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# PREAMBLE

## Document Issues

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| **Date** | **Issue** | **Author(s)** | **Updating purpose** |
| 16/06/2017 | 1 | E. Ledinot | Creation of the document |

## Executive Summary

This document provides the certification objectives of the RESSAC use case, in order to support experimentation of the Overarching Properties as a candidate Accepted Means of Compliance to FAR 2x/CS 2x airworthiness regulation.

It proposes a comprehensive and consistent set of CS 25[[1]](#footnote-1) sections that can be transposed to the use case, though Part 25 FAR/CS regulation applies to large airplanes, not to drones.

This transposition aims at extracting from regulation the functional safety requirements[[2]](#footnote-2) applicable to µXAV, whose correct and complete enforcement is the aim of development assurance, be it based on baseline industrial standards (ARP 4754, DO-178, DO-254), or on the upcoming Overarching Properties (OPs).

µXAV’s certification basis, derived by transposition of CS25 clauses, covers the following technical areas:

* Flight
* Flight control
* Power plant
* Wind and icing environmental conditions,
* Electrical Wiring and Information System (EWIS),
* Electrical generation and distribution,
* Hydraulics
* Braking,
* Alerting,

The AMC clauses that supplement the selected regulatory clauses in CS 25 Amendment 18 are given as well. When these AMC sections are too extensive for integral quotes, they are limited to the parts that are anticipated as being the most useful for the use case and the “Streamlining” WG.

# Purpose of the document

This document is intended to help support the activities of the RESSAC use case that are devoted to conformity substantiation.

System specification, design and implementation must ensure aircraft level behavioural properties that conform with airworthiness regulatory constraints, as stated in the in Part 2x FAR/CS[[3]](#footnote-3) documents.

The purpose of this document is to constitute an equivalent of CS/FAR 25 for the toy air vehicle named µXAV, in spite of the fact that Part 25 regulates large planes, not drones. This airworthiness equivalent was derived by selecting in CS 25 Amendment 18 the technical clauses that could be transposed to the use case, with drastic simplification.

Failure Conditions (see [1]) are not the unique source to derive the functional safety requirements. Any development inherits the safety constraints defined by the documents of the program’s certification basis. This document is intended to *make explicit* these inherited and implicit safety requirements. They are of primary importance for development assurance, especially regarding demonstration of conformity.

This document is not mentioned in [3] because it does not exist on actual programs. These regulatory safety constraints are part of the safety culture of any company. They are ‘compiled’ by OEMs into their designs to meet them, without collecting the applicable subset in a document as it is done here.

This document is a didactic auxiliary, intended to isolate the airworthiness contract applicable to µXAV at layer 0 and layer 1, and to exemplify the Authority’s viewpoint on safety. It is expected to help getting a thorough view of what an alternative means of compliance to a certification basis should mean.

# references

[1] µXAV Air Vehicle level Functional Hazard Analysis.

[2] Certification Specification and Accepted Means of Compliance for large Aeroplanes – CS 25 Amendment 18. EASA 22 Juin 2016.

[3] µXAV Life-cycle processes

# introduction TO certification specification

Part 25 Certification Specification is a 1500-page document made of two books:

* **Book 1** contains regulation per se (320 pages). It is structured into 9 subparts that cover definite technical areas. These subparts are supplemented with 14 appendices.
* **Book 2** specifies the Accepted Means of Compliance (AMC) to demonstrate conformity to the safety constraints stated in book 1. The structure of book 2 almost exactly mirrors that of book 1. Some sections of book 1 do not have a corresponding AMC section. When an AMC section exists, it is numbered with the CS section number it refers to.

For expected comfort of the reader a section wise interleaving of book 1 and book 2 has been performed in the following.

At top level, book 1’s decomposition into subparts is reused. For each of these technical domains a selection of the certification specification clauses has been made. For each selected clause numbered CS25.xyzt, are given:

1. A **selection** of CS25.xyzt’s sub-articles. The selection targets the aspects used in the case study. They are quoted verbatim,
2. A **transposition** of the selected clauses into use case compatible equivalents,
3. A partial **AMC** 25.xyzt, that corresponds to the selected and transposed CS clauses. So doing, the AMC quotes can be read in context with their corresponding CS objective. No transposition was made on the AMC clauses, only selection by relevance was performed.

Like in [1] the verbatim excerpts are in italic. When AMC sections are too long to be comprehensively imported, a summary is given with a few OPs-relevant excerpts. In this first release of the document, the AMC sections were limited to that for CS 25.1309 and CS 25.1301, plus a few illustrative ones. The other will be supplemented as needed on the use case.

The transposed certification specification of µXAV keeps the structure of a network of numbered sections. Notation (**µ**CS25.xyzt) is used to distinguish the transposed articles from the original ones.

# flight

## Proof of Compliance (CS 25.21)

### Selection

*(a) Each requirement of this Subpart must be met at each appropriate combination of weight and centre of gravity within the range of loading conditions for which certification is requested. This must be shown:*

*–(1) By tests upon an aeroplane of the type for which certification is requested, or by calculations based on, and equal in accuracy to, the results of testing;*

*and (2) By systematic investigation of each probable combination of weight and centre of gravity, if compliance cannot be reasonably inferred from combinations investigated.*

*(c) The controllability, stability, trim, and stalling characteristics of the aeroplane must be shown for each altitude up to the maximum expected in operation*

### Transposition

µCS 25.21 is CS25.21(a), (c) where aeroplane is replaced by drone.

### AMC

There is no AMC for paragraphs (a) and (c). There is an extensive AMC 25.21 (g) on icing conditions in relation to the many CS paragraphs that are devoted to flight and performance. This AMC is ignored for the icing aspects of the use case.

## Load Distribution Limits (CS 25.23)

### Selection

*(a) Ranges of weights and centres of gravity within which the aeroplane may be safely operated must be established. If a weight and centre of gravity combination is allowable only within certain load distribution limits (such as spanwise) that could be inadvertently exceeded, these limits and the corresponding weight and centre of gravity combinations must be established.*

### Transposition

µCS 25.23 is CS25.23 a), where aeroplane is replaced by drone.

### AMC

There is no AMC 25.23.

## Weight Limits (CS 25.25)

### Selection

*(a) Maximum weights. Maximum weights corresponding to the aeroplane operating conditions (such as ramp, ground taxi, take-off, en-route and landing) environmental conditions (such as altitude and temperature), and loading conditions (such as zero fuel weight, centre of gravity position and weight distribution) must be established so that they are not more than –*

*(1) The highest weight selected by the applicant for the particular conditions; or*

*(2) The highest weight at which compliance with each applicable structural loading and flight requirement is shown.*

*(3) The highest weight at which compliance is shown with the noise certification requirements.*

*(b) Minimum weight. The minimum weight (the lowest weight at which compliance with each applicable requirement of this CS–25 is shown) must be established so that it is not less than –*

*(1) The lowest weight selected by the applicant;*

*(2) The design minimum weight (the lowest weight at which compliance with each structural loading condition of this CS–25 is shown); or*

*(3) The lowest weight at which compliance with each applicable flight requirement is shown.*

### Transposition

(a) **Maximum weights**. Maximum weights corresponding to the drone operating conditions (such as take-off, en-route and landing) environmental conditions (such as altitude), and loading conditions (such as zero payload centre of gravity position and weight distribution) must be established so that they are not more than –

(1) The highest weight selected by the applicant for the particular conditions; or

(2) The highest weight at which compliance with each applicable structural loading and flight requirement is shown.

(3) The highest weight at which compliance is shown with the noise certification requirements.

(b) **Minimum weight**. The minimum weight (the lowest weight at which compliance with each applicable requirement of this µCS–25 is shown) must be established so that it is not less than –

(1) The lowest weight selected by the applicant;

(2) The design minimum weight (the lowest weight at which compliance with each structural loading condition of this CS–25 is shown); or

(3) The lowest weight at which compliance with each applicable flight requirement is shown.

This text is identified µCS 25.25.

### AMC

There is no AMC 25.25.

