.</td>
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<tr>
<td><strong>UL5.6.</strong> Resultant manoeuvring loads</td>
<td>The loads resulting from the application of manoeuvring load factors are assumed to act at the centre of each vertical lifting element(s) hub and each auxiliary lifting surface, and to act in directions, and with distributions of load among the vertical lifting element(s) and auxiliary lifting surfaces, so as to represent each critical manoeuvring condition, including power-on and (where applicable) power-off flight with the maximum design vertical lifting element(s) tip speed ratio. The vertical lifting element(s) tip speed ratio is the ratio of the UA flight velocity component in the plane of the vertical lifting element(s) disc to the rotational tip speed of the vertical lifting element(s) blades, and is expressed as follows: $\mu = V \cos \alpha \Omega R$ where -</td>
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<td></td>
<td>$V = \text{The airspeed along the flight path (m/s);}$</td>
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<td></td>
<td>$\alpha = \text{The angle between the projection, in the plane of symmetry, of the axis of no feathering and a line perpendicular to the flight path (radians, positive when the axis is pointing aft)};$</td>
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<td>$\Omega = \text{The angular velocity of the vertical lifting element(s) (radians per second); and}$</td>
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<td>$R = \text{The vertical lifting element(s) radius (m).}$</td>
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<tr>
<td><strong>UL5.7.</strong> Yawing conditions</td>
<td>(a) Each UA must be designed for the loads resulting from the manoeuvres specified in subparagraphs (b) and (c) with -</td>
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<td>(1) Unbalanced aerodynamic moments about the centre of gravity which the aircraft reacts to in a rational or conservative manner considering the principal masses furnishing the reacting inertia forces; and</td>
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<td>(2) Maximum main vertical lifting element speed.</td>
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| (b) To produce the load required in sub-paragraph(a), in unaccelerated flight with zero yaw, at forward speed from zero up to 0.6 VNE - | (1) Displace the directional control suddenly to the maximum deflection limited by the control stop or by the FCS.  
(2) Attain a resulting sideslip angle of 90°, whichever is less; and  
(3) Return the directional control suddenly to neutral. | |
| (c) To produce the load required in sub-paragraph (a), in unaccelerated flight with zero yaw, at forward speeds from 0.6 VNE up to VNE or VH, whichever is less - | (1) Displace the–directional control suddenly to the maximum deflection limited by the control stops or by the FCS.  
(2) Attain a resulting sideslip angle of 15°, whichever is less, at the lesser speed of VNE or VH.  
(3) Vary the sideslip angles of sub-paragraphs (b)(2) and (c)(2) directly with speed; and  
(4) Return the directional control suddenly to neutral. | |
| UL5.8. Engine Torque | (a) For turbine engines, the limit torque may not be less than the highest of:  
(1) The mean torque for maximum continuous power multiplied by 1.25;  
(2) The torque required in Annex F.  
(3) The torquè imposed by sudden engine stoppage due to malfunction or structural failure (such as compressor jamming). | |
| (b) For internal combustion engines, the limit torque may not be less than the mean torque for maximum continuous power multiplied by: | (1) 1.33, for engines with five or more cylinders; and  
(2) Two, three, and four, for engines with four, three, and two cylinders, respectively. | |
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<td>(c) For electrical engines, the limit torque may not be less than the mean torque for maximum continuous power multiplied by a factor not less than 1.25</td>
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<tr>
<td><strong>UL5.9</strong> Unsymmetrical loads</td>
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<tr>
<td>(a) Horizontal tail surfaces and their supporting structure must be designed for unsymmetrical loads arising from yawing and vertical lifting element(s) wake effects in combination with the prescribed flight conditions.</td>
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<tr>
<td>(b) To meet the design criteria of sub-paragraph (a), in the absence of more rational data, both of the following must be met:</td>
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<td>(1) 100 % of the maximum loading from the symmetrical flight conditions acts on the surface on one side of the plane of symmetry and no loading acts on the other side.</td>
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<tr>
<td>(2) 50 % of the maximum loading from the symmetrical flight conditions acts on the surface on each side of the plane of symmetry but in opposite directions.</td>
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<td>(c) For empennage arrangements where the horizontal tail surfaces are supported by the vertical tail surfaces, the vertical tail surfaces and supporting structure must be designed for the combined vertical horizontal surface loads resulting from each prescribed flight condition, considered separately. The flight conditions must be selected so the maximum design loads are obtained on each surface. In the absence of more rational data, the unsymmetrical horizontal tail surface loading distributions described in this paragraph must be assumed.</td>
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<tr>
<td><strong>UL5.10</strong> Control System Loads</td>
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<tr>
<td><strong>UL5.10.1</strong> Control System Loads</td>
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<tr>
<td>Each control system including its supporting structure, must be designed as follows:</td>
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<td>(a) The system must withstand loads resulting from the control forces derived from UL5.10.2.</td>
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<td>(b) Notwithstanding sub-paragraph (c) of this section, when power-operated actuator controls or power boost controls are used, the system must also</td>
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<tr>
<td>Withstand the loads resulting from the force output of each normally energized power device, including any single power boost or actuator system failure.</td>
<td><strong>UL5.10.2</strong> Control Forces and Torques</td>
<td></td>
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<tr>
<td>(c) If the system design or the normal operating loads are such that a part of the system cannot react to the forces derived from UL5.10.2, that part of the system must be designed to withstand the maximum loads that can be obtained in normal operation. The minimum design loads must, in any case, provide a rugged system for service use, including consideration of fatigue, jamming, ground gusts, control inertia and friction loads.</td>
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<td>(d) If operational loads may be exceeded through jamming, ground gusts, control inertia, or friction, the system must withstand the control forces derived from UL5.13.2, without yielding.</td>
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<tr>
<td><strong>UL5.10.3</strong> Secondary Flight Control (where applicable)</td>
<td>Secondary flight controls (as defined in ANNEX A.2 Terms and Definitions) must be designed for the maximum forces that the actuating device is likely to apply to those controls. (where applicable)</td>
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<tr>
<td><strong>UL5.10.4</strong> Ground clearance: anti-torque device guard</td>
<td>(a) It must be impossible for any anti-torque device to contact the landing surface during a normal landing.</td>
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<td>(b) If a guard is required to show compliance with sub-paragraph (a) -</td>
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<td>(1) Suitable design loads must be established for the guard; and</td>
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<tr>
<td>(2) The guard and its supporting structure must be designed to withstand those loads.</td>
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<td>ME6 Assumptions and analysis of the design loads on-ground</td>
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<tr>
<td>UL5.11 Any other specific load condition in-flight not included in the previous paragraphs</td>
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<tr>
<td><strong>UL.6 Ground loads and Main Components Requirements</strong></td>
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<tr>
<td>The Applicant must identify all loads that the PSEs must withstand on the ground, considering external forces in equilibrium with inertial forces.</td>
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<tr>
<td><strong>UL6.1 Launch / Catapult (where applicable)</strong></td>
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<td>- For both the launch system and the UA PSEs, determine a longitudinal load corresponding to the maximum continuous load factor applied by the launch system / operator at the maximum and minimum take-off weight.</td>
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<td>- Demonstrate that either the assumptions for launching loads determination are sufficiently conservative or that the acceleration and the rate of change of acceleration (jerk) imposed by the launcher are controlled such that the UAS does not sustain damage during launch.</td>
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<tr>
<td><strong>UL6.2 Landing impact at the maximum design weight</strong></td>
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<tr>
<td>Taking into account the specific design usage spectrum as per UL.0, the worst combination of loads corresponding to all the reasonably possible scenarios of impact in the landing phase must be determined. For conventional landing gear configurations see Annex B as a reference.</td>
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<tr>
<td><strong>UL6.3 General, Ground Loads</strong></td>
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<tr>
<td>(a) Loads and equilibrium. For ground loads-</td>
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<tr>
<td>(1) The ground loads obtained in the landing conditions in this paragraph must be considered to be external loads that would occur in the UA structure if it were acting as a rigid body; and</td>
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<tr>
<td>(2) In each specified landing condition, the external loads must be placed in equilibrium with linear and angular inertia loads in a rational or conservative manner.</td>
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<td>(b) Critical centres of gravity. The critical centres of gravity within the range for which certification is requested must be selected so that the maximum design loads are obtained in each landing gear element.</td>
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<tr>
<td>UL6.4 Ground loading conditions and assumptions</td>
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<tr>
<td>(a) For specified landing conditions, a design maximum weight must be used that is not less than the maximum weight. Vertical lifting element(s) lift may be assumed to act through the centre of gravity throughout the landing impact. This lift may not exceed two-thirds of the design maximum weight.</td>
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<td>(b) Unless otherwise prescribed, for each specified landing condition, the UA must be designed for a limit load factor of not less than the limit inertia load factor substantiated under ANNEX B.</td>
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<tr>
<td>UL6.5 Any other specific load condition on ground not included in the previous paragraphs, such as landing gears with skids or ski operation, or load conditions on water operation such as float landing conditions, as agreed with the Certifying Authority. as per (CS-VLR may be used as a guide).</td>
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<td>UL6.6 Vertical lifting element(s) structure</td>
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<td>(a) Each main vertical lifting assembly (including but not limited to assembly of rotating components which may include the vertical lifting element(s) hub, blades, blade dampers, pitch control mechanisms, and all other parts which rotate with the assembly) must be designed as prescribed in this paragraph.</td>
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<td>(b) (Reserved)</td>
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<td>(c) The vertical lifting element structure must be designed to withstand the manoeuvring load factor and the design gust loading conditions.</td>
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<td>(1) Critical flight loads.</td>
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<td>(2) Loads occurring under normal conditions of autorotation (if implemented). For this condition, the vertical lifting element rpm must be selected to include the effects of altitude.</td>
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<td>(d) The main vertical lifting element structure must be designed to withstand loads</td>
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<td>simulating -</td>
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<td>(1) For the vertical lifting elements (e.g. for rotorcraft, blades, hubs, and flapping hinges), the impact force of each lifting element surface against its stop during ground operation; and</td>
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<td>(2) Any other critical condition expected in normal operation.</td>
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<td>(e) Each vertical lifting element structure must be designed to withstand the limit torque at any rotational speed including zero. In addition -</td>
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<td>(1) The limit torque need not be greater than the torque defined by a torque limiting device (where provided), and may not be less than the greater of -</td>
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<td>(ii) The limit engine torque specified in UL.5.8.</td>
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<tr>
<td>(2) The limit torque must be distributed to the vertical lifting element surfaces in a rational manner.</td>
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<tr>
<td>UL6.7 Fuselage, landing gear, and vertical lifting element pylon structures</td>
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<tr>
<td>(a) Each fuselage, landing gear, and vertical lifting element pylon structure must be designed as prescribed in this paragraph. Resultant vertical lifting element forces may be represented as a single force applied at the vertical lifting element hub attachment point.</td>
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<tr>
<td>(b) Each structure must be designed to withstand the applicable flight and ground loads as prescribed in sections UL.5 and UL.6.</td>
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<td>(c) Auxiliary vertical lifting element thrust, and the balancing air and inertia loads occurring under accelerated flight conditions, must be considered.</td>
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<tr>
<td>(d) Each engine mount and adjacent fuselage structure must be designed to withstand the loads occurring under accelerated flight and landing conditions, including engine torque.</td>
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<td>ER.1.1.1.2 Where applicable to the system, consideration must be</td>
<td>N/A</td>
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<td>given to the loads and likely failures induced by emergency landings either on land or water.</td>
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| ER.1.1.1.3 Dynamic effects must be covered in the structural response to these loads. | UL.7 Structural dynamic load response –  
UL.7.1 The airframe and dynamic components (e.g. rotors, transmissions, drive shafts, gearboxes) should be monitored in flight tests and ground tests in order to assess whether the dynamic response to flight and ground loads is relevant, or not, be as agreed by the Certifying Authority. If the dynamic contribution in flight or ground operations is shown to be relevant, a dynamic response analysis should be performed using the most significant dynamic loading conditions.  
UL 7.2 For dynamic components (e.g. rotors, transmissions, drive shafts, gearboxes) a dynamic response should be performed using the most significant dynamic loading conditions.  | ME7 A combination of tests and analyses |
| ER.1.1.2 The UA must be free from any aero–servo–elastic instability and excessive vibration. | UL.8 Aeroservoelastic effects and Excessive vibration – A rational compelling set of arguments must be provided to the satisfaction of the Certifying Authority, in order to show that the UA is free from flutter, control reversal, divergence and excessive vibration under each appropriate speed and power condition in all configurations.  
Simplified analytical or computational conservative methods may be used.  
The UA must be free from excessive airframe vibrations, flutter, or control divergence at any speed within the design usage spectrum as per UL.0. | ME8 A combination of assumptions, tests and analyses |
| ER.1.1.3 The manufacturing processes and materials used in the construction of the UA must result in known and reproducible structural properties. Any changes in material performance related to the operational environment must be accounted for. | UL.9 The Applicant must identify the material allowables used in structure design, so that no structural part is under strength as a result of material variations or load concentration.  
UL9.1 The sources for material allowables determination must be declared and be as agreed by the Certifying Authority.  
UL9.2 The following criteria in choosing material allowables should be used.  
- Where applied loads are eventually distributed through a single member within an assembly, the failure of which would result in the loss of the structural integrity of the component involved, the guaranteed minimum design mechanical properties (‘A’ values - | ME9 Description of the used materials and their allowables. Evidence of compliance could be given in the Design Criteria of ME1. |
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<td>value above which at least 99% of the population of values is expected to fall with a confidence of 95%) should be met.</td>
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<td>- Redundant structures, in which the failure of the individual elements would result in applied loads being safely distributed to other load carrying members, may be designed on the basis of the 90% probability values (‘B’ basis).</td>
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<td>- When the Applicant is unable to provide satisfactory statistical justification for A and B values, especially in the case of manufacturing of composite materials, an additional safety super factor should be applied to ensure that A/B values are met. Material properties handbooks like MMPDS-03, CMH-17 could be used.</td>
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<td>UL9.3 Where temperature and moisture have significant effects on the material strength capabilities (e.g. composites), the allowable design values must be considered in the worst operational conditions (see also UL 2.4).</td>
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<td>UL 10 The Applicant must identify the materials and manufacturing processes used in the construction of the UA and the criteria implemented to control materials performance variability among specimens. Manufactured parts, assemblies, and the complete UAS must be produced in accordance with the manufacturer’s Quality Management System, approved as per AS/EN-9100 certification or equivalent.</td>
<td>ME10 AS/EN-9100 Certification or equivalent.</td>
<td></td>
</tr>
<tr>
<td>ER.1.1.4 The effects of cyclic loading, environmental degradation, accidental, and discrete source damage must not reduce the structural integrity below an acceptable residual strength level. All necessary instructions for ensuring continued airworthiness in this regard must be promulgated.</td>
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<tr>
<td>UL 11 Fatigue</td>
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<tr>
<td>UL 11.1 Fatigue evaluation of flight structure</td>
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</tr>
<tr>
<td>(a) General. Each portion of the flight structure (the flight structure includes vertical lifting element(s), vertical lifting element(s) drive systems between the engines and the vertical lifting element(s) hubs, controls, fuselage, landing gear and their related primary attachments) the failure of which could be catastrophic, must be identified and must be evaluated in subparagraph b). The following apply to each fatigue evaluation:</td>
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<tr>
<td>(1) The procedure for the evaluation must be approved.</td>
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<tr>
<td>(2) The locations of probable failure must be determined.</td>
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<tr>
<td>(3) In-flight measurement must be included in determining the following:</td>
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</table>

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<table>
<thead>
<tr>
<th>AIRWORTHINESS ESSENTIAL REQUIREMENTS</th>
<th>MEANS OF COMPLIANCE</th>
<th>MEANS OF EVIDENCE</th>
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</thead>
<tbody>
<tr>
<td>(i) Loads or stresses in all critical conditions throughout the range of limitations in UL.2.8, except that manoeuvring load factors need not exceed the maximum values expected in operation.</td>
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<tr>
<td>(ii) The effect of altitude upon these loads or stresses.</td>
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<tr>
<td>(4) The loading spectra must be as severe as those expected in operation including ground-air-ground cycles. The loading spectra must be based on loads or stresses determined in sub-paragraph (a) (3).</td>
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<tr>
<td>(b) Fatigue tolerance evaluation. It must be shown that the fatigue tolerance of the structure ensures that the probability of catastrophic fatigue failure is extremely remote without establishing replacement times, inspection intervals or other procedures and listed in the instructions for continued airworthiness (see UL.39).</td>
<td></td>
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<tr>
<td>(c) Replacement time evaluation. It must be shown that the probability of catastrophic fatigue failure is extremely remote within a replacement time furnished in the instructions for continued airworthiness under the “airworthiness limitations” paragraph.</td>
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</tr>
</tbody>
</table>

**UL 11.2** The structure must be designed, as far as practicable, to avoid points of stress concentration where variable stresses above the fatigue limit are likely to occur in normal service.

**UL 11.3** There must be sufficient evidence that PSEs have strength capabilities to achieve an adequate safe-life.

**UL 11.3.1** For Aluminium and Steel Alloys, the use of stress levels less than half of the rupture tensile strength may be taken as sufficient evidence, in conjunction with good design practices to eliminate stress concentrations, that structural items have adequate safe-livés.

**UL 11.3.2** For wood, ANC-18 should be used as a reference.

**UL 11.3.3** For Composite materials, the use of strain levels compatible with the no-growth criterion for the Damage Tolerance (as per UL13.1.1 or UL13.1.2) may be taken as sufficient evidence, in conjunction with good design precautions to avoid the local...
<table>
<thead>
<tr>
<th>AIRWORTHINESS ESSENTIAL REQUIREMENTS</th>
<th>MEANS OF COMPLIANCE</th>
<th>MEANS OF EVIDENCE</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>development of out-of-plane stresses(^2), that structural items have adequate safe-lives.</td>
<td></td>
</tr>
<tr>
<td>UL.12 Protection of the structure against weathering, corrosion and wear, as well as suitable ventilation and drainage, must be provided as required.</td>
<td>ME12 Description of protection criteria against environmental degradation and corresponding inspection and test where applicable</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UL.13 The Applicant must identify all reasonable accidental and discrete sources of damage relevant for the operational conditions and determine protection design features for each of them.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UL13.1 Impact damage on composite PSEs</td>
<td></td>
</tr>
<tr>
<td>For composite PSEs, it must be shown that delamination or barely visible flaws related to impact damages realistically expected from manufacturing and service will not reduce the structural strength below ultimate load capability and will not grow.</td>
<td></td>
</tr>
<tr>
<td>The following alternative arguments are acceptable means to comply with this requirement.</td>
<td></td>
</tr>
<tr>
<td>UL13.1.1 For composite PSEs, a special factor ( \geq 6.0 ) multiplying the factor of safety of UL.2.3 could be used.</td>
<td></td>
</tr>
<tr>
<td>To demonstrate strength and damage tolerance for damaged critical design features the Certifying Authority may require tests at detail, sub-component or component levels.</td>
<td></td>
</tr>
<tr>
<td>UL13.1.2 Composite PSE parts could be designed not to exceed the following Damage Tolerance Strains:</td>
<td></td>
</tr>
<tr>
<td>Loading</td>
<td>Damage Tolerance Strain(( \mu ))</td>
</tr>
</tbody>
</table>

\(^2\) Corners, ply drop-off, stringer run-outs are of primary importance.

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To demonstrate strength and damage tolerance for damaged critical design features, the Certifying Authority may require tests at detailed sub-component or component levels.

This allowable strain must be used in absence of a compelling argument in the choice of allowables in composite material, taking into account reduction of strength capabilities down to barely visible impact damage strength after impact.

Note - The damage tolerance strain values in the above table should only be used if the degradation of Hot Wet (HW) properties is less than 50% of the Room Temperature Dry (RTD) properties. Otherwise, a safety factor of 6.0 should be used.

Note - The above strain values may be increased if the Applicant shows by other evidence (e.g. analytical evidence; analysis with a representative composite material; specimen tests; repeated landing demonstration test in conjunction with composite inspections) that the typical damages within the design usage spectrum have no negative influence on the composite structure, including the consideration of material properties, possible impact zones, and protection layers, etc.

UL13.2 Bird strike

Bird strike protection for the UA must be as agreed by the Certifying Authority, according to the intended UA size, use and technological constraints.

The UA should be designed so that the impact with a 0.2kg bird does not result in a catastrophic event at any speed within the design usage spectrum.

UL.14 The designed configuration must provide accessibility for PSEs and control system inspection, adjustment, maintenance and repair, where necessary.

ME14 Description of accessibility provisions and corresponding
<table>
<thead>
<tr>
<th>UL. 15</th>
<th>The Applicant must promulgate all necessary instructions for ensuring continued airworthiness.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME15</td>
<td>Set of instructions for continued airworthiness to be provided in the operational manuals.</td>
</tr>
</tbody>
</table>
ER.1.2 Propulsion and Electrical Power

The integrity of the propulsion system (i.e. engine and, where appropriate, vertical lifting elements) and electrical power system must be demonstrated throughout, and by a defined margin beyond, the operational envelope of the propulsion and electrical power system and must be maintained for the operational life of the propulsion and electrical system.

<table>
<thead>
<tr>
<th>UL.16</th>
<th>Engine and drive systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL16.1 For spark and compression ignition engines, the installed engine must comply with the requirements of Annex C, be as agreed by the Certifying Authority. For electric engines, the installed engine must comply with the requirements of Annex D, be as agreed by the Certifying Authority. For turbine engines, the installed engine must comply with the requirements of Annex E, be as agreed by the Certifying Authority.</td>
<td></td>
</tr>
<tr>
<td>UL16.2 The installation must provide accessibility for servicing, inspection and maintenance.</td>
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</tbody>
</table>
| UL16.3 The fire hazard must be assessed as per UL.30. If the fire hazard risk is not compliant with the hazard reference system:  
- detection means should be installed, on–board, and warnings provided in the UCS / UCB so that the operator can take appropriate actions;  
- a fire expansion assessment should be conducted in order to evaluate time for fire propagation to catastrophic event;  
- the operating manuals must contain procedures following a fire detection. |

UL16.4 Engine and Drive System Cooling Fan

(a) The engine must meet the requirement of UL18.4 and the specifications of Annex C or D or E.

(b) Engine or drive system cooling fan blade protection.

(1) If an engine or vertical lifting element(s) drive system cooling fan is installed, there must be a means to protect the UA and allow a safe landing if a fan blade fails. This must be shown by showing that –

(i) The fan blades are contained in case of failure;

(ii) Each fan is located so that a failure will not jeopardise safety; or

(iii) Each fan blade can withstand an ultimate load of 1.5 times the centrifugal force resulting from operation limited by the following:

(A) For fans driven directly by the engine -

ME16 Declaration of compliance by the Engine Manufacturer, together with the complete set of compliance evidence Safety Assessment Report Where necessary, description of fire detection and warning system and description of the procedure to take in case fire, together with fire expansion analysis or test
(aa) The terminal engine r.p.m. under uncontrolled conditions; or
(ab) An over-speed limiting device.

(B) For fans driven by the vertical lifting element(s) drive system, the maximum vertical lifting element(s) drive system rotational speed to be expected in service, including transients.

(2) Unless a fatigue evaluation under UL.11 is conducted, it must be shown that cooling fan blades are not operating at resonant conditions within the operating limits of the UA.

