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LIGHT UNMANNED AIRCRAFT SYSTEMS AIRWORTHINESS REQUIREMENTS

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NORTH ATLANTIC TREATY ORGANIZATION

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NATO LETTER OF PROMULGATION

4 September 2014

1. The enclosed Allied Engineering Publication AEP-83, LIGHT UNMANNED AIRCRAFT SYSTEMS AIRWORTHINESS REQUIREMENTS, which has been approved by the nations in the NNAG, is promulgated herewith. The recommendation of nations to use this publication is recorded in STANAG 4703.

2. AEP-83 Edition A is effective upon receipt.

4. This publication shall be handled in accordance with C-M(2002)60.

Edvardas MAŽEIKIS
Major General, LTUAF
Director, NATO Standardization Office

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
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.	

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RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
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.	

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LIGHT UNMANNED AERIAL VEHICLE SYSTEMS AIRWORTHINESS REQUIREMENTS

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1. Scope

This document contains the minimum set of technical airworthiness requirements intended for the airworthiness certification of fixed-wing 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 UAS below the 66J impact energy threshold, it is reasonable that a number of requirements can be relaxed. Specific airworthiness requirements must be agreed with the Certifying Authority on a case-by-case basis. Annex J of this document provides applicable guidelines, that is not limited to fixed wing aspects.

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).

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 codes 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).

Creating this hybrid approach, the top-level starting point is the set of the Military Essential Requirements for Airworthiness. This STANAG also establishes means to comply with each of these mandatory minimum essential requirements in order to obtain a Type Certificate (or equivalent document) for UA with Maximum Take Off Weight of 150 kg, or less, for flight in non-segregated airspace.

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[1] The impact energy must be calculated using the worst case terminal velocity based on the foreseeable failure conditions, as agreed with the Certifying Authority.

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.

- direct evidence from analysis;
- direct evidence from demonstration (rig testing, representative prototype ground 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),
- CS-VLA (Certification Specifications for Very Light Aeroplanes),
- CS-22 Amendment 1 (Certification Specifications for Sailplanes And Powered Sailplanes),
- ASTM F2245-06 (Standard Specification for Design and Performance of a Light Sport Airplane),
- 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 agreed with 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 Minimum Essential Requirements for Airworthiness;

II. the second column presents a detailed argument to elaborate 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 compliance with the detailed arguments in the second column.

Compliance with the Airworthiness Essential Requirements (first column) is mandatory and must be demonstrated through a comprehensive set of arguments (of the type mentioned in §3).

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.

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 agreed with the Certifying Authority, wherever a “should” statement appears.

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
ER.1 System integrity System integrity must be assured for all anticipated flight conditions and ground operations for the operational life of the UAS. Compliance with all requirements must be shown by assessment or analysis, supported, where necessary, by tests.	*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 like 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).* *In all the identified conditions the Applicant must verify to the satisfaction of the Certifying Authority the requirements of the following paragraphs.*	*ME0 Description of the design usage spectrum*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	UL.1 The Applicant must identify design criteria, standards and practices used to design UA structure, engine, propeller, and UAS and equipment.	*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*
ER.1.1 <u>Structures and materials</u> The integrity of the structure must be ensured throughout, and by a defined margin beyond, the operational envelope for the UA, including its propulsion system, and maintained for the operational life of the UA.	*UL.2 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. The following margins should be taken into account, unless more rational means are agreed by the Certifying Authority.* *UL2.1 a positive margin between the maximum design speed [V_D] and the maximum operating speed [V_{Cmax}] (the maximum operating speed should be no more than 0.9 the maximum design speed);* *UL2.2 a limit load factor of safety ≥1.0 to determine the limit loads (loads at which the structure must not exhibit detrimental deformations) as the maximum operational loads multiplied by this factor:* *- a factor ≥1.25 to determine limit loads on the control system components and its supporting structure from the computed hinge moments of the movable control surface;* *UL2.3 an ultimate load factor of safety ≥1.5 (for structure whose failure would lead to a Hazardous or more serious failure condition) or ≥1.25 (for other structure), to determine the ultimate loads (loads at which the structure must not collapse) as the maximum operational loads multiplied by this factor;* *UL2.4 the factor of safety of UL2.3 should be multiplied by a further special factor in the following cases:*	*ME2 A description of the rationale for the design loads margins to be included in Design Criteria in ME1*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	- ≥2.0 on castings, *- ≥1.15 on fittings,* *- ≥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 chose to use a further justified special factor >1 to cover any uncertainty not previously mentioned.*	
ER.1.1.1 All parts of the UA, the failure of which could reduce 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.	*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 propulsion forces; control surface and control system structural elements, control surface hinges; structural elements of systems used in launching and recovery phases).*	*ME3 Description of the PSEs*
	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 obtained by multiplying the maximum operational loads identified under UL.5 to UL.6 by the limit load factors of safety in UL.2, and* *- no rupture against the Ultimate Loads obtained by multiplying the maximum operational 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 limit loads are applied to the controls and the surfaces; additionally the*	*ME4 Proof of Structure by a compelling combination of conservative analyses and tests*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	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 maximum operational loads identified under UL.5 to UL.6 by the ultimate load factors of safety in UL.2.*	
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 maximum operational loads that PSEs must withstand in flight, at each critical combination of altitude, speed, weight, centre of gravity, payload configuration, and fuel distribution.* *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:* - *the UAS nominal modes of control,* - *the UAS failure modes where probability of occurrence is higher than extremely remote,* - *Non-symmetrical loads due to engine failure (for multi-engine configurations).* *UL5.2. A symmetric limit manoeuvring load factor ≥3.8 should be established. A symmetric negative limit manoeuvring load factor ≤-1.5 should be established.* *Manoeuvring 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.* *There should be means to avoid maximum load factor exceedances 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*	*ME5 Assumptions and analysis of the design loads in-flight*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	adequate limit load factor of safety >1.0 should be considered as per UL2.2. *UL5.3. The UA is assumed to be subjected to symmetrical vertical and lateral gusts in level flight.* *The limit load factors resulting from gusts should correspond to the conditions determined as follows. Positive (up) and negative (down) gust values at V_C and V_{Cmax} should be determined by rational analysis of the intended use of the UAS, 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.* - *positive (up) and negative (down) gusts of 15.2 m/s (50 fps at V_C should be considered at altitudes between sea level and 6096 m (20,000 ft). Where applicable, the gust velocity may be reduced linearly from 15.2 m/s (50 fps) at 6096 m (20,000 ft) to 7.6 m/s (25 fps) at 15,240 m (50,000 ft).* - *Positive and negative gusts of 7.6 m/s (25 fps) at V_{Cmax} should be considered at altitudes between sea level and 6096 m (20,000 ft). Where applicable, the gust velocity may be reduced linearly from 7.6 m/s (25 fps) at 6096 m (20,000) ft to 3.8 m/s (12.5 fps) at 15,240 m (50,000 ft).* *The same values should be used for lateral gust.* *Potential limitations may be established, where applicable, and documented in operating manuals, taking due account of the design usage spectrum as per UL.0.* *UL5.4. Recovery with parachute (for applications with normal parachute landing operations) - 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.* *UL5.5. 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.* *UL5.6. Any other specific load condition in-flight not included in the previous paragraphs.*	

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	UL.6 Ground loads *The Applicant must identify all maximum operational loads that the PSEs must withstand on the ground, considering external forces in equilibrium with inertial forces.* *UL.6.1 Launch / Catapult (where applicable)* *- 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.* *- 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.* *UL.6.2 Landing impact at the maximum design weight* *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.* *UL.6.3 Any other specific load condition on-ground not included in the previous paragraphs.*	*ME6 Assumptions and analysis of the design loads on-ground*
ER.1.1.1.2 Where applicable to the system, consideration must be given to the loads and likely failures induced by emergency landings either on land or water.	*N/A*	
ER.1.1.1.3 Dynamic effects must be covered in the structural response to these loads.	*UL.7 Structural dynamic load response – The airframe 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, as agreed with 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.*	*ME7 A combination of tests and analyses*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	DETAILED ARGUMENTS	MEANS OF EVIDENCE
ER.1.1.2 The UA must be free from any aero–servo-elastic instability and excessive vibration.	*UL.8 Aeroservoelastic effects – 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, and divergence in all configurations. A margin ≥1.2[2] V_D should be applied.* *Simplified analytical or computational conservative methods may be used.* *Though specific flutter flight tests with appropriate excitation are not mandatory, flight tests survey should not reveal 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 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 - value above which at least 99% of the population of values is expected to fall with a confidence of 95%) should be met.* *- 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).* *- 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.*	*ME9 Description of the used materials and their allowables. Evidence of compliance could be given in the Design Criteria of ME1.*

[2] Flutter flight tests with appropriate excitation could allow reduction of this margin up to 1.15.