# performance

## General (CS 25.101)

### Selection

*(a) Unless otherwise prescribed, aeroplanes must meet the applicable performance requirements of this Subpart for ambient atmospheric conditions and still air.*

*(b) The performance, as affected by engine power or thrust, must be based on the following relative humidities:*

*(1) 80 %, at and below standard temperatures; and*

*(2) 34 %, at and above standard temperatures plus 28ºC (50ºF).*

*Between these two temperatures, the relative humidity must vary linearly.*

*(d) Unless otherwise prescribed, the applicant must select the take-off, en-route, approach, and landing configuration for the aeroplane.*

*(e) The aeroplane configurations may vary with weight, altitude, and temperature, to the extent they are compatible with the operating procedures required by sub-paragraph (f) of this paragraph.*

*(f) Unless otherwise prescribed, in determining the accelerate-stop distances, take-off flight paths, take-off distances, and landing distances, changes in the aeroplane’s configuration, speed, power, and thrust, must be made in accordance with procedures established by the applicant for operation in service.*

### Transposition

µCS 25.101 is CS 25.101 (a), (b), (d), (e), (f) in which ‘aeroplanes’ is substituted by ‘drones’.

### AMC

There is an AMC 25.101 for paragraphs (c), (g), (h), (i), but for the selected ones.

## Stall Speed (CS 25.103)

### Selection



*maximum during the manoeuvre prescribed in sub-paragraph (c) of this paragraph. In addition, when the manoeuvre is limited by a device that abruptly pushes the nose down at a selected angle of attack (e.g. a stick pusher), VCLMAX may not be less than the speed existing at the instant the device operates;*

*nzw =Load factor normal to the flight path at VCLMAX;*

*W =Aeroplane gross weight;*

*S =Aerodynamic reference wing area; and*

*q =Dynamic pressure.*

### Transposition

µCS 25.103 is the following text: “The reference stall speed VSR is a calibrated air speed defined by the applicant”.

### AMC

There is an AMC 25.103 for (b), (c), (d), but not for (a).

## Take-Off (CS 25.105)

### Selection

*(a) The take-off speeds prescribed by CS 25.107, the accelerate-stop distance prescribed by CS 25.109, the take-off path prescribed by CS 25.111, the take-off distance and take-off run prescribed by CS 25.113, and the net takeoff flight path prescribed by CS 25.115, must be determined in the selected configuration for take-off at each weight, altitude, and ambient temperature within the operational limits selected by the applicant –*

*(1) In non-icing conditions; and*

*(2) In icing conditions, if in the configuration used to show compliance with CS 25.121(b), and with the most critical of the “Take-off Ice” accretion(s) defined in Appendices C and O, as applicable, in accordance with S 25.21(g):*

*(i) The stall speed at maximum take-off weight exceeds that in nonicing conditions by more than the greater of 5.6 km/h (3 knots) CAS or 3 % of VSR; or*

*(ii) The degradation of the gradient of climb determined in accordance with CS 25.121(b) is greater than one-half of the applicable actual-to-net take-off flight path gradient reduction defined in CS 25.115(b).*

### Transposition

(a) The take-off speeds prescribed by µCS 25.107, the take-off path prescribed by µCS 25.111 must be determined in the selected configuration for take-off at each weight, altitude, and ambient temperature within the operational limits selected by the applicant –

(1) In non-icing conditions; and

(2) In icing conditions, if in the configuration used to show compliance with µCS 25.121(b), and with the most critical of the “Take-off Ice” accretion(s) defined in Appendices µC and µO.

### AMC

No AMC for CS 25.105.

## Take-Off Speeds (CS 25.107)

### Selection

*a) V1 must be established in relation to VEF as follows:*

*(1) VEF is the calibrated airspeed at which the critical engine is assumed to fail. VEF must be selected by the applicant, but may not be less than VMCG determined under CS 25.149 (e).*

*(2) V1, in terms of calibrated airspeed, is selected by the applicant; however, V1 may not be less than VEF plus the speed gained with the critical engine inoperative during the time interval between the instant at hich the critical engine is failed, and the instant at which the pilot recognises and reacts to the engine failure, as indicated by the pilot’s initiation of the first action (e.g. applying brakes, reducing thrust, deploying speed brakes) to stop the aeroplane during accelerate-stop tests.*

*(d) VMU is the calibrated airspeed at and above which the aeroplane can safely lift off the ground, and continue the take-off. VMU speeds must be selected by the applicant throughout the range of thrust-to-weight ratios to be certificated. These speeds may be established from free air data if these data are verified by ground take-off tests. (See AMC 25.107(d))*

### Transposition

a) V1 must be established in relation to VEF as follows:

(1) VEF is the calibrated airspeed at which the critical engine is assumed to fail. VEF must be selected by the applicant

(2) V1, in terms of calibrated airspeed, is selected by the applicant; however, V1 may not be less than VEF plus the speed gained with the critical engine inoperative during the time interval between the instant at which the critical engine is failed, and the instant at which the operator recognizes and reacts to the engine failure

(d) VMU is the calibrated airspeed at and above which the drone can safely lift off the ground, and continue the take-off. VMU speeds must be selected by the applicant throughout the range of thrust-to-weight ratios to be certificated. These speeds may be established from free air data if these data are verified by ground take-off tests. (See µAMC 25.107(d)).

### AMC

There is an AMC 25.107 (d), included thereafter.

*1 If cases are encountered where it is not possible to obtain the actual VMU at forward centre of gravity with aeroplanes having limited elevator power (including those aeroplanes which have limited elevator power only over a portion of the take-off weight range), it will be permissible to test with a more aft centre of gravity and/or more than normal nose-up trim to obtain VMU.*

*1.1 When VMU is obtained in this manner, the values should be corrected to those which would have been attained at forward centre of gravity if sufficient elevator power had been available. The variation of VMU with centre of gravity may be assumed to be the same as the variation of stalling speed in free air with centre of gravity for this correction.*

*1.2 In such cases where VMU has been measured with a more aft centre of gravity and/or with more than normal nose-up trim, the VR selected should (in addition to complying with the requirements of CS 25.107(e)) be greater by an adequate margin than the lowest speed at which the nose wheel can be raised from the runway with centre of gravity at its most critical position and with the trim set to the normal take-off setting for the weight and centre of gravity.*

*NOTE: A margin of 9,3 km/h (5 kt) between the lowest nose-wheel raising speed and VR would normally be considered to be adequate.*

*2 Take-offs made to demonstrate VMU should be continued until the aeroplane is out of ground* *effect. The aeroplane pitch attitude should not be decreased after lift -off.*

## Take-Off Path (CS 25.111)

### Selection

*(a) The take-off path extends from a standing start to a point in the take-off at which the aeroplane is 457 m (1500 ft) above the take-off surface, or at which the transition from the take-off to the en-route configuration is completed and VFTO is reached, whichever point is higher. In addition –*

*(1) The take-off path must be based on the procedures prescribed in CS 25.101(f);*

*(2) The aeroplane must be accelerated on the ground to VEF, at which point the critical engine must be made inoperative and remain inoperative for the rest of the take-off; and*

*(3) After reaching VEF, the aeroplane must be accelerated to V2.*

*(d) The take-off path must be determined by a continuous demonstrated take-off or by synthesis from segments. If the take-off path is determined by the segmental method –*

*(1) The segments must be clearly defined and must relate to the distinct changes in the configuration, power or thrust, and speed;*

*(2) The weight of the aeroplane, the configuration, and the power or thrust must be constant throughout each segment and must correspond to the most critical condition prevailing in the segment;*

*(3) The flight path must be based on the aeroplane’s performance without ground effect; and*

*(4) The take-off path data must be checked by continuous demonstrated takeoffs up to the point at which the aeroplane is out of ground effect and its speed is estabilised, to ensure that the path is conservative to the continuous path.*

*The aeroplane is considered to be out of the ground effect when it reaches a height equal to its wing span.*

### Transposition

(a) The take-off path extends from a standing start to a point in the take-off at which the drone is 100 m (330 ft) above the take-off surface.

(d) The take-off path must be determined by a continuous demonstrated take-off or by synthesis from segments. If the take-off path is determined by the segmental method –

(1) The segments must be clearly defined and must relate to the distinct changes in the configuration, power or thrust, and speed;

(2) The weight of the drone, the configuration, and the power or thrust must be constant throughout each segment and must correspond to the most critical condition prevailing in the segment;

(3) The take-off path data must be checked by continuous demonstrated takeoffs up to the point at which the drone’s speed is established.

### AMC

*The height references in CS 25.111 should be interpreted as geometrical heights.*

In addition to this general information, there is an AMC 25.111 (b) on rotation speed and gear retraction.