UL16.5 Engine vibration

(a) The engine must be installed to prevent the harmful vibration of any part of the engine or UA.

(b) The addition of the vertical lifting element(s) and the vertical lifting element(s) drive system to the engine must not subject the principle rotating parts of the engine to excessive vibrations or vibration stresses. (see Annex C, D or E as applicable).

(c) No part of the vertical lifting element(s) drive system may be subjected to excessive vibration stresses.
UL.17 Vertical Lift Elements.

For rotorcraft designed VTOL the installed rotor drive system must comply with the requirements of Annex F.

UL.17.1 If autorotation capability is implemented for a powered vertical lift UA or for multi-engine powered vertical lift UA. Where MEi capability is implemented: and the autorotation and/or MEi capability relies on a system to disengage a failed engine or engines from the rotor/fan drive system, then activation of the unit must be automatic, unless it can be demonstrated that autorotation capability or continued safe flight are not adversely impacted by the inoperative engine.

UL.17.1.1 If autorotation capability is implemented, each lift drive system must be arranged so that each vertical lifting element necessary for control in autorotation will continue to operate after failure of the engine(s).

(a) Each lift drive system must be arranged so that each vertical lifting element necessary for control in autorotation will continue to operate after failure of the engine(s).

UL.17.2 If a torque limiting device is used in the lifting drive system, it must be located so as to allow continued control of the UA when the device is operating. If a torque limiting device is used in any Vertical Lifting drive system, it must allow continued control of the UA when the device is operating.

UL.17.3 Vertical lifting element(s) Rotor/Fan brake: If there is a means to control the rotation of the drive system independently of the engine, any limitations on the use of that means must be specified, and the control for that means must be guarded to prevent inadvertent operation.

Rotor brake

If there is a means to control the rotation of the rotor drive system independently of the engine, any limitations on the use of that means must be specified, and the control for that means must be guarded to prevent inadvertent operation.

Additionally the associated limitation and controls must be in compliance with the design operational limitation.

UL.17.4 Vertical lifting element(s) Rotor/Fan brake controls

(a) It must be impossible to apply the vertical lifting element(s)/fan brake inadvertently in flight.

(b) There must be means to warn the crew if the vertical lifting element(s) brake has not been completely released before take-off.
### UL17.5 Rotor/Fan brake

Any relevant limitations on the use of a rotor brake if they are installed must be specified clearly to the UA crew in the control station.

### UL17.6 Main vertical lifting element(s) speed and pitch limits

(a) **Main vertical lifting element(s) speed limits.** A range of main vertical lifting element(s) speeds must be established so that:

1. With power-on, provides adequate margin to accommodate the variations in vertical lifting element(s) speed occurring in any appropriate manoeuvre, and is consistent with the kind of governor or synchronizer used; and
2. With power-off, if autorotation capability is implemented, allows each appropriate autorotative manoeuvre to be performed throughout the ranges of airspeed, altitude and weight for which certification is requested.

(b) **Normal main vertical lifting element(s) high pitch limits (power-on).** For Light VTOL UAV, except Light Helicopter UAV required to have a main vertical lifting element(s) low speed warning under subparagraph (e), it must be shown, with power-on and without exceeding approved engine maximum limitations that main vertical lifting element(s) speeds substantially less than the minimum approved main vertical lifting element(s) speed will not occur under any sustained flight condition. This must be met by:

1. Appropriate setting of the main vertical lifting element(s) (i.e. rotor, etc.) high pitch stop; or
2. Adequate means to prevent unsafe main vertical lifting element(s) speeds.

(c) **Normal main vertical lifting element(s) low pitch limits (power-off).** If autorotation capability is implemented, it must be shown, with power-off, that:

1. The normal main vertical lifting element(s) low pitch limit provides sufficient vertical lifting element(s) speed, in any autorotative condition, under the most critical combinations of weight and airspeed; and
2. Overspeeding of the vertical lifting element(s) is protected by the flight control system in compliance with UL 58.
(d) Emergency high pitch. If the main vertical lifting element(s) high pitch stop is set to meet subparagraph (b) (1), and if that stop cannot be exceeded in normal mode, additional pitch may be made available for emergency use.

(e) Main rotor low speed warning for Light Helicopter UAVs. For each single-engine Light Helicopter UAV, and each multi-engine Light Helicopter UAV that does not have an approved device that automatically increases power on the operating engines when one engine fails, there must be a main rotor low speed warning which meets the following requirements:

1. The warning must be furnished to the operator in the Light VTOL UAV control station in all flight conditions, including power-on flight and, if autorotation capability is implemented, power-off flight when the speed of a main rotor approaches a value that can jeopardize safe flight.

2. The warning must be clear and distinct under all conditions, and must be clearly distinguishable from all other warnings. A visual device that requires the attention of the operator is not acceptable by itself.

3. If a warning device is used, the device must automatically de-activate and reset when the low-speed condition is corrected. If the device has an audible warning, it must also be equipped with a means for the operator to manually silence the audible warning before the low-speed condition is corrected.

**ER.1.2.1** The propulsion system must produce, within its stated limits, the thrust or power demanded of it at all required flight conditions, taking into account environmental effects and conditions.

**UL.18 Propulsion system compatibility**

**UL18.1 NOT USED**

**UL18.2** The installation must comply with the instructions provided by the engine and Vertical Lifting Elements manufacturers (see UL.RE.1, UL.EE.1, UL.TE.1 and UL.P.1).

**UL18.3** Performance compatibility between UA design usage spectrum requirements identified in UL.0 and the engine and Vertical Lifting Elements limits verified under UL.16, UL.17, must be assured. Flight demonstration should be performed at the more severe and demanding operating conditions.

**UL18.4** Environmental compatibility between UA design usage spectrum requirements identified in UL.0 and the engine and Vertical Lifting Elements limits verified under UL.16, UL.17, must be assured. In particular, UA power-plant cooling provisions must maintain the temperatures of propulsion system components and engine fluids within the temperature limits established by

**ME18 Description of requirements compatibility, analyses, ground and flight test evidence be as agreed by the Certifying Authority**
the engine manufacturer during all likely operating conditions. Flight demonstrations should be performed at the more severe and demanding operating conditions.

**UL18.5 Air inlet**

**UL18.5.1 Air induction (for reciprocating engine applications)**

- The air induction system must supply the air required by the engine under the operating conditions defined in UL.0.
- If operating conditions defined in UL.0 specify operations in icing conditions, then the air-induction system must have means to prevent and eliminate icing.

**UL18.5.2 Air inlet (for turbine engine applications)**

- The installation of turbine engine must be compatible with maximum distortion limits allowed by the engine.
- There must be means to prevent hazardous quantities of fuel leakage or overflow from drains, vents or other components of flammable fluid systems from entering the engine intake system.
- The air intake duct should be located or protected so as to minimize foreign objects ingestion in hazardous quantity during take-off, landing and taxiing.

**UL18.6 The exhaust system (where applicable) must ensure safe disposal of exhaust gases without posing a fire hazard to the UA.**

**UL18.7 Not Applicable**

**UL18.8 Pressure venting and drainage of vertical lifting elements and blades should be considered where design and construction introduce these factors.**

(a) For each vertical lifting element and blades -

(1) There should be means for venting the internal pressure of the vertical lifting elements and blades;

(2) Drainage holes must be provided for the vertical lifting elements and blades; and

(3) The vertical lifting elements and blades must be designed to prevent water from becoming trapped in it.

(b) Sub-paragraphs (a) (1) and (2) do not apply to sealed capable of withstanding the maximum pressure differentials expected in service.
UL18.9 Mass balance
- The vertical lifting element(s) and blades must be mass balanced as necessary to -
  (a) Prevent excessive vibration; and
  (b) Prevent flutter at any speed up to the maximum forward speed.
- The structural integrity of the mass balance installation must be substantiated.

UL18.10 Vertical lifting element(s) blade clearance
There must be enough clearance between the vertical lifting element(s) blades and other parts of the structure to prevent the blades from striking any part of the structure during any operating condition.

UL18.11 Ground resonance prevention means
(a) The UA may have no dangerous tendency to oscillate on the ground with the vertical lifting element(s) turning.
(b) The reliability of the means for preventing ground resonance must be shown either by analysis and tests, or reliable service experience, or by showing through analysis or tests that malfunction or failure of a single means will not cause ground resonance.
(c) The probable range of variations, during service, of the damping action of the ground resonance prevention means must be established and must be investigated during the test required by (a) of UL18.11.

UL18.12 Low Cycle Fatigue (LCF) and temperature considerations: The Applicant must demonstrate sufficient LCF margin where Catastrophic or Hazardous conditions are a result of a failure of the propulsion system.

ER.1.2.2 The fabrication process and materials used in the construction of the propulsion system must result in known and reproducible structural behaviour. Any changes in material performance related to the

This Essential Requirement is met by compliance with UL.16 and UL.17.
operational environment must be accounted for.

**ER.1.2.3** The effects of cyclic loading, environmental and operational degradation and likely subsequent part failures must not reduce the integrity of the propulsion system below acceptable levels. All necessary instructions for ensuring continued airworthiness in this regard must be promulgated.

*This Essential Requirement is met by compliance with UL.16 and UL.17.*

**ER.1.2.4** All necessary instructions, information and requirements for the safe and correct interface between the propulsion system and the UA must be promulgated.

*This Essential Requirement is met by compliance with UL.16 and UL.17.*

**ER.1.2.5 Fuel and Electrical Power system**

The engine must be safely fed by the quantity of fuel required to perform the UA missions it is certified for. The electrical power system must safely provide the electrical power required to perform the UA missions it is certified for.

**UL.19 Fuel system**

- **UL19.1** The fuel system must be able to provide the necessary fuel flow at the necessary conditions required by the engine(s) throughout the operational envelope, under the most critical conditions.

- **UL19.2** The unusable fuel quantity for each tank must be established by test and must not be less than the quantity at which the first evidence of engine fuel starvation occurs under each intended flight operation and manoeuvre.

- **UL19.3** Tanks must be protected against wear from vibrations, and their installation must be able to withstand the applicable inertial loads.

- **UL19.4** Fuel tanks and associated supporting structure should be designed to withstand the pressure developed during maximum ultimate acceleration with a full tank.

- **UL19.5** Fire hazard related to fuel vapour accumulation in the tank zone must be minimized (e.g. each tank should be vented).

**ME19 Description and tests of the fuel system.**
UL19.6 There must be means to ensure the engine is fed with fuel meeting the engine manufacturer specification with respect to the maximum acceptable level of contaminants and water (e.g. safe drainage to remove water and contaminants; a fuel strainer or filter accessible for cleaning and replacement).

UL19.7 The fuel lines must be properly supported and protected from vibrations and wear.

UL19.8 Fuel lines located in an area subject to high heat (engine compartments) must be fire-resistant or protected with a fire-resistant covering.

UL19.9 Depending on the safety analysis results, the possibility of introducing a fuel shutoff valve which can be activated by the remote operator should be considered (e.g. taking into account engine fire risk, shutoff valve failure effects, temperature sensor failure effects, etc.).

UL19.10 The maximum exposed surface temperature of any component in the fuel tank must be less, by a safe margin, than the lowest expected auto-ignition temperature of the fuel or fuel vapour in the tank. Compliance with this requirement must be shown under all operating and all failure or malfunction conditions of all components inside the tank.

UL19.11 The fuel system design must take into account the following:

a. Possible sources of ignition including electrical faults, over-heating of equipment and the malfunction of protective devices
b. Possible sources and paths of fluid leakage and means of detecting leakage.
c. Flammability characteristics of fluids, including effects of any combustible or absorbing materials.

UL 20 Electric Power

UL 20.1 Electrical system

UL 20.1.1 The electrical power subsystem must be able to provide the necessary voltage and current required by the engine and electrical equipment throughout the operational envelope. An electrical Load Analysis should be provided.

UL 20.1.2 The electrical system should include overload protection devices (fuses or circuit breakers), a failure warning system and enough power to meet peak load.

UL 20.1.3 Electrical bonding should be guaranteed be installed in accordance with standard aerospace practices, (e.g. STANAG 3659 or equivalent can be used as a guideline).

ME20 Description and tests of the battery.
UL.20.1.4 The electrical wiring should be installed in accordance with standard aerospace practices, SAE AS50881 or equivalent can be used as a guideline.

UL.20.1.5 The electrical system should be installed such that the risk from mechanical damage and/or damage caused by fluids, vapours, or sources of heat, is minimized.

UL.20.1.6 The power subsystem must include a voltage sensor.

UL.20.1.7 There must be a master switch or switches arranged to allow ready disconnection of all electric power sources. The point of disconnection must be adjacent to the sources controlled by the switch.

UL.20.1.8 The electrical System must be designed that the risk of electrical shock is reduced to a minimum.

UL.20.2 Battery System

UL.20.2.1 The battery installation must be able to withstand the applicable inertial loads.

UL.20.2.2 The installation provisions, the environment and the intended usage of all batteries must meet all performance, operating and safety requirements established by the battery manufacturer.

UL.20.2.3 There must be means to minimize the risk of battery overheating/explosion (e.g. cooling, temperature sensor, active battery management system).

UL.20.2.4 A minimum voltage threshold that indicates low remaining capacity must be determined in the worst environmental conditions. A low battery warning must be provided in the UCS/UCB in order to alert the UA operator that the battery has discharged to a level which requires immediate UA recovery actions. The procedure to be followed in case of low battery warning must be established and provided in the Flight Manual.

UL.20.2.5 The battery pack charger must be considered part of the UAS. The charger must have indicators for fault and charging status.

UL.20.2.6 Information concerning battery storage, operation, handling, maintenance, safety limitations and battery health conditions must be provided in the applicable manuals.

UL.20.2.7 Saltwater compatibility must be considered (where applicable) as per UL.0.

UL.20.2.8 For rechargeable Lithium batteries, installed separately or in avionics equipment aboard aircraft, RTCA-DO-311 (or equivalent, as agreed by the Certifying Authority) must be
ER.1.3 Systems and equipment

ER.1.3.1 The UAS must not have design features or details that experience has shown to be hazardous in their intended application.

| UL.21 | The Applicant should substantiate that the design criteria are either derived from standard aerospace practices or that novel design criteria are based on sound engineering principles. As examples:  
|       | - positive drainage of moisture should be provided wherever necessary (e.g. static pressure measuring devices);  
|       | - drainage and venting should be provided where flammable fluid vapour may accumulate; |
| ME21  | Design criteria (see ME1) |
| UL.22 | See UL.65. |
| ME22  | Description of the safety tracking system |
| UL.23 | Flight test experience must be accumulated before Type Certification, exploring the complete design usage spectrum as per UL.0, in order to provide a sufficient level of confidence to the Certifying Authority. The flight test campaign plan must be provided to the Certifying Authority. Any technical events that occur during this flight test experience must be reported, analysed and corrected when necessary. Both the occurrences and their corrective actions must be made available to and accepted by the Certifying Authority. |
| ME23  | Evidence of accumulated flight test activity and problem report tracking. |
ER.1.3.2 The UAS, with those systems, equipment and appliances required for type-certification, or by operating rules (e.g. under operational air traffic (OAT) and general air traffic (GAT)), must function as intended under any foreseeable operating conditions, throughout and by a defined margin beyond the operational envelope of the UAS, taking due account of the system, equipment or appliance operating environment. Other systems, equipment and appliance not required for type-certification, or by operating rules, whether functioning properly or improperly, must not reduce safety and must not adversely affect the proper functioning of any system, equipment or appliance required for type-certification or by operating rules. Systems, equipment and appliances must be operable without needing exceptional skill or strength.

UL.24 Equipment

UL24.1 All equipment required for type-certification or by operating rules must function properly within the design usage spectrum (UL.0), including icing conditions, if required.

UL24.2 Equipment Specification and Declaration of Design and Performance (DDP)

- For all installed equipment the UAS manufacturer should approve its technical specification, in order to assess compatibility with UAS higher-level requirements.
- All equipment should have a Declaration of Design and Performance (DDP), or equivalent, released by its manufacturer and accepted by the UAS manufacturer showing compliance with applicable specifications.

UL24.3 The installation provisions, environment and the intended usage of all equipment must meet all performance, operating and safety limitations to which the equipment is qualified (i.e. it meets its specifications).

UL24.4 The minimum necessary accuracy of each measuring device used to control UA trajectory and to acquire navigation data must be established by the UAS manufacturer and be compatible with UA high-level requirements.

UL24.5 Each measuring device must be calibrated as necessary (e.g. airspeed sensors).

UL24.6 Any equipment whose failure could lead to loss of functions or misleading data with hazardous or catastrophic effects on safety must have fault detection / fault isolation capabilities be as agreed by the Certifying Authority.

A minimum essential set of Built-In-Test (BIT) performance should be included in the design. For example:

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<th>Computers</th>
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<td>Data Link Health</td>
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<td>GPS Receiver</td>
<td>Receiver failure indication from power-up, self-test or background BIT</td>
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<tr>
<td>Motherboards</td>
<td>Under-voltage</td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
</tr>
</tbody>
</table>
UA faults and status information must be transmitted to the UCS/UCB for display to the operator, when the link is available

<table>
<thead>
<tr>
<th>UCS/UCB</th>
<th>Checksum</th>
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<tbody>
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<tr>
<td>Temperature</td>
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</table>

UL.25 Each sub-system of the UA, UCB/UCS, Data-Link, Launch/Recovery equipment (where applicable) and of any other system required for type-certification or by operating rules must function as intended within the design usage spectrum in UL 0.

- Identify all functions of each sub-system.
- Characterize the operational environment of each sub-system.
- Perform all necessary functional tests at sub-system level.
- Perform all necessary environmental tests (e.g. vibration, humidity, EMC/HIRF, etc.).
- Show that the operation of any sub-system or item of installed equipment not required for type-certification or by operating rules does not reduce safety and it is installed in a way that does not adversely affect the proper functioning of those sub-systems or items of installed equipment required for type-certification or by operating rules.

The test plans must be provided to the Certifying Authority. Test plans must include, but not limited to: test objectives, applicable standards/specifications, test article description, test description, test instrumentation, test condition, test acceptance criteria.

UL.26 Command and control data link subsystem

A UAS must include a command and control data link (such as a radio-frequency link) for control of the UA with the following functions.

- transmittal of UA crew commands from the UCS/UCB to the UA (uplink), and

ME25 Functional and environmental tests.

ME26 Functional tests + EMI/EMC test.
UL26.1 The command and control data link must be electromagnetically compatible (EMC) with other UCS/UCB and UA equipment, protected against electromagnetic interference (EMI).

UL26.2 Data link performance:
- the effective maximum range for the full range of operating altitudes must be determined and provided to the operator in the operating manual;
- latencies must be determined and provided to the operator in the operating manuals as a function of all relevant conditions; these latencies must not lead to an unsafe condition in any FCS operating mode (including manual direct piloting conditions, where applicable);
- performing a transfer of the UA command and control from one data link channel to another channel within the same UCS/UCB must not lead to an unsafe condition;
- minimum information to be provided to the UCS/UCB display is in UL.32;
- warning cues should be provided to alert the operator of detrimental degradation in data link capabilities (e.g. approaching antenna masking attitudes where applicable, approaching external interfering antennas, approaching maximum data link range, etc.) in order to prevent potential total loss of the data link.
- The capacity of the data link must be determined to provide an acceptable safety margin under the highest usage condition expected as determined by UL.30

UL26.3 In case of data link loss, an automatic reacquisition process must try to re-establish the command and control data link in a time period and with a flight behaviour be as agreed by the Certifying Authority.

In case the reacquisition fails:
- a warning must alert the operator, and the Applicant must specify whether the alert will be audible, visual, or both,
- the alert should sound/be displayed continuously until acknowledged and extinguished,
- A loss strategy must be established and be as agreed by the Certifying Authority. The data link loss strategy must be provided to the operator in the operating manual.

<table>
<thead>
<tr>
<th>UL27 UCS/UCB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UL27.1</strong> UCS/UCB. The UCS/UCB must guarantee correct functioning of all functions necessary to safely accomplish all design missions under all conditions of the design usage spectrum in UL.0, including the performance of emergency and recovery procedures.</td>
</tr>
<tr>
<td><strong>UL27.2</strong> The UCS/UCB must be able to display the minimum information required by UL.32</td>
</tr>
<tr>
<td><strong>UL27.3</strong> UCS/UCB Human-Machine Interface aspects must be designed to facilitate the safe accomplishment of the design missions under all the conditions of the design usage spectrum in UL.0. Particular consideration must be given to the information layout, to the information readability in all external lighting conditions, to aural signals (where applicable) and announcements. The risks of controls interference and misuse of controls must be minimized.</td>
</tr>
<tr>
<td><strong>UL27.4</strong> A communication system should be provided, as agreed by the Certifying Authority in order to allow a two-way communication with the ATC.</td>
</tr>
<tr>
<td><strong>UL27.5</strong> The Data Recorder in the UCS/UCB and/or on the UA, if required, should comply with the following:</td>
</tr>
<tr>
<td>(a) All the data transmitted via the command and control data link is continuously recorded;</td>
</tr>
<tr>
<td>(b) The same data as per UL.32 is recorded;</td>
</tr>
<tr>
<td>(c) The storage capacity of the data recorder should be compatible with recording the maximum duration of flight for which the certification is requested;</td>
</tr>
<tr>
<td>(d) There is an aural or visual means for pre-flight checking of the recorder for proper recording of data in the storage medium;</td>
</tr>
<tr>
<td>(e) A universal time reference signal is recorded. For instance, the GPS time signal can be used for this purpose.</td>
</tr>
<tr>
<td>(f) The data recorder should be designed to prevent unauthorised or unintentional editing;</td>
</tr>
</tbody>
</table>

**ME27** Technical description + Functional tests + Human Machine Interface evaluations.
(g) For UCS/UCB data recorders, the UCS/UCB should provide a function that is able to read the data recorder for post-flight operation;

(h) The recorder container mounted to the UA, if required, must:
   (1) Be either bright orange or bright yellow;
   (2) Have reflective tape affixed to its external surface to facilitate its location under water; and
   (3) Have an underwater locating device, when required by the operating rules, on or adjacent to the container which is secured in such a manner that they are not likely to be separated during crash impact;

(i) On board flight recorder has a means to automatically stop recording immediately after a crash of the UA in order to avoid overwriting of data.

(j) On board flight recorders should comply with EUROCAE ED-112 or ETSO-C124a or any equivalent standard, as approved by the Certifying Authority.

A data recorder should be provided as agreed by the Certifying Authority in order to store a complete typical flight set of data exchanged between the UCS/UCB and the UA in addition to autopilot and operator commands. The same data as per UL.32 should be recorded.

**UL.27.6** UCS/UCB electrical systems (when installed) must be:
- free from both internal and external hazards;
- designed to prevent electrical shock;
- designed to be protected against electrostatic, lightning and EME hazards.

**UL.27.7** The UCS/UCB power supply must be designed such that the operations in normal and failure conditions shall not lead to an unsafe condition; the corresponding minimum UCS power required must be stated in the UAS operating manual.

**UL.28** Payload

**UL28.1** The payload equipment, whether functioning properly or improperly, must not adversely affect the safe flight and control of the UA.

**UL28.2** The payload equipment must be electromagnetically compatible with other UAS components.

**ME28** Evaluation of the effects of payload normal functioning and failures on the other UA sub-systems.
**UL28.3** All potential hazards caused by the payload (including lasers) to crew, ground staff or third parties must be assessed and minimized.