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	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 UL2.4).	
	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.	*ME10 AS/EN-9100 Certification or equivalent.*
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.	*UL.11 Fatigue* *UL11.1. 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.* *UL11.2. There must be sufficient evidence that PSEs have strength capabilities to achieve an adequate safe-life.* *UL11.2.1. 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-lives.* *UL11.2.2. For wood, ANC-18 should be used as a reference.* *UL11.2.3. 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 development of out-of-plane stresses[3], that structural items have adequate safe-lives.*	*ME11 Structural design criteria (refer to ME1) and stress analysis.*

[3] Corners, ply drop-off, stringer run-outs are of primary importance.

<table>
<tr><th>AIRWORTHINESS ESSENTIAL REQUIREMENTS</th><th>DETAILED ARGUMENTS</th><th>MEANS OF EVIDENCE</th></tr>
<tr><td></td><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</td></tr>
<tr><td></td><td>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.

UL13.1 Impact damage on composite PSEs

For composite PSEs, it must be shown that delaminations 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.

The following alternative arguments are acceptable means to comply with this requirement.

UL13.1.1 For composite PSEs, a special factor ≥ 6.0 multiplying the factor of safety of UL2.3 could be used.

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

UL13.1.2 Composite PSE parts could be designed not to exceed the following Damage Tolerance Strains:
<table>
<tr><th>Loading</th><th colspan="2">Damage Tolerance Strain(με)</th></tr>
<tr><td></td><td>Sandwich skin
Full Laminates with thickness ≤2 mm</td><td>Full Laminates with thickness > 2 mm</td></tr>
<tr><td>Tension</td><td>5000</td><td>5000</td></tr>
<tr><td>Compression</td><td>2600</td><td>3000</td></tr>
<tr><td>Shear</td><td>5200</td><td>6000</td></tr>
</table>
</td><td>ME13 Description of protection criteria against accidental discrete damage sources and corresponding analyses and tests where applicable.</td></tr>
</table>

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	To demonstrate strength and damage tolerance for damaged critical design features, the Certifying Authority may require tests at detail, 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 agreed with the Certifying Authority, according to the intended UA size, use and technological constraints.*	
	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*
	UL.15 The Applicant must promulgate all necessary instructions for ensuring continued airworthiness.	*ME15 Set of instructions for continued airworthiness to be provided in the*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
		operational manuals.

AIRWORTHINESS ESSENTIAL REQUIREMENTS	DETAILED ARGUMENTS	MEANS OF EVIDENCE
ER.1.2 <u>Propulsion</u> The integrity of the propulsion system (i.e. engine and, where appropriate, propeller) must be demonstrated throughout, and by a defined margin beyond, the operational envelope of the propulsion system and must be maintained for the operational life of the propulsion system.	*UL.16 Engine* *UL16.1 For spark and compression ignition engines, the installed engine must comply with the requirements of Annex C, as agreed by the Certifying Authority.* *For electric engines, the installed engine must comply with the requirements of Annex D, as agreed by the Certifying Authority.* *For turbine engines, the installed engine must comply with the requirements of Annex E, as agreed by the Certifying Authority.* *UL16.2 The installation must provide accessibility for servicing, inspection and maintenance.* *UL16.3 The fire hazard must be assessed as per UL30.3.* *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.*	*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*
	UL.17 Propeller - The installed propeller must comply with the requirements of Annex F.	*ME17 Declaration of compliance by the Propeller Manufacturer, together with the complete set of compliance evidence*
ER.1.2.1 The propulsion system must produce, within its stated limits, the thrust or power	*UL.18 Propulsion system compatibility* *UL18.1 Compatibility between engine and propeller requirements and limits must be assured:*	*ME18 Description of requirements compatibility, analyses,*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
demanded of it at all required flight conditions, taking into account environmental effects and conditions.	- *engine power and propeller shaft rotational speed must not exceed the propeller limits;* - *maximum engine RPM must not be exceeded with full throttle setting during take-off, climb or flight at V_{Cmax}; 110% maximum continuous RPM must not be exceeded during a glide at V_{Cmax} with throttle closed;* - *each propeller with metal blades or highly stressed metal components must have vibration stresses in normal operating conditions, not exceeding values demonstrated by the propeller manufacturer, to be safe for continuous operation (see UL.P.8).* *UL18.2 The installation must comply with the instructions provided by the engine and propeller manufacturers (see UL.RE.1, UL.EE.1, UL.TE.1, UL.P.1).* *UL18.3 Performance compatibility between UA design usage spectrum requirements identified in UL.0 and the engine and propeller limits verified under UL.16 and 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 propeller limits verified under UL.16 and 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 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* *18.5.1. 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.* *18.5.2. 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*	*ground and flight test evidence as agreed by the Certifying Authority.*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	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 For reciprocating and turbine engine applications, the electrical system of the UAS must provide the necessary electrical power for ignition and operation of the engine electronic controls.*	
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 operational environment must be accounted for.	*This Essential Requirement is met by compliance with UL.16 and UL.17.*	
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.*	

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
ER.1.2.4 All necessary instructions, information and requirements for the safe and correct interface between the propulsion system and the UAS must be promulgated.	*This Essential Requirement is met by compliance with UL.16 and UL.17.*	
ER.1.2.5 Fuel system The engine must be safely fed by the quantity of fuel required to perform the UA missions it is certified for. [Fuel is to be interpreted as electrical power for electrical engine applications]	***UL.19*** *Fuel system for spark and compression ignition engines* ***UL19.1*** *The fuel system must be able to provide the necessary fuel flow at the necessary conditions required by the engine throughout the operational envelope.* ***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).* ***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.*	***ME19*** *Description and tests of the fuel system.*

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	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.).*	
	UL.20 Electric power subsystem: battery pack, associated power management electronic circuits and battery charger *UL20.1. 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.* *UL20.2. The power subsystem must include a voltage sensor.* *UL20.3. The battery installation must be able to withstand the applicable inertial loads.* *UL20.4. 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.* *UL20.5. There must be means to minimize the risk of battery overheating/explosion (e.g. cooling, temperature sensor, active battery management system).* *UL20.6. For electrical engine applications, a minimum voltage threshold that indicates low remaining capacity should 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.* *UL20.7. For electrical engine applications, the battery pack charger must be considered part of the UAS. The charger must have indicators for fault and charging status.* *UL20.8. Information concerning battery storage, operation, handling, maintenance, safety limitations and battery health conditions must be provided in the applicable manuals.* *UL20.9. Saltwater compatibility must be considered if applicable as per UL.0.*	*ME20 Description and tests of the battery.*

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ER.1.3 <u>Systems and equipment</u>		
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:* *- the electrical system should include overload protection devices (fuses or circuit breakers);* *- electrical bonding should be guaranteed;* *- the electrical wires must be sized to accommodate the expected electrical loads;* *- 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;* *- 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].*	*ME21 Design criteria (see ME1)*
	UL.22 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.	*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, analyzed and corrected when necessary.* *Both the occurrences and their corrective actions must be made available to 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	*UL.24 Equipment* *UL24.1 All equipment must function properly within the design usage spectrum (UL.0), including icing*	*ME24 Evidence of the detailed requirement*

<table>
<tr><th>AIRWORTHINESS ESSENTIAL REQUIREMENTS</th><th>DETAILED ARGUMENTS</th><th>MEANS OF EVIDENCE</th></tr>
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<td>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 other system, equipment or appliance. Systems, equipment and appliances must be operable without needing exceptional skill or strength.</td>
<td>
conditions, if required.