## Climb: General (CS 25.117)

### Selection

*Compliance with the requirements of CS 25.119 and 25.121 must be shown at each weight, altitude, and ambient temperature within the operational limits established for the aeroplane and with the most unfavourable centre of gravity for each configuration.*

### Transposition

Compliance with the requirements of µCS 25.121 must be shown at each weight, altitude, within the operational limits established for the drone and with the most unfavourable centre of gravity for each configuration.

### AMC

No AMC 25.117.

## Climb: One Engine Inoperative (CS 25.121)

### Selection

*(a) Take-off; landing gear extended. (See AMC 25.121(a)) In the critical take-off configuration existing along the flight path (between the points at which the aeroplane reaches VLOF and at which the landing gear is fully retracted) and in the configuration used in CS 25.111 but without ground effect, the steady gradient of climb must be positive for two engine aeroplanes, and not less than 0·3 % for three-engined aeroplanes or 0·5 % for fourengined aeroplanes, at VLOF and with –*

*(1) The critical engine inoperative and the remaining engines at the power or thrust available when retraction of the landing gear is begun in accordance with CS 25.111 unless there is a more critical power operating condition existing later along the flight path but before the point at which the landing gear is fully retracted (see AMC 25.121(a)(1)); and*

*(2) The weight equal to the weight existing when retraction of the landing gear is begun determined under CS 25.111.*

### Transposition

*(a) Take-off (See AMC 25.121(a)) In the critical take-off configuration existing along the flight path and in the configuration used in µCS 25.111 the steady gradient of climb must be positive and not less than 0·3 % with –*

*(1) The critical engine inoperative in accordance with µCS 25.111 unless there is a more critical power operating condition existing later along the flight path*

*(2) The weight equal to the weight determined under µCS 25.111.*

### AMC

*AMC 25.121*

*1 In showing compliance with CS 25.121 it is accepted that bank angles of up to 2° to 3° toward the operating engine(s) may be used.*

*2 The height references in CS 25.121 should be interpreted as geometrical heights.*

*AMC 25.121(a)*

*The configuration of the landing gear used in showing compliance with the climb requirements of CS 25.121(a) may be that finally achieved following ‘gear down’ selection.*

*AMC 25.121(a)(1)*

*A ‘power operating condition’ more critical than that existing at the time when retraction of the landing gear is begun would occur, for example, if water injection were discontinued prior to reaching the point at which the landing gear is fully retracted.*

## En-route Flght Paths (CS 25.123)

### Selection

*(a) For the en-route configuration, the flight paths prescribed in sub-paragraphs (b) and (c) of this paragraph must be determined at each weight, altitude, and ambient temperature, within the operating limits established for the aeroplane. The variation of weight along the flight path, accounting for the progressive consumption of fuel and oil by the operating engines, may be included in the computation.*

*The flight paths must be determined at a selected speed not less than VFTO, with –*

*(1) The most unfavourable centre of gravity;*

*(2) The critical engines inoperative;*

*(3) The remaining engines at the available maximum continuous power or thrust; and*

*(4) The means for controlling the engine-cooling air supply in the position that provides adequate cooling in the hot-day condition.*

### Transposition

(a) For the en-route configuration, the flight paths must be determined at each weight and altitude, within the operating limits established for the drone. The flight paths must be determined with –

(1) The most unfavourable centre of gravity;

(2) The critical engines inoperative;

(3) The remaining engines at the available maximum continuous power or thrust

### AMC

*If, in showing compliance with CS 25.123, any credit is to be taken for the progressive use of fuel by the operating engines, the fuel flow rate should be assumed to be 80% of the engine specification flow rate at maximum continuous power, unless a more appropriate figure has been substantiated by flight tests*.

## Landing (CS 25.125)

### Selection

*(a) The horizontal distance necessary to land and to come to a complete stop from a point 15 m (50 ft) above the landing surface must be determined (for standard temperatures, at each weight, altitude and wind within the operational limits established by the applicant for the aeroplane):*

*(1) In non-icing conditions; and*

*(2) In icing conditions with the most critical of the “Landing Ice” accretion(s) defined in Appendices C and O, as applicable, in accordance with CS 25.21(g) if VREF for icing conditions exceeds VREF for non-icing conditions by more than 9.3 km/h (5 knots) CAS at the maximum landing weight.*

### Transposition

(a) The horizontal distance necessary to land and to come to a complete stop from a point 15 m (50 ft) above the landing surface must be determined (at each weight, altitude and wind within the operational limits established by the applicant for the drone):

(1) In non-icing conditions; and

(2) In icing conditions with the most critical of the “Landing Ice” accretion(s) defined in Appendices µC and µO.

### AMC

No AMC for 25.125 (a).

# stability

## General (CS 25.171)

### Selection

*The aeroplane must be longitudinally, directionally and laterally stable in accordance with the provisions of CS 25.173 to 25.177. In addition, suitable stability and control feel (static stability) is required in any condition normally encountered in service, if flight tests show it is necessary for safe operation.*

### Transposition

The drone must be longitudinally, directionally and laterally stable.. In addition, suitable stability and control feel (static stability) is required in any condition normally encountered in service, if flight tests show it is necessary for safe operation.

### AMC

No AMC for CS 25.171.

## Dynamic Stability (CS 25.181)

### Selection

*(a) Any short period oscillation, not including combined lateral-directional oscillations, occurring between 1·13 VSR and maximum allowable speed appropriate to the configuration of the aeroplane must be heavily damped with the primary controls –*

*(1) Free; and*

*(2) In a fixed position.*

*(b) Any combined lateral-directional oscillations (‘Dutch roll’) occurring between 1·13 VSR and maximum allowable speed appropriate to the configuration of the aeroplane must be positively damped with controls free, and must be controllable with normal use of the primary controls without requiring exceptional pilot skill.*

### Transposition

µCS 25.181 is CS 25.181 where ‘aeroplane’ is replaced by ‘drone’.

### AMC

*The requirements of CS 25.181 are applicable at all speeds between the stalling speed and VFE, VLE or VFC/MFC, as appropriate.*

# ground handling characteristics

## Wind Velocities (CS 25.237)

### Selection

*(a) The following applies:*

*(1) A 90º cross component of wind velocity, demonstrated to be safe for take-off and landing, must be established for dry runways and must be at least 37 km/h (20 kt) or 0·2 VSR0, hichever is greater, except that it need not exceed 46 km/h (25 kt).*

*(2) The crosswind component for takeoff established without ice accretions is valid in icing conditions.*

*(3) The landing crosswind component must be established for:*

*(i) Non-icing conditions, and*

*(ii) Icing conditions with the most critical of the landing ice accretion(s) defined in Appendices C and O, as applicable, in accordance with CS 25.21(g)*

### Transposition

(a) The following applies:

(1) A 90º cross component of wind velocity, demonstrated to be safe for take-off and landing, must be established for at least 37 km/h (20 kt) except that it need not exceed 46 km/h (25 kt).

(2) The crosswind component for takeoff established without ice accretions is valid in icing conditions.

(3) The landing crosswind component must be established for:

(i) Non-icing conditions, and

(ii) Icing conditions with the most critical of the landing ice accretion(s) defined in Appendices C and O, as applicable, in accordance with µCS 25.21(g)

### AMC

None.

# miscellaneous flight requirements

## High-Speed Characteristics (CS 25.253)

### Selection

*(a) Speed increase and recovery characteristics. The following speed increase and recovery characteristics must be met:*

*(1) Operating conditions and characteristics likely to cause inadvertent speed increases (including upsets in pitch and roll) must be simulated with the aeroplane trimmed at any likely cruise speed up to VMO/MMO. These conditions and characteristics include gust upsets, inadvertent control movements, low stick force gradient in relation to control friction, passenger movement, levelling off from climb, and descent from Mach to air speed limit altitudes.*

### Transposition

(a) Speed increase and recovery characteristics. The following speed increase and recovery characteristics must be met:

(1) Operating conditions and characteristics likely to cause inadvertent speed increases (including upsets in pitch and roll) must be simulated with the drone at any likely cruise speed up maximum speed defined by the applicant. These conditions and characteristics include gust upsets, inadvertent control movements, and levelling off from climb.

### AMC

There is an AMC for CS 25.53 (a).(4) and (a).(5) but not for (a).(1).

To illustrate the functional safety nature and the operational nature of the compliance constraints, AMC for CS 25.53 (a).(4) is quoted as a whole.