**UL.29** Integration at UAS level

The UA, the UCB / UCS, the Data-Link, Launch/Recovery equipment (where applicable) and any other system required for type-certification or by operating rules must function as intended when operated all together.

**ME29** The evidence given in ME23 may be sufficient, however the Certifying Authority may ask for additional evidence (e.g., integration rig test report).

**ER.1.3.3** The UAS, equipment and associated appliances, including the control station, its data links etc., considered separately and in relation to each other, must be designed such that any catastrophic failure condition does not result from a single failure not shown to be extremely improbable. An inverse relationship must exist between the probability of a failure condition and the severity of its effect on the UA, crew, ground-crew or other third parties. Due allowance must be made for the size and broad configuration of the UAS (including specific military UL.30 A Safety Assessment must be performed for the UAS (including all contributions coming from the UA, UCS/UCB, Data Link and any other equipment necessary to operate the UAS) and submitted to the Certifying Authority, which includes but is not limited to:

- the definition of a Hazard Reference System to be as agreed by the Certifying Authority. (see Annex G);

- A Functional Hazard Assessment (FHA) (see SAE ARP 4761 – “Guidelines and methods for conducting the safety assessment process on civil airborne systems and Equipment” or similar civil or military aviation standard),

- Based on failure conditions identified in FHA, Preliminary System Safety Assessment (PSSA) and System Safety Assessment (SSA) should be conducted to show that the implemented systems meet their safety requirements (see SAE ARP 4761 – “Guidelines and methods for conducting the safety assessment process on civil airborne systems and Equipment” or similar civil or military aviation standard to be agreed by the Certifying Authority). The PSSA and SSA must take into account the complexity of the UAS systems and be agreed with Certifying Authority.

- A Failure Mode Effect and Criticality Analysis (see SAE ARP 4761 – “Guidelines and methods for conducting the safety assessment process on civil airborne systems and Equipment” or similar civil or military aviation standard);

- A Fault Tree Analysis (see SAE ARP 4761 – “Guidelines and methods for conducting the safety assessment process on civil airborne systems and Equipment” or similar civil or military aviation standard) for failure conditions of Catastrophic or Hazardous severity.

**ME30** Safety Assessment Report
systems and operations). This may prevent this single failure criterion from being met for some parts and some systems on helicopters, small or single engine aeroplanes and uninhabited aerial vehicles. (with no persons onboard the aircraft, the airworthiness objective is primarily targeted at the protection of people on the ground).

- Common Cause Analysis (CCA) (see SAE ARP 4761 – “Guidelines and methods for conducting the safety assessment process on civil airborne systems and Equipment” or similar civil or military aviation standard). The CCA must take into account the complexity of the UAS systems and be agreed with Certifying Authority.

**The Safety Assessment must demonstrate compliance with the following.**

**UL30.1** All credible, hazards must be identified and their consequences determined. The associated failure conditions must be determined and classified IAW UL.HRS.1.

**UL30.2** Each failure condition must meet the Hazard Reference System criteria in Annex G, as agreed with the Certifying Authority. Failure conditions that do not comply with these criteria due to state of the art technology and technological constraints shall be submitted to the Certifying Authority and may be accepted on a case by case basis, showing well proven methods for the design and construction and on the basis of appropriate justification (for instance through operational restrictions, through a rationale considering UA weight and or kinetic energy at impact, based upon the risk to UAS crew, ground staff and third parties) and provided their number is reduced to the strict minimum.

**UL30.3** The cumulative probability per flight hour for all catastrophic failure conditions (with all the contribution of all UAS systems and sub-systems, including propulsion, navigation, data-link, UCS/UCB, etc.) must not be greater than the Hazard Reference System cumulative safety requirement (UL.HRS.2) as agreed with the Certifying Authority.

**UL31 Software Development Assurance Levels**

The software integrated in the UAS should perform intended functions with a level of confidence in safety that complies with the following requirements.

**UL31.1** A software safety program should provide software development assurance evidence of safe software engineering (e.g., RTCA/DO-178 for software and RTCA/DO-254 for firmware), and analyse safe use within the context of hardware design (e.g., using guidelines in the US DoD Joint Software System Safety Committee Software System Safety Handbook, MIL-STD-882, and/or STANAG 4404).

**UL31.2** The software life cycle assurance process be as agreed by the Certifying Authority, should be demonstrated with the approach defined in RTCA DO-178/ ED-12 “Software considerations in airborne systems and equipment certification”, for the process objectives and outputs by software level. If equivalent standards are provided, a Plan

**ME31** The minimum software life-cycle data to be submitted to the Certifying Authority are:

a. Software / Hardware architecture and DAL allocation

b. Plan for Software Aspects of Certification

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for Software Airworthiness should be provided and be as agreed by the Certifying Authority, in order to present how the quoted standards will be applied.

**UL31.3**
The Functional Development Assurance Level (FDAL) and Item Development Assurance Level (IDAL) should be based upon contribution to potential failure conditions as determined in the Safety Assessment Process described in UL.30. The FDAL allocation should follow the FDAL Assignment with System Architecture Consideration process described in ARP4754:

<table>
<thead>
<tr>
<th>TOP-LEVEL FAILURE CONDITION CLASSIFICATION</th>
<th>DEVELOPMENT ASSURANCE LEVEL (NOTES 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FUNCTIONAL FAILURE SETS WITH A SINGLE MEMBER</strong></td>
<td><strong>FUNCTIONAL FAILURE SETS WITH MULTIPLE MEMBERS</strong></td>
</tr>
<tr>
<td><strong>Option 1</strong> (NOTE 3)</td>
<td><strong>Option 2</strong></td>
</tr>
<tr>
<td>FDAL B for one Member, additional Member(s) contributing to the top-level Failure Condition at the level associated with the most severe individual effects of an error in their development process for all applicable top-level Failure Conditions</td>
<td>FDAL C for two of the Members leading to top-level Failure Condition. The other Members at the level associated with the most severe individual effects of an error in their development process for all applicable top-level Failure Conditions (but no</td>
</tr>
</tbody>
</table>

Catastrophic

FDAL B (Note 1)
<table>
<thead>
<tr>
<th>Hazardous</th>
<th>FDAL C</th>
<th>Conditions (but no lower than level D for the additional Members).</th>
<th>lower than level D for the additional Members.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td>FDAL C</td>
<td>FDAL C for one Member, additional Member(s) contributing to the top-level Failure Condition at the level associated with the most severe individual effects of an error in their development process for all applicable top-level Failure Conditions (but no lower than level D for the additional Members)</td>
<td>See Note 4</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Minor</th>
<th>FDAL D</th>
<th>FDAL D for one Member, additional Member(s) contributing to the top-level Failure Condition at the level associated with the most severe individual effects of an error in their development process for all applicable top-level Failure Conditions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Safety Effect</td>
<td>FDAL E</td>
<td>FDAL E</td>
</tr>
</tbody>
</table>

NOTE 1: When a FFS has a single Member and the mitigation strategy for systematic errors is to be FDAL B alone, then the applicant may be required to substantiate that the development process for that Member has sufficient independent validation/verification activities, techniques and completion criteria as agreed by the Certifying Authority to ensure that potential development error(s) having a catastrophic effect have been removed or mitigated.

NOTE 2: It is necessary to stay in the same row no matter the number of functional decompositions performed (e.g. for a Catastrophic Failure Condition any degree of decomposition from a top FDAL B FFS should include at least one FDAL B or two FDAL C Members).

NOTE 3: If there is a large disparity on the numerical availability of the Members in the Functional Failure Set, the higher level FDAL should generally be assigned to the higher availability Member.

NOTE 4: Exceptionally, FDAL D for two members leading to the top level failure conditions may be accepted on a case by case basis, as agreed by the certifying authority. The applicant is responsible for providing sufficient evidence to the certifying authority to demonstrate an equivalent level of safety.

Minimum Software Functional Design Assurance Levels

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<table>
<thead>
<tr>
<th>ER.1.3.4 Information needed for the safe conduct of the flight and information concerning unsafe conditions must be provided to the crew, or maintenance personnel, as appropriate, in a clear, consistent and unambiguous manner. Systems, equipment and controls, including signs and announcements must be designed and located to minimise errors which could contribute to the creation of hazards.</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL31.4 In case of new hardware development with use of a PLD (programmable logic device), the development assurance level process should be as agreed by the Certifying Authority, by use of a specific Special Condition.</td>
</tr>
<tr>
<td>UL31.5 The use of legacy software must be as agreed by the Certifying Authority. The Applicant must provide a cross reference comparison between the followed process objectives and the objectives defined by RTCA DO-178 be as agreed by the Certifying Authority. The Applicant must provide an equivalent level of confidence of the legacy software used and the corresponding level required as per UL 30.3.</td>
</tr>
<tr>
<td>UL.32 Depending on the UAS design features complexity, the Applicant must define and be as agreed by the Certifying Authority, the minimum information on the UA (e.g. dangerous areas warnings, basic assembling indications), in the UCS/UCB (e.g. warnings, announcements, flight data, navigation data, power-plant data, other sub-system data) and on any other equipment necessary to operate the UA (e.g. warnings on the antenna apparatus or on the battery charger) to be provided to the UA operator and ground staff in order to allow the safe conduct of operations under the design usage spectrum in UL.0, including the management of the failure conditions which may occur.</td>
</tr>
<tr>
<td>UL32.1 (a) The minimum flight and navigation data that should be displayed at all times in the UCS/UCB at an update rate consistent with safe operation are:</td>
</tr>
<tr>
<td>- indicated airspeed,</td>
</tr>
<tr>
<td>- ground speed,</td>
</tr>
<tr>
<td>- pressure altitude and related altimeter setting,</td>
</tr>
<tr>
<td>- heading; and track,</td>
</tr>
<tr>
<td>- UA position on a map at a scale selectable by the operator;</td>
</tr>
<tr>
<td>- where semi-automatic flight control modes (e.g. altitude hold, heading hold, airspeed hold) are activated, the commanded flight or navigation parameters sent to the UA operator.</td>
</tr>
<tr>
<td>ME32 Description of the minimum information displayed to the operator.</td>
</tr>
</tbody>
</table>
(b) The following are the minimum required flight and navigation data that shall be selectable or available when queried by the UA Crew for display in the UCS/UCB at an update rate consistent with safe operation are:

- airspeed limitations and corresponding speed warnings
- UA attitude,
- vertical speed,
- navigation system status,
- UA position relative to the LOS data link transmitter/receiver displayed in terms of range, bearing and altitude,
- the deviation between the planned ground track and the actual UA flight path (see also UL44.3),
- sideslip angle,
- height above ground,
- g-meter (in order to record exceeding the structural limit in manual direct piloting conditions, where there are no other alternative means to restrict flight loads e.g. FCS).

UL32.2 The minimum propulsion system data that should be displayed in the UCS/UCB at an update rate consistent with safe operation are:

- for reciprocating and turbine engines, information concerning the remaining usable fuel quantity in each tank and the rate of fuel consumption should be provided to the operator,
- for electrical engines, the information concerning the remaining level of battery charge should be provided to the operator,
- a means to indicate engine health status such as engine RPM, engine cylinder head (for internal combustion engines) or exhaust gas (for turbine engines) or case (for electrical engines) temperature, along with corresponding caution and warning alerts when specified minimum and maximum limitations are being approached, reached, and/or exceeded. (e.g. Oil pressure, Low fuel/Battery, Rotor speed,…)
- the rpm for rotating vertical lift elements.
| UL32.3 | As a minimum, information concerning the Data Link system, the strength and integrity (i.e. frame/bit error rate) of the uplink and downlink should be provided and continuously monitored at a refresh rate consistent with safe operation. |
| UL32.4 | The UCS/UCB should include an automatic diagnostic and monitoring capability for the status of the UAS and all monitored subsystems and provide to the UA crew appropriate warning indication, with the following colour codes:  
- red, for warning information (information indicating a hazard which may require immediate corrective action);  
- amber, for caution information (information indicating the possible need for future corrective action);  
- green, for safe operation information. |
| UL33 | The necessary information must be displayed in UCS/UCB in a clear, consistent, unambiguous manner, in such a way that a trained crew of average skill allowed to remotely control the UA is capable of managing any situation (both in normal functioning conditions and in failure conditions) which may occur under UL.0. This should be demonstrated with a representative trained crew of average skill by inspection, simulation and/or flight test.  
The necessary information displayed in UCS/UCB must be visible under all lighting conditions. |
| UL34 | Depending on the complexity of the UAS, the Applicant must define for agreement by the Certifying Authority, and provide the minimum information to be provided on the UA, on the UCS/UCB and on any other equipment necessary to operate the UAS to be given to the maintenance personnel in order to allow the safe conduct of servicing and maintenance operations. (This minimum information must be in accordance with the instructions for continued airworthiness of the UAS of paragraph UL 37). |
| ER.1.3.5 Design precautions must be taken to minimise the hazards to the UAS, crew or other third parties from reasonably probable threats, both inside and external to the UAS, including protecting against the possibility of |
| UL35 | External Threats |
| UL35.1 | The behaviour of the UAS must be determined and demonstrated in all weather conditions as defined in the design usage spectrum per UL.0 (including where applicable rain, hail, lightning, cold weather, hot weather, sand and dust, HIRF, etc.) Design precautions and/or operating limitations must be established in order to minimise hazards to the UAS, the operator or other third parties. |
| ME33 | Demonstration of effectiveness of the information provided to a “minimum operator” |
| ME34 | Description of the minimum information to be provided to maintenance personnel |
| ME35 | Description of the reasonably probable external threats, the derived hazards, the design mitigations, the eventual operating limitations mitigations. Verification of protection measures used to |
### UL35.2
Any UAS equipment (including redundant equipment) performing functions whose failure could lead to loss of functions or misleading data with hazardous or catastrophic effects on safety must pass appropriate environmental tests (see UL.25). RTCA-DO-160D or MIL-STD-810F should be used as reference material for UAS equipment environmental tests.

### UL35.3
Identify the hazards which may be created by simultaneous operation of more than one UA by the same UCS/UCB, or by hand over of a UA between two UCS/UCB, and develop design precautions and/or operating limitations in order to prevent occurrence (see UL.66 and UL.67).

### UL35.4
Identify the hazards which may be created by simultaneous operation of more than one UA in close proximity and develop design precautions and/or operating limitations in order to prevent occurrence.

### UL35.5
External lighting system requirements must be approved by the Certifying Authority and must be consistent with the intended airspace and system usage.

### UL35.6
Frangibility (for UA <= 8lb)

If the UA is intended to be operated in operational scenario that pose at risk other aircrafts/helicopters in flight, the UA and its components should be configured and constructed such that, in the event of a mid-air collision with another aircraft/helicopter, the energy impacted by the UA and its components is dissipated in a manner that minimizes damage to other aircraft. Particular attention should be given to the effect of traditionally dense and solid UA components such as, but not necessarily limited to batteries, payloads and motors and their associated propeller assemblies during a collision.

UA frangibility design features may include one or more of the following:

- (a) fracture points within UA airframe to aid dissipation of UA kinetic energy;
- (b) incorporation of energy absorbing structure into the UA;
- (c) distribution of high mass and high density components around the UA in a configuration that will reduce the likelihood of a ‘train’ of high mass and high density components impacting the same point during a collision;
- (d) external shape that encourages deflection during a collision.

minimize the hazards to the UAS, crew, ground staff or third parties from reasonable probable threats, both inside and external to the UAS.
### UL36 Internal threats

**UL36.1** There must be design features adequate to prevent incorrect installation of equipment (e.g. installation in the wrong place or with the wrong orientation).

**UL36.2** It must be demonstrated that any risk of incorrect in-field structural assembling by the operator (where applicable) has been reduced to the minimum by adequate mitigating solutions (e.g. appropriate joints design features, warnings labelled on the UA, pre-flight checks, etc.).

**UL36.3** The UAS should have (where applicable) design features which limit and segregate the consequences of an equipment disruption or failure in order to reduce, to the maximum extent, its effects on UAS function and structural integrity.

**UL36.4** If not covered by other evidence, the Certifying Authority may deem necessary to require, in addition to the safety analysis per UL.30, a Hazard Zonal Analysis to cover hazards derived from installation aspects.

**UL36.5** Considering the UA operator as an element internal to the system, all foreseeable hazards which may arise from human errors when operating the UA in all FCS operating modes, under all operational environmental conditions (as per UL.0), with normal functioning performance, must be identified and mitigated to a level acceptable to the Certifying Authority.

**UL36.6** Foreseeable hazards which may arise from operating the UAS with degraded performance in condition of failure, including the risks associated to human errors, must be identified and mitigated to a level acceptable to the Certifying Authority.

**UL36.7** Electromagnetic radiation hazards (EMRADHAZ): the system design must protect personnel, fuels (where applicable), and ordnance (where applicable) from hazardous effects of electromagnetic radiation. MIL-STD-464A may be used as a reference.

  **UL36.7.1** Hazards of electromagnetic radiation to personnel (HERP): personnel must not be exposed to an electromagnetic field whose energy exceeds the permissible exposure limits specified in approved current standards (e.g. US-DoD policy 6055.11, EU-ICNIRP).

  **UL36.7.2** A minimum safe distance from the data link antenna must be established and the value provided to the UA operator (mandatory information must be given in the flight manual; safe distance should be labelled on the antenna apparatus, where possible).

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**ME36** Description of the reasonably probable internal threats, the derived hazards, the design mitigations, the eventual operating limitations mitigations.

- Human errors analysis.
- Zonal Hazard Analysis may be required by the Certifying Authority.
- EMRADHAZ test and/or analysis report.
<table>
<thead>
<tr>
<th>Section</th>
<th>Text</th>
</tr>
</thead>
</table>
| ER.1.4 Continued airworthiness of the UAS | **UL.37** Identify and provide the instructions for continued airworthiness for the UAS which must include the information essential to the continued airworthiness of the UAS. In particular, provide instructions for continued airworthiness of the UA structure, engine, gearboxes, vertical lifting elements (fan, rotorblade, propeller, etc.) and any subsystem for which inspection, substitution (e.g. life limited parts), adjustment, lubrication are required. Information must be given to cover for:  
UL37.1 UAS maintenance schedules and instructions, as well as instructions for unscheduled maintenance (to include system and subsystem overhaul and refurbishment schedules),  
UL37.2 UAS repair and replace instructions,  
UL37.3 UAS troubleshooting information,  
UL37.4 UAS structural inspection intervals and procedures,  
UL37.5 UAS servicing information,  
UL37.6 UAS assembling and disassembling instructions (where applicable).  
UL37.7 For UAS which are required to be assembled before being operated, pre-flight and/or post-flight structural integrity checks (and any mandated tool requirements) must be prescribed. |
<p>| ER.1.4.2 Means must be provided to allow inspection, adjustment, lubrication, removal or replacement of parts and appliances as necessary for continued airworthiness. | <strong>UL.38</strong> Means must be provided to allow inspection, adjustment, lubrication, removal or replacement of parts and appliances as necessary for continued airworthiness. |
| ER.1.4.3 The instructions for continued airworthiness must be in a format appropriate for the quantity of data to be provided (e.g. paper or electronic). | See <strong>UL.37</strong> and ME37. |
| ME37 Instructions for continued airworthiness are given in the form of a manual or manuals, as appropriate for the quantity of data to be provided. The format of the manual or manuals must be as agreed by the Certifying Authority, and may differ according to National Regulations. Appropriate labelling on the UA may be necessary. |
| ME38 Description of the means provided to allow continued airworthiness implementation. |</p>
<table>
<thead>
<tr>
<th>Instructions must cover maintenance and repair instructions, servicing information, trouble-shooting and inspection procedures.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ER.1.4.4</strong> The instructions for continued airworthiness must contain airworthiness limitations that set forth each mandatory replacement time, inspection interval and related inspection procedure.</td>
</tr>
<tr>
<td><strong>UL.39</strong> A specific section called “Airworthiness Limitations” should be clearly distinguishable in the applicable manuals, containing prescriptions for each mandatory replacement time, inspection interval and related inspection procedure.</td>
</tr>
<tr>
<td><strong>ME39</strong> Section called “Airworthiness Limitations” in the manual or manuals as per ME37.</td>
</tr>
<tr>
<td><strong>ER.2</strong> Airworthiness aspects of system operation</td>
</tr>
<tr>
<td><strong>ER.2.1</strong> The following must be shown to have been addressed to ensure a satisfactory level of safety for those on the ground during the operation of the system.</td>
</tr>
<tr>
<td><strong>See the following.</strong></td>
</tr>
<tr>
<td><strong>ER.2.1.1</strong> The kinds of operation for which the UAS is approved must be established and limitations and information necessary for safe operation, including environmental limitations and performance, must be established.</td>
</tr>
<tr>
<td><strong>Structure, engine, gearboxes, vertical lifting elements, and general UA sub-system integrity within the limitations identified in design usage spectrum of UL.0 has been previously demonstrated. Only the aspects deriving from the UA flight characteristics are hereby addressed.</strong></td>
</tr>
<tr>
<td><strong>NOTE</strong> The performance in the following paragraphs should be determined as “minimum values” at the most severe conditions according to the design usage spectrum in UL.0, considering mass and balance, environmental conditions, wind, etc.</td>
</tr>
<tr>
<td><strong>UL.40</strong> Kinds of operation:</td>
</tr>
<tr>
<td><strong>UL40.1</strong> Identify the airspace classes for which the UA may be authorized, taking into account the UAS design features.</td>
</tr>
</tbody>
</table>
| **ME40** Justification of the airspace classes in which the UA may be authorized to fly and
UL40.2 All platforms, both stationary and moving, from which UA operations will be conducted, to include launch, command and control and recovery, must be considered and incorporated in the UAS design to ensure required levels of safety and airworthiness are maintained.

<table>
<thead>
<tr>
<th>UL41 Performance at minimum operating speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL41.1 NOT USED</td>
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<tr>
<td>UL41.2 NOT USED</td>
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<tr>
<td>UL41.3 NOT USED</td>
</tr>
<tr>
<td>UL41.4 NOT USED</td>
</tr>
<tr>
<td>UL41.5 The hovering ceiling must be determined, over the ranges of weight, altitude and temperature for which certification is requested, with</td>
</tr>
<tr>
<td>(1) Take-off power;</td>
</tr>
<tr>
<td>(2) The UA in ground effect at a height consistent with normal take-off procedures; and</td>
</tr>
<tr>
<td>UL41.6 The hovering ceiling determined under UL41.5 must be at least 915m (3000 ft) at maximum weight with a standard atmosphere.</td>
</tr>
<tr>
<td>UL41.7 HOGE hovering performance</td>
</tr>
<tr>
<td>The out-of-ground-effect hovering performance must be determined over the ranges of weight, altitude and temperature for which certification is requested, using take-off power.</td>
</tr>
</tbody>
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<tr>
<th>UL42 Take-off/launch</th>
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</thead>
<tbody>
<tr>
<td>UL42.1 It must be shown that the take-off / launch sequence is a reliable, repeatable and predictable safe operation, for each weight, altitude, temperature, and wind conditions, within the operational limits in UL0.</td>
</tr>
<tr>
<td>UL42.2 A take-off / launch safety trace must be determined as the area in which there may be a hazard which could result in an unacceptable a risk to UAS crew, ground staff or third parties. Winds, navigational accuracies, communication latencies, etc. must be considered in the establishment of the take-off safety trace.</td>
</tr>
<tr>
<td>UL42.3 NOT USED</td>
</tr>
</tbody>
</table>

platforms other than land from which operations may be conducted.