UL24.2 Equipment Specification and Declaration of Design and Performance (DDP)
- For all installed equipment the UAS manufacturer must approve its technical specification, in order to assess compatibility with UAS higher-level requirements.
- All equipment must 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 as agreed by the Certifying Authority.
A minimum essential set of Built-In-Test (BIT) performance should be included in the design. For example:
<table>
<tr><td colspan="2">Air Vehicle</td></tr>
<tr><td>Computers</td><td>Checksum
Data Link Health</td></tr>
<tr><td>GPS Receiver</td><td>Receiver failure indication from power-up, self-test or background BIT</td></tr>
<tr><td>Motherboards</td><td>Under-voltage
Temperature</td></tr>
<tr><td colspan="2">UA faults and status information must be transmitted to the UCS/UCB for display to</td></tr>
</table>
</td>
<td>deployment from high level requirements to sub-systems and to equipment specifications.

+ Collection of the DDPs.</td>
</tr>
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<table>
<tr><td colspan="2">the operator, when the link is available</td></tr>
<tr><td colspan="2">UCS/UCB</td></tr>
<tr><td>Computers</td><td>Checksum
Data Link Health</td></tr>
<tr><td>Motherboards</td><td>Under-voltage
Temperature</td></tr>
</table>
</td><td></td></tr>
<tr><td></td><td>UL.25 Each sub-system of the UAS affecting safe operation (e.g. UA, UCB / UCS, Data-Link etc.) must perform its intended function under any operating condition identified 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 other sub-system or item of installed equipment does not adversely affect the operation of those sub-systems that affect safe operation.
The test plans must be provided to the Certifying Authority.</td><td>ME25 Functional and environmental tests.</td></tr>
<tr><td></td><td>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
- transmittal of UA status data from the UA to the UCS/UCB (downlink). The UA status data must include, to the appropriate extent, navigational information, response to UA crew commands, and equipment operating parameters in accordance with UL.32.
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) and electromagnetic vulnerability (EMV).</td><td>ME26 Functional tests + EMI/EMC test.</td></tr>
</table>

AIRWORTHINESS ESSENTIAL REQUIREMENTS	DETAILED ARGUMENTS	MEANS OF EVIDENCE
	UL26.2 Data link performances: - *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.* *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 agreed with 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 agreed by the Certifying Authority. The data link loss strategy must be provided to the operator in the operating manual.*	
	UL.27 UCS/UCB *UL27.1 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.*	*ME27 Technical description + Functional tests + Human Machine Interface evaluations.*

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	UL27.2 The UCS/UCB must be able to display the minimum information required by UL.32. *UL27.3 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 (if applicable) and announcements. The risks of controls interference and misuse of controls must be minimized.* *UL27.4 A communication system should be provided as agreed by the Certifying Authority in order to allow a two-way communication with the ATC.* *UL27.5 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.* *UL27.6 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.* *UL27.7 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.* *UL28.3 All potential hazards caused by the payload (including lasers) to crew, ground staff or third parties must be assessed and minimized.*	*ME28 Evaluation of the effects of payload normal functioning and failures on the other UA sub-systems.*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	UL.29 Integration *The UA, the UCB / UCS, the Data-Link, Launch/Recovery equipment (where applicable) and any other system necessary for operation must function properly when operated all together.*	*ME29 The evidence given in ME23 should be enough, except the Certifying Authority ask for additional evidence.*
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 systems and operations) and that this may prevent this single failure criterion from being met for some parts and some systems on helicopters, small or	*UL.30 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) and submitted to the Certifying Authority, which includes but is not limited to:* - *the definition of a Hazard Reference System to be agreed by the Certifying Authority (see Annex G);* - *a Functional Hazard 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 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.* *The safety analysis must demonstrate compliance with the following.* *UL30.1 all credible hazards and accidents must be identified, the associated accident sequences must be defined and the associated risks must be determined.* *UL30.2 The cumulative probability per flight hour for a catastrophic event (with all the contribution of all UAS and sub-systems, including propulsion, navigation, data-link, UCS/UCB, etc.) must not be greater than the Hazard Reference System cumulative safety requirement as agreed with the*	*ME30 Safety Assessment Report*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	DETAILED ARGUMENTS	MEANS OF EVIDENCE
single engine aeroplanes and uninhabited aerial vehicles.[4]	*Certifying Authority.* *UL30.3 All identified safety risks must be reduced to the minimum levels that are compatible with technological constraints, and each failure condition must be acceptable according to the Hazard Reference System criteria in Annex G, as agreed with the Certifying Authority.*	
	UL.31 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-178B or AOP-52 for software and RTCA/DO-254 for firmware), and analyze 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 agreed with the Certifying Authority should be demonstrated with the approach defined in RTCA DO-178B / ED-12B "Software considerations in airborne systems and equipment certification", for the process objectives and outputs by software level. The use of AOP-52 is also recognized as an applicable standard. If equivalent standards are provided, a Plan for Software Airworthiness should be provided and agreed with the Certifying Authority in order to present how the quoted standards will be applied.* *UL31.3 The software Development Assurance Levels should be based upon the contribution of*	*ME31 The minimum software life-cycle data to be submitted to the Certifying Authority are:* - *Software / Hardware architecture and DAL allocation* - *Plan for Software Aspects of Certification* - *Software Configuration Index* - *Software Accomplishment Summary*

[4] With no persons onboard the aircraft, the airworthiness objective is primarily targeted at the protection of people on the ground.
category

<table>
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<tr><td></td><td>software to potential failure conditions as determined with Development Assurance Level (DAL) derived from the safety analysis. The DAL allocation should be as follows.
<table>
<tr><td>Failure condition</td><td>Minimum Software DAL</td></tr>
<tr><td>Catastrophic</td><td>B</td></tr>
<tr><td>Hazardous</td><td>C</td></tr>
<tr><td>Major</td><td>D</td></tr>
<tr><td>Minor</td><td>D</td></tr>
</table>
Appropriate architectural choices (redundancy, partitioning, monitoring, dissimilarity, independency, etc.) could justify, if deemed satisfactory to the Certifying Authority, any downgrade of the above DALs, in accordance with ARP-4754 guidelines.

UL31.4 In case of new hardware development with use of a PLD (programmable logic device), the development assurance level process should be agreed with the Certifying Authority by use of a specific Special Condition.

UL31.5 The use of legacy software must be 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-178B, AOP-52, or other standard, 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 UL31.3.</td><td></td></tr>
<tr><td>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</td><td>UL.32 Depending on the UAS design features complexity, the Applicant must define and agree with 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 operator 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><td>ME32 Description of the minimum information displayed to the operator</td></tr>
</table>

AIRWORTHINESS ESSENTIAL REQUIREMENTS	DETAILED ARGUMENTS	MEANS OF EVIDENCE
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.	UL32.1 *The minimum flight and navigation data that should be displayed in the UCS/UCB at an update rate consistent with safe operation are:* - *indicated airspeed,* - *ground speed,* - *pressure altitude and related altimeter setting,* - *heading,* - *track,* - *UA position on a map at a scale selectable by the operator, together with the deviation between the planned ground track and the actual UA flight path (see also UL44.3),* - *UA position relative to the LOS data link transmitter/receiver displayed in terms of range, bearing and altitude,* - *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 must be displayed,* - *airspeed minimum and maximum limitations (see UL2.1) and corresponding speed warnings,* - *UA attitude,* - *vertical speed,* - *navigation system status,* - *g-meter (in order to avoid structural limit exceedances in manual direct piloting conditions, where there are no other alternative means to avoid g exceedances).* 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*	

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	engines) temperature, along with corresponding caution and warning alerts when specified minimum and maximum limitations are being approached, reached, and/or exceeded. *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.*	
	UL.33 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.*	*ME33 Demonstration of effectiveness of the information provided to a "minimum operator"*
	UL.34 Depending on the complexity of the UAS, the Applicant must define, agree by the Certifying Authority and provide the minimum information 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.	*ME34 Description of the minimum information to be provided to maintenance personnel*

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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 a significant failure in, or disruption of, any UAS appliance.	*UL.35 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.* *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 Identify and agree with the Certifying Authority the minimum external lighting system.*	*ME35 Description of the reasonably probable external threats, the derived hazards, the design mitigations, the eventual operating limitations mitigations.*
	UL.36 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,*	*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*

