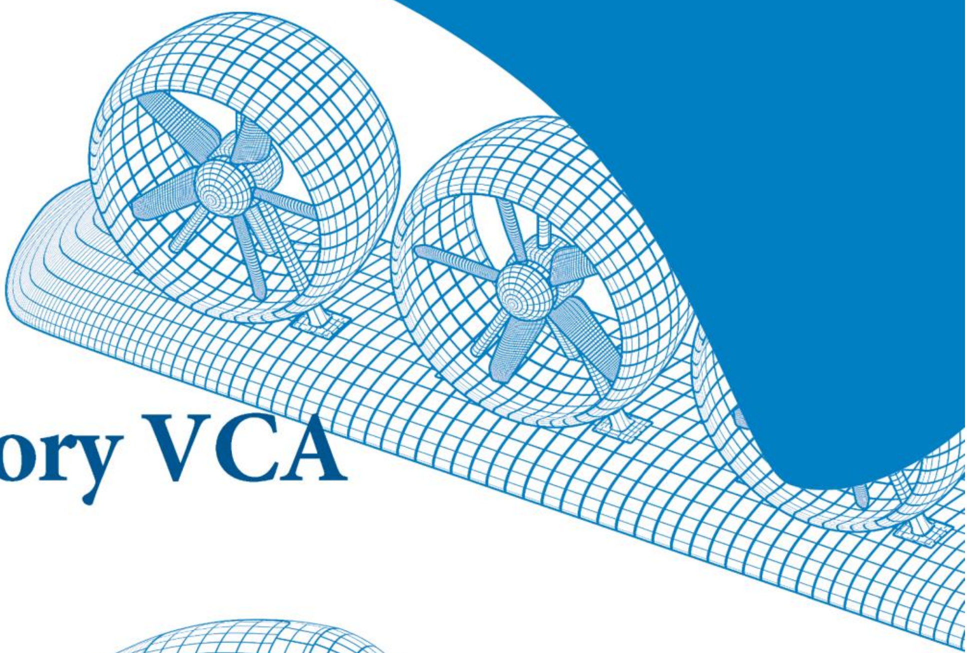
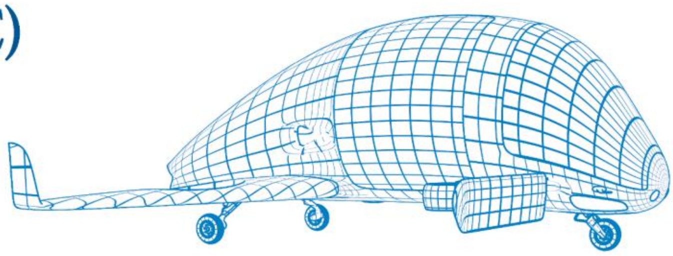
European Union Aviation Safety Agency