<table>
<thead>
<tr>
<th>ME41 Flight test and analysis report.</th>
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<table>
<thead>
<tr>
<th>ME42 Flight Test and analysis report.</th>
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</thead>
</table>
UL42.7 When an automatic take-off system is provided it must comply with the following requirements:

(a) Once the automatic take-off mode has been engaged, the process is fully automatic and the UAS crew monitors the take-off from the UAS control station, via the command and control data link, but is not required to perform any manual "piloting action", except manual abort, where required, as per provisions of UL 42.11.

(b) The automatic function will reside in the UAS airborne control laws algorithms and will utilize navigation and flight path tracking inputs in such a manner as not to degrade the overall redundancy or level of safety of the flight control system. When off-board sensors are utilized via data-links, the continued safe flight of the vehicle must be ensured in the event of a loss of that data-link.

(c) The automatic system must not cause any unsafe sustained oscillations or undue attitude changes or control activity as a result of configuration or power changes or any other disturbance to be expected in normal operation.

(d) In case of failure that could adversely affect safe flight or exceedance from predefined limits occurring during the take-off process an automatic abort function shall be provided to land the rotorcraft UAV on the pad up to "Take-off Rejection Point."

(e) The automatic take-off system must incorporate a manual abort command. Its control shall be easily accessible to the UAS crew in order to interrupt take-off and either land or hover the VTOL UAV up to "take-off rejection point."

(f) Specific abort procedure shall be provided in the UAS System Flight Manual.

UL42.8 Take-off/Launch procedures and performance must be provided to the operator in the flight manual.

UL42.9 Take-off

(a) The take-off, with take-off power and rpm, at the most critical centre of gravity:

(1) May not require exceptional skill from the UAS crew or exceptionally favourable conditions throughout the range of altitude from standard sea-level conditions to the maximum altitude for which take-off and landing certification is requested.
(2) Must be made in such a manner that no single or complete engine failure will lead to a Catastrophic or Hazardous failure condition.

(b) Sub-paragraph (a) must be met throughout the ranges of altitude, temperature and weight for which certification is requested.

UL42.10 The UA must remain in a stable and controllable condition throughout the take-off/launch phase and during the transition to normal flight conditions.

UL42.11 Safe take-off/launch procedures and settings must be determined for all launch conditions. Due account should be taken of the variability of force and launch angle in hand launches.

<table>
<thead>
<tr>
<th>UL.43</th>
<th>Climb and descent</th>
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<tbody>
<tr>
<td>UL43.1</td>
<td>NOT USED</td>
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<tr>
<td>UL43.2</td>
<td>NOT USED</td>
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<tr>
<td>UL43.3</td>
<td>NOT USED</td>
</tr>
<tr>
<td>UL43.4</td>
<td>NOT USED</td>
</tr>
</tbody>
</table>
| UL43.5 | The steady rate of climb must be determined at maximum continuous power:
  (a) At a speed for which certification is requested;
  (b) From sea level up to an altitude for which certification is requested;
  (c) At weights and temperatures for which certification is requested. |

UL.44 Navigation accuracy

UL44.1 Navigation accuracy must be as agreed by the Certifying Authority, and verified by flight test in all the operational modes, in terms of maximum error from an established waypoint on ground, altitude and speed.

UL44.2 The information about the worst possible navigation accuracy must be provided to the UA operator in the flight manual.

UL44.3 Where automatic or semi-automatic FCS modes are activated, a flight-path deviation warning must be displayed and the appropriate procedure established (see ER.2.1.5) when excessive...
deviation (be as agreed by the Certifying Authority) from the pre-programmed flight-path occurs.

**UL.45 Glide**

**UL45.1** If autorotation capability is implemented, the following applies:

(a) The glide performances and instructions to achieve the best glide range must be provided to the UA operator in the flight manual.

(b) Glide performance

The minimum rate of descent airspeed and the best angle-of-glide airspeed must be determined in autorotation at –

1. Maximum weight; and

2. Vertical lifting element speed(s) selected by the applicant.

**UL.46 Landing**

**UL46.1** It must be shown that the landing sequence is a reliable, repeatable and predictable safe operation.

**UL46.2** A landing safety trace must be determined as the area (associated with a UA conventional, arrested, or parachute), in which there may be a hazard which could result in an unacceptable risk to UAS crew, ground staff or third parties. Winds, navigational accuracies, communication latencies, etc. must be considered in the establishment of the landing safety trace.

**UL46.3 NOT USED**

**UL46.4** Recovery with parachute:

- a minimum parachute safety height must be determined and provided to the operator;

- the normal landing under parachute must be made without excessive vertical acceleration or tendency to bounce, nose over, ground loop or porpoise;

- the landing accuracy must be determined.

**UL46.5** Recovery by arrestment

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**ME45 Flight Test and analysis report.**

**ME46 Flight Test and analysis report.**
a safe landing speed and a safe gradient of descent must be determined for any landing configuration the systems is capable of.

- the landing accuracy must be determined.

- for automatic recoveries, a predefined go-around feature should be incorporated into the UAS design such that, when conditions established to promote safe and successful recovery cannot be achieved, the UAS commands the UA to go-around.

- the recovery rate performance (defined as the statistical percentage of successful recoveries of the UA to its recovery device while operating under all established operational and environmental envelopes) must be determined and provided.

UL46.6 NOT USED.

UL46.7 When an automatic landing system is provided it must comply with the following requirements:

(a) Once the automatic landing mode has been engaged, the process is fully automatic and the UAS crew monitors the landing from the UA control station, via the command and control data link, but is not required to perform any manual “piloting action”; except manual abort, where required, as per provisions of (e).

(b) The automatic function will reside in the UA airborne control laws algorithms and will utilize navigation and flight path tracking inputs in such a manner as not to degrade the overall redundancy or level of safety of the flight control system. When off-board sensors are utilized via data-links, the continued safe flight of the vehicle must be ensured in the event of a loss of that data-link.

(c) The automatic system must not cause any unsafe sustained oscillations or undue attitude changes or control activity as a result of configuration or power changes or any other disturbance to be expected in normal operation.

(d) In case of failure or exceedance from the predefined limits occurring during the approach, an automatic go around function shall be provided before “Landing Rejection Point.”

(e) The automatic landing system must incorporate a manual abort command. Its control shall be easily accessible to the UAS crew in order to continue to a safe and stabilized airborne state (e.g. go around or hover) during the landing phase.

(f) Specific go around procedure shall be provided in the UAS System Flight Manual.
**UL46.8** Landing procedures and performances must be provided to the operator in the flight manual.

**UL46.9** Limiting height-speed envelope

(a) If there is any combination of height and forward speed (including hover) under which emergency procedures and/or flight terminating systems will not be successful and an applicable power failure condition as described under (b), a limiting height-speed envelope must be established (including all pertinent information) for that condition, throughout the ranges of -

1. Weight, from the maximum weight (at sea-level) to the lesser weight for each altitude selected by the applicant; and

2. The weight at altitudes above sea-level may not be less than the maximum weight or the highest weight allowing hovering out of ground effect whichever is lower.

(b) The applicable power failure conditions are

1. For single-engine UA, engine power-off and, if for rotorcraft designed VTOL UA autorotation capability is implemented, full autorotation.

2. For multi-engine UA, OEI and the remaining engine(s) within approved limits.

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**ER 2.1.2** The UA must be safely controllable and manoeuvrable under all anticipated operating conditions and, where applicable, up to the activation of the recovery system. Due account must be taken of UCS environment, UA Operator workload and other human-factor considerations and of the phase of flight and its duration.

**UL.47** Controllability and Manoeuvrability

**UL47.1** The Flight Control System (including sensors, actuators, computers and all those elements necessary to control the attitude, speed and trajectory of the UA) should be designed to provide UA control in the following operational modes:

- Automatic: the UA attitude, speed and flight path are fully controlled by the flight control system. No input from the UCS/UCB is needed other than to load or modify the required flight plan.

- Semi-automatic: the UA operator commands outer loop parameters such as altitude, heading and air speed. The flight control system operates the UA controls to achieve the commanded outer loop parameter value.

- Manual direct piloting mode: the UA operator directly commands UA controls. This control mode may be limited to some flight phases (e.g. take-off and landing) or emergency conditions, be as agreed by the Certifying Authority.

**ME47** Flight Test Report.
**UL47.2** There must be a clear unambiguous means in the UCS/UCB to indicate to the UA operator the active mode of control of the FCS.

**UL47.3** Controllability and manoeuvrability

(a) The UA must be safely controllable and manoeuvrable in all FCS operating modes and in manual direct piloting mode (where applicable), in the most severe operating conditions as per UL.0, during all flight phases appropriate to the type, including:

1. Take-off;
2. Climb;
3. Hover;
4. Level flight;
5. Turning flight;
6. Landing (power-on and (if applicable) power-off); and

(b) If autorotation capability is implemented, control of the UA throughout the full phase of during autorotation must be maintained.

(c) If MEI capability is implemented, control of the UA over the defined MEI envelope must be maintained. The applicant may consider defining multi-engine failure ratings: OEI, 2EI, 3EI, etc. if the ratings required to sustain propulsion capability vary. Sustained propulsion capability is defined as the propulsion ratings required for continued safe flight and landing, following failure of one or more engine(s) as applicable to the specific UA.

(d) Wind Velocities determined by the applicant and approved by the Certifying Authority from all azimuths, must be established in which the UA can be operated without loss of control:

1. On or near the ground (i.e., in ground effect) in any manoeuvre appropriate to the type, such as crosswind takeoffs, sideward flight and rearward flight with altitude, from standard sea-level conditions to the maximum take-off, landing altitude capability of the rotorcraft UA with:

   (i) Critical weight;
   (ii) Critical centre of gravity; and
(iii) Critical rpm.

(iv) Altitude from standard sea level conditions to the maximum altitude for which certification is sought.

and;

(2) Out of ground effect in any manoeuvre appropriate to the type with:

(i) Weight selected by the applicant;

(ii) Critical centre of gravity; and

(iii) RPM selected by the applicant.

(iv) Altitude from standard sea level conditions to the maximum altitude for which certification is sought.

(e) If controllability and maneuverability after complete engine failure is implemented, the VTOL UA must be controllable over the range of speeds and altitudes for which certification is requested when such power failure occurs with maximum continuous power and critical weight. If direct piloting mode is applicable, No corrective action time delay for any condition following power failure may be less than one second.

UL47.4 The UA flight mechanics behaviour when it encounters the gust per UL5.3 must be characterized and potential limitations (taking due account of the design usage spectrum as per UL.6) established where applicable and documented in operating manuals.

UL47.5 Never-exceed speed

(a) The never-exceed speed, VNE, must be established so that it is not more than the lesser of:

(1) 0.9 times the maximum forward speeds established under UL.2.8; or

(2) 0.9 times the maximum speed shown under UL.8;

(3) Where applicable 0.9 times the maximum speed substantiated for advancing blade tip Mach number effects.

(b) VNE may vary with altitude, temperature and weight if the system is able to automatically maintain the relevant limitation based on the appropriate influencing parameters.
c)-If controllability and manoeuvrability after complete engine failure is implemented, a stabilized power-off VNE denoted as VNE (power-off) should be established.

**UL.48 Trim**

The Flight Control System (FCS) must trim the UA in such a manner that a maximum of control remains and that dynamic characteristics and safety margins are not compromised.

**UL.49 NOT USED**

**UL.50 Stability (see Annex H for additional guidance)**

**UL50.1** The UA in all its operating modes, both augmented by the FCS and in manual direct piloting conditions (where applicable), including the effects of sensor and computational errors and delays, must be longitudinally, directionally and laterally stable in any condition normally encountered in service, at any combination of weight and centre of gravity for which certification is requested.

**UL50.2** Transient response in all axes during transition between different flight conditions and FCS flight modes must be smooth, convergent, and exhibit damping characteristics with minimal overshoot of the intended flight path.

**UL50.3** In addition to data obtained by computation or modelling, stability analysis must be supported by the results of relevant flight tests.

**UL50.4** Stability also must be assessed in manual direct piloting conditions (where applicable), taking due account of data-link latencies.

**UL50.5** Pilot (UA Operator) induced oscillation (PIO) tendencies must be safe, with particular consideration to manual direct piloting conditions flight characteristics (where applicable).

**UL.51** A qualitative evaluation of the UA Operator workload and degree of difficulty in all FCS operating modes including manual direct piloting (where applicable) and in all flight phases (e.g. launching strength) should be done in order to demonstrate that the probability of piloting errors is reduced to the minimum. Workloads in emergency conditions and in case of possible deconflicting manoeuvres should also be evaluated.

Note - Depending on the UAS design features complexity, the Certifying Authority may issue recommendations concerning UA Operator training syllabus as necessary.
**ER.2.1.3** It must be possible to make smooth transition(s) from one flight phase to another without requiring exceptional piloting skill, alertness, or workload under any probable operating condition.

**UL.52** It must be possible to make a smooth transition from one flight phase to another without danger of exceeding the operating limitations of the UA, under any probable operating condition, (including, for multi-engine UA, those conditions normally encountered in the sudden failure of any engine).

Where applicable, consideration must be given to the transition from take-off/launch phase and normal flight condition, as well as the transition from normal flight condition to landing/recovery phase.

**ME52 Flight Test Report.**

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**ER.2.1.4** The UA must have handling qualities that ensures the demands made on the UA Operator are not excessive taking into account the phase of flight and its duration.

**N/A**

It concentrates on handling qualities effects on UA Operator controls, it is assumed that there is no artificial feedback on the controls in direct mode piloting condition.

In ER 2.1.2 due account has already been taken of UA Operator strength, flight deck environment, UA Operator workload and other human-factor considerations.

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**ER.2.1.5** Procedures for normal operations, failure and emergency conditions must be established.

**UL.53** Emergency recovery capability

**UL53.1** The UAS must integrate an emergency recovery capability that consists of:

- a flight termination system, procedure or function that aims to immediately end normal flight, or

- an emergency recovery procedure that is implemented through UA crew command or through the execution of a predefined course of events in order to mitigate the effects of critical failures with the intent of minimising the risk to third parties, or,

- any combination of the previous two options.

**UL53.2** The emergency recovery capability must function as desired over the whole flight envelope under the most adverse combination of environmental conditions.

**UL53.3** The emergency recovery capability must be safeguarded from interference leading to inadvertent operation.

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**ME53 Technical description**
UL.54 Conflict Avoidance Manoeuvres

Possible conflict avoidance manoeuvres should be investigated according to the UA manoeuvrability and identified in order to minimize the risk of in-flight collision.

UL.55 Engine Failure Procedure

In the event of an engine failure, an appropriate procedure must be defined and provided in the flight manual; the following apply.

UL55.1 If there is no capability for controlled flight following loss of one or more engines or MEI capability is not implemented, then procedures requiring the activation of the emergency recovery capability specified in UL 53, must be provided in the Flight Manual unless the emergency recovery capability is automatically activated.

UL55.2 The emergency electrical power must be designed in such a way that its reliability and duration are compatible with UL55.1. The duration must consider the time period needed to reach a forced landing area from maximum certificated altitude to sea level (ISA conditions) includes the time needed for the UA crew to recognize the failure and to take appropriate action, if required.

UL55.3 If MEI capability is implemented then:

a) The number of operating engines, the location of the inoperative engines, phases of flight, duration and envelope (weight, altitude, temperature, wind etc.) must be determined where the capability will permit safe flight.

b) Procedures required to be completed by the UAS crew to utilize the capability must be provided in the Flight Manual including performance information such as the decision points, critical speeds and flight profiles appropriate to the phases of flight where the capability is implemented.

Any required engine ratings, including transients, in excess of maximum continuous power rating must be established and demonstrated in accordance with Annex F3.

c) When the UA OEI/MEI rating(s) require the monitoring of operation parameters (to control temperature, RPM, for example), then automatic control system(s) are required, unless sufficient operation parameters margins have been demonstrated.
<table>
<thead>
<tr>
<th>UL55.4 If an autorotation capability is implemented then:</th>
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<tbody>
<tr>
<td>a) The limiting height and velocity envelope where a safe landing cannot be made must be determined and the information provided in the flight manual unless the emergency recovery capability specified in UL 53 is automatically activated within this envelope.</td>
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<tr>
<td>b) Procedures required to be completed by the UAS crew to utilize the capability must be provided in the Flight Manual along with pertinent performance information such as speeds and rotor rpm.</td>
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<table>
<thead>
<tr>
<th>UL.56 The Flight Manual provided to the UA operator must clearly and unambiguously define all the:</th>
<th>ME56 Flight Manual</th>
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<tbody>
<tr>
<td>- operating procedures, and</td>
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<td>- operating limitations, and</td>
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<td>- performance information,</td>
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<td>for</td>
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<td>- normal operations, and</td>
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<tr>
<td>- failure conditions and emergency conditions. Where the emergency recovery capability includes a pre-programmed course of action to reach a predefined site where it can be reasonably expected that fatality will not occur, the dimensions of such areas must be stated in the UAS Flight Manual,</td>
<td></td>
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<tr>
<td>- possible conflict avoidance manoeuvres.</td>
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</tbody>
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<thead>
<tr>
<th>ER.2.1.6 Warnings, or other deterrents intended to prevent exceeding the normal flight envelope, must be provided, as appropriate to type.</th>
<th>UL.57 The UAS should be designed so that:</th>
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<tbody>
<tr>
<td></td>
<td>UL57.1 NOT USED</td>
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<tr>
<td></td>
<td>UL57.2 NOT USED</td>
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<tr>
<td></td>
<td>UL57.3 NOT USED</td>
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<tr>
<td></td>
<td>UL57.4 NOT USED</td>
</tr>
<tr>
<td></td>
<td>UL57.5 In automatic or semi-automatic operating modes, the UA should remain within a flight envelope sufficiently protected by the FCS in order to avoid any unsafe condition (see UL.58).</td>
</tr>
</tbody>
</table>

| ME57 Technical description of UA flight envelope protection design features |       |
**UL57.6** In manual direct piloting mode (where applicable), the operator should be alerted with sufficient margin when approaching any unsafe condition.

**UL.58 Flight Envelope Protection (where applicable)**

**UL58.1** Flight envelope protection must be implemented in the flight control system as follows.
- Characteristics of each envelope protection feature must be smooth, appropriate to the phase of flight and type of manoeuvre.
- Limit values of protected flight parameters must be compatible with:
  - UA structural limits,
  - vertical lift element(s) limits (e.g. rotational speed limits and stall limits of rotor blades)
  - required safe and controllable manoeuvring of the UA,
  - margin to catastrophic failure conditions.
- engine and transmission torque limits.
- The UA must respond to intentional dynamic manoeuvring within the established flight envelope parameter limits.
- Dynamic characteristics such as damping and overshoot must also be appropriate for the manoeuvre and limit parameter concerned.
- Characteristics of the flight control system must not result in residual oscillations in commanded output due to combinations of flight envelope protection limits and any other flight control internal limit.

**UL58.2** When simultaneous envelope protection limits are engaged, adverse coupling or adverse priority must not result.

**UL58.3** The Applicant must define clearly the borders and prioritization within the control system of the flight envelope protection maintained by the flight control system.

**ER.2.1.7** The characteristics of the UA and its systems must allow a safe return from extremes of the

**UL59** A safe return from the extremes of the flight envelope that may be encountered in all operating modes must be demonstrated by simulation and it should be demonstrated in flight.

**ME58** Technical description of UA flight envelope protection design features + model simulation analysis + flight test report.

**ME59** Flight Test Report.
<table>
<thead>
<tr>
<th>Issue</th>
<th>Description</th>
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<tbody>
<tr>
<td>ER.2.2</td>
<td>The operating limitations and other information necessary for safe operation must be made available to the crew members. The information needed for the safe conduct of the flight and information concerning unsafe conditions are displayed in the UCS/UCB as per UL.32 and UL.33. UL.60 The Flight Manual provided to the UA operator must clearly and unambiguously define all the operating limitations and other information necessary for safe operation (see also UL.56).</td>
</tr>
<tr>
<td>ER.2.3</td>
<td>System operations must be protected from hazards resulting from adverse external and internal conditions, including environmental conditions. See UL.35 and UL.36. In particular, environmental tests are required by UL.35.2.</td>
</tr>
<tr>
<td>ER.2.3.1</td>
<td>In particular, account must be taken of the exposure to phenomena such as, but not limited to, adverse weather, lightning, bird strike, high frequency radiated fields, ozone, etc., expected to occur during system operation. Consideration to bird-strike is given in UL.13.</td>
</tr>
<tr>
<td>ER.2.3.2</td>
<td>Where applicable, cabin compartments must provide passengers with suitable transport conditions and adequate protection from any expected hazard arising in flight operations or resulting in emergency situations, including fire, smoke, toxic gases and rapid decompression hazards. Provisions must be made to give occupants every reasonable N/A For the UCS/UCB see also UL.26.2 and UL.30.</td>
</tr>
</tbody>
</table>
chance of avoiding serious injury and quickly evacuating the aircraft and to protect them from the effect of the deceleration forces in the event of an emergency landing on land or water. Clear and unambiguous signs or announcements must be provided, as necessary, to instruct occupants in appropriate safe behaviour and the location and correct use of safety equipment. Required safety equipment must be readily accessible.

<table>
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<tr>
<th>ER.2.3.3 Crew compartments must be arranged in order to facilitate flight operations, including means providing situational awareness, and management of any expected situation and emergencies. The environment of crew compartments must not jeopardise the crew's ability to perform their tasks and its design must be such as to avoid interference during operation and misuse of the controls.</th>
</tr>
</thead>
<tbody>
<tr>
<td>For the UCS/UCB See UL.27, UL.32, UL.33. In particular human-machine interface aspects are covered by UL.27.3 Error! Reference source not found..</td>
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</tbody>
</table>
**ER.3 Organisations**  
(It includes natural persons undertaking design, manufacture or maintenance).