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	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 performances, 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 operator (mandatory information must be given in the flight manual; safe distance should be labelled on the antenna apparatus, where possible).*	*may be required by the Certifying Authority.* *EMRADHAZ test and/or analysis report.*
ER.1.4 <u>Continued airworthiness of the UAS</u>		
ER.1.4.1 Instructions for continued airworthiness must be	*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.*	*ME37 Instructions for continued airworthiness*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
established to ensure that the UAS type certification airworthiness standard is maintained throughout the operational life of the UAS.	*In particular, provide instructions for continued airworthiness of the UA structure, engine, propeller 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 UA structural inspection intervals and procedures,* *UL37.5 UAS servicing information,* *UL37.6 UA assembling and disassembling instructions (where applicable as for Micro UA).* *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.*	*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 agreed with the Certifying Authority and may differ according to National Regulations.* *Appropriate labelling on the UA may be necessary.*
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.	*UL.38 Means must be provided to allow inspection, adjustment, lubrication, removal or replacement of parts and appliances as necessary for continued airworthiness.*	*ME38 Description of the means provided to allow continued airworthiness implementation.*
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). The instructions must cover maintenance and repair	*See UL.37 and ME37.*	

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
instructions, servicing information, trouble-shooting and inspection procedures.		
ER.1.4.4 The instructions for continued airworthiness must contain airworthiness limitations that set forth each mandatory replacement time, inspection interval and related inspection procedure.	*UL.39 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.*	*ME39 Section called "Airworthiness Limitations" in the manual or manuals as per ME37.*
ER.2 <u>Airworthiness aspects of system operation</u>		
ER.2.1 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:	*See the following.*	
ER.2.1.1 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	*Structure, engine, propeller, 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.* *<u>NOTE</u>* *The performances 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.*	

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
be established.	*UL.40 Kinds of operation:* *UL40.1. Identify the airspace classes for which the UA may be authorized, taking into account the UAS design features.* *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.*	*ME40 Justification of the airspace classes in which the UA may be authorized to fly and platforms other than land from which operations may be conducted.*
	UL.41 Stalling speeds *UL41.1 Wing level stalling speeds at all relevant aerodynamic configurations must be determined for the most appropriate combination of weight and CG either by analysis (as agreed by the Certifying Authority) or by flight test (at a rate of speed decrease of 1knot/s or less and closed throttle).* *UL41.2 If the stalling speeds are not demonstrated by flight test, a "minimum demonstration speed" [$V_{minDEMO}$] must be demonstrated in flight, sufficiently below the minimum operational speed [V_{C-min}].* *UL41.3 If stall is used as a means to recover or land the UA, the stall speeds must be demonstrated by flight test.* *UL41.4 Stalling speeds must be provided to the operator, when necessary to avoid undesirable conditions as agreed with the Certifying Authority.*	*ME41 Flight test and analysis report.*
	UL.42 Takeoff / launch *UL42.1 It must be shown that the takeoff / launch sequence is a reliable, repeatable and predictable safe operation, for each weight, altitude, temperature, and wind conditions, within the operational limits in UL.0.* *UL42.2 A takeoff safety trace must be determined as the area (associated with a UA conventional takeoff or launch by catapult or by hand) in which there may be a hazard which could result in*	*ME42 Flight Test and analysis report.*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	a risk to personnel, third parties, equipment and/or property. Winds, navigational accuracies, communication latencies, etc. must be considered in the establishment of the takeoff safety trace. *UL42.3 For conventional takeoff procedures, with the UA at MTOW and full throttle, the following must be measured:* *- ground roll distance to takeoff on a runaway with minimal grade,* *- distance to clear a 15m (50 ft) obstacle,* *- speed at 15m (50 ft) height greater than the stalling speed by a defined margin to be agreed with the Certifying Authority (e.g. 1.2 V_S),* *- rotation speed (speed at which the UA crew or the flight control system makes a control input with the intention of lifting the UA out of contact with the runway) such that the required 50 ft obstacle climb speed is obtained.* *UL42.4 For catapult assist or hand launch the UA must remain in a stable and controllable condition throughout the launch phase and during the transition to normal flight conditions.* *UL42.5 For catapult assisted UAS, with the UA at MTOW, safe takeoff procedures and UA/catapult settings must be determined and the following must be measured:* *- distance to clear a 15 m (50 ft) obstacle,* *- speed at 15m (50 ft) height greater than the stalling speed by a defined margin to be agreed with the Certifying Authority (e.g. 1.2 V_S),* *- end of catapult airspeed such that the required 50 ft obstacle climb speed is obtained.* *UL42.6 For hand launch UAS, with the UA at MTOW, safe takeoff procedures and settings must be determined and the following must be measured:* *- distance to clear a 15 m (50 ft) obstacle,* *- speed at 15m (50 ft) height greater than the stalling speed by a defined margin to be agreed with the Certifying Authority (e.g. 1.2 V_S).* *Due account should be taken of the variability of force and launch angle in hand launches.*	

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	UL42.7 When an automatic takeoff system is provided, - *it must not cause 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;* - *where a UAS is designed for conventional take-off on a runway, it should incorporate a manual abort function, easily accessible to the UA operator in order to stop the UA on the runway during the take-off run at every speed up a pre-determined maximum abort speed.* *UL42.8 Takeoff procedures and performances must be provided to the operator in the flight manual.*	
	UL.43 Climb and descent *UL43.1 The ISA sea level rate of climb at V_y (speed for best rate of climb) should be at least 1.5 m/s with no more than takeoff power, at MTOW, retracted landing gear (where applicable), wing flaps in takeoff position (where applicable).* *UL43.2 The ISA sea level gradient of climb at V_x (speed for best angle of climb) must be determined with no more than takeoff power, at MTOW, retracted landing gear (where applicable), wing flaps in takeoff position (where applicable).* *UL43.3 The climb performances at V_x and V_y must be provided to the operator in the flight manual.* *UL43.4 The climb performances for flaps retracted (if applicable) at maximum continuous power for the UL.0 usage envelope airspeeds and altitudes must be provided to the operator in the flight manual.*	*ME43 Flight Test and analysis report.*
	UL.44 Navigation accuracy *UL44.1 Navigation accuracy must be agreed with the Certifying Authority and verified by flight test in all the UA operational modes, in terms of maximum error from an established waypoint on ground, altitude and speed.*	*ME44 Flight Test report.*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	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 (as agreed by the Certifying Authority) from the pre-programmed flight-path occurs.*	
	UL.45 Glide *UL45.1 The maximum horizontal distance travelled in still air, in nautical miles per 1,000 ft of altitude lost in a glide, the speed necessary to achieve this and the glide time must be determined with the engine inoperative and its propeller in the minimum drag position, landing gear and wing flaps in the most favourable available position* *UL45.2 The glide performances and instructions to achieve the best glide range must be provided to the UA operator in the flight manual.*	*ME45 Flight Test and analysis report.*
	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, parachute or stalling landing), in which there may be a hazard which could result in a risk to personnel, third parties, equipment and/or property. Winds, navigational accuracies, communication latencies, etc. must be considered in the establishment of the landing safety trace.* *UL46.3 Conventional landing:* *- a safe landing speed and a safe gradient of descent must be determined with sufficient margin above stalling speed in landing configuration;* *- the horizontal distance necessary to land and come to a complete stop from a point 15 m*	*ME46 Flight Test and analysis report.*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	DETAILED ARGUMENTS	MEANS OF EVIDENCE
	(50 ft) above the landing surface must be determined; - *minimum safe balked landing height must be determined together with the corresponding gradient of climb.* *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* - *a safe landing speed and a safe gradient of descent must be determined with sufficient margin above stalling speed in landing configuration;* - *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 When normal recovery is done by stalling the UA, the landing accuracy must be determined.* *UL46.7 When an automatic landing system is provided,* - *it must not cause 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;* - *where a UAS is designed for conventional landing on a runway, it should incorporate a manual abort function, easily accessible to the UA operator in order to initiate a go-around procedure during the landing phase at every height down to a pre-determined decision point. Specific go-around procedures must be provided in the UAS flight manual (where applicable).*	