*AMC 25.253(a)(4)*

*An acceptable method of demonstrating compliance with CS 25.253(a)(4) is as follows:*

*1 Establish a steady 20° banked turn at a speed close to VDF/MDF limited to the extent necessary to accomplish the following manoeuvre and recovery without exceeding VDF/MDF. Using lateral control alone, it should be demonstrated that the aeroplane can be rolled to 20° bank angle in the other direction in not more than 8 seconds. The demonstration should be made in the most adverse direction. The manoeuvre may be unchecked.*

*2 For aeroplanes that exhibit an adverse effect on roll rate when rudder is used, it should also be demonstrated that use of rudder in a conventional manner will not result in a roll capability significantly below that specified above.*

*3 Conditions for 1 and 2:*

*- Wing-flaps retracted.*

*- Speedbrakes retracted and extended.*

*- Landing gear retracted.*

*- Trim. The aeroplane trimmed for straight flight at VMO/MMO.*

*The trimming controls should not be moved during the manoeuvre.*

*- Power:*

*(i) All engines operating at the power required to maintain level flight at VMO/MMO, except that maximum continuous power need not be exceeded; and*

*(ii) if the effect of power is significant, with the throttles closed.*

# flight manoeuvre and gust conditions

## Gust and Turbulence Loads (CS 25.341)

### Selection

*(a) Discrete Gust Design Criteria. The aeroplane is assumed to be subjected to symmetrical vertical and lateral gusts in level flight. Limit gust loads must be determined in accordance with the following provisions:*

*(1) Loads on each part of the structure must be determined by dynamic analysis. The analysis must take into account unsteady aerodynamic characteristics and all significant structural degrees of freedom including rigid body motions.*

**

*(2) The shape of the gust must be taken as follows:*

*for 0 ≤ s ≤ 2H*

*U = 0 for s > 2H*

*where –*

*s = distance penetrated into the gust (metre );*

*Uds = the design gust velocity in equivalent airspeed specified in sub-paragraph (a) (4) of this paragraph;*

*H = the gust gradient which is the distance (metre) parallel to the aeroplane’s flight path for the gust to reach its peak velocity.*

### Transposition

µCS 25.341 is the selected text where ‘aero plane’ is replaced by drone.

### AMC

There is 15-page AMC 25.341.

*This AMC addresses both discrete gust and continuous turbulence (or continuous gust) requirements of CS-25. It provides some of the acceptable methods of modelling aeroplanes, aeroplane components, and configurations, and the validation of those modelling methods for the purpose of determining the response of the aeroplane to encounters with gusts.*

It addresses aspects of physical modelling that go far beyond those encountered with µXAV. No detail is given, but systems and software play a prominent role in aerodynamic and structural control.

# pilot control force limits

## Ground Gust Conditions (CS 25.415)

### Selection

*(a) The flight control systems and surfaces must be designed for the limit loads generated when the aircraft is subjected to a horizontal 33.44 m/sec (65 knots) ground gust from any direction, while taxying with the controls locked and unlocked and while parked with the controls locked.*

### Transposition

The flight control systems and surfaces must be designed for the limit loads generated when the drone is subjected to a horizontal 33.44 m/sec (65 knots) ground gust from any direction.

### AMC

3-page AMC, dealing with operational procedures and design aspects.

*Guidance information is provided for showing compliance with CS 25.415, relating to structural design of the control surfaces and systems while taxiing with control locks engaged and disengaged and when parked with control locks engaged. Other methods of compliance with the requirements may be acceptable.*

# emergency landing conditions

## General (CS 25.561)

### Selection

*(a) The aeroplane, although it may be damaged in emergency landing conditions on land or water, must be designed as prescribed in this paragraph to protect each occupant under those conditions.*

### Transposition

The drone, although it may be damaged in emergency landing conditions must be designed as prescribed in this paragraph to protect each cargo under those conditions.

### AMC

0.5-page AMC focused on structural loads applied to seats and equipments.

## Emergency Landing Dynamic Conditions (CS 25.562)

### Selection

*b).(1) A change in downward vertical velocity, (Δv) of not less than 10·7 m/s, (35 ft/s) with the aeroplane’s longitudinal axis canted downward 30 degrees with respect to the horizontal plane and with the wings level.*

*Peak floor deceleration must occur in not more than 0·08 seconds after impact and must reach a minimum of 14 g.*

*b).(2) A change in forward longitudinal velocity (Δv) of not less than 13·4 m/s, (44ft/s) with the aeroplane’s longitudinal axis horizontal and yawed 10 degrees either right or left, whichever would cause the greatest likelihood of the upper torso restraint system (where installed) moving off the occupant’s shoulder, and with the wings level. Peak floor deceleration must occur in not more than 0·09 seconds after impact and must reach a minimum of 16 g. Where floor rails or floor fittings are used to attach the seating devices to the test fixture, the rails or fittings must be misaligned with respect to the adjacent set of rails or fittings by at least 10 degrees vertically (i.e. out of parallel) with one rolled 10 degrees*

### Transposition

TBDL when mechanical and control constants are numerically defined.

### AMC

*The FAA AC 25.562-1B, Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes, dated 10.1.2006, except paragraph 5.e.(5)(d), and the FAA AC 20-146, Methodology for Dynamic Seat Certification by Analysis for Use in Parts 23, 25, 27, and 29 Airplanes and Rotorcraft, dated 19.5.2003, are accepted by the Agency as providing an Acceptable Means of Compliance to CS 25.562*.

# control systems

## General (CS 25.671)

### Selection

*a) Each control and control system must operate with the ease, smoothness, and positiveness appropriate to its function. (See AMC 25.671 (a).)*

### Transposition

µCS 25.671 is CS 25.671 a)

### AMC

*AMC 25.671(a)*

*Control systems for essential services should be so designed that when a movement to one position has been selected, a different position can be selected without waiting for the completion of the initially selected movement, and the system should arrive at the finally selected position without further attention. The movements which follow and the time taken by the system to allow the required sequence of selection should not be such as to adversely affect the airworthiness of the aeroplane.*

## Stability Augmentation and Automatic and Power-Operated Systems (CS 25.672)

### Selection

*If the functioning of stability augmentation or other automatic or power-operated systems is necessary to show compliance with the flight characteristics requirements of this CS-25, such systems must comply with CS 25.671 and the following:*

*(a) A warning, which is clearly distinguishable to the pilot under expected flight conditions without requiring his attention, must be provided for any failure in the stability augmentation system or in any other automatic or power-operated system, which could result in an unsafe condition if the pilot were not aware of the failure. Warning systems must not activate the control systems*

*(c) It must be shown that after any single failure of the stability augmentation system or any other automatic or power-operated system–*

*(1) The aeroplane is safely controllable when the failure or malfunction occurs at any speed or altitude within the approved operating limitations that is critical for the type of failure being considered. (See AMC 25.672 (c) (1).)*

*(2) The controllability and manoeuvrability requirements of this CS-25 are met within a practical operational flight envelope (for example, speed, altitude, normal acceleration, and aeroplane configurations) which is described in the Aeroplane Flight Manual;*

### Transposition

If the functioning of stability augmentation or other automatic or power-operated systems is necessary to show compliance with the flight characteristics requirements of this µCS-25, such systems must comply with µCS 25.671 and the following:

(a) A warning, which is clearly distinguishable to the operator under expected flight conditions without requiring his attention, must be provided for any failure in the stability augmentation system or in any other automatic or power-operated system, which could result in an unsafe condition if the operator were not aware of the failure. Warning systems must not activate the control systems.

(c) It must be shown that after any single failure of the stability augmentation system or any other automatic or power-operated system–

(1) The drone is safely controllable when the failure or malfunction occurs at any speed or altitude within the approved operating limitations that is critical for the type of failure being considered. (See AMC 25.672 (c) (1).)