<table>
<thead>
<tr>
<th>ER.3.1 Organisations involved in design (including flight test), production (manufacture) or maintenance activities must satisfy the following conditions.</th>
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<tr>
<td><strong>UL.61</strong> The Applicant should ensure certification as per AS/EN 9100 for undertaking UAS design and production activities and the documented statement of the quality policy should explicitly include system safety as one of the main objectives: this should give a minimum confidence that safety management is implemented and that safety-related work is undertaken by competent individuals, in adequate facilities, with adequate tools, material, procedures and data.</td>
</tr>
<tr>
<td><strong>ME61</strong> Approved AS/EN 9100 Certificate or equivalent.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ER.3.1.1 The organisation must have all the means necessary for the scope of work. These means comprise, but are not limited to the following: facilities, personnel, equipment, tools and material, documentation of tasks, responsibilities and procedures, access to relevant data and record-keeping.</th>
</tr>
</thead>
</table>
| **UL.62** The Applicant must ensure implementation, documentation, operation and maintenance of an auditable Safety Management System.  
Safety must be considered from the earliest stage in a programme and used to influence all activities from the concept of requirements definition, the development phase, production, operation, etc., until disposal.  
Safety management should be integrated into a Systems Engineering approach that gives due consideration to safety alongside related issues.  
The Applicant must submit to the Certifying Authority a Safety Management Plan which details the specific actions and arrangements required to operate the Safety Management System and define safety milestones for the project. It must provide the link between safety requirements and general management processes for the project, to ensure that safety is achieved and maintained for the complete UAS life cycle. |
| **ME62** The minimum evidence to comply with this requirement is a Safety Management Plan, which is a significant document that provides a basis on which to achieve trust in the effectiveness of the Safety Management System.  
Guidelines on information to be |
<table>
<thead>
<tr>
<th><strong>The Certifying Authority may audit the Safety Management System at its discretion.</strong></th>
<th>included in the Safety Management Plan are provided in Annex I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>**UL.63 **The aim for continuous improvement must be verified when assessing the Company management system. Normally it is covered under AS/EN 9100. Additional confidence may be obtained by complying with ISO 9004 [present title: Quality Management Systems – Guidelines for Performance Improvement] [future title: Managing for sustainable success – A quality management approach].</td>
<td><strong>ME63</strong> Approved AS/EN 9100 certificate + ISO 9004 or equivalent.</td>
</tr>
<tr>
<td><strong>ER.3.1.3</strong> The organisation must establish arrangements with other relevant organisations, as necessary, to ensure continuing compliance with these essential requirements for airworthiness.</td>
<td><strong>UL.64</strong> The organisation must establish an interface with other relevant organisations, as necessary, to ensure continuing compliance with these essential requirements for airworthiness.</td>
</tr>
<tr>
<td><strong>ER.3.1.4</strong> The organisation must establish an occurrence reporting and/or handling system, which must be used by the management system under point ER.3.1.2 and the arrangements under point ER.3.1.3, in order to contribute to the aim of continuous improvement of the safety of systems (&quot;continued airworthiness of the type design&quot;).</td>
<td><strong>UL.65</strong> The organisation must establish an occurrence reporting and/or handling system, which must be used by the management system under point ER.3.1.2 and the arrangements under point ER.3.1.3, in order to contribute to the aim of continuous improvement of the safety of systems (&quot;continued airworthiness of the type design&quot;). The reporting system should include interaction with other relevant organisations to ensure the continuing airworthiness of the type design including for example Airworthiness Directives, post incident recommendations, service bulletins and technical instructions.</td>
</tr>
<tr>
<td><strong>ER.3.2</strong> In the case of maintenance training organisations, the conditions under points ER.3.1.3 and ER.3.1.4 do not apply.</td>
<td>N/A</td>
</tr>
</tbody>
</table>
### ER.3.3 UA HANOVER (where applicable)

**UL.66** Where the UAS is designed for UA hand over between two UCS/UCB:
- **UL66.1** The in-control UCS/UCB must be clearly identified to all UA operators.
- **UL66.2** Positive control must be maintained during handover.
- **UL66.3** The command and control functions that are transferred during handover must be approved by the Certifying Authority and defined in the UAS Flight Manual.
- **UL66.4** Handover between two UCS/UCB must not lead to unsafe conditions.
- **UL66.5** The in-control UCS/UCB must have the required functionality to accommodate emergency situations.

**ME66** Technical description + Flight test report.

**UL.67** Where a UCS/UCB is designed to command and control multiple UA:
- **UL67.1** The minimum UAS crew must be established so that it is sufficient for safe operation of each UA and emergency condition.
- **UL67.2** The UA data must be displayed in the UCS/UCB in a manner that prevents confusion and inadvertent operation.
- **UL67.3** The UA controls must be available to the UA crew for each UA of which it has command and control, in a manner that prevents confusion and inadvertent operation.
- **UL67.4** All indicators and warnings must be available to the UA crew for each UA, in a manner that prevents confusion and inadvertent operation.

**ME67** Technical description + Flight test report.

**UL.68** Where the UCS has more than one workstation designed for controlling the UA:
- **UL68.1** The in-control workstation must be clearly identified to all UA crew members.
- **UL68.2** Positive control must be maintained during handover.
- **UL68.3** The command and control functions that are transferred during handover must be approved by the Certifying Authority and defined in the UAS Flight Manual.
- **UL68.4** Handover within the same UA UCS must not lead to unsafe conditions.
- **UL68.5** The in-control workstation must have the required functionality to accommodate emergency situations.

**ME68** Technical description + Flight test report.
<table>
<thead>
<tr>
<th>UL. 69</th>
<th>Where the UCS/UCB is designed to monitor multiple UA, there must be a means to clearly indicate to the UAS crew the UA over which it has command and control.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME69</td>
<td>Technical description + Flight test report.</td>
</tr>
</tbody>
</table>
### A. Acronyms and Abbreviations

#### A.1. Terms and Definitions

The following acronyms are used for the purpose of this agreement.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>ARP</td>
<td>Aerospace Recommended Practices</td>
</tr>
<tr>
<td>BIT</td>
<td>Built in Test</td>
</tr>
<tr>
<td>CG</td>
<td>Centre of Gravity</td>
</tr>
<tr>
<td>DAL</td>
<td>Development Assurance Level</td>
</tr>
<tr>
<td>DDP</td>
<td>Declaration of Design and Performance</td>
</tr>
<tr>
<td>EMC</td>
<td>Electromagnetic Compatibility</td>
</tr>
<tr>
<td>EME</td>
<td>Electromagnetic Emission</td>
</tr>
<tr>
<td>EMI</td>
<td>Electromagnetic Interference</td>
</tr>
<tr>
<td>EMRADHAZ</td>
<td>Hazards of Electromagnetic Radiation to Personnel</td>
</tr>
<tr>
<td>FCS</td>
<td>Flight Control System</td>
</tr>
<tr>
<td>GAT</td>
<td>General Air Traffic</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>h</td>
<td>Hour</td>
</tr>
<tr>
<td>HIGE</td>
<td>Hover in Ground Effect</td>
</tr>
<tr>
<td>HIRF</td>
<td>High Intensity Radiated Fields</td>
</tr>
<tr>
<td>HOGE</td>
<td>Hover out of Ground Effect</td>
</tr>
<tr>
<td>HW</td>
<td>Hot Wet</td>
</tr>
<tr>
<td>LOS</td>
<td>Line of Sight</td>
</tr>
<tr>
<td>MEI</td>
<td>Multi-Engine Inoperative</td>
</tr>
<tr>
<td>MTOW</td>
<td>Maximum Take-Off Weight</td>
</tr>
<tr>
<td>NATO</td>
<td>North Atlantic Treaty Organization</td>
</tr>
<tr>
<td>OAT</td>
<td>Operational Air Traffic</td>
</tr>
<tr>
<td>PII</td>
<td>Pilot Induced Instabilities</td>
</tr>
<tr>
<td>PLD</td>
<td>Programmable Logic Device</td>
</tr>
<tr>
<td>PSE</td>
<td>Primary Structural Elements</td>
</tr>
<tr>
<td>RPM</td>
<td>Revolutions per Minute</td>
</tr>
<tr>
<td>RTD</td>
<td>Room Temperature Dry</td>
</tr>
<tr>
<td>SSA</td>
<td>System Safety Assessment</td>
</tr>
<tr>
<td>STANAG</td>
<td>(NATO) Standard Agreement</td>
</tr>
<tr>
<td>STANREC</td>
<td>NATO) Standard Recommendation</td>
</tr>
<tr>
<td>UA</td>
<td>Unmanned Aircraft</td>
</tr>
<tr>
<td>UAS</td>
<td>Unmanned Aircraft System</td>
</tr>
<tr>
<td>UCB / UCS</td>
<td>UA Control Box / UA Control Station</td>
</tr>
</tbody>
</table>
**USAR**  UAV Systems Airworthiness Requirements

**V\textsubscript{H}**  Max speed in level flight with max continuous power

**VNE**  Never Exceed Speed

**VNO**  maximum structural cruising speed

### A.2. Terms and Definitions

The following terms and definitions are used for the purpose of this agreement.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicant</td>
<td>The entity applying for the Type Certificate</td>
</tr>
<tr>
<td>Automatic</td>
<td>The execution of a predefined process or event that requires UAV crew initiation</td>
</tr>
<tr>
<td>Autorotation</td>
<td>Light VTOL UAV flight condition in which the vertical lifting element(s) is driven entirely by action of the air when the Light VTOL UAV is in motion.</td>
</tr>
<tr>
<td>Continued Airworthiness</td>
<td>All tasks to be carried-out to verify that the conditions under which a type-certificate or a supplemental type-certificate has been granted continue to be fulfilled at any time during its period of validity.</td>
</tr>
<tr>
<td>Continuing Airworthiness</td>
<td>All of the processes ensuring that, at any time in its operating life, the aircraft complies with the airworthiness requirements in force and is in a condition for safe operation</td>
</tr>
<tr>
<td>Data link</td>
<td>Wireless communication channel between one or more UCS and one or more UAV, or between multiple UAV. Its utility may include but is not limited to exchange of command &amp; control or payload data. A data link may consist of:</td>
</tr>
<tr>
<td></td>
<td>• Uplink - Transmittal of UAS crew commands from the UCS to the UAV.</td>
</tr>
<tr>
<td></td>
<td>• Downlink - Transmittal of UAV status data from the UAV to the UCS.</td>
</tr>
<tr>
<td>Design usage spectrum</td>
<td>The Applicant uses this information as the basis for assumptions underpinning fatigue and damage tolerance and associated individual UAS tracking. The design usage spectrum is therefore necessary for producing and maintaining the Fatigue Type Record or equivalent document. The applicant also uses the design usage spectrum to identify any gross deviation between design assumptions and Service usage. The design usage spectrum is descriptive, rather than prescriptive. The design usage spectrum contains a breakdown of the typical Sortie Profiles Codes (SPCs) or any equivalent for UAS type in each of its roles and at each typical operating location. SPCs or any equivalent are expressed in terms of height, time, speed, mass and configuration data, which are derived from recorded sortie information. The initial issue of the design usage spectrum should be produced as early as possible in the project life cycle and should be reviewed and updated throughout the life of type.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Effective maximum range</td>
<td>Measure of data link coverage over a horizontal distance that is a function of frequency, availability, bit error rate, climate area and altitude.</td>
</tr>
<tr>
<td>Electromagnetic Compatibility EMC</td>
<td>Ability of equipment or a system to function in its electromagnetic environment without causing intolerable electromagnetic disturbances to anything in that environment.</td>
</tr>
<tr>
<td>Electromagnetic Environment EME</td>
<td>The totality of electromagnetic phenomena existing at a given location.</td>
</tr>
<tr>
<td>Electromagnetic Interference EMI</td>
<td>Any electromagnetic disturbance, whether intentional or not, which interrupts, obstructs, or otherwise degrades or limits the effective performance of electronic or electrical equipment.</td>
</tr>
<tr>
<td>Emergency recovery capability</td>
<td>Procedure that is implemented by UAS crew command or by means of autonomous design in order to mitigate the effects of critical failures with the intent of minimizing the risk to third parties. This may include automatic pre-programmed course of action to reach a predefined and unpopulated forced landing or recovery area.</td>
</tr>
<tr>
<td>Emergency landing</td>
<td>Exceptional landing condition that could lead to a severe level constraint on the structure.</td>
</tr>
<tr>
<td>Failure conditions</td>
<td>A condition having an effect on either the UAS or third parties, or both, either direct or consequential, which is caused or contributed to by one or more failures or errors considering flight phase and relevant adverse operational or environmental conditions or external events.</td>
</tr>
<tr>
<td>Fire-resistant</td>
<td>With respect to materials, components and equipment, means the capability to withstand the application of heat by a flame, as defined for 'Fireproof', for a period of 5 minutes without any failure that would create a hazard to the UAS. For materials this may be considered to be equivalent to the capability to withstand a fire at least as well as aluminium alloy in dimensions appropriate for the purposes for which they are used.</td>
</tr>
</tbody>
</table>
| Flight control system FCS                      | The flight control system comprises sensors, actuators, computers and all those elements of the UAV System, necessary to control the attitude, speed and flight path of the UAV. The flight control system can be divided into 2 parts:  
  Flight control computer - A programmable electronic system that operates the flight controls in order to carry out the intended inputs.  
  Flight controls - Sensors, actuators and all those elements of the UAV System (except the flight control computer), necessary to control the attitude, speed and flight path of the UAV. |
<p>| Flight load factor                              | Ratio of the aerodynamic force component (acting normal to the assumed longitudinal axis of the UAV) to the weight of the UAV. A positive flight load factor is one in which the aerodynamic force acts upward, with respect to the UAV. |
| Flight Envelope Protection                     | System that prevents the UAV from exceeding its designed operating limits.                                                               |</p>
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight termination system</td>
<td>System to immediately terminate flight.</td>
</tr>
<tr>
<td>Forced landing</td>
<td>Condition resulting from one or a combination of failure conditions.</td>
</tr>
<tr>
<td>Ground staff</td>
<td>Qualified personnel necessary for ground operations (such as supplying the UAS with fuel and maintenance) as stated in the UAS System Flight Manual or in the UAS Maintenance Manual.</td>
</tr>
<tr>
<td>Hand over</td>
<td>Operation that consists in performing a UAV command and control transfer from one UCS to another one or from one workstation to another one in the same UCS.</td>
</tr>
<tr>
<td>Landing</td>
<td>The process in which an aircraft is brought from a safe flight condition to a standstill on the intended landing surface (ground, sea surface, etc.).</td>
</tr>
<tr>
<td>Landing Rejection point:</td>
<td>Point in the landing trajectory beyond which the Light VTOL UAV has automatically determined to continue to its touchdown. Beyond this point, the Light VTOL UAV will only abort the landing and continue to a safe and stabilized airborne state if manually aborted by the Light VTOL UAV crew.</td>
</tr>
<tr>
<td>Lift Drive System</td>
<td>The includes any part necessary to transmit power from the engines to the vertical lifting element(s) hubs, ducted fan drive hub or shrouded vertical lifting element(s) hubs. This includes gear boxes, shafting, universal joints, couplings, vertical lifting element(s) brake assemblies, clutches, supporting bearings for shafting, any attendant accessory pads or drives, and any cooling fans that are a part of, attached to, or mounted on the vertical lifting element(s), fan or shrouded vertical lifting element(s) drive systems.</td>
</tr>
<tr>
<td>Lifting Element</td>
<td>A powered device such as a fan, propeller or rotor that provides a reactive force, when in motion relative to surrounding air, that can lift or control a UAV in flight</td>
</tr>
<tr>
<td>Line of Sight</td>
<td>Visually unobstructed straight line through space between the transmitter and receiver.</td>
</tr>
<tr>
<td>Masking</td>
<td>Blockage of data link due to fuselage blockage or unfavourable UAV attitude.</td>
</tr>
<tr>
<td>Multi-Engine Inoperative</td>
<td>When more than one engine fails to supply adequate power during any phase of flight.</td>
</tr>
<tr>
<td>Must</td>
<td>Indicates a mandatory requirement (see also “shall”).</td>
</tr>
<tr>
<td>Payload</td>
<td>Device or equipment carried by the UAV which performs the mission assigned. The payload comprises all elements of the air vehicle that are not necessary for flight but are carried for the purpose of fulfilling specific mission objectives.</td>
</tr>
<tr>
<td>Pcumcat</td>
<td>The cumulative probability resulting from the probabilities per flight hour of all Individual Catastrophic Failure Conditions caused by all systems</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>------</td>
<td>------------</td>
</tr>
<tr>
<td>Safety trace</td>
<td>Area associated with the take-off/launch and landing/recovery phases of a UAV in which an otherwise unacceptable risk is mitigated by clearing that area.</td>
</tr>
<tr>
<td>Secondary flight control</td>
<td>All flight controls other than primary flight controls such as wheel brakes, vertical lifting element(s) brakes controls.</td>
</tr>
<tr>
<td>Shall</td>
<td>Indicates a mandatory requirement (see also &quot;must&quot;).</td>
</tr>
<tr>
<td>Should</td>
<td>Indicates a preferred, but not mandatory, method of accomplishment.</td>
</tr>
<tr>
<td>Take-off</td>
<td>Process by which an aircraft leaves the surface and attains controlled flight (includes launch via catapult or rocket assistance).</td>
</tr>
<tr>
<td>Take-off Rejection Point</td>
<td>Point in the take-off trajectory before which a rejected take-off results in the Light VTOL UAV: either automatically returning to a touchdown (if already airborne), or holding on the pad (if not already airborne); and after which, the Light VTOL UAV will automatically continue to a safe and stabilized airborne state.</td>
</tr>
<tr>
<td>Third Party</td>
<td>Members of the public and any non-participating personnel</td>
</tr>
<tr>
<td>UA Operator</td>
<td>The UAS designated UA operator in the UA Control Station tasked with overall responsibility for operation and safety of the UAS. Equivalent to the pilot in command of a manned aircraft.</td>
</tr>
<tr>
<td>UAV Control Box / UAV Control Station</td>
<td>A facility or device from which the UAV is controlled and/or monitored for all phases of flight.</td>
</tr>
<tr>
<td>Unmanned Aircraft System</td>
<td>A UAS comprises individual UAS elements consisting of the UA, the UA control station and any other UAS elements necessary to enable flight, such as a command and control data link, communication system, and take-off and landing element. There may be multiple UA, UCS, or take-off and landing elements within a UAS. Includes the UA, modular mission payloads, data links, launch and recovery equipment, mission planning and control stations, data exploitation stations and logistic support.</td>
</tr>
<tr>
<td>Unmanned Aerial Vehicle UAV</td>
<td>Aircraft which is designed to operate with no human pilot on board and which does not carry personnel. Moreover a UAV is:</td>
</tr>
<tr>
<td>UCS flight control</td>
<td>Flight controls used by the UAV crew in the UCS to operate the UAV in the semi-automatic mode of control.</td>
</tr>
<tr>
<td>Unsafe</td>
<td>Condition or situation that is likely to cause a Hazardous or more serious event.</td>
</tr>
<tr>
<td>Workload</td>
<td>Amount of work assigned to or expected from a person in a specified time.</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Workstation</td>
<td>Computer interface between an individual UAS crew member and the UAS to perform the functions of mission planning, flight control and monitoring and for display and evaluation of the downloaded image and data (where applicable).</td>
</tr>
<tr>
<td>Vertical Take-Off and Landing VTOL</td>
<td>An aircraft that uses powered lift to ascend or descend vertically or near vertically and does not require forward flight to generate continuous lift by a fixed non-moving lifting surface to remain airborne. Light VTOL aircraft may exhibit forward, rearward and side to side flight or hover in place.</td>
</tr>
</tbody>
</table>
LANDING GEAR

UL.GL.1  Shock absorption tests

The landing inertia load factor and the reserve energy absorption capacity of the landing gear must be substantiated by the tests prescribed in UL.GL.2 and UL.GL.3, respectively or by analysis. These tests must be conducted on the complete rotorcraft or on undercarriage units in their proper relation.

UL.GL.2  Limit drop test

The limit drop test must be conducted as follows:

(a) The drop height must be 0.20 m (8 inches) from the lowest point of the landing gear to the ground; or

(b) If considered, the rotor lifting specified in UL.6.2 (a) must be introduced into the drop test by appropriate energy absorbing devices or by the use of an effective mass.

(c) Each landing gear unit must be tested in the attitude simulating the landing condition that is most critical from the standpoint of the energy to be absorbed by it.

(d) When an effective mass is used in showing compliance with sub-paragraph (b) the following formula may be used instead of more rational computations:

\[ W_e = W \frac{h + (1 - L)d}{h + d} \]

\[ n = n_j \frac{W_e}{W} + L \]

We = the effective weight to be used in the drop test.

W=WM for main gear units, equal to the static reaction on the particular unit with the rotorcraft UAV in the most critical attitude. A rational method may be used in computing a main gear static reaction, taking into consideration the moment arm between the main wheel reaction and the rotorcraft centre of gravity.

W=WN for nose gear units, equal to the vertical component of the static reaction that would exist at the nose wheel, assuming that the mass of the rotorcraft acts at the centre of gravity and exerts a force of 1.0 g downward and 0.25 g forward.

W=WT for tail wheel units equal to whichever of the following is critical:

(1) The static weight on the tail wheel with the rotorcraft UAV resting on all wheels; or
(2) The vertical component of the ground reaction that would occur at the tail wheel, assuming that the mass of the rotorcraft UAV acts at the centre of gravity and exerts a force of 1 g downward with the rotorcraft in the maximum nose-up attitude considered in the nose-up landing conditions.

h = specified free drop height.

L = ratio of assumed rotor lifting to the rotorcraft weight.

d = deflection under impact of the tyre (at the proper inflation pressure) plus the vertical component of the axle travel relative to the drop mass.

n = limit inertia load factor.

nj = the load factor developed, during impact, on the mass used in the drop test (i.e., the acceleration dv/dt in g recorded in the drop test plus 1.0).
UL.GL.3 Reserve energy absorption drop tests

The reserve energy absorption drop test must be conducted as follows:

(a) The drop height must be 1.5 times that specified in UL.GL.2(a).

(b) Rotor lifting, where considered in a manner similar to that prescribed in UL.GL.2(b), may not exceed 1.5 times the lifting allowed under that paragraph.

(c) The landing gear must withstand this test without collapsing. Collapse of the landing gear occurs when a member of the nose, tail, or main gear will not support the rotorcraft in the proper attitude or allows the rotorcraft UAV structure, other than the landing gear and external accessories, to impact the landing surface.

UL.GL.4 Skis

The maximum load rating of each ski must equal or exceed the maximum load determined under the applicable ground load requirements of this code.

UL.GL.5 Main float buoyancy

(a) For main floats, the buoyancy necessary to support the maximum weight of the rotorcraft in fresh water must be exceeded by -

1. 50 %, for single floats; and
2. 60 %, for multiple floats.

(b) Each main float must have enough watertight compartments so that, with any single main float compartment flooded, the main floats will provide a margin of positive stability great enough to minimize the probability of capsizing.

UL.GL.6 Main float design

(a) Bag floats. Each bag float must be designed to withstand -

1. The maximum pressure differential that might be developed at the maximum altitude for which certification with that float is requested; and
2. The vertical loads prescribed in CS VLR.521(a), distributed along the length of the bag over three-quarters of its projected area.

(b) Rigid floats. Each rigid float must be able to withstand the vertical, horizontal, and side loads prescribed in CS VLR.521. These loads may be distributed along the length of the float.

UL.GL.7 Hulls

For each rotorcraft UAV, with a hull and auxiliary floats, that is to be approved for both taking off from and landing on water, the hull and auxiliary floats must have enough watertight compartments so that, with any single compartment flooded, the buoyancy of the hull and auxiliary floats (and wheel tires if used) provides a margin of positive stability great enough to minimize the probability of capsizing.
GENERAL

UL.RE.1 Instruction manual

An instruction manual containing the necessary information essential for installing, operating, servicing and maintaining the engine must be provided.

UL.RE.2 Engine ratings and operating limitations

Engine ratings, including transients, and operating limitations are to be established and based on the operating conditions demonstrated during the bench tests prescribed in this Annex. They include power ratings and operational limitations relating to speeds, temperatures, pressures, fuels and oils which are necessary for the safe operation of the engine(s).

UL.RE.3 Selection of engine power ratings

Each selected rating, including transients, must be for the lowest power that all engines of the same type may be expected to produce under the conditions to determine that rating.