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	UL46.8 Landing procedures and performances must be provided to the operator in the flight manual.	
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 DUO (Designated UA Operator) strength, flight deck environment, DUO 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 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, as agreed by the Certifying Authority.* *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 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 including* - *takeoff;* - *climb;* - *level flight, including mission relevant special manoeuvres;* - *descent;* - *go-around (except where UA is designed to be recovered by parachute);* - *landing (power on and power off) with the wing flaps extended and retracted (except where UA is designed to be recovered by parachute);* - *ground taxi and arresting (with maximum allowable crosswind component).*	*ME47 Flight Test Report.*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	UL47.4 The UA flight mechanics behaviour when it encounters the gust as per UL5.3 must be characterized and potential limitations (taking due account of the design usage spectrum as per UL.0) established where applicable and documented in operating manuals. Potential stalling condition due to gust and FCS recovery capabilities must be taken into account when applicable.	
	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.*	*ME48 Flight Test Report.*
	UL.49 Minimum Control Speed (for multi engine configurations that are capable of safe flight with one engine inoperative) - *The Minimum Control Speed must be determined as the airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the UA, with that engine still inoperative, and thereafter maintain straight flight at the same speed with an appropriate angle of bank. The method used to simulate critical engine failure must represent the most critical mode of power plant failure and most critical configuration with respect to controllability expected in service.* - *The Minimum Control Speed must be provided to the operator.* - *The Minimum Control Speed for take-off must not exceed a fixed margin above the stalling speed agreed by the Certifying Authority.*	*ME49 Flight Test Report. Model based analysis may be deemed sufficient by the Certifying Authority.*
	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*	*ME50 Model analysis and flight test.*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	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 (DUO) 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 DUO 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 DUO training syllabus as necessary.*	*ME51 Flight Test Report including workload assessment.*
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, strength or workload under any probable operating condition.	*UL.52 It must be possible to make a smooth transition from one flight phase and/or condition to another (including turns and slips) without danger of exceeding the limit load factor, 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 launch phase and normal flight condition, as well as the transition from normal flight condition to recovery phase.*	*ME52 Flight Test Report.*
ER.2.1.4 The UA must have handling qualities that ensures the	*N/A* [*It concentrates on handling qualities effects on DUO controls; it is assumed that there is no artificial*	

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
demands made on the DUO are not excessive taking into account the phase of flight and its duration.	*feedback on the controls in direct mode piloting condition.* *In ER 2.1.2 due account has already been taken of DUO strength, flight deck environment, DUO workload and other human-factor considerations].*	
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.*	*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.*	*ME54 Flight Test Report*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	***DETAILED ARGUMENTS***	***MEANS OF EVIDENCE***
	UL.55 Engine shut down procedure *In the event of an engine failure that causes loss of thrust, an appropriate procedure must be defined and provided in the flight manual; the following apply.* *UL55.1 The UA must be designed to retain sufficient control and manoeuvrability until it has reached a forced landing area.* *UL55.2 The emergency electrical power must be designed in such a way that its reliability and duration are compatible with UL55.1. The time period needed to perform a glide from maximum certificated altitude to sea level (ISA conditions) and reach a forced landing area includes the time needed for the UA crew to recognise the failure and to take appropriate action, if required.* *UL55.3 The engine shut down procedure must be analysed considering the existence of the emergency recovery capability specified in UL.53.*	*ME55 Technical description*
	UL.56 The Flight Manual provided to the UA operator must clearly and unambiguously define all the - *operating procedures, and* - *operating limitations, and* - *performance information,* *for* - *normal operations, and* - *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,* - *possible conflict avoidance manoeuvres.*	*ME56 Flight Manual*
ER.2.1.6 Warnings, or other deterrents intended to prevent exceeding the normal flight envelope, must be provided, as	*UL.57 The UAS should be designed so that:* *UL57.1 in automatic or semi-automatic operating modes, the UA should be automatically protected from stalling (except in auto-landing modes in which stall is the design means to land the UA);*	*ME57 Technical description of UA flight envelope protection*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	DETAILED ARGUMENTS	MEANS OF EVIDENCE
appropriate to type.	*UL57.2 in manual direct piloting mode (where applicable) a stall warning should alert the operator when approaching stalling conditions and should include a sufficient safety margin;* *UL57.3 in automatic or semi-automatic operating modes, the UA should be inherently incapable of spinning, due to FCS flight envelope protection or any other means;* *UL57.4 in manual direct piloting mode (where applicable), if the UA is capable of spinning, sufficient information should be given to the operator in order to prevent unintentional entering into this condition;* *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);* *UL57.6 in manual direct piloting mode (where applicable), the operator should be alerted with sufficient margin when approaching any unsafe condition.*	*design features*
	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,* - *required safe and controllable manoeuvring of the UA,* - *margin to catastrophic failure conditions.* - *The minimum speed allowed by the flight control system must be compatible with the margin specified in UL41.2.* - *The UA must respond to intentional dynamic manoeuvring within a suitable range of parameter limit.* - *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*	*ME58 Technical description of UA flight envelope protection design features + model simulation analysis + flight test report*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	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 flight envelope that may be encountered.	*UL.59 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.*	*ME59 Flight Test Report.*
ER.2.2 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).*	*ME60 Flight Manual*
ER.2.3 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 UL35.2.* *Consideration to bird-strike is given in UL.13.*	
ER.2.3.1 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,		

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
etc., expected to occur during system operation.		
ER.2.3.2 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 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.	*N/A* *For the UCS/UCB see also UL.27 and UL.30.*	

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
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.	*See UL.27, UL.32, UL.33.* *In particular human-machine interface aspects are covered by UL27.3.*	
ER.3 Organisations (It includes natural persons undertaking design, manufacture or maintenance)		
ER.3.1 Organisations involved in design (including flight test), production (manufacture) or maintenance activities must satisfy the following conditions:		
ER.3.1.1 The organisation must have all the means necessary for the scope of work. These means comprise, but are	*UL.61 The Applicant should ensure certification as per AS/EN 9100 for undertaking Light 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,*	*ME61 Approved AS/EN 9100 Certificate or equivalent.*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	DETAILED ARGUMENTS		MEANS OF EVIDENCE
not limited to the following: facilities, personnel, equipment, tools and material, documentation of tasks, responsibilities and procedures, access to relevant data and record-keeping.		*with adequate tools, material, procedures and data.*	
ER.3.1.2 The organisation must implement and maintain a management system to ensure compliance with these essential requirements for airworthiness, and aim for continuous improvement of this system.	*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.* *The Certifying Authority may audit the Safety Management System at its discretion.*	*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 included in the Safety Management Plan are provided in Annex I.*
	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].*	*ME63 Approved AS/EN 9100 certificate + ISO 9004 or equivalent*
ER.3.1.3 The organisation must establish arrangements with	*UL.64*	*The organisation must establish an interface with other relevant organisations, as necessary, to ensure continuing compliance with these essential requirements for airworthiness.*	*ME64 The Safety Management Plan (see*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	DETAILED ARGUMENTS	MEANS OF EVIDENCE
other relevant organisations, as necessary, to ensure continuing compliance with these essential requirements for airworthiness.		*Annex I).*
ER.3.1.4 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 ("continuing airworthiness of the type design").	*UL.65 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 ("continuing airworthiness of the type design").*	*ME65 The Safety Management Plan (see Annex I)*
ER.3.2 In the case of maintenance training organisations, the conditions under points 3.3.1.3 and 3.3.1.4 do not apply.	*N/A*	
UA HANDOVER (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*	*ME66 Technical description + Flight test report*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	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*	
	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*

AIRWORTHINESS ESSENTIAL REQUIREMENTS	*DETAILED ARGUMENTS*	*MEANS OF EVIDENCE*
	UL.69 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.	*ME69 Technical description + Flight test report*

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ANNEX A TO
AEP-83

TERMS AND DEFINITIONS

1 **Acronyms and Abbreviations.** The following acronyms are used for the purpose of this agreement.

Applicant	The entity applying for the Type Certificate
Automatic	The execution of a predefined process or event that requires UAS crew initiation
CG	Centre of Gravity
DUO	Designated UA Operator
FCS	Flight Control System
MTOW	Maximum Take Off Weight
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System.
	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.
UCB / UCS	UA Control Box / UA Control Station
	A facility or device from which the UA is controlled and/or monitored for all phases of flight.
$V_{C\text{-}min}$	Minimum cruise speed – it is the minimum operational speed
V_C	Design cruise speed – it is the design operational speed
$V_{C\text{-}max}$	Maximum cruise speed – it is the maximum operational speed
V_D	Dive speed – it is the maximum design speed
V_S	Stalling speed
$V_{minDEMO}$	Minimum demonstration speed
V_x	Speed for best angle of climb
V_y	Speed for best rate of climb
PSE	Primary Structural Elements
HW	Hot Wet

RTD	Room Temperature Dry
RPM	Revolutions per Minute
DDP	Declaration of Design and Performance
BIT	Built in Test
FCS	Flight Control System
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMV	Electromagnetic Vulnerability
EME	Electromagnetic Emission
ATC	Air Traffic Control
DAL	Development Assurance Level
PLD	Programmable Logic Device
LOS	Line of Sight
HIRF	High Intensity Radio Frequency
EMRADHAZ	Hazards of Electromagnetic Radiation to Personnel
PIO	Pilot Induced Oscillation
GAT	General Air Traffic
OAT	Operational Air Traffic

ANNEX B TO
AEP-83

LANDING CONDITIONS FOR CONVENTIONAL LANDING GEAR CONFIGURATIONS (WHERE APPLICABLE)

This guidance is based on traditional manned aircraft configurations. Alternative design solutions may require a case by case tailoring.