(2) The controllability and manoeuvrability requirements of this µCS-25 are met within a practical operational flight envelope (for example, speed, altitude, and payload configurations) which is described in the Drone Flight Manual;

### AMC

*AMC 25.672(c)(1)*

*The severity of the flying quality requirement should be related to the probability of the occurrence in a progressive manner such that probable occurrences have not more than minor effects and improbable occurrences have not more than major effects.*

# landing gear

## Brakes and Braking Systems (CS 25.735)

### Selection

*(b) Brake system capability. The brake system, associated systems and components must be designed and constructed so that:*

*(1) If any electrical, pneumatic, hydraulic, or mechanical connecting or transmitting element fails, or if any single source of hydraulic or other brake operating energy supply is lost, it is possible to bring the aeroplane to rest with a braked roll stopping distance of not more than two times that obtained in determining the landing distance as prescribed in CS 25.125.*

*(f) Kinetic energy capacity— (2) Maximum kinetic energy accelerate-stop. The maximum kinetic energy accelerate-stop is a rejected takeoff for the most critical combination of aeroplane take-off weight and speed. The accelerate-stop brake kinetic energy absorption requirement of each wheel, brake, and tyre assembly must be determined. It must be substantiated by dynamometer testing that the wheel brake and tyre assembly is capable of absorbing not less than this level of kinetic energy throughout the defined wear range of the brake. The energy absorption rate derived from the aeroplane's braking requirements must be achieved. The mean deceleration must not be less than 1.8 m/s2 (6 fps2).*

### Transposition

(b) Brake system capability. The brake system, associated systems and components must be designed and constructed so that:

(1) If any electrical, hydraulic, or mechanical connecting or transmitting element fails, or if any single source of hydraulic energy supply is lost, it is possible to bring the drone to rest with a braked stopping distance of not more than two times that obtained in determining the landing distance as prescribed in µCS 25.125.

(f) Kinetic energy capacity— (2) Maximum kinetic energy accelerate-stop. The maximum kinetic energy accelerate-stop is a rejected take-off for the most critical combination of drone take-off weight and speed. The accelerate-stop brake kinetic energy absorption requirement must be determined. The energy absorption rate derived from the drone’s braking requirements must be achieved. The mean deceleration must not be less than 1.8 m/s2 (6 fps2).

### AMC

*AMC 25.735(b)*

*(1) The system should be designed so that no single failure of the system degrades the aeroplane stopping performance beyond doubling the braked roll stopping distance (refer to CS 25.735(b)(1)).*

*Failures are considered to be fracture, leakage, or jamming of a component in the system, or loss of an energy source. Components of the system include all parts that contribute to transmitting the pilot's braking command to the actual generation of braking force. Multiple failures resulting from a single cause should be considered a single failure (e.g., fracture of two or more hydraulic lines as a result of a single tyre failure).*

*Sub-components within the brake assembly, such as brake discs and actuators (or their equivalents), should be considered as connecting or transmitting elements, unless it is shown that leakage of hydraulic fluid resulting from failure of the sealing elements in these sub-components within the brake assembly would not reduce the braking effectiveness below that specified in CS 25.735(b)(1).*

*(a) In order to meet the stopping distance requirements of CS 25.735(b)(1) in the event of failure of the normal brake system, it is common practice to provide an alternate brake system. The normal and alternate braking systems should be independent, being supplied by separate power sources. Following a failure of the normal system, the changeover to a second system (whether manually or by automatic means) and the functioning of a secondary power source should be effected rapidly and safely. The changeover should not involve risk of wheel locking, whether the brakes are applied or not at the time of changeover.*

*(b) The brake systems and components should be separated or appropriately shielded so that complete failure of the braking system(s) as a result of a single cause is minimised.*

*(2) Compliance with CS 25.735(b)(2) may be achieved by:*

*(a) Showing that fluid released would not impinge on the brake, or any part of the assembly*

*that might cause the fluid to ignite;*

*(b) Showing that the fluid will not ignite; or*

*(c) Showing that the maximum amount of fluid released is not sufficient to sustain a fire.*

*(3) Additionally, in the case of a fire, it may be shown that the fire is not hazardous, taking into consideration such factors as landing gear geometry, location of fire sensitive (susceptibility) equipment and installations, system status, flight mode, etc.*

*If more than one fluid is allowed for the hydraulic system, compliance should be addressed for all fluids.*

*AMC 25.735(f)*

*For determination of the design landing brake kinetic energy capacity rating, the initial condition of the brakes may be selected and can be any condition representative of service use, including new, and which satisfies the applicable ETSO or other acceptable brake qualification test standard.*

# Equipment

## Functions and Installations (CS 25.1301)

### Selection

*(a) Each item of installed equipment must –*

*(1) Be of a kind and design appropriate to its intended function;*

*(2) Be labelled as to its identification,function, or operating limitations, or any applicable combination of these factors. (See AMC 25.1301(a)(2))*

*(3) Be installed according to limitations specified for that equipment*

### Transposition

µCS 25.1301 = µCS 25.1301.(a).

### AMC

*AMC 25.1301(a)(2)*

*When pipelines are marked for the purpose of distinguishing their functions, the markings should be such that the risk of confusion by maintenance or servicing personnel will be minimised. Distinction by means of colour markings alone is not acceptable. The use of alphabetic or numerical symbols will be acceptable if recognition depends upon reference to a master key and any relation between symbol and function is carefully avoided. Specification ISO.12 version 2ED 1987 gives acceptable graphical markings.*

## Equipment, Systems and Installations (CS 25.1309)

### Selection

*The requirements of this paragraph, except as identified below, are applicable, in addition to specific design requirements of CS-25, to any equipment or system as installed in the aeroplane. Although this paragraph does not apply to the performance and flight characteristic requirements of Subpart B and the structural requirements of Subparts C and D, it does apply to any system on which compliance with any of those requirements is dependent. Certain single failures or jams covered by CS 25.671(c)(1) and CS 25.671(c)(3) are excepted from the requirements of CS 25.1309(b)(1)(ii). Certain single failures covered by CS 25.735(b) are excepted from the requirements of CS 25.1309(b). The failure effects covered by CS 25.810(a)(1)(v) and CS 25.812 are excepted from the requirements of CS 25.1309(b). The requirements of CS 25.1309(b) apply to powerplant installations as specified in CS 25.901(c).*

*(a) The aeroplane equipment and systems must be designed and installed so that:*

*(1) Those required for type certification or by operating rules, or whose improper functioning would reduce safety, perform as intended under the aeroplane operating and environmental conditions.*

*(2) Other equipment and systems are not a source of danger in themselves and do not adversely affect the proper functioning of those covered by sub-paragraph (a)(1) of this paragraph.*

*(b) The aeroplane systems and associated components, considered separately and in relation to other systems, must be designed so that -*

*(1) Any catastrophic failure condition*

*(i) is extremely improbable; and*

*(ii) does not result from a single failure; and*

*(2) Any hazardous failure condition is extremely remote; and*

*(3) Any major failure condition is remote.*

*(c) Information concerning unsafe system operating conditions must be provided to the crew to enable them to take appropriate corrective action. A warning indication must be provided if immediate corrective action is required. Systems and controls, including indications and annunciations must be designed to minimise crew errors, which could create additional hazards.*

*(d) Electrical wiring interconnection systems must be assessed in accordance with the requirements of CS 25.1709. [Amdt. No.: 25/5] [Amdt. No.: 25/6]*

### Transposition

Identical text, where ‘aeroplane’ is replaced by ‘drone’, and the references to other CS sections are filtered according to the selection of this document.

### Accepted Means of Compliance

AMC 25.1309 is a 20-page part, along with 4 appendices. The first two ones are devoted to safety assessment methods and processes (further detailed by ARP 4761), and the last two ones address probability calculations.

The OPs and criteria are primarily intended to be an alternative means to comply with this AMC 25.1309. More specifically, they are intended to be an alternative means to comply with the regulatory requirements that involve *deterministic* aspects, i.e functional aspects, as opposed to probabilistic ones[[4]](#footnote-4).

In the following, a list of excerpts is given. All of them are thought to be in the scope of the OPs, i.e to be of some relevance regarding this question: “are the OPs and criteria correct and complete, individually and collectively, with respect to AMC 25.1309?”