ENGINE CONTROL SYSTEM

UL.RE.4 It must be substantiated by tests, analysis or a combination thereof that the Engine Control System performs the intended functions in all its control modes and in accordance with the design usage spectrum as per UL.0:

- without exceeding operating limits within the flight envelope,
- allowing adequate modulation of power/thrust,
- without creating excessive power/thrust oscillations,
- with safe transition between different control modes,
- without surge and stall of the engine.

DESIGN AND CONSTRUCTION

UL.RE.5 Materials

The suitability and durability of materials used in the engine must:

(a) be established on the basis of experience or tests;
(b) conform to approved specifications that ensure their having the strength and other properties assumed in the design data;
(c) demonstrate that measures are taken to ensure protection from corrosion and deterioration.
UL.RE.6 Strength

The maximum stresses developed in the Engine must not exceed values conforming to those established by satisfactory practice for the material involved, due account being taken of the particular form of construction and the most severe operating conditions.

UL.RE.7 Fire prevention

(a) The design and construction of the engine and the materials used must minimise the probability of the occurrence and spread of fire because of structural failure, overheating or other causes.

(b) Each tank, external line or fitting that conveys flammable fluids must be at least fire resistant. Components must be shielded or located to safeguard against the ignition of leaking flammable fluid.

UL.RE.8 Electrical bonding

Any components, modules, equipment and accessories that are susceptible to or are potential sources of static discharges or currents from electrical faults, must be designed and constructed so as to be grounded to the main Engine earth, as necessary to minimise the accumulation of electro-static or electrical charge that would cause:

- Injury from electrical shock,
- Unintentional ignition in areas where flammable fluids or vapours could be present,
- Unacceptable interference with electrical or electronic equipment.

UL.RE.9 Durability

Engine design and construction must minimise the probability of occurrence of an unsafe condition of the engine between overhauls;

(a) The effects of cyclic loading, environmental and operational degradation must not reduce the integrity of the engine below acceptable levels.

(b) The effects of likely subsequent part failures must not reduce the integrity of the engine below acceptable levels.

UL.RE.10 Engine cooling

Engine design and construction must provide the necessary cooling under conditions in which the UA is expected to operate.

UL.RE.11 Engine mounting attachments and structure

(a) The maximum allowable loads for engine mounting attachments and related structure must be specified, taking account of the flight and ground loads calculated from the UA design usage spectrum (UL.0).
(b) The engine mounting attachments and related structure must be able to withstand the specified loads without failure, malfunction or permanent deformation.

UL.RE.12 Accessory attachment

Each accessory drive and mounting attachment must be designed and constructed so that the engine will operate properly with the accessories attached. The design of the engine must allow the examination, adjustment or removal of each essential engine accessory.

UL.RE.13 Vibration

The engine must be designed and constructed to function throughout its normal operating range of crankshaft rotational speeds and engine powers without inducing excessive stress in any of the engine parts because of vibration and without imparting excessive vibration forces to the structure of the UA.

UL.RE.14 Fuel and induction system

(a) The fuel system of the engine must be designed and constructed to supply the appropriate mixture of fuel to the combustion chambers throughout the complete operating range of the engine under all starting, flight and atmospheric conditions.

(b) The intake passages of the engine through which air, or fuel in combination with air, passes must be designed and constructed to minimise ice accretion and vapour condensation in those passages. The engine must be designed and constructed to permit the use of a means for ice prevention.

(c) Filters, strainers or other equivalent means must be provided to protect the fuel system from malfunction due to contaminants. These devices must have the capacity to accommodate any likely quantity of contaminants, including water, in relation to recommended servicing intervals and, if provided, the blockage or by-pass indication system. The Applicant must show (e.g. within the endurance test prescribed in UL.22.RE (a)) that foreign particles passing through the prescribed filtering means will not critically impair engine fuel system functioning.

Any main fuel filter or strainer having a significant function for the control of the power must have a means to permit indication to the UA Operator of impending blockage of the filter or strainer and all necessary instructions must be provided.

If a by-pass means is provided on any filter or strainer, it must be demonstrated that open by-pass operation is safe.

(d) Each passage in the induction system that conducts a mixture of fuel and air, and in which fuel may accumulate, must be self-draining to prevent a liquid lock in the combustion chambers. This applies to all attitudes that the Applicant establishes as those the engine can have when the UA in which it is installed is in the static ground attitude.

UL.RE.15 Oil system (four-stroke engines only)
ANNEX C

(a) The oil system of the engine must be designed and constructed so that it will function properly in all attitudes and atmospheric conditions in which the UA is expected to operate. In wet-sump engines this requirement must be met when the engine contains only the minimum oil quantity, the minimum quantity being not more than half the maximum quantity.

In particular the oil breather (vent) must be resistant to blockage caused by icing.

(b) The oil system of the engine must be designed and constructed to allow installing a means of cooling the lubricant.

(c) The crankcase must be vented to preclude leakage of oil from excessive pressure in the crankcase.

(d) All parts of the oil system that are not inherently capable of accepting contaminants likely to be present in the oil or otherwise introduced into the oil system must be protected by suitable filter(s) or strainer(s). These must provide a degree of filtration sufficient to preclude damage to the engine and engine equipment and have adequate capacity to accommodate contaminants in relation to the specified servicing intervals.

If the most critical main oil filter does not incorporate a by-pass, then it must have provision for appropriate indication to the UA Operator of impending blockage and all necessary instructions must be provided.

If a by-pass means is provided on any filter or strainer, it must be demonstrated that open by-pass operation is safe. Indication of by-pass operation must be provided to permit appropriate maintenance action to be initiated.

(e) Each oil tank must:
- have, or have provision for, an oil quantity indicator;
- have an expansion space of an adequate size which must be impossible to inadvertently fill.

(f) Each brand and type of oil to be approved, and the associated limitations, must be declared and substantiated.

UL.RE.16 Electromagnetic Compatibility

The reciprocating engine spark ignition system and the other UAS components (e.g. data links, communication) must be electromagnetically compatible.

UL.RE.17 All engine components must be resistant to humidity (applicable standards that should be used as a reference to tailor a humidity test are RTCA-DO-160D or MIL-STD-810).

UL.RE.18 A failure analysis of the engine and its installation, including the control system, must be made to establish that the engine does not introduce unacceptable hazards as per the UAS Hazard Reference System.
BENCH TESTS

UL.RE.19 Vibration test
The engine must undergo a vibration survey to establish crankshaft torsional and bending characteristics over a range of rotational speeds from idling to 110% of the maximum continuous speed or 103% of the maximum desired take-off speed, whichever is the greater. The survey must be conducted with a representative vertical lifting element (the vertical lifting element should be so chosen that the prescribed maximum rotational speed is obtained at full throttle or at the desired maximum permissible manifold pressure, whichever is appropriate). No hazardous condition may be present.

UL.RE.20 Calibration test
Each engine must be subjected to the calibration tests necessary to establish its power characteristics and the conditions for the endurance test specified in UL.RE.22 (a). The results of the power characteristics calibration tests form the basis for establishing the characteristics of the engine over its entire operating range of crankshaft rotational speeds, manifold pressures, and fuel/air mixture settings. Power ratings are based on standard atmospheric conditions at sea-level.

UL.RE.21 Detonation test (spark ignition only)
The engine must be tested to establish that it can function without detonation throughout the range of intended conditions of operation.

UL.RE.22 Endurance test
(a) The engine must be subjected to an endurance test (with a representative vertical lifting element) that includes a total of 50 hours of operation and consists of the cycles representative of the Design Usage Spectrum (UL.0) and as agreed by the Certifying Authority.
(b) Additional endurance testing at particular rotational speed(s) may be required depending on the results of the tests prescribed in UL.RE.19, to establish the ability of the engine to operate without fatigue failure.
(c) The endurance test must be representative of the Design Usage Spectrum (UL.0) as agreed by the Certifying Authority.
(d) During or following the endurance test the fuel and oil consumption must be determined.

UL.RE.23 Operation test
The operation test must include the demonstration of backfire characteristics, starting, idling, acceleration, over-speeding and any other operational characteristics of the engine.
UL.RE.24 Engine component test

(a) For engine components that cannot be adequately substantiated by endurance testing in accordance with UL.RE.22 (a), the Applicant must ensure that additional tests are conducted to establish that components are able to function reliably in all normally anticipated flight and atmospheric conditions.

(b) Temperature limits must be established for each component that requires temperature controlling provisions to ensure satisfactory functioning, reliability and durability.

UL.RE.25 Teardown inspection

After the endurance test has been completed the engine must be completely disassembled. No essential component may show rupture, cracks or excessive wear.

UL.RE.26 Engine adjustment and parts replacement

Service and minor repairs to the engine may be made during the bench tests. If major repairs or replacements of parts is necessary during the tests or after the teardown inspection, or if essential parts have to be replaced, the engine must be subjected to any additional tests the Certifying Authority may require.

RESTARTING CAPABILITY (where applicable)

UL.RE.27 According to the specific application, the Certifying Authority may require a restarting capability as follows:

an altitude and airspeed envelope must be established for the aeroplane for in-flight engine restarting and the installed engine must have a restart capability within that envelope.
ELECTRIC ENGINES

GENERAL

UL.EE.1 Instruction manual

An instruction manual containing the necessary information essential for installing, operating, servicing and maintaining the engine must be provided.

UL.EE.2 Engine ratings and operating limitations

Engine ratings, including transients, and operating limitations are to be established and based on the operating conditions demonstrated during the bench tests prescribed in this Annex. They include power ratings and operational limitations relating to voltage, current, speeds and temperatures which are necessary for the safe operation of the engine(s).

UL.EE.3 Selection of engine power ratings

Each selected rating, including transients, must be for the lowest power that all engines of the same type may be expected to produce under the conditions to determine that rating.

ENGINE CONTROL SYSTEM

UL.EE.4 It must be substantiated by tests, analysis or a combination thereof that the Engine Control System performs the intended functions in all its control modes and in accordance with the design usage spectrum as per UL.0:

- without exceeding operating limits within the flight envelope,
- allowing adequate modulation of power/thrust,
- without creating excessive power/thrust oscillations,
- with safe transition between different control modes,
- without surge and stall of the engine.

DESIGN AND CONSTRUCTION

UL.EE.5 Materials

The suitability and durability of materials used in the engine must:

(a) be established on the basis of experience or tests;
(b) conform to approved specifications that ensure their having the strength and other properties assumed in the design data;
(c) demonstrate that measures are taken to ensure protection from corrosion and deterioration.
UL.EE.6  Strength
The maximum stresses developed in the Engine must not exceed values
conforming to those established by satisfactory practice for the material involved,
due account being taken of the particular form of construction and the most severe
operating conditions.

UL.EE.7  Fire prevention - N/A

UL.EE.8  Electrical bonding.
Any components, modules, equipment and accessories that are susceptible to or
are potential sources of static discharges or currents from electrical faults, must
be designed and constructed so as to be grounded to the main Engine earth, as
necessary to minimise the accumulation of electro-static or electrical charge that
would cause:
- Injury from electrical shock,
- Unintentional ignition in areas where flammable fluids or vapours could be
  present,
- Unacceptable interference with electrical or electronic equipment.

UL.EE.9  Durability
Engine design and construction must minimise the probability of occurrence of an
unsafe condition of the engine between overhauls.
(a) The effects of cyclic loading, environmental and operational degradation
    must not reduce the integrity of the engine below acceptable levels.
(b) The effects of likely subsequent part failures must not reduce the integrity of
    the engine below acceptable levels.

UL.EE.10 Engine cooling
Engine design and construction must provide the necessary cooling under
conditions in which the UA is expected to operate.

UL.EE.11 Engine mounting attachments and structure
(a) The maximum allowable loads for engine mounting attachments and related
    structure must be specified, taking account of the flight and ground loads
    calculated from the UA design usage spectrum (UL.0).
(b) The engine mounting attachments and related structure must be able to
    withstand the specified loads without failure, malfunction or permanent
    deformation.

UL.EE.12 Accessory attachment
Each accessory drive and mounting attachment must be designed and constructed
so that the engine will operate properly with the accessories attached. The design
of the engine must allow the examination, adjustment or removal of each essential
engine accessory.
UL.EE.13  Vibration
The engine must be designed and constructed to function throughout its normal
operating range of speeds and engine powers without inducing excessive stress
in any of the engine parts because of vibration and without imparting excessive
vibration forces to the structure of the UA.

UL.EE.14  Fuel and induction system - N/A

UL.EE.15  Lubrication system - N/A

UL.EE.16  Electromagnetic Compatibility
The electrical engine must be electromagnetically compatible with the
electromagnetic environment of the installation.

UL.EE.17  Humidity
The electrical engine must function properly in a humid environment (see
UL.EE.25.

UL.EE.18  A failure analysis of the engine and its installation, including the control system,
must be made to establish that the engine does not introduce unacceptable
hazards as per the UAS Hazard Reference System.

BENCH TESTS

UL.EE.19  Vibration test - N/A

UL.EE.20  Calibration test
Each engine must be subjected to the calibration tests necessary to establish its
power characteristics and the conditions for the endurance test specified in
UL.EE.22. The results of the power characteristics calibration tests form the basis
for establishing the characteristics of the engine over its entire operating range of
rotational speeds.

UL.EE.21  Detonation test - N/A

UL.EE.22  Endurance test
(a) The electric engine assembly, as installed in the UA, must be subjected to an
endurance test (with a representative vertical lifting element) that includes a
total of 50 hours of operation and consists of the cycles specified in
UL.EE.22(c).

(b) N/A

(c) The endurance test procedure must be as agreed by the Certifying
Authority and shall be more severe than the engine design duty cycle. If the
UA is designed to stress engine above maximum continuous power, this must be addressed in the endurance test procedure.

As an example, each cycle could be conducted as follows:

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Environmental Temperature</th>
<th>Duration [min]</th>
<th>Power setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Cold</td>
<td>2</td>
<td>Maximum continuous</td>
</tr>
<tr>
<td>1.2</td>
<td>Cold</td>
<td>43</td>
<td>Nominal power</td>
</tr>
<tr>
<td>1.3</td>
<td>Cold</td>
<td>2</td>
<td>Maximum continuous</td>
</tr>
<tr>
<td>1.4</td>
<td>Cold</td>
<td>43</td>
<td>Nominal power</td>
</tr>
</tbody>
</table>

**TOTAL DURATION CYCLE 1:** 90 [min]

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Environmental Temperature</th>
<th>Duration [min]</th>
<th>Power setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Ambient</td>
<td>2</td>
<td>Maximum continuous</td>
</tr>
<tr>
<td>2.2</td>
<td>Ambient</td>
<td>43</td>
<td>Nominal power</td>
</tr>
<tr>
<td>2.3</td>
<td>Ambient</td>
<td>2</td>
<td>Maximum continuous</td>
</tr>
<tr>
<td>2.4</td>
<td>Ambient</td>
<td>43</td>
<td>Nominal power</td>
</tr>
</tbody>
</table>

**TOTAL DURATION CYCLE 2:** 90 [min]

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Environmental Temperature</th>
<th>Duration [min]</th>
<th>Power setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Hot</td>
<td>2</td>
<td>Maximum continuous</td>
</tr>
<tr>
<td>3.2</td>
<td>Hot</td>
<td>43</td>
<td>Nominal power</td>
</tr>
<tr>
<td>3.3</td>
<td>Hot</td>
<td>2</td>
<td>Maximum continuous</td>
</tr>
<tr>
<td>3.4</td>
<td>Hot</td>
<td>43</td>
<td>Nominal power</td>
</tr>
</tbody>
</table>

**TOTAL DURATION CYCLE 3:** 90 [min]

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Environmental Temperature</th>
<th>Duration [min]</th>
<th>Power setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Ambient</td>
<td>3</td>
<td>Maximum continuous</td>
</tr>
<tr>
<td>4.2</td>
<td>Ambient</td>
<td>102</td>
<td>Nominal power</td>
</tr>
</tbody>
</table>

**TOTAL DURATION CYCLE 4:** 105 [min]

**TOTAL SEQUENCE DURATION (1 to 4):** 375 [min]

Iterate the previous 4-cycle sequence 8 times.

Cold temperature setting = minimum temperature according to the design usage spectrum as per UL.0

Ambient temperature setting = ISA sea level temperature (15°C)

Hot temperature setting = maximum temperature according to the design usage spectrum as per UL.0
UL.EE.23 Operation test

The operation test must include the demonstration starting, loiter and cruise related power settings, acceleration, over-speeding and any other operational characteristics of the engine.

UL.EE.24 Engine component test

(a) For engine components that cannot be adequately substantiated by endurance testing in accordance with UL.EE.22(a) to (c), the Applicant must ensure that additional tests are conducted to establish that components are able to function reliably in all normally anticipated flight and atmospheric conditions.

(b) Temperature limits must be established for each component that requires temperature controlling provisions to ensure satisfactory functioning, reliability and durability.

UL.EE.25 Humidity test

The electric engine assembly should be subjected to combined temperature and humidity test according to a procedure to be as agreed by the Certifying Authority, (RTCA-DO-160D should be used as a reference to tailor a humidity test). The procedure should include a series of functional tests after performing each block of Environmental Cycling Conditioning at Cold, Ambient and Hot temperature combined with 95 ± 5 % Relative Humidity. The influence of humidity aspects in the design of the engines could also be assessed using the Endurance Test (UL.EE.22) if, in addition to the Temperature, the Relative Humidity is also controlled during endurance cycling be as agreed by the Certifying Authority.

UL.EE.26 Teardown inspection

After the endurance test has been completed the engine must be completely disassembled. No essential component may show rupture, cracks or excessive wear.

UL.EE.27 Engine adjustment and parts replacement

Service and minor repairs to the engine may be made during the bench tests. If major repairs or replacements of parts is necessary during the tests or after the teardown inspection, or if essential parts have to be replaced, the engine must be subjected to any additional tests the Certifying Authority may require.
UL.TE.1 Instruction manual

An instruction manual containing the necessary information essential for installing, operating, servicing and maintaining the engine must be provided. The instruction manual must also contain all appropriate safety procedures that the operator and ground crew must respect during maintenance, pre-flight checks, taxiing, take-off and landing, as identified in 0.

UL.TE.2 Engine ratings and operating limitations

Engine ratings, including transients, and operating limitations are to be established and based on the operating conditions demonstrated during the bench tests prescribed in this Annex. They include thrust/power ratings, specific fuel consumptions, operational limitations relating to speeds, temperatures, pressures, fuels and oils which are necessary for the safe operation of the engine(s).

UL.TE.3 Selection of engine power ratings

Each selected rating, including transients, must be for the lowest thrust/power that all engines of the same type may be expected to produce under the conditions to determine that rating.

ENGINE CONTROL SYSTEM

UL.TE.4 It must be substantiated by tests, analysis or a combination thereof that the Engine Control System performs the intended functions in all its control modes and in accordance with the design usage spectrum as per UL.0:
- without exceeding operating limits within the flight envelope,
- allowing adequate modulation of power/thrust,
- without creating excessive power/thrust oscillations,
- with safe transition between different control modes,
- without surge and stall of the engine.

UL.TE.5 Over-speed protection should be provided (either electronic, hydromechanical or mechanical) with reasonable assurance that it functions correctly. If over-speed protection is not provided, the applicant must show compliance with additional test requirements, in order to show at least that:
- each rotor does not burst up to 120% of the maximum permissible rotor speed;
- no detrimental vibrations occur for the entire UA up to 120% of the maximum permissible rotor speed.

SAFETY

A system safety assessment (including the engine control system, power supply, starting system and any applicable interfaces with UAS) must be completed for the
engine to ensure that the UAS safety requirements are met (as per UL.30). Particular consideration must be given but not limited to the following hazards: uncontrolled fire, burst, uncontained high-energy debris, non-restartable in-flight shutdown and loss of shutdown capability, release of the vertical lifting element by the drive system (where applicable). The safety assessment must also identify all appropriate precautions and/or actions that the operator and ground crew must respect during maintenance, pre-flight checks, taxiing, take-off and landing.

UL.TE.6 Software design assurance level must be compatible with UL31.

DESIGN AND CONSTRUCTION

UL.TE.7 Materials

The suitability and durability of materials used in the engine must:

(a) be established on the basis of experience or tests;

(b) conform to approved specifications that ensure their having the strength and other properties assumed in the design data;

(c) demonstrate that measures are taken to ensure protection from corrosion and deterioration.

UL.TE.8 Strength

(a) The maximum stresses developed in the engine must not exceed values conforming to those established by satisfactory practice for the material involved, due account being taken of the particular form of construction and the most severe operating conditions.

(b) The strength verification must consider all applicable loading conditions resulting from normal operation. Loads from abnormal speeds and temperature must be considered if over-speed and over-temperature protection are not implemented. Gyroscopic loads resulting from normal flight manoeuvres must be considered.

(c) The following factors of safety should be used to design all engine components (including tanks):

<table>
<thead>
<tr>
<th>Load type</th>
<th>Limit Load</th>
<th>Ultimate Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Externally applied loads</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Thermal loads</td>
<td>1.0</td>
<td>1.5 (1.0 could be used in case of over-temperature protection)</td>
</tr>
<tr>
<td>Thrust loads</td>
<td>1.0</td>
<td>1.2 (1.0 could be used in case a Full Authority Digital Engine Control Unit prevents maximum thrust exceedance)</td>
</tr>
<tr>
<td>Internal pressures</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>UA flow field loads</td>
<td>1.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>
(d) Blade-out condition

Subsequent to blade failure at maximum allowable steady state speed, the engine must not experience: uncontrolled high-energy debris, uncontrolled fire; catastrophic rotor, bearing, support or mount failures; over-speed conditions; leakage of flammable fluid lines; loss of ability to shut down the engine.

Unbalance loads transmitted to the UA structure in engine blade-out conditions must be determined and considered in the UA strength assessment.

(e) Bird ingestion protection must be as agreed by the Certifying Authority, in accordance with UL.13UL13.2.

UL.TE.9 Fracture critical parts

(a) Fracture critical parts must be clearly identified in a summary, as those parts of the engine (and of the starting system, where applicable) whose failure may result in catastrophic outcome as a result of non-containment either due to direct part failure or by causing other progressive part failures. Examples of fracture critical parts are disks (including blisks), radial compressors and turbines.

(b) An Engineering Plan, a Manufacturing Plan and a Service Management Plan must be established by the Applicant to identify processes and tasks that guarantee each critical part will be withdrawn from service at an approved life before structural failure can occur.

(c) For each fracture critical part, the containment should be established by test, analysis, or a combination thereof in the most critical condition with respect to part integrity, be as agreed by the Certifying Authority.

For fracture critical parts not shown to be contained appropriate damage tolerance assessments should be performed to address the potential for failure from material, manufacturing and service-induced anomalies within the approved life of the part. The damage tolerance assessment should identify inspection intervals adequate to prevent initial flaws to grow to critical length before they will be detected. The methodology for damage tolerance assessment must be detailed in the previous Plans and be as agreed by the Certifying Authority.

The Certifying Authority may exempt the Applicant from assessing damage tolerance. For instance, the following cases may apply:

- engines intended to be used for a sufficiently short life (expressed in engine total accumulated cycles) with adequate field or test experience, be as agreed by the Certifying Authority;
- sufficiently short life limitations for fracture critical parts.