UL.GL.1 Basic Landing Condiitons

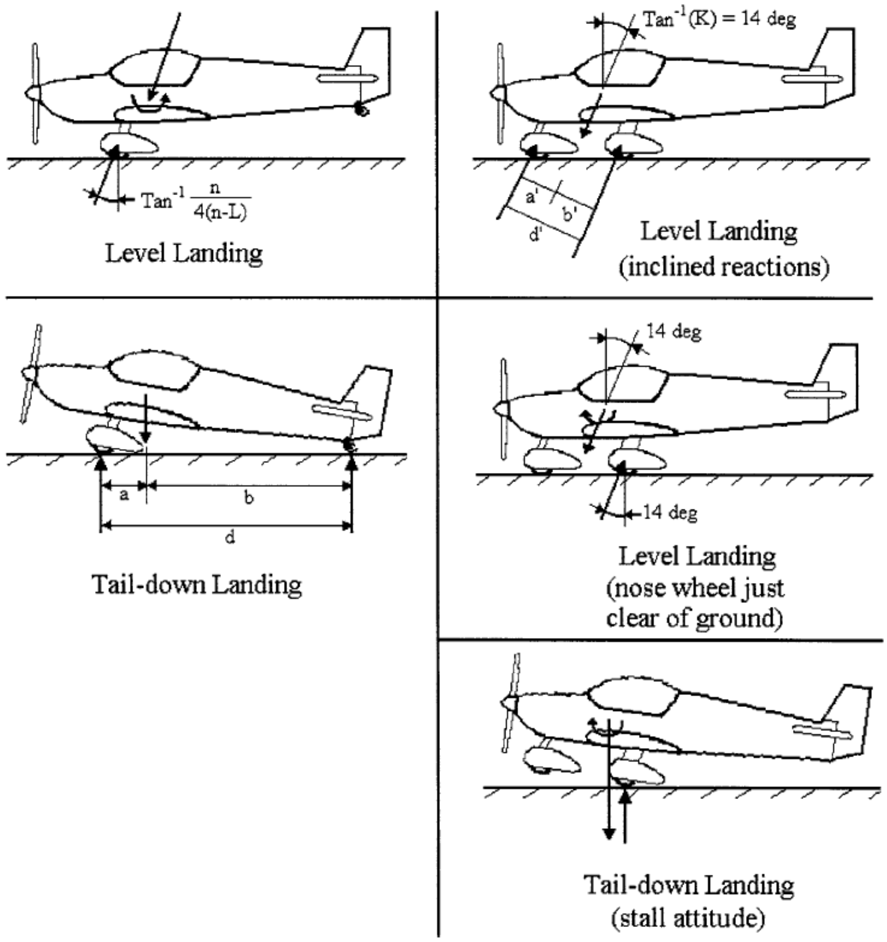
The loads for the basic landing conditions are given in the following table and figure

Table – Basic landing condition

NOTE 1—$K = 0.25$
$L = ⅔$ = ratio of the assumed wing lift to the airplane weight
$n = n_j + ⅔$ = load factor
n_j = load factor on wheels
NOTE 2—See Fig. for the airplane landing conditions.

Condition	Tail Wheel Type: Level Landing	Tail Wheel Type: Tail-down Landing	Nose Wheel Type: Level Landing with Inclined Reactions	Nose Wheel Type: Level Landing with Nose Wheel Just Clear of Ground	Nose Wheel Type: Tail-Down Landing
Vertical component at CG	nW	nW	nW	nW	nW
Fore and aft component at CG	KnW	0	KnW	KnW	0
Lateral component in either direction at CG	0	0	0	0	0
Shock absorber deflection (rubber or spring shock absorber), %	100 %	100 %	100 %	100 %	100 %
Tire deflection	Static	Static	Static	Static	Static
Main wheel loads (V_r)	(n-L)W	(n-L)Wb/d	(n–L)Wa'/d'	(n-L)W	(n-L)W
(both wheels) (D_r)	KnW	0	KnWa'/d'	KnW	0
Tail (nose) wheels (V_r)	0	(n-L)Wa/d	(n-L)W'/d'	0	0
Loads (D_r)	0	0	KnWb'/d'	0	0

Figure – Basic landing condition



1.1 The load factor on the wheels, n_j, may be calculated as follows:

$$n_j = \frac{h + d/3}{ef \times d},$$

where

h = drop height [in] = $3.6 \times \sqrt{W/S}$ with W/S in [lb/ft^2], but h larger than 9 in.,
d = total shock absorber travel [in] = $d_{tire} + d_{shock}$,
ef = shock efficiency, and
ef x d = 0.5 x d for tire and rubber or spring shocs, or
= 0.5 x d_{tire} + 0.65 x d_{shock} for hydraulic shock absorbers.

1.2 If n_j is larger than the maximum load factor in UL5.2 minus 0.67 (n_{max} - 0.67), all concentrated masses (engine, fuel tanks, ballast, payload, etc.) must be substantiated for a limit landing load factor of n = n_j + 0.67 which is greater than n_{max}.

1.3 The usual ultimate factor of safety of 1.5 applies to this conditions, unless a drop test from the reserve energy height, hr=1.44h, shows that a lower factor may be used. If the shock absorber is of a fast energy absorbing type, the ultimate loads are the limit loads multiplied by the conservative reserve energy factor of 1.2.

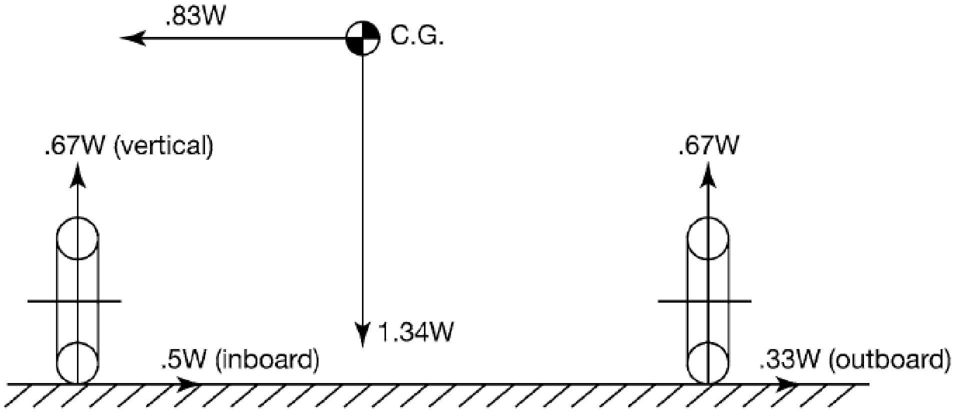
UL.GL.2 One-wheel landing condition

For the one-wheel landing condition, the UA is assumed to be in the level attitude and to contact the ground on one side of the main landing gear. In this attitude, the ground reactions must be the same as those obtained on that side under Level Landing conditions of §UL.GL.1.

UL.GL.3 Side Load Conditions

The loads for the side load conditions on the main wheels in a level attitude are given in the following figure (the shock absorbers and tires are assumed to be in their static position).