***6.(b) Fail-Safe Design Concept***

*The CS-25 airworthiness standards are based on, and incorporate, the objectives and principles or techniques of the fail-safe design concept, which considers the effects of failures and combinations of failures in defining a safe design.*

*(1) The following basic objectives pertaining to failures apply:*

*(i) In any system or subsystem, the failure of any single element, component, or connection during any one flight should be assumed, regardless of its probability. Such single failures should not be Catastrophic.*

*(ii) Subsequent failures during the same flight, whether detected or latent, and combinations thereof, should also be assumed, unless their joint probability with the first failure is shown to be extremely*

*improbable.*

*(2) The fail-safe design concept uses the following design principles or techniques in order to ensure a safe design. The use of only one of these principles or techniques is seldom adequate. A combination of two or more is usually needed to provide a fail -safe design; i.e. to ensure that Major Failure Conditions are Remote, Hazardous Failure Conditions are Extremely Remote, and Catastrophic Failure Conditions are Extremely Improbable:*

*(i) Designed Integrity and Quality, including Life Limits, to ensure intended function and prevent failures.*

*(ii) Redundancy or Backup Systems to enable continued function after any single (or other defined*

*number of) failure(s); e.g., two or more engines, hydraulic systems, flight control systems, etc.*

*(iii) Isolation and/or Segregation of Systems, Components, and Elements so that the failure of one does*

*not cause the failure of another.*

*(v) Failure Warning or Indication to provide detection.*

*(vi) Flight crew Procedures specifying corrective action for use after failure detection.*

*(vii) Checkability: the capability to check a component's condition.*

*(viii) Designed Failure Effect Limits, including the capability to sustain damage, to limit the safety impact*

*or effects of a failure.*

*(ix) Designed Failure Path to control and direct the effects of a failure in a way that limits its safety*

*impact.*

*(x) Margins or Factors of Safety to allow for any undefined or unforeseeable adverse conditions.*

*(xi) Error-Tolerance that considers adverse effects of foreseeable errors during the aeroplane's design,*

*test, manufacture, operation, and maintenance.*

***9.(a). Compliance with CS 25.1309(a)****.*

*(1) Equipment covered by 25.1309(a)(1) must be shown to function properly when installed. The aeroplane operating and environmental conditions over which proper functioning of the equipment, systems, and installation is required to be considered includes the full normal operating envelope of the aeroplane as defined by the Aeroplane Flight Manual together with any modification to that envelope associated with abnormal or emergency procedures. Other external environmental conditions such as atmospheric turbulence, HIRF, lightning, and precipitation, which the aeroplane is reasonably expected to encounter, should also be considered. The severity of the external environmental conditions which should be considered are limited to those established by certification standards and precedence.*

*(2) In addition to the external operating and environmental conditions, the effect of the environment within the aeroplane should be considered. These effects should include vibration and acceleration loads, variations in fluid pressure and electrical power, fluid or vapour contamination, due either to the normal environment or accidental leaks or spillage and handling by personnel. Document referenced in paragraph 3b(1) defines a series of standard environmental test conditions and procedures, which may be used to support compliance. Equipment covered by (CS) Technical Standard Orders containing environmental test procedures or equipment qualified to other environmental test standards can be used to support compliance. The conditions under which the installed equipment will be operated should be equal to or less severe than the environment for which the equipment is qualified.*

*(3) The required substantiation of the proper functioning of equipment, systems, and instal lations under the operating and environmental conditions approved for the aeroplane may be shown by test and/or analysis or reference to comparable service experience on other aeroplanes. It must be shown that the comparable service experience is valid for the proposed installation. For the equipment systems and installations covered by CS 25.1309(a)(1), the compliance demonstration should also confirm that the normal functioning of such equipment, systems, and installations does not interfere with the prop er functioning of other equipment, systems, or installations covered by CS 25.1309(a)(1).*

***9.(b). Compliance with CS 25.1309(b)****.*

*Paragraph 25.1309(b) requires that the aeroplane systems and associated components, considered separately and in relation to other systems must be designed so that any Catastrophic Failure Condition is Extremely Improbable and does not result from a single failure. It also requires that any Hazardous Failure Condition is extremely Remote, and that any Major Failure Condition is Remote. An analysis should always consider the* ***application of the Fail -Safe design concept described in paragraph 6b****, and give special attention to ensuring the effective use of design techniques that would prevent single failures or other events from damaging or otherwise adversely affecting more than one redundant system channel or more than one system performing operationally similar functions.*

*(1) General. Compliance with the requirements of CS 25.1309(b) should be shown by analysis and, where necessary, by appropriate ground, flight, or simulator tests. Failure Conditions should be identified and their effects assessed. The maximum allowable probability of the occurrence of each Failure Condition is determined from the Failure Condition’s effects, and when assessing the probabilities of Failure Conditions appropriate analysis considerations should be accounted for. Any analysis must consider:*

*(i) Possible Failure Conditions and their causes, modes of failure, and damage from sources external to the system.*

*(ii) The possibility of multiple failures and undetected failures.*

*(iii) The possibility of requirement, design and implementation errors.*

*(iv) The effect of reasonably anticipated crew errors after the occurrence of a failure or Failure Condition.*

*(v) The effect of reasonably anticipated errors when performing maintenance actions.*

*(vi) The crew alerting cues, corrective action required, and the capability of detecting faults.*

*(vii) The resulting effects on the aeroplane and occupants, considering the stage of flight and operating and environmental conditions.*

***11.(b) Single Failure Considerations***

*(1) According to the requirements of CS 25.1309b(1)(ii), a Catastrophic Failure Condition must not result from the failure of a single component, part, or element of a system.* ***Failure containment should be provided by the system design to limit the propagation of the effects of any single failure*** *to preclude Catastrophic Failure Conditions. In addition, there must be no common cause failure, which could affect both the single component, part, or element, and its failure containment provisions. A single failure includes any set of failures, which cannot be shown to be independent from each other. Appendix 1 and Document referenced in paragraph 3b(3) describe types of common cause analyses, which may be conducted, to assure that independence is maintained. Failure containment techniques available to establish independence may include partitioning, separation, and isolation.*

*(2) While single failures must normally be assumed to occur, there are cases where it is obvious that, from a realistic and practical viewpoint, any knowledgeable, experienced person would unequivocally conclude that a failure mode simply would not occur, unless it is associated with a wholly unrelated Failure Condition that would itself be Catastrophic. Once identified and accepted, such cases need not be considered failures in the context of CS 25.1309. For example, with simply loaded static elements, any failure mode, resulting from fatigue fracture, can be assumed to be prevented if this element is shown to meet the damage tolerance requirements of CS 25.571.*

***11.(c). Common Cause Failure Considerations****. An analysis should consider the application of the fail –safe design concept described in paragraph 6b and give special attention to ensure the effective use of design and installation techniques that would prevent single failures or other events from damaging or otherwise adversely affecting more than one redundant system channel, more than one system performing operationally similar functions, or any system and an associated safeguard. When considering such common-cause failures or other events, consequential or cascading effects should be taken into account. Some examples of such potential common cause failures or other events would include rapid release of energy from concentrated sources such as uncontained failures of rotating parts (other than engines and propellers) or pressure vessels, pressure differentials, non-catastrophic structural failures, loss of environmental conditioning, disconnection of more than one subsystem or component by over temperature protection devices, contamination by fluids, damage from localised fires, loss of power supply or return (e.g. mechanical damage or deterioration of connections), excessive voltage, physical or environmental interactions among parts, errors, or events external to the system or to the aeroplane (see Document referenced in paragraph 3b(3)).*

***11.(h). Justification of Assumptions, Data Sources and Analytical Techniques.***

*(1) Any analysis is only as accurate as the assumptions, data, and analytical techniques it uses. Therefore, to show compliance with the requirements, the underlying assumptions, data, and analytic techniques should be identified and justified to assure that the conclusions of the analysis are valid. Variability may be inherent in elements such as failure modes, failure effects, failure rates, failure probability distribution functions, failure exposure times, failure detection methods, fault independence, limitation of analytical methods, processes, and assumptions. The justification of the assumptions made with respect to the above items should be an integral part of the analysis. Assumptions can be validated by using experience with identical or similar systems or components with due allowance made for differences of design, duty cycle and environment. Where it is not possible to fully justify the adequacy of the safety analysis and where data or assumptions are critical to the acceptability of the Failure Condition, extra conservatism should be built into either the analysis or the design. Alternatively any uncertainty in the data and assumptions should be evaluated to the degree necessary to demonstrate that the analysis conclusions are insensitive to that uncertainty.*

*(2) Where adequate validation data is not available (e.g., new or novel systems), and extra conservatism is built into the analysis, then the normal post-certification in-service follow-up may be performed to obtain the data necessary to alleviate any consequence of the extra conservatism. This data may be used, for example, to extend system check intervals.*

## Power Source Capacity and Distribution (CS 25.1310)

### Selection

*(a) Each installation whose functioning is required for type certification or by operating rules and that requires a power supply is an "essential load" on the power supply. The power sources and the system must be able to supply the following power loads in probable operating combinations and for probable durations (see AMC 25.1310(a)):*