UL.TE.10 Fire prevention

(a) The design and construction of the engine and the materials used must minimise the probability of the occurrence and spread of fire because of structural failure, overheating or other causes.
(b) Each tank, external line or fitting that conveys flammable fluids must be at least fire-resistant. Components must be shielded or located to safeguard against the ignition of leaking flammable fluid.

(c) Engine control system components which are located in a fire zone must be at least fire resistant.

(d) Unintentional accumulation of hazardous quantities of flammable fluid within the engine must be prevented by draining and venting.

(e) Those features of the engine which form part of the mounting structure or engine attachment points must be at least fire-resistant.

UL.TE.11 Electrical bonding.

Any components, modules, equipment and accessories that are susceptible to or are potential sources of static discharges or currents from electrical faults, must be designed and constructed so as to be grounded to the main Engine earth, as necessary to minimise the accumulation of electro-static or electrical charge that would cause:
- Injury from electrical shock,
- Unintentional ignition in areas where flammable fluids or vapours could be present,
- Unacceptable interference with electrical or electronic equipment.

UL.TE.12 Durability

The engine service life must be demonstrated for the engine usage determined in accordance with the UAS design usage spectrum as per UL.0.

(a) Low Cycle Fatigue (LCF) life for cold parts and hot parts must be demonstrated.

(b) Engine structural components operating under combined steady and vibratory stress conditions must be designed to ensure resistance to High Cycle Fatigue (HCF) cracking(3).

3 An acceptable means of compliance to this requirement is to show that the natural frequencies of this components are outside of the engine operating range with a minimum of 20% margin. All fracture critical parts should be designed according to this criterion. For other components it should be shown that the vibratory (HCF) stress should be restricted to 40% of the material capability in a Haigh diagram (in the absence of data at a number of values of mean stress, the diagram could be constructed by connecting a straight line from the data point from fully reversed alternating stress around zero mean stress and the Yield Tensile Stress. A maximum allowable vibratory stress limit should be established. Besides the high mean stress regime should be avoided.
UL.TE.13 Engine cooling
Engine design and construction must provide the necessary cooling under conditions in which the UA is expected to operate.

UL.TE.14 Engine mounting attachments and structure
(a) The maximum allowable loads for engine mounting attachments and related structure must be specified, taking account of the flight and ground loads calculated from the UA design usage spectrum (UL.0).
(b) The engine mounting attachments and related structure must be able to withstand the specified loads without failure, malfunction or permanent deformation.

UL.TE.15 Accessory attachment
Each accessory drive and mounting attachment must be designed and constructed so that the engine will operate properly with the accessories attached. The design of the engine must allow the examination, adjustment or removal of each essential engine accessory.

UL.TE.16 Vibration
The engine must be designed and constructed to function throughout the specified UA flight envelope and its normal operating range of rotational speeds and engine powers without inducing excessive stress in any of the engine parts because of vibration and without imparting excessive vibration forces to the structure of the UA.

UL.TE.17 Fuel system
(a) The fuel system of the engine must be designed and constructed to supply the appropriate fuel flow at the appropriate temperature and pressure conditions to the combustion chambers throughout the complete operating range of the engine under all starting, flight and atmospheric conditions. The engine fuel pump must have a margin of capacity over the maximum engine demand in the flight envelope consistent with the assumed UA installation specifications.
(b) Each fuel specification to be approved, including any additive, and the associated limitations in flow, temperature and pressure that ensure proper engine functioning under all intended operating conditions must be declared and substantiated.

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All engine parts should have a minimum HCF life of 10⁹ cycles. A reduction to lower values (e.g. 10⁷ cycles for steel parts and 3*10⁷ cycles for non-ferrous alloy parts) may be acceptable if it is demonstrated that this established number of HCF cycles will not occur in a component during its lifetime (consider that a part subjected to a frequency of 5 kHz for 60 hours accumulates 10⁹ cycles).
(c) Filters, strainers or other equivalent means must be provided to protect the fuel system from malfunction due to contaminants. These devices must have the capacity to accommodate any likely quantity of contaminants, including water, in relation to recommended servicing intervals and, if provided, the blockage or by-pass indication system.

The Applicant must show (e.g. within the endurance test prescribed in UL.TE.25 (a)) that foreign particles passing through the prescribed filtering means will not critically impair engine fuel system functioning.

Any main fuel filter or strainer having a significant function for the control of the thrust or power must have a means to permit indication to the UA Operator of impending blockage of the filter or strainer and all necessary instructions must be provided.

If a by-pass means is provided on any filter or strainer, it must be demonstrated that open by-pass operation is safe.

UL.TE.18 Oil system

(a) The design of the oil system must be such as to ensure its proper functioning under all intended flight attitudes, installation, atmospheric and operating conditions, including oil temperature and expansion factors.

(b) The oil system, including the oil tank expansion space, must be adequately vented. All atmospheric vents in the oil system must be located, or protected, to minimise ingress of foreign matter that could affect satisfactory Engine functioning. Venting must be so arranged that condensed water vapour which might freeze and obstruct the line cannot accumulate at any point.

(c) All parts of the oil system that are not inherently capable of accepting contaminants likely to be present in the oil or otherwise introduced into the oil system must be protected by suitable filter(s) or strainer(s). These must provide a degree of filtration sufficient to preclude damage to the engine and engine equipment and have adequate capacity to accommodate contaminants in relation to the specified servicing intervals.

If the most critical main oil filter does not incorporate a by-pass, then it must have provision for appropriate indication to the UA Operator of impending blockage and all necessary instructions must be provided.

If a by-pass means is provided on any filter or strainer, it must be demonstrated that open by-pass operation is safe. Indication of by-pass operation must be provided to permit appropriate maintenance action to be initiated.

(d) Each oil tank must:
- have, or have provision for, an oil quantity indicator;
- have an expansion space of an adequate size which must be impossible to inadvertently fill.

(e) Each brand and type of oil to be approved, and the associated limitations, must be declared and substantiated.
UL.TE.19  Electromagnetic Compatibility

The engine ignition system and control unit and the other UAS (e.g. data links, communication) must be electromagnetically compatible.

**ATMOSPHERIC CONDITIONS**

UL.TE.20  All engine components must be resistant to humidity (applicable standards that should be used as a reference to tailor a humidity test are RTCA-DO-160D or MIL-STD-810).

UL.TE.21  It must be demonstrated that the engine can operate satisfactorily under the meteorological conditions prescribed as per the UAS design usage spectrum (UL.0), with particular consideration to:

- icing conditions (where applicable),
- sand and dust (where applicable),
- hail ingestion (where applicable),
- atmospheric liquid water ingestion capability (where applicable).

**BENCH TESTS**

UL.TE.22  All tests must be made with a representative test item configuration including air intake, acceptable representative jet pipes, propelling nozzle and the designated engine control system.

UL.TE.23  Vibration test

Each Engine must undergo vibration surveys to establish that the vibration characteristics of those components that may be subject to mechanically or aerodynamically induced vibratory excitations are acceptable throughout the declared flight envelope.

The surveys must cover the ranges of power or thrust and both the physical and corrected rotational speeds for each rotor system, corresponding to operations throughout the range of ambient conditions in the declared flight envelope, from the minimum rotational speed up to 103% of the maximum physical and corrected rotational speed permitted for rating periods of two minutes or longer and up to 100% of all other permitted physical and corrected rotational speeds, including those that are Over-speeds. If there is any indication of a stress peak arising at the highest of those required physical or corrected rotational speeds, the surveys must be extended sufficiently to reveal the maximum stress values present, except that the extension need not cover more than a further 2 percentage points increase beyond those speeds.

Consideration should be given to the effect on vibration characteristics of excitation forces caused by typical fault conditions.

NATO UNCLASSIFIED
In order to identify the engine thrust/power changes that may occur during the endurance test specified in UL.TE.25, each test engine must be subjected to the calibration tests necessary to establish its thrust/power and specific fuel consumption characteristics. The results of the thrust/power characteristics calibration tests form the basis for establishing the characteristics of the engine over its entire operating range of rotational speeds, pressures, temperatures and altitudes. Thrust/power ratings are based on standard atmospheric conditions at sea-level.

**UL.TE.25  Endurance test**

(a) The engine must be subjected to an accelerated endurance test to be as agreed by the Certifying Authority. The duration and type of cycles of the test must be established in order to demonstrate that the engine is durable for its entire design service life:

- an appropriate combination of different types of throttle cycles (Start-Max-Shutdown, Idle-Max-Idle, Cruise-Max-Cruise) should test a low cycle fatigue life at least equivalent to one design service life;
- rapid accelerations to max thrust/power should be included in the test; additional time at particular rotational speed(s) may be required depending on the results of the tests prescribed in UL.TE.23, to establish the ability of the engine to operate without high cycle fatigue failures for its entire service life;
- during the endurance test the total time spent at the maximum turbine inlet temperature should be as long as during the design service life;
- the ignition system should be operated during the test for periods representative of the duration and frequency of operation of the system during the design service life;
- a sufficient number of cold starts and hot starts (including consecutive hot starts if allowed by the engine) should be performed during the test;
- part of the test should be performed with contaminated fuel as per UL.TE.17;
- part of the test should be performed with the minimum allowed oil quantity.

An alternative acceptable endurance test for Turbine Engines is made by the repetition of the following 6 hours stages in a number equivalent to the entire engine design service life (but never more than 25):

**Part 1**

One hour of alternate 5-minute periods at take-off Power or Thrust and minimum ground idle.

**Part 2**

30 minutes at

(A) Rated Maximum Continuous Power/Thrust during 3/5 of the total number of the 6-hour endurance test stages.

(B) Rated take-off Power/Thrust during 2/5 of the total number of the 6-hour endurance test stages.
ANNEX E

Where Engine rotational speeds between Maximum Continuous and take-off may be used in service, and these speeds would not be adequately covered by other Parts of the endurance test, then the following Part 2 must be substituted:

(C) Rated Maximum Continuous Power/Thrust during 2/5 of the total number of the 6-hour endurance test stages.

(D) Rated take-off Power/Thrust during 1/5 of the total number of the 6-hour endurance test stages.

(E) 2/5 of the total number of the 6-hour endurance test stages covering the range in 6 approximately equal speed increments between Maximum Continuous and take-off Power/Thrust.

Part 3 One hour and 30 minutes at Maximum Continuous Power/Thrust.

Part 4 2 hours and 30 minutes covering the range in 15 approximately equal speed increments from Ground Idling up to but not including Maximum Continuous Power/Thrust.

Part 5 30 minutes of accelerations and decelerations consisting of 6 cycles from Ground Idling to take-off Power/Thrust, maintaining take-off Power/Thrust for a period of 30 seconds, the remaining time being at Ground Idling.

NOTES

- During scheduled accelerations and decelerations in Parts 1 and 5 the power or thrust control lever must be moved from one extreme position to the other in a time not greater than one second.
- The oil pressure during the various stages must be varied in the complete range from minimum to maximum.
- If a significant peak blade vibration is found to exist at any condition within the operating range of the Engine, not less than 10 hours, but not exceeding 50%, of the incremental periods of Part 4 of the endurance test must be run with the rotational speed varied continuously over the range for which vibrations of the largest amplitude were disclosed by the vibration survey; if there are other ranges of rotational speed within the operational range of the Engine where approximately the same amplitude exists, a further 10 hours must be run in the same way for each such range.
- An adequate part of the cycles should be performed with contaminated fuel as per UL.TE.17.
- A sufficient number of cold starts and hot starts (including consecutive hot starts if allowed by the engine) should be performed during the test.
(b) Performance retention. The deteriorated engine after the endurance test must retain adequate thrust/power and specific fuel consumption, as agreed by the Certifying Authority.

UL.TE.26 Operation test

The operation test must include the demonstration of starting, idling, maximum acceleration, over-speeding, shut-down, re-light (where applicable), engine response characteristics (if required by the UA) and any other operational characteristics of the engine required by the UA in the most severe conditions of the operating envelope.

The engine should be run for sufficient time at the excess pressures and thrusts which would result from operation at a defined margin (to be as agreed by the Certifying Authority) above the maximum operational speed ($V_{C\text{-max}}$), under the most critical ambient pressure and temperature conditions, with maximum continuous thrust/power selected.

UL.TE.27 Engine component test

(a) For engine components (including gearbox, where applicable) that cannot be adequately substantiated by endurance testing in accordance with UL.TE.25, the Applicant must ensure that additional tests are conducted to establish that components are able to function reliably in all normally anticipated flight and atmospheric conditions.

(b) Temperature limits must be established for each component that requires temperature controlling provisions to ensure satisfactory functioning, reliability and durability.

UL.TE.28 Teardown inspection

After the endurance test has been completed the engine must be completely disassembled. No essential component may show rupture, cracks or excessive wear and deterioration.

UL.TE.29 Engine adjustment and parts replacement

Service and minor repairs to the engine may be made during the bench tests. If major repairs or replacements of parts is necessary during the tests or after the teardown inspection, or if essential parts have to be replaced, the engine must be subjected to any additional tests the Certifying Authority may require.

FUNCTIONING

UL.TE.30 Surge and instability

The engine must be free from dangerous surge and instability throughout the specified UA flight envelope and its operating range of ambient and running conditions within air intake pressure and temperature conditions compatible with the installation on the UA.
RESTARTING CAPABILITY (where applicable)

UL.TE.31 According to the specific application, the Certifying Authority may require a restarting capability as follows:

an altitude and airspeed envelope must be established for the aeroplane for in-flight engine restarting and the installed engine must have a restart capability within that envelope.
VERTICLE LIFTING ELEMENTS and DRIVE SYSTEMS

GENERAL

F-1

Rotor/Fan drive system and control mechanisms

UL.VLEDS.1 Rotor/Fan drive system and control mechanism tests.

UL.VLEDS.1.1 Each part tested as prescribed in this paragraph must be in a serviceable condition at the end of the tests. No intervening disassembly which might affect test results may be conducted.

UL.VLEDS.1.2 Each vertical lifting drive system and control mechanism must be tested for a duration of hours based on the intended design usage spectrum as agreed to by applicant and the certifying authority or for not less than 100 hours. The test must be conducted on the VTOL UAV, and the torque must be absorbed by the rotors to be installed, except that other ground or flight test facilities with other appropriate methods of torque absorption may be used if the conditions of support and vibration closely simulate the conditions that would exist during a test on the VTOL UAV.

UL.VLEDS.1.3 A 60-hour part of the test prescribed in UL.VLEDS.2 must be run at not less than maximum continuous torque and the maximum speed for use with maximum continuous torque. In this test, the main vertical lifting controls must be set in the position that will give maximum longitudinal cyclic pitch change to simulate forward flight. The auxiliary vertical lifting controls must be in the position for normal operation under the conditions of the test.

UL.VLEDS.1.4 A 30-hour or, for VTOL UAV for which the use of either 30-minute OEI/MEI power or continuous OEI/MEI power is requested, a 25-hour part of the test prescribed in subparagraph UL.VLEDS.1.2 must be run at not less than 75% of maximum continuous torque and the minimum speed for use with 75% of maximum continuous torque. The main and auxiliary vertical lifting controls must be in the position for normal operation under the conditions of the test.

UL.VLEDS.1.5 A 10-hour part of the test prescribed in sub-paragraph UL.VLEDS.1.2 must be run at not less than take-off torque and the maximum speed for use with take-off torque. The main and auxiliary vertical lifting controls must be in the normal position for vertical ascent.
(a) For multi-engine VTOL UAV for which the use of 2½ minute OEI/MEI power is requested, 12 runs during the 10-hour test must be conducted as follows:

(1) Each run must consist of at least one period of 2½ minutes with take-off torque and the maximum speed for use with take-off torque on all engines.

(2) Each run must consist of at least one period for each engine in sequence, during which that engine simulates a power failure and the remaining engines are run at 2½-minute OEI/MEI torque and the maximum speed for use with 2½-minute OEI/MEI torque for 2½ minutes.

(b) For multi-engine turbine-powered VTOL UAV for which the use of 30-second and 2-minute OEI/MEI power is requested, 10 runs must be conducted as follows:

(1) Immediately following a take-off run of at least 5 minutes, each power source must simulate a failure, in turn, and apply the maximum torque and the maximum speed for use with 30-second OEI/MEI power to the remaining affected drive system power inputs for not less than 30 seconds, followed by application of the maximum torque and the maximum speed for use with 2-minute OEI/MEI power for not less than 2 minutes. At least one run sequence must be conducted from a simulated ‘flight idle’ condition. When conducted on a bench test, the test sequence must be conducted following stabilization at take-off power.

(2) For the purpose of this paragraph, an affected power input includes all parts of the vertical lifting drive system which can be adversely affected by the application of higher or asymmetric torque and speed prescribed by the test.

(3) This test may be conducted on a representative bench test facility when engine limitations either preclude repeated use of this power or would result in premature engine removal during the test. The loads, the vibration frequency, and the methods of application to the affected vertical lifting drive system components must be representative of VTOL UAV conditions. Test components must be those used to show compliance with the remainder of this paragraph.

UL.VLEDS.1.6 The parts of the test prescribed in UL.VLEDS.1.3 and UL.VLEDS.1.4 must be conducted in intervals of not less than 30 minutes and may be accomplished either on the ground or in flight. The part of the test prescribed in sub-paragraph UL.VLEDS.1.5 must be conducted in intervals of not less than 5 minutes.
UL.VLEDS.1.7 At intervals of not more than five hours during the tests prescribed in UL.VLEDS.1.3, UL.VLEDS.1.4 and UL.VLEDS.1.5, the engine must be stopped rapidly enough to allow the engine and vertical lifting drive to be automatically disengaged from the vertical lifting elements.

UL.VLEDS.1.8 Under the operating conditions specified in UL.VLEDS.1.3, 500 complete cycles of lateral control, 500 complete cycles of longitudinal control of the main vertical lifting element(s) s, and 500 complete cycles of control of each auxiliary vertical lifting must be accomplished. A 'complete cycle' involves movement of the controls from the neutral position, through both extreme positions, and back to the neutral position, except that control movements need not produce loads or flapping motions exceeding the maximum loads or motions encountered in flight. The cycling may be accomplished during the testing prescribed in sub-paragraph UL.VLEDS.1.3.

UL.VLEDS.1.9 At least 200 start-up clutch engagements must be accomplished:
(a) So that the shaft on the driven side of the clutch is accelerated; and
(b) Using a speed and method selected by the applicant.

UL.VLEDS.1.10 For multi-engine VTOL UAV for which the use of 30-minute OEI/MEI power is requested, five runs must be made at 30-minute OEI/MEI torque and the maximum speed for use with 30-minute OEI/MEI torque, in which each engine, in sequence, is made inoperative and the remaining engine(s) is run for a 30-minute period.

UL.VLEDS.1.11 For multi-engine VTOL UAV for which the use of continuous OEI/MEI power is requested, five runs must be made at continuous OEI/MEI torque and the maximum speed for use with continuous OEI/MEI torque, in which each engine, in sequence, is made inoperative and the remaining engine(s) is run for a 1-hour period.

UL.VLEDS.2 Additional tests

UL.VLEDS.2.1 Any additional dynamic, endurance, and operational tests, and vibratory investigations necessary to determine that the vertical lifting drive mechanism is safe, must be performed.

UL.VLEDS.2.2 If turbine engine torque output to the transmission can exceed the highest engine or transmission torque rating limit, under normal operation the following test must be made:
(a) Under conditions associated with all engines operating, make 200 applications, for 10 seconds each, of torque that is at least equal to the lesser of:
(1) The maximum torque used as required in Vertical lifting drive system and control mechanism tests in meeting UL.VLEDS.1 plus 10%; or

(2) The maximum attainable torque output of the engines, assuming that torque limiting devices, if any, function properly.

(b) For multi-engine VTOL UAV under conditions associated with each engine or a series of engines in turn becoming inoperative, apply to the remaining transmission torque inputs, the maximum torque attainable under probable operating conditions, assuming that torque limiting devices, if any, function properly. Each transmission input must be tested at this maximum torque for at least 15 minutes.

(c) The tests prescribed in this paragraph must be conducted on the VTOL UAV at the maximum rotational speed intended for the power condition of the test and the torque must be absorbed by the vertical lifting to be installed, except that other ground or flight test facilities with other appropriate methods of torque absorption may be used if the conditions of support and vibration closely simulate the conditions that would exist during a test on the VTOL UAV.

UL.VLEDS.2.3 If autorotation capability is implemented, it must be shown by tests that the vertical lifting drive system is capable of operating under autorotative conditions for 15 minutes after the loss of pressure in the vertical lifting drive primary oil system.

UL.VLEDS.3 Shafting critical speed

NOTE: Advisory Circular paragraph § AC 27.931 provides guidance as to acceptable means of compliance.

UL.VLEDS.3.1 The critical speeds of any shafting must be determined by demonstration except that analytical methods may be used if reliable methods of analysis are available for the particular design.

UL.VLEDS.3.2 If any critical speed lies within, or close to, the operating ranges for idling, power on, and autorotative conditions; if autorotation capability is implemented, the stresses occurring at that speed must be within safe limits. This must be shown by tests.

UL.VLEDS.3.3 If analytical methods are used and show that no critical speed lies within the permissible operating ranges, the margins between the calculated critical speeds and the limits of the allowable operating ranges must be adequate to allow for possible variations between the computed and actual values.
UL.VLEDS.4 Shafting joints

UL.VLEDS.4.1 Each universal joint, slip joint, and other shafting joints whose lubrication is necessary for operation must have provision for lubrication.

UL.VLEDS.5 Transmissions and gearboxes: general

UL.VLEDS.5.1 If autorotation capability is implemented: The lubrication system for components of the vertical lifting drive system that requires continuous lubrication must be sufficiently independent of the lubrication systems of the engine(s) to ensure lubrication during autorotation.
PROPELLERS

GENERAL

UL.P.1 Instruction manual

An instruction manual containing the information considered essential for installing, servicing and maintaining the propeller must be provided.

UL.P.2 Propeller operating limitations

Propeller operating limitations must be established on the basis of the conditions demonstrated during the tests specified in this Annex.

DESIGN AND CONSTRUCTION

UL.P.3 Materials

The suitability and durability of materials used in the propeller must:

(a) Be established on the basis of experience or tests; and

(b) Conform to approved specifications that ensure their having the strength and other properties assumed in the design data.

UL.P.4 Durability

Propeller design and construction must minimise the possibility of the occurrence of an unsafe condition of the propeller between overhauls.

(a) The effects of cyclic loading, environmental and operational degradation must not reduce the integrity of the propeller below acceptable levels.

(b) The effects of likely subsequent part failures must not reduce the integrity of the propeller below acceptable levels.

UL.P.5 Pitch Control

(a) Failure of the propeller pitch control may not cause a hazardous overspeed event under intended operating conditions.

(b) If the propeller can be feathered the control system must be designed to minimize:

(1) consequential hazards, such as a propeller runaway resulting from malfunction or failure of the control system.

(2) the possibility of an unintentional operation.
UL.P.6 General
It must be shown that the propeller and its main accessories complete the tests and inspections prescribed in UL.P.7 through UL.P.12 without evidence of failure or malfunction.

UL.P.7 Blade retention test
The hub and blade retention arrangement of propellers with detachable blades must be subjected to a load equal to twice the centrifugal force occurring at the maximum rotational speed (other than transient overspeed) for which approval is sought, or the maximum governed rotational speed, as appropriate. This may be done either by a whirl test or a static pull test.