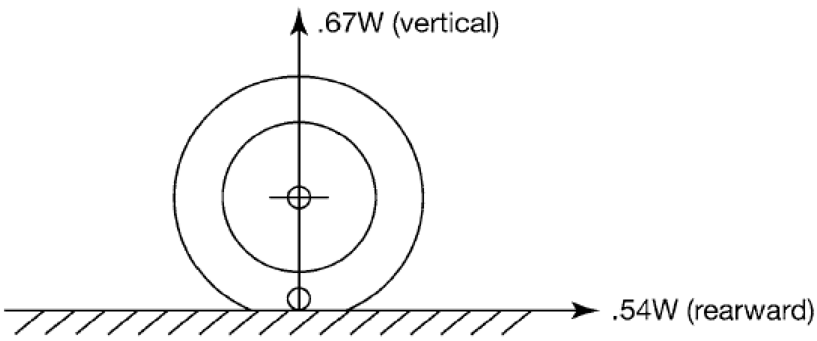
Figure – Side Load Conditions



UL.GL.4 Braked Roll Condiitons

The loads for the braked roll conditions on the main wheels in a level attitude are given in the following figure (the shock absorbers and tires are assumed to be in their static position*).*

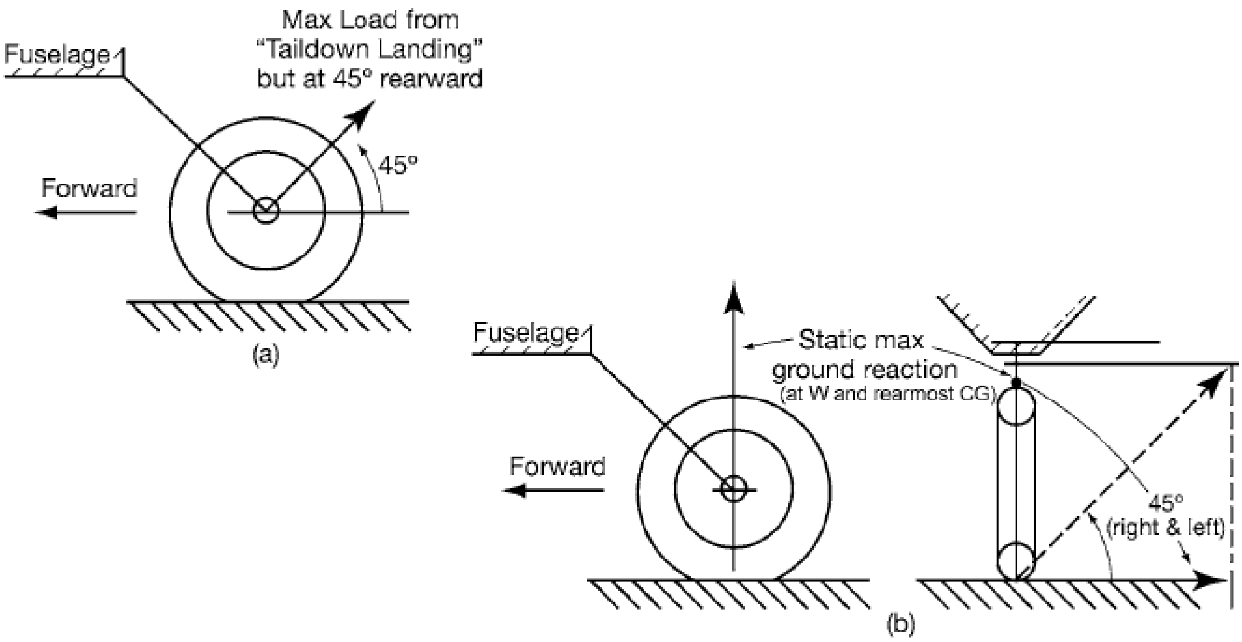
Figure – Braked Roll Conditions



UL.GL.5 Supplementary Conditions for Tail Wheel

The loads for the tail wheel conditions in a tail down attitude are given in the following figure (the shock absorbers and tires are assumed to be in their static position).

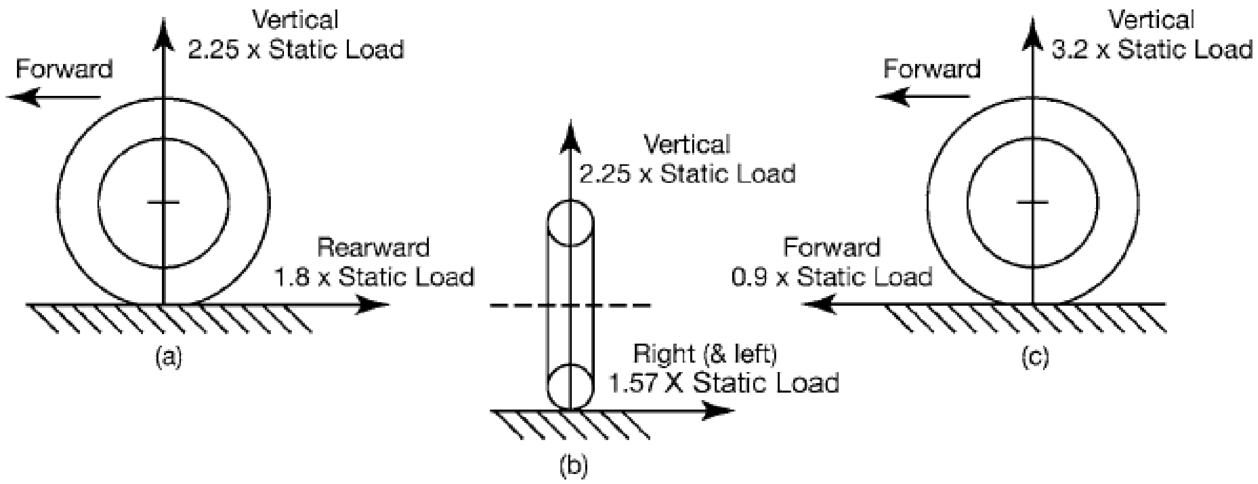
Figure – Supplementary Conditions for Tail Wheel Conditions



UL.GL.6 Supplementary Conditions for Nose Wheel

The loads for supplementary conditions for nose wheels are given in the following figure (the static load is at the combination of weight and CG that gives the maximum loads; the shock absorbers and tires are assumed to be in their static position).

Figure – Supplementary Conditions for Nose Wheel



ANNEX C TO
AEP-83

SPARK AND COMPRESSION IGNITION RECIPROCATING ENGINES

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 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.

UL.RE.3 Selection of engine power ratings

Each selected rating 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.RE.22(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 DUO 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)

(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 DUO 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 (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

Except where the engine is of a type of construction known not to be prone to hazardous vibration, 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 propeller (the propeller 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) to (c). 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 propeller) that includes a total of 50 hours of operation and consists of the cycles specified in UL.RE.22(c).

(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) Each cycle must be conducted as follows:

Sequence	Duration (Minutes)	Operating Conditions
1	5	Starting – Idle
2	5	Take-off power
3	5	Cooling run (Idle)
4	5	Take-off power
5	5	Cooling run (Idle)
6	5	Take-off power
7	5	Cooling run (Idle)
8	15	75% of maximum continuous power
9	5	Cooling run (Idle)
10	60	Maximum continuous power
11	5	Cooling run and stop
Total:	120	

(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) 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.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.

ANNEX D TO
AEP-83

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 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.

UL.EE.3 Selection of engine power ratings
Each selected rating 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 propeller) 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 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:

Sequence	Environmental Temperature	Duration [min]	Power setting
1.1	Cold	2	Maximum continuous power

Sequence	Environmental Temperature	Duration [min]	Power setting
1.2	Cold	43	Nominal power
1.3	Cold	2	Maximum continuous power
1.4	Cold	43	Nominal power
TOTAL DURATION CYCLE 1: 90 [min]			
2.1	Ambient	2	Maximum continuous power
2.2	Ambient	43	Nominal power
2.3	Ambient	2	Maximum continuous power
2.4	Ambient	43	Nominal power
TOTAL DURATION CYCLE 2: 90 [min]			
3.1	Hot	2	Maximum continuous power
3.2	Hot	43	Nominal power
3.3	Hot	2	Maximum continuous power
3.4	Hot	43	Nominal power
TOTAL DURATION CYCLE 3: 90 [min]			
4.1	Ambient	3	Maximum continuous power
4.2	Ambient	102	Nominal power
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			

(d) N/A

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 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 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.

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ANNEX E TO
AEP-83

TURBINE ENGINES

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 UL.TE.6.

UL.TE.2 Engine ratings and operating limitations

Engine ratings 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.

UL.TE.3 Selection of engine power ratings

Each selected rating 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

UL.TE.6 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 perUL.30). Particular consideration must be given but not limited to the following hazards: uncontrolled fire, burst, uncontainment of high-energy debris, non-restartable in-flight shutdown and loss of shutdown capability, release of the propeller by the engine(if 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.7 Software design assurance level must be compatible with UL.31.

DESIGN AND CONSTRUCTION

UL.TE.8 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.9 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):

Load type	Limit Load	Ultimate Load = (Limit Load) x (Factor of Safety)
Externally applied loads	1.0	1.5
Thermal loads	1.0	1.5 (1.0 could be used in case of over-temperature protection)
Thrust loads	1.0	1.2 (1.0 could be used in case a Full Authority Digital Engine Control Unit prevents maximum thrust exceedance)
Internal pressures	1.0	2.0
UA flow field loads	1.0	1.5

(d) Blade-out condition
Subsequent to blade failure at maximum allowable steady state speed, the engine must not experience: uncontainment of 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 agreed with the Certifying Authority in accordance with UL13.2.

UL.TE.10 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, 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 agreed with 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, as agreed with the Certifying Authority;
- sufficiently short life limitations for fracture critical parts.

UL.TE.11 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.12 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.13 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[(5)].

(c) All engine parts must not creep to the extent that an hazard may occur.

UL.TE.14 Engine cooling

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

UL.TE.15 Engine mounting attachments and structure

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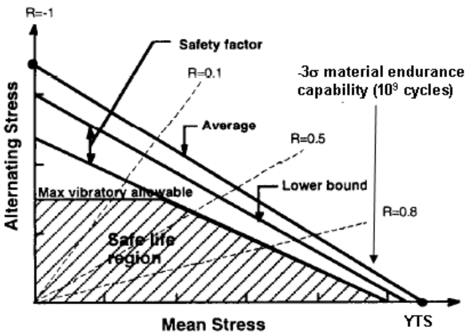
[5] *An acceptable means of compliance to this requirement is to show that the natural frequencies of this components are outside of the engine operating range with a minimum of 20% margin. All fracture critical parts should be designed according to this criterion. For other components it should be shown 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 Yeld Tensile Stress. A maximum allowable vibratory stress limit should be established. Besides the high mean stress regime should be avoided.*



All engine parts should have a minimum HCF life of 10^9 cycles. A reduction to lower values (e.g. 10^7 cycles for steel parts and $3*10^7$ 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 10^9 cycles).

(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.16 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.17 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.18 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.
(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.26(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 DUO 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.19 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 DUO 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.20 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.21 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.22 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.23 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.24 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.

UL.TE.25 Calibration test

In order to identify the engine thrust/power changes that may occur during the endurance test specified in UL.TE.26, 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.26 Endurance test

(a) The engine must be subjected to an accelerated endurance test to be agreed with 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.24, 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.18;
- 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. 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 Takeoff 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.18.
- 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 with the Certifying Authority.

UL.TE.27 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 agreed with 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.28 Engine component test

(a) For engine components (including gearbox, where applicable) that cannot be adequately substantiated by endurance testing in accordance with UL.TE.26, 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.29 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.30 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.31 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.32 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.

ANNEX F TO
AEP-83

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.

TESTS AND INSPECTIONS

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 DUO 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 2.

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 dis-assembled. 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.

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ANNEX G TO
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HAZARD REFERENCE SYSTEM

UL.HRS.1 Severity Reference System

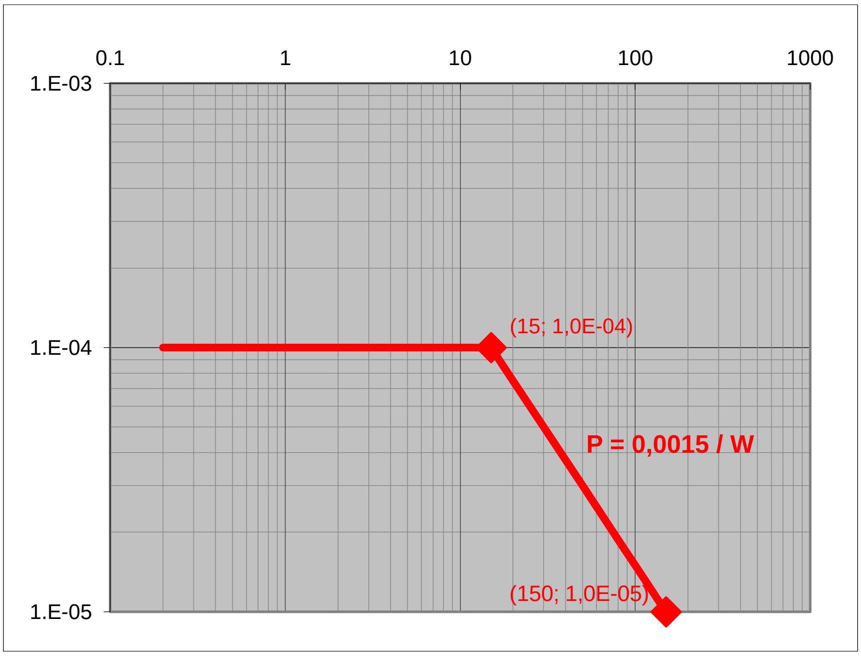
Catastrophic	Failure conditions that are expected to result in at least uncontrolled flight (including flight outside of pre-planned or contingency flight profiles/areas) and/or uncontrolled crash. Or Failure conditions which may result in a fatality to UA crew or ground staff.
Hazardous	Failure conditions 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 UA crew or ground staff 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 UA crew or ground staff.
Minor	Failure conditions that do not significantly reduce UA safety and involve UA 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 UA 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:

for MTOW below 15kg	$P_{CUM\text{-}CAT} = 10^{-4}$
for MTOW between 15kg and 150kg	$P_{CUM\text{-}CAT} = 0.0015 / (MTOW)$



UL.HRS.3 Probability Level Reference System

The number of expected catastrophic failure conditions should be determined, as derived by the Preliminary Safety Assessment and agreed by the Certifying Authority.

Alternatively a fixed number of 10 expected catastrophic failure conditions may be used.

The following probability reference system should be used:

(E) Extremely Improbable	$P_{(E)} \leq \frac{P_{CUM-CAT}}{\text{Number of expected catastrophic failure conditions}}$
(D) Extremely Remote	$P_{(E)} < P_{(D)} \leq 10 \times P_{(E)}$
(C) Remote	$10 \times P_{(E)} < P_{(C)} \leq 100 \times P_{(E)}$
(B) Probable.	$100 \times P_{(E)} < P_{(B)} \leq 1000 \times P_{(E)}$
(A) Frequent	$P_{(A)} > 1000 \times P_{(E)}$

UL.HRS.4 Hazard Acceptability Criteria

Hazard Risk Index (HRI)	(1) CATASTROPHIC	(2) HAZARDOUS	(3) MAJOR	(4) MINOR
(A) FREQUENT	1A Unacceptable	2A Unacceptable	3A Unacceptable	4A Unacceptable
(B) PROBABLE	1B Unacceptable	2B Unacceptable	3B Unacceptable	4B Acceptable
(C) REMOTE	1C Unacceptable	2C Unacceptable	3C Acceptable	4C Acceptable
(D) EXTREMELY REMOTE	1D Unacceptable	2D Acceptable	3D Acceptable	4D Acceptable
(E) EXTREMELY IMPROBABLE	1E Acceptable	2E Acceptable	3E Acceptable	4E Acceptable

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ANNEX H TO
AEP-83

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 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;
- airspeed, heading or track, turn rate, 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 exceedances 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 agreed with 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 agreed with 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 air speed to:

- fall below the minimum allowed air speed,

- exceed a defined margin agreed with the Certifying Authority slightly above $V_{C\text{-}max}$ and sufficiently below V_D.

UL.SR.3 Pilot (DUO) Induced Oscillations

The absence of PIO 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 DUO 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 agreed with 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 7 6).

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 regulator/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.

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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:

- 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 like 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).

2. General Requirements

The Applicant should ensure certification as per AS/EN 9001 for undertaking Light 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.

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 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 DUO.

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.

3. Structures and Materials

Structural integrity

The UA must withstand, without rupture, the maximum operational 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.

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 as agreed by the Certifying Authority.

<u>Safety</u>
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[6].

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 agreed with 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.

[6] The probability threshold for extremely remote failures is of the order of 1e-3 /fh