*(1) Loads connected to the system with the system functioning normally.*

*(2) Essential loads, after failure of any one prime mover, power converter, or energy storage device.*

*(3) Essential loads after failure of -*

*(i) Any one engine on two-engine aeroplanes; and*

*(ii) Any two engines on three-or more engine aeroplanes.*

*(4) Essential loads for which an alternate source of power is required, after any failure or malfunction in any one-power supply system, distribution system, or other utilisation system.*

*(b) In determining compliance with subparagraphs (a)(2) and (3) of this paragraph, the power loads may be assumed to be reduced under a monitoring procedure consistent with safety in the kinds of operation authorised. Loads not required in controlled flight need not be considered for the two-engine-inoperative condition on aeroplanes with three or more engines. e addressed when discussing safety in the criteria.*

### Transposition

Identical text, where ‘aeroplane’ is replaced by ‘drone’,

### AMC

*AMC 25.1310(a).*

*When alternative or multiplication of systems and equipment is provided to meet the requirements of CS 25.1310(a), the segregation between circuits should be such as to minimise the risk of a single occurrence causing multiple failures of circuits or power supplies of the system concerned. For example, electrical cable bundles or groups of hydraulic pipes should be so segregated as to prevent damage to the main and alternative systems and power supplies.*

No AMC 25.1310.(b).

# instruments: installation

## Flight Crew Alerting (CS 25.1322)

### Selection

*(a) Flight crew alerts must:*

*(1) provide the flight crew with the information needed to:*

*(i) identify non-normal operation or aeroplane system conditions, and*

*(ii) determine the appropriate actions, if any;*

*(2) be readily and easily detectable and intelligible by the flight crew under all foreseeable operating conditions, including conditions where multiple alerts are provided;*

*(3) be removed when the alerting condition no longer exists.*

*(b) Alerts must conform to the following prioritisation hierarchy based on the urgency of flight crew awareness and response:*

*(1) Warning: For conditions that require immediate flight crew awareness and immediate flight crew response.*

*(2) Caution: For conditions that require immediate flight crew awareness and subsequent flight crew response.*

*(3) Advisory: For conditions that require flight crew awareness and may require subsequent flight crew response.*

*(c) Warning and Caution alerts must:*

*(1) be prioritised within each category, when necessary;*

*(d) The alert function must be designed to minimise the effects of false and nuisance alerts. In particular, it must be designed to:*

*(1) prevent the presentation of an alert when it is inappropriate or unnecessary;*

### Transposition

Alerts must:

(1) provide the operator with the information needed to:

(i) identify non-normal operation or drone system conditions, and

(ii) determine the appropriate actions, if any;

(2) be readily and easily detectable and intelligible by the operators under all foreseeable operating conditions, including conditions where multiple alerts are provided;

(3) be removed when the alerting condition no longer exists.

(b) Alerts must conform to the following prioritisation hierarchy based on the urgency of operator awareness and response:

(1) Warning: For conditions that require immediate operator awareness and immediate response.

(2) Caution: For conditions that require immediate operator awareness and subsequent operator response.

(3) Advisory: For conditions that require operator awareness and may require subsequent response.

(c) Warning and Caution alerts must:

(1) be prioritised within each category, when necessary;

(d) The alert function must be designed to minimise the effects of false and nuisance alerts. In particular, it must be designed to:

(1) prevent the presentation of an alert when it is inappropriate or unnecessary;

### AMC

10-page AMC, structured as a 16-section sub-document instead of mirroring the CS articles. This local document is supplemented by five extensive appendices.

Little relevance for µXAV, at least for increments 1 and 2. Possibly some imports at increment 3.

# electrical systems and equipment

## General (CS 25.1351)

### Selection

*(a) Electrical system capacity. The required generating capacity, and number and kinds of power sources must –*

*(1) Be determined by an electrical load analysis; and*

*(2) Meet the requirements of CS25.1309.*

*(b) Generating system. The generating system includes electrical power sources, main power busses, transmission cables, and associated control, regulation, and protective devices. It must be designed so that:*

*(1) Power sources function properly when independent and when connected in combination;*

*(2) No failure or malfunction of any power source can create a hazard or impair the ability of remaining sources to supply essential loads;*

*(3) The system voltage and frequency (as applicable) at the terminals of all essential load equipment can be maintained within the limits for which the equipment is designed, during any probable operating condition;*

*(4) System transients due to switching, fault clearing, or other causes do not make essential loads inoperative, and do not cause a smoke or fire hazard*

*(d) Operation without normal electrical power. (See AMC 25.1351 (d)) The following apply:*

*(1) Unless it can be shown that the loss of the normal electrical power generating system(s) is Extremely*

*Improbable, alternate high integrity electrical power system(s), independent of the normal electrical power generating system(s), must be provided to power those services necessary to complete a flight and make a safe landing.*

*(2) The services to be powered must include –*

*(i) Those required for immediate safety and which must continue to operate following the loss of the normal electrical power generating system(s), without the need for flight crew action;*

*(ii) Those required for continued controlled flight; and*

*(iii) Those required for descent, approach and landing*.

### Transposition

(a) Electrical system capacity. The required generating capacity, and number and kinds of power sources must –

(1) Be determined by an electrical load analysis; and

(2) Meet the requirements of µCS25.1309.

(b) Generating system. The generating system includes electrical power sources, transmission cables, and associated control, and protective devices. It must be designed so that:

(1) Power sources function properly when independent and when connected in combination;

(2) No failure or malfunction of any power source can create a hazard or impair the ability of remaining sources to supply essential loads;

(3) The system voltage at the terminals of all essential load equipment can be maintained within the limits for which the equipment is designed, during any probable operating condition;

(4) System transients due to switching, or other causes do not make essential loads inoperative

(d) Operation without normal electrical power. (See AMC 25.1351 (d)) The following apply:

(1) Unless it can be shown that the loss of the normal electrical power generating system(s) is Extremely Improbable, alternate high integrity electrical power system(s), independent of the normal electrical power generating system(s), must be provided to power those services necessary to complete a flight and make a safe landing.

(2) The services to be powered must include –

(i) Those required for continued controlled flight; and

(ii) Those required for descent, approach and landing.

### AMC

No AMC for (a),(b),(d).

# miscellaneous equipment

## Hydraulic Systems (CS 25.1435)

### Selection

*(a) Element design. Each element of the hydraulic system must be designed to:*

*(1) Withstand the proof pressure without permanent deformation that would prevent it from performing its intended function, and the ultimate pressure without rupture. The proof and ultimate pressures are defined in terms of the design operating pressure (DOP) as follows:*



*(5) Perform as intended under all environmental conditions for which the aeroplane is certificated.*

*(b) System design. Each hydraulic system must:*

*(2) Have means to ensure that system pressures, including transient pressures and pressures from fluid volumetric changes in elements that are likely to remain closed long enough for such changes to occur, are within the design capabilities of each element, such that they meet the requirements defined in CS 25.1435(a)(1) through CS 25.1435(a)(5) inclusive;*

### Transposition

Identical text with replacement of aeroplane by drone.

### AMC

*AMC 25.1435.(a) Element Design*

*(1) Ref. CS 25.1435(a)(1) The design operating pressure (DOP) is the normal maximum steady pressure. Excluded are reasonable tolerances, and transient pressure effects such as may arise from acceptable pump ripple or reactions to system functioning, or demands that may affect fatigue. Fatigue is addressed in sub-paragraph (a)(4) of this paragraph.*

*The DOP for low-pressure elements (e.g., return, case-drain, suction, reservoirs, etc.) is the maximum pressure expected to occur during normal user system operating modes. Included are transient pressures that may occur during separate or simultaneous operation of user systems such as slats, flaps, landing gears, thrust reverses, flight controls, power transfer units, etc. Short term transient pressures, commonly referred to as pressure spikes, that may occur during the selection and operation of user systems (e.g., those pressure transients due to the opening and closing of selector/control valves, etc.) may be excluded, provided the fatigue effect of such transients is addressed in accordance with sub-paragraph (a)(4) of this paragraph.*

*In local areas of systems and elements the DOP may be different from the above due to the range of normally anticipated aeroplane operational, dynamic and environmental conditions. Such differences should be taken into account. At proof pressure, seal leakage not exceeding the allowed maximum in-service leak rate is permitted. Each element should be able to perform its intended functions when the DOP is restored.*