UL.P.8 Vibration load limit test
The vibration load limits of each metal hub and blade, and of each primary load-carrying metal component of non-metallic blades, must be determined for all reasonably foreseeable vibration load patterns.

UL.P.9 Endurance test
(a) Fixed-pitch or ground-adjustable propellers. Fixed-pitch or ground-adjustable propellers must be subjected to one of the following tests:

(1) A 50-hour flight test in level flight or in climb. At least five hours of this flight test must be with the propeller at the rated rotational speed and the remainder of the 50 hours must be with the propeller operated at not less than 90% of the rated rotational speed. This test must be conducted on a propeller of the greatest diameter for which certification is requested.

(2) A 50-hour endurance bench test on an engine at the power and propeller rotational speed for which certification is sought. This test must be conducted on a propeller of the greatest diameter for which certification is requested.

(b) Variable pitch propellers. Variable pitch propellers (propellers the pitch of which can be changed by the UA Operator or by automatic means while the propeller is rotating) must be subjected to one of the following tests:

(1) A 50-hour test on an engine with the same power and rotational speed characteristics as the engine or engines with which the propeller is to be used. Each test must be made at the maximum continuous rotational speed and power rating of the propeller. If a take-off performance greater than the maximum continuous rating is to be established, an additional 10-hour bench test must be made at the maximum power and rotational speed for the take-off rating.

(2) Operation of the propeller throughout the engine endurance tests prescribed in Annex RE 22, Annex EE22 or Annex TE-25.
UL.P.10 Functional tests

(a) Each variable pitch propeller must be subjected to all applicable functional tests of this paragraph. The same propeller used in the endurance test must be used in the functional test and must be driven by an engine on a test stand or on a UA.

(b) Manually controllable propellers. 500 complete cycles of control throughout the pitch and rotational speed ranges, excluding the feathering range.

(c) Automatically controllable propellers. 1500 complete cycles of control throughout the pitch and rotational speed ranges, excluding the feathering range.

UL.P.11 Teardown inspection

After the endurance test has been completed the propeller must be completely disassembled. No essential component may show rupture, cracks or excessive wear.

UL.P.12 Propeller adjustments and parts replacement

During the tests, service and minor repairs may be made to the propeller. If major repairs or replacement of parts is found necessary during the tests or in the teardown inspection, any additional tests that the Certifying Authority finds necessary must be conducted.
MEI. 1: Multiple Engine Inoperative (MEI) tests.

1. As per UL. 55.3 the Applicant must demonstrate the OEI/MEI rating(s) by flight test and must demonstrate Unmanned Aircraft (UA) controllability without requiring exceptional operator's skills. The Applicant must demonstrate the worst condition.

If more than max continuous power is required, the applicant must define the ratings (e.g. torque, RPM, temperature, etc.).

Deleted

Applicant must define and substantiate the required maintenance actions (including if no maintenance action is required) following the use of MEI rating(s).

The Applicant may consider offering multi-engine failure ratings: OEI, 2EI, 3EI, etc. if the ratings required to sustain propulsion capability vary\(^1\).

2. Endurance Test(s):

   a) Endurance testing must account for the maximum UA OEI/MEI Rating(s);

   b) Considerations to be included in the maintenance action(s) required following OEI/MEI operation (Maintenance limitations);

   c) Propulsion Unit (i.e. the engine/motor, propeller, rotor drive train, and drive train) endurance tests should be combined; and

   d) Endurance testing of OEI/MEI ratings: Applicable to all engine types: Turbine (creep, torque, cooling, etc.), see Annex E, electrical (cooling, temperature of windings, high RPM, etc.) see Annex D, piston spark and compression ignition (cooling, torque, creep, etc.) see Annex C. As detailed in the applicable annex(s) to this engine type.

If the UA OEI/MEI rating(s) require the monitoring of operation parameters (to control temperature, RPM, for example), then automatic control system(s) may be required, unless sufficient operation parameters margins have been demonstrated in the endurance test requirement of automatic system(s).

Low Cycle Fatigue (LCF) and temperature considerations: The Applicant must demonstrate sufficient LCF margin with OEI/MEI (mostly for Turbine
propulsion engines, however may also be applicable to certain piston and electrical propulsion unit(s)).

**Note**

Sustained Propulsion Capability: Is defined as the propulsion ratings required for continued safe flight and landing, following failure of one or more engine(s)/motor(s), as applicable to the specific UA.
## HAZARD REFERENCE SYSTEM

### UL.HRS.1 Severity Reference System

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
</table>
| Catastrophic | Failure conditions that are expected to result in at least uncontrolled flight (including flight outside of pre-planned or contingency flight profiles/areas) and/or uncontrolled crash.  
Or  
Failure conditions which may result in a fatality to UAS crew, ground staff or third parties. |
| Hazardous  | Failure conditions that either by themselves or in conjunction with increased crew workload, are expected to result in a controlled-trajectory termination or forced landing potentially leading to the loss of the UA where it can be reasonably expected that a fatality will not occur.  
Or  
Failure conditions for which it can be reasonably expected that a fatality to UAS crew, ground staff or third parties will not occur. |
| Major      | Failure conditions that either by themselves or in conjunction with increased crew workload, are expected to result in an emergency landing of the UA on a predefined site where it can be reasonably expected that a serious injury will not occur.  
Or  
Failure conditions which could potentially result in injury to UAS crew, ground staff or third parties. |
| Minor      | Failure conditions that do not significantly reduce UAS safety and involve UAS crew actions that are well within their capabilities.  
These conditions may include a slight reduction in safety margins or functional capabilities, and a slight increase in UAS crew workload. |

### UL.HRS.2 Cumulative Safety Requirement

The cumulative probability for catastrophic event (i.e. resulting from the combination of all catastrophic failure conditions) takes into account all the contributions of all UAS and sub-systems, including propulsion, navigation, data-link, UCS/UCB etc.
The cumulative probability per flight hour should be established as follows:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>for MTOW below 15kg</td>
<td>$P_{\text{CUM-CAT}} = 10^{-4}$</td>
</tr>
<tr>
<td>for MTOW between 15kg and 150kg</td>
<td>$P_{\text{CUM-CAT}} = 0.0015 / (\text{MTOW})$</td>
</tr>
</tbody>
</table>

The cumulative probability per flight hour is an upper limit; therefore, the result of quantitative safety assessment process should be demonstrated as less than or equal to $P_{\text{CUM-CAT}}$.

UL.HRS.3 Probability Level Reference System

The following individual failure probability per flight hour safety objectives must be used. The probability reference system is based on 10 individual catastrophic failure conditions. Exceptionally, the individual failure quantitative safety objective ($P_{\text{IND-CAT}}$) for each catastrophic failure condition given by the result of the $P_{\text{CUM-CAT}}$ quantitative divided by $N_{\text{CATFC}}$ may be used as agreed with the certifying authority. The number of individual catastrophic failure conditions should be determined from the FHA.

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>(E)</td>
<td>Extremely Improbable</td>
<td>$P_{(E)} \leq \frac{P_{\text{CUM-CAT}}}{10}$</td>
</tr>
<tr>
<td>(D)</td>
<td>Extremely Remote</td>
<td>$P_{(E)} &lt; P_{(D)} \leq 10 \times P_{(E)}$</td>
</tr>
<tr>
<td>Level</td>
<td>Description</td>
<td>Probability Range</td>
</tr>
<tr>
<td>-------</td>
<td>--------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>(C)</td>
<td>Remote</td>
<td>$10 \times P(E) &lt; P(C) \leq 100 \times P(E)$</td>
</tr>
<tr>
<td>(B)</td>
<td>Probable</td>
<td>$100 \times P(E) &lt; P(B) \leq 1000 \times P(E)$</td>
</tr>
<tr>
<td>(A)</td>
<td>Frequent</td>
<td>$P(A) &gt; 1000 \times P(E)$</td>
</tr>
</tbody>
</table>
UL.HRS.4 Hazard Acceptability Criteria

<table>
<thead>
<tr>
<th>Hazard Risk Index (HRI)</th>
<th>(1) CATASTROPHIC</th>
<th>(2) HAZARDOUS</th>
<th>(3) MAJOR</th>
<th>(4) MINOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) FREQUENT</td>
<td>1A Unacceptable</td>
<td>2A Unacceptable</td>
<td>3A Unacceptable</td>
<td>4A Unacceptable</td>
</tr>
<tr>
<td>(B) PROBABLE</td>
<td>1B Unacceptable</td>
<td>2B Unacceptable</td>
<td>3B Unacceptable</td>
<td>4B Unacceptable</td>
</tr>
<tr>
<td>(C) REMOTE</td>
<td>1C Unacceptable</td>
<td>2C Unacceptable</td>
<td>3C Acceptable</td>
<td>4C Acceptable</td>
</tr>
<tr>
<td>(D) EXTREMELY REMOTE</td>
<td>1D Unacceptable</td>
<td>2D Acceptable</td>
<td>3D Acceptable</td>
<td>4D Acceptable</td>
</tr>
<tr>
<td>(E) EXTREMELY IMPROBABLE</td>
<td>1E Acceptable</td>
<td>2E Acceptable</td>
<td>3E Acceptable</td>
<td>4E Acceptable</td>
</tr>
</tbody>
</table>
STABILITY AND RESPONSE ASSESSMENT GUIDANCE

This Annex should be used by the Applicant and the Certifying Authority as guidance to demonstrate compliance with UA stability requirements concerning longitudinal / lateral stability and transient response.

The accuracy and stability quantitative requirements should be established according to the design usage spectrum as per UL.0 (e.g. best cruise height compared to a minimum safe clearance above patrolled area buildings).

UL.SR.1 Accuracy

The UAS must be capable of maintaining the desired flight parameters in smooth air with a sufficiently small static error, to be agreed by the Applicant and be as agreed by the Certifying Authority. This should be demonstrated by model-based analyses and verified by flight tests, for the following parameters, throughout the normal flight envelope:

- attitude: pitch and roll angles;
- all airspeeds to include forward flight – rearward flight and sideways flight, heading or track, HOGE/HIGE, and altitude.

UL.SR.2 Transient response

It must be demonstrated for the entire flight envelope that:

UL.SR.2.1 Pitch and Roll response following an abrupt command input or gusts, are suitably damped so as not to cause exceedance of the:

- limit load factor,
- maximum torque allowed by the control surface actuators.

UL.SR.2.2 Transition to a selected altitude, or engagement of an altitude hold function should not cause a deviation (overshoot) of the commanded value by a tolerance greater than 3 times the tolerance be as agreed by the Certifying Authority under paragraph UL.SR.1.

UL.SR.2.3 Transition to a selected heading or engagement of a heading hold function should not cause transient deviation (overshoot) of the commanded value by a tolerance greater than 3 times the tolerance be as agreed by the Certifying Authority under paragraph UL.SR.1.

UL.SR.2.4 Transition to a selected airspeed or selection of an airspeed hold function, within the permissible flight envelope protection, should not cause the aircraft to:

- enter a condition that induces vortex ring state,
- exceed any defined margin(s) be as agreed by the Certifying Authority within the Limiting height-speed envelope.
UL.SR.3 Pilot Induced instabilities (PII)

The absence of PII tendencies which may lead to unsafe conditions should be demonstrated in flight for each FCS operational mode, with particular attention to manual direct piloting mode (where applicable). Model based simulations with the UA Operator in the loop may be used to integrate flight test evidence in extreme operational conditions.
THE SAFETY MANAGEMENT PLAN

SAFETY MANAGEMENT

UL.SMP.1 The Safety Management Plan sets out to:

- Describe how the Safety Management System works, including descriptions of organisational structure, processes, procedures and methodologies used to enable the direction and control of the activities necessary to meet safety requirements and objectives.
- Describe the project’s safety related timescales, milestones, targets and other relevant date related information.

UL.SMP.1.1 The Safety Management Plan should link directly to the project management plan, but focus on specific safety activities. Key safety milestones should be included in the overall project management plan alongside other engineering and design activities.

UL.SMP.1.2 The Safety Management Plan would typically address the following:

- A description of the system and its purpose sufficient to provide an understanding of what the Plan is referring to.
- Initial definition of all key safety requirements.
- Details of the Safety Management System to be operated.
- A description of defined safety tasks, including:
  - Ownership.
  - Methodology.
  - Resource requirements.
  - Definition of milestones.
  - Tolerability Criteria.
  - Risk management processes, including the definition of methods.
  - The identification of specific tools to be utilised (such as hazard log software).
  - The safety programme.
  - The safety audit plan.
  - The compliance matrix for this STANAG, indicating procedures and methods to be used.
  - A list of deliverables and their format.

The safety programme usually comprises a ‘Gantt’ chart depicting timescales, safety milestones and deliverables. It should also include a treatment of potential unprogrammed activities such as analysis of incidents and accidents. The programme can be developed as required e.g. it could include the safety audit plan.
UL.SMP.1.3 Some of these items may be included by summarising and referencing other management and engineering documents but, as a key deliverable, the Safety Management Plan should contain an adequate level of information and detail to provide a comprehensive understanding of the way safety management will be implemented and maintained.

UL.SMP.2 There are a number of events that could lead to a revision of the Safety Management Plan e.g. change in overall requirements, changes in organisation, major operational changes or problems etc.

The Safety Management Plan must consider the full life of the system and the Applicant will be required to review and update it through the system life-cycle.

UL.SMP.3 The Safety Management Plan is a significant document and one that provides a basis on which to assess the effectiveness of the safety management process. It is therefore important that the contents of the Safety Management Plan are be as agreed by the Certifying Authority at the earliest possible stage in the Certification Process.

UL.SMP.4 A Safety Management System provides the Applicant with the means of managing safety and defining the processes to be followed to achieve his objectives. The Safety Management System should be fully documented within the Safety Management Plan, so that processes for the management of safety for the specific project are clearly defined and the effectiveness of the implementation of the Safety Management System can be assessed.

UL.SMP.4.1 An effective Safety Management System will ensure co-ordination of the right mix of resources to plan, organise, implement, monitor, review, audit and improve specified tasks. The Safety Management System should address safety policy and/or strategy, defined levels of authority, lines of communication and procedures. The Safety Management System would typically at least address the following:

- The strategy for managing safety.
- The definition of individual and organisational roles and allocation of safety authority and responsibilities including identification of the ‘sign-off’ authority.
- The interface arrangements, particularly with other Safety Management Systems (e.g. Sub-Contractors, Production Organization, Maintenance Organization, Armed Forces, etc.).
- The definition of competency requirements and mechanisms for measuring and ensuring competence of individuals performing tasks affecting safety.
- The identification and allocation of resources required for the Safety Management System to be implemented effectively.
- The identification of applicable legislation, regulations and standards to be met.
The interface with Occupational Health (e.g. applicable to the UCS/UCB) and Safety arrangements as appropriate, either directly or by reference.
- The audit arrangements.
- The change management arrangements.
- The arrangements for monitoring defect/failure reports and incident/accident/near miss reports, and identifying and implementing remedial action.
- The arrangements for managing and acting on feedback in respect of the impact of such actions on safety requirements and safety achievements.
- The arrangements for measuring the effectiveness of safety management activities.
- The definition of a hazard reference system (as mentioned in Annex G).

**UL.SMP.4.2** The Safety Management System should demonstrate positive safety culture. Safety culture is the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, safety management.

**UL.SMP.4.3** The effectiveness of the implementation of the Safety Management System must be assessed measuring the degree of achievement of the objectives. Measuring the performance of the Safety Management System provides the necessary information to implement a continuous improvement of the Safety Management System performances in time.

**UL.SMP.5** It is important that safety is considered with all other engineering disciplines and not as a separate entity, particularly as experience has shown that poor safety management can be a significant source of project risk. As part of implementing a systems engineering approach, different processes, documents, etc., may be merged. However, the need to be able to consider safety issues independently should be recognised, particularly when involving specialist experts and Certifying Authority/certification organisations. As a result, it may be necessary for safety material to be tagged as such, to enable it to be differentiated from non-safety material.
GUIDELINES FOR AIRWORTHINESS REQUIREMENTS APPLICABLE TO
UA BELOW THE 66J IMPACT ENERGY

This Annex should be used by the Applicant and the Certifying Authority as guidance material to establish minimum airworthiness requirements for UA with an impact energy below 66 J (calculated using the worst case terminal velocity based on the foreseeable failure conditions).

1. **Design Usage Spectrum**

   The Applicant must identify the design usage spectrum as the set of all the foreseen operational conditions of the UAS:
   
   (a) typical design missions;
   (b) in-flight operation conditions;
   (c) on-ground operation conditions;
   (d) operational modes (automatic, speed-hold, altitude hold, direct manual, etc.);
   (e) take-off / launch / ramp conditions;
   (f) landing / recovery conditions;
   (g) locations and platforms (e.g. land vehicle, water vessel, aircraft, building, etc.) from which launch, command and control, and recovery operations will be performed (e.g., land, littoral/maritime, air);
   (h) number of air vehicles to be operated simultaneously;
   (i) transport conditions (define the transportation and storage environment of the UAS (e.g., bag, package, truck or whatever is required);
   (j) operating environmental conditions:
   (k) natural climate (altitude, temperature, pressure, humidity, wind, rainfall rate, lightning, ice, salt fog, fungus, hail, bird strike, sand and dust, etc.);
   (l) electromagnetic environmental effects (electromagnetic environment among all sub-systems and equipment, electromagnetic effects caused by external environment, electromagnetic interference among more than one UAS operated in proximity);
   (m) lighting conditions (e.g., day, night, dawn, dusk, mixed, etc.);
   (n) identify all the possible mass configurations (minimum and maximum flying weight, empty CG, most forward CG, most rearward CG must be identified).

2. **General Requirements**

   The Applicant should ensure certification as per AS/EN 9001 for undertaking Light VTOL UAV design and production activities and the documented statement of the quality policy should explicitly include system safety as one of the main objectives: this should give a minimum confidence that safety management is implemented and that safety-related work is undertaken by competent individuals, in adequate facilities, with adequate tools, material, procedures and data.
The Applicant must identify design criteria, standards and practices used to design UA structure, engine, propeller and UAS equipment.

The UA must be stable and controllable in all sequences of flight and in all operational modes.

Navigation accuracy must be as agreed with the Certifying Authority.

There must be a means to monitor and indicate the flight path and UAS (including Data Link) status to the UA Operator.

Human-Machine Interface aspects must be considered.

There should be a means for flight termination in emergency conditions.

Standard operating and emergency procedures must be established and documented.

For certification, the Applicant must demonstrate the whole usage spectrum by flight test. The test plan must be accepted by the Certifying Authority. The flight test plan must include, but not limited to:

- test objectives
- applicable standards/specifications
- test article description
- flight test instrumentation
- test condition
- acceptance criteria.

3. Structures and Materials

Structural integrity
The UA must withstand, without rupture, the limit loads multiplied by a factor of safety, at each critical combination of parameters. The significance of loads induced by transportation and handling must be considered.

The factor of safety must be agreed with the Certifying Authority, taking into account all the uncertainty factors in the design criteria (e.g. load modelling, stress modelling, material allowables, environmental effects, barely visible damage effects on composites, etc.).

The structural integrity should be considered also in relation to fatigue and the expected service life of the air vehicle.

Materials
The Applicant must identify the materials and manufacturing processes used in the construction of the UA and the criteria implemented to control materials performance variability among specimens. Materials must be compatible with the usage spectrum. Manufactured parts, assemblies, and the complete UAS must be produced in accordance with the manufacturer’s Quality Management System.
Frangibility

The RPAS and its components should be configured and constructed such, that in the event of a mid-air collision with another aircraft, the energy impacted by the RPAS and its components is dissipated in a manner that minimizes damage to the other aircraft. Particular attention should be given to the effect of traditionally dense and solid RPAS components such as, but not necessarily limited to, batteries, payloads and motors and their associated propeller assemblies during a collision.

Emphasis should be placed on minimizing damage to vulnerable flight critical components of manned aircraft, namely rotary-wing aircraft transparencies, rotor blades and tail rotors and fixed wing aircraft transparencies, leading edges, propellers and jet engines. For transparencies, the objective is the prevention of RPAS components penetrating into the flight crew compartment.

RPAS frangibility design features may include one or more of the following:

(a) Fracture points within RPAS airframe to aid dissipation of RPAS kinetic energy.
(b) Incorporation of energy absorbing structure into the RPAS.
(c) Distribution of high mass and high density components around the RPAS in a configuration that will reduce the likelihood of a ‘train’ of high mass and high density components impacting the same point during a collision.
(d) External shape that encourages deflection during a collision.

4. Propulsion system

The entire propulsion system must be subjected to an endurance test, followed by tear down inspection, according to a duration and a cycle to be agreed with the Certifying Authority, in accordance with the design usage spectrum.

For electrical engine applications, the battery must be able to provide the necessary voltage and current required by the engine and electrical equipment throughout the operational envelope.

There must be means to minimize the risk of battery overheating/explosion (e.g. cooling, temperature sensor, active battery management system).

Provisions must be provided to alert the UA Operator that the battery has discharged to a level which requires immediate UA recovery actions.

Information concerning battery storage, operation, handling, maintenance, safety limitations and battery health conditions must be provided in the applicable manuals.

5. Systems and equipment

All equipment (including Commercial-Off-The-Shelf) and subsystems (including Data Link) must function properly within the design usage spectrum, when integrated in the UAS.
The installation provisions, environment and the intended usage of all equipment must meet all performance, operating and safety limitations to which the equipment is qualified (i.e. it meets its specifications).

Environmental Electromagnetic Effects (E^3) must be considered as agreed with the Certifying Authority.

A data recorder should be provided in order to store typical flight data be as agreed by the Certifying Authority.

**Safety**
A System Safety Assessment must be performed for the UAS (including all contributions coming from the UA, UCS/UCB, Data Link and any other equipment necessary to operate the UAS). This assessment should include a Functional Hazard Analysis, a Failure Mode Effect and Criticality Analysis and a Fault Tree Analysis.

It must be verified that the probability of failures expected to result in at least uncontrolled flight (including flight outside of pre-planned or contingency flight profiles/areas) and/or uncontrolled crash is extremely remote as agreed with the Certifying Authority in accordance with Annex G probability thresholds.  

A minimum essential set of Built-In-Tests (BIT) should be agreed with the Certifying Authority (e.g. power-up self-test).

The software life cycle assurance process for the UAS must be agreed with the Certifying Authority. A Plan for Software Airworthiness should be provided and be as agreed by the Certifying Authority. Each configuration software item whose failure could lead to uncontrolled flight and/or crash should be equivalent to Design Assurance Level (DAL) C as per RTCA DO-178B / ED-12B.

6. **Continued Airworthiness**

The Applicant must promulgate all necessary instructions for ensuring continued airworthiness.

The Applicant must provide a method to track technical occurrences affecting safety throughout the life of the program and implement preventive and corrective actions as necessary.

A Flight Manual must be provided to the UA Operator that clearly and unambiguously defines all the operating procedures, limitations and performance information for normal operations and emergency conditions.

**UA assembling and disassembling instructions (where applicable).**

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4 The probability threshold for extremely remote failures is of the order of 1e-3 /fh
NOTE: At the present time, the requirements and means of compliance for this Annex have not been developed. However, unique features of the design may be covered by special conditions; taking into account the safety aim of the essential requirements of the code.
NON CONVENTIONAL VERTICAL LIFT DESIGNS

UNSHROUDED MULTI-ROTOR

VECTORED AND UNVECTORED THRUST SYSTEMS

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