*For sub-paragraphs (a)(1), (a)(2) and (a)(3) of this paragraph, the pressure and structural loads, as applicable, should be sustained for sufficient time to enable adequate determination that compliance is demonstrated. Typically a time of 2 minutes for proof conditions and 1 minute for ultimate conditions will be considered acceptable.*

*The term "pressure vessels" is not intended to include small volume elements such as lines, fittings, gauges, etc. It may be necessary to use special factors for elements fabricated from nonmetallic composite materials.*

*(2) Ref. CS 25.1435(a)(2) Limit structural loads are defined in CS 25.301(a). The loading conditions of CS-25, subpart C to be considered include, but are not limited to, flight and ground manoeuvres, and gust and turbulence conditions. The loads arising in these conditions should be combined with the maximum hydraulic pressures, including transients that could occur simultaneously. Where appropriate, thermal effects should also be accounted for in the strength justification. For hydraulic actuators equipped with hydraulic or mechanical locking features, such as flight control actuators and power steering actuators, the actuators and other loaded elements should be designed for the most severe combination of internal and external loads that may occur in use. For hydraulic actuators that are free to move with external loads, i.e. do not have locking features , the structural loads are the same as the loads produced by the hydraulic actuators. At limit load, seal leakage not exceeding the allowed maximum in-service leak rate is permitted.*

*(3) Ref. CS 25.1435(a)(3) For compliance, the combined effects of the ul timate structura load(s) as defined in CS 25.301 and 25.303 and the DOP, which can reasonably occur simultaneously, should be taken into account with a factor of 1.5 applied to the DOP. In this case the overall structural integrity of the element should be maintained. However, it may be permissible for this element to suffer leakage, permanent deformation, operational/functional failure or any combination of these conditions. Where appropriate, thermal effects should also be accounted for in the strength justification.*

*(4) Ref. CS 25.1435(a)(4) Fatigue, the repeated load cycles of an element, is a significant contributor to element failure. Hydraulic elements are mainly subjected to pressure loads, but may also see externally induced load cycles (e.g. structural, thermal, etc.). The applicant should define the load cycles for each element. The number of load cycles should be evaluated to produce equivalent fatigue damage encountered during the life of the aeroplane or to support the assumptions used in demonstrating compliance with CS 25.1309. For example, if the failure analysis of the system allows that an element failure may occur at 25% of aeroplane life, the element fatigue life should at least support this assumption.*

*(5) Ref. CS 25.1435(a)(5) Aeroplane environmental conditions that an element should be designed for are those under which proper function is required. They may include, but are not limited to temperature, humidity, vibration, acceleration forces, icing, ambient pressure, electromagnetic effects, salt spray, cleaning agents, galvanic, sand, dust and fungus. They may be location specific (e.g., in pressurised cabin vs. in un-pressurised area) or general (e.g. attitude). For further guidance on environmental testing, suitable references include, but are not limited to, Military Standard, MILSTD-810 "Environmental Test Methods and Engineering Guidelines", The European Organisation for Civil Aviation Equipment Document ED-14G "Environmental Conditions and Test Procedures for Airborne Equipment" or International Organisation for Standardisation Document No. ISO 7137 "Environmental Conditions and Test Procedures for Airborne Equipment".*

*AMC 25.1435.(b) System Design*

*Ref. CS 25.1435(b) Design features that should be considered for the elimination of undesirable conditions and effects are:*

*(a) Design and install hydraulic pumps such that loss of fluid to or from the pump cannot lead to events that create a hazard that might prevent continued safe operation. For example, engine driven pump shaft seal failure or leakage in combination with a blocked fluid drain, resulting in engine gearbox contamination with hydraulic fluid and subsequent engine failure.*

*(b) Design the system to avoid hazards arising from the effects of abnormally high temperatures, which may occur in the system under fault conditions.*

*(1) Ref. CS 25.1435(b)(1) Appropriate system parameters may include, but are not limited to,pump or system temperatures and pressures, system fluid quantities, and any other parameters which give the pilot indication of the functional level of the hydraulic systems.*

*(2) Ref. CS 25.1435(b)(2) Compliance may be shown by designing the systems and elements to sustain the transients without damage or failure, or by providing dampers, pressure relief devices, etc.*

*(3) Ref. CS 25.1435(b)(3) Harmful or hazardous fluid or vapour concentrations are those that can cause short term incapacitation of the flight crew or long term health effects to the passengers or crew. Compliance may be shown by taking design precautions, to minimise the likelihood of releases and, in the event of a release, to minimise the concentrations. Suitable precautions, based on good engineering judgement, include separation of air conditioning and hydraulic systems, shut –off capability to hydraulic lines, reducing the number of joints and elements, shrouding, etc. In case of leakage, sufficient drainage should be provided.*

*(4) Ref. CS 25.1435(b)(4) Unless it has been demonstrated that there are no circumstances which can exist (on the aeroplane) under which the hydraulic fluid can be ignited in any of its physical forms (liquid, atomised, etc.), the hydraulic fluid should be considered to be flammable.*

*(5) Ref. CS 25.1435(b)(5) If more than one approved fluid is specified, the term “suitable hydraulic fluid” is intended to include acceptable mixtures. Typical nameplate marking locations for hydraulic fluid use, are all hydraulic components having elastomer seals such as cylinders, valves, reservoirs, etc.*

*(c) Tests*

*Ref. CS 25.1435(c) Test conditions should be representative of the environment that the element, subsystem or system may be exposed to in the design flight envelope. This may include loads, temperature, altitude effects, humidity, and other influences (electrical, pneumatic, etc.). Testing may be conducted in simulators, or stand-alone rigs, integrated laboratory rigs, or on the aeroplane. The test plan should describe the objectives and test methods. All interfaces between the aeroplane elements and the test facilities should be adequately represented.*

*(1) Ref. CS 25.1435(c)(1) Testing for performance should demonstrate rates and responses required for proper system operation. Testing for fatigue (the repeated load cycling of an element) and endurance (the ability of parts moving relative to each other to continue to perform their intended function) should be sufficient to show that the assumptions used in demonstrating compliance with CS 25.1309 are correct, but are not necessary to demonstrate aeroplane design life. As part of demonstrating that the element(s), sub-system(s), or system(s) perform their intended functions, the manufacturer (applicant) may select procedures and factors of safety identified in accepted manufacturing, national, military, or industry standards, provided that it can be established that they are suitable for the intended application. Minimum design factors specified in those standards or the requirements may be used unless more conservative factors have been agreed with the Agency.*

*An acceptable test approach for fatigue or endurance testing is to:*

*(a) Define the intended element life;*

*(b) Determine the anticipated element duty cycle;*

*(c) Conduct testing using the anticipated or an equivalent duty cycle.*

*(2) Ref. CS 25.1435(c)(2) The tests should include simulation of hydraulic system failure conditions in order to investigate the effect(s) of those failures, and to correlate with the failure conditions considered for demonstrating compliance with CS 25.1309. Relevant failure conditions to be tested are those, which cannot be shown to be extremely improbable, and have effects assessed to be major, hazardous, or have significant system interaction or operational implications.*

*(3) Ref. CS 25.1435(c)(3) Compliance with CS 25.1435(c)(3) can be accomplished by applying a test pressure to the system using aeroplane pumps or an alternate pressure source (e.g. ground cart). The test pressure to be used should be just below the pressure required to initiate system pressure relief (cracking pressure). Return and suction pressures are allowed to be those, which result from application of the test pressure to the pressure side of the system. Some parts of the system(s) may need to be separately pressurised to ensure the system is completely tested. Similarly, it may be permissible that certain parts of the system need not be tested if it can be shown that they do not constitute a significant part of the system with respect to the evaluation of adequate clearances or detrimental effects.*

1. More precisely CS 25 / Amendment 18, 22 Juin 2016 [↑](#footnote-ref-1)
2. In this document, “functional safety requirement” is used in the broad sense of requirement related to safety without referring to probability measures. In other words, requirement related to safety whose correct implementation is checked by the development process, and the qualitative part of the assessment process. [↑](#footnote-ref-2)
3. CS means Certification Specifications, they are the airworthiness regulatory documents edited by EASA in Europe. In the United States the equivalent documents are the FAR 2x, Federal Aviation Regulation, edited by FAA.. [↑](#footnote-ref-3)
4. Probabilistic aspects are ignored, since they are not in the perimeter of « Streamlining » [↑](#footnote-ref-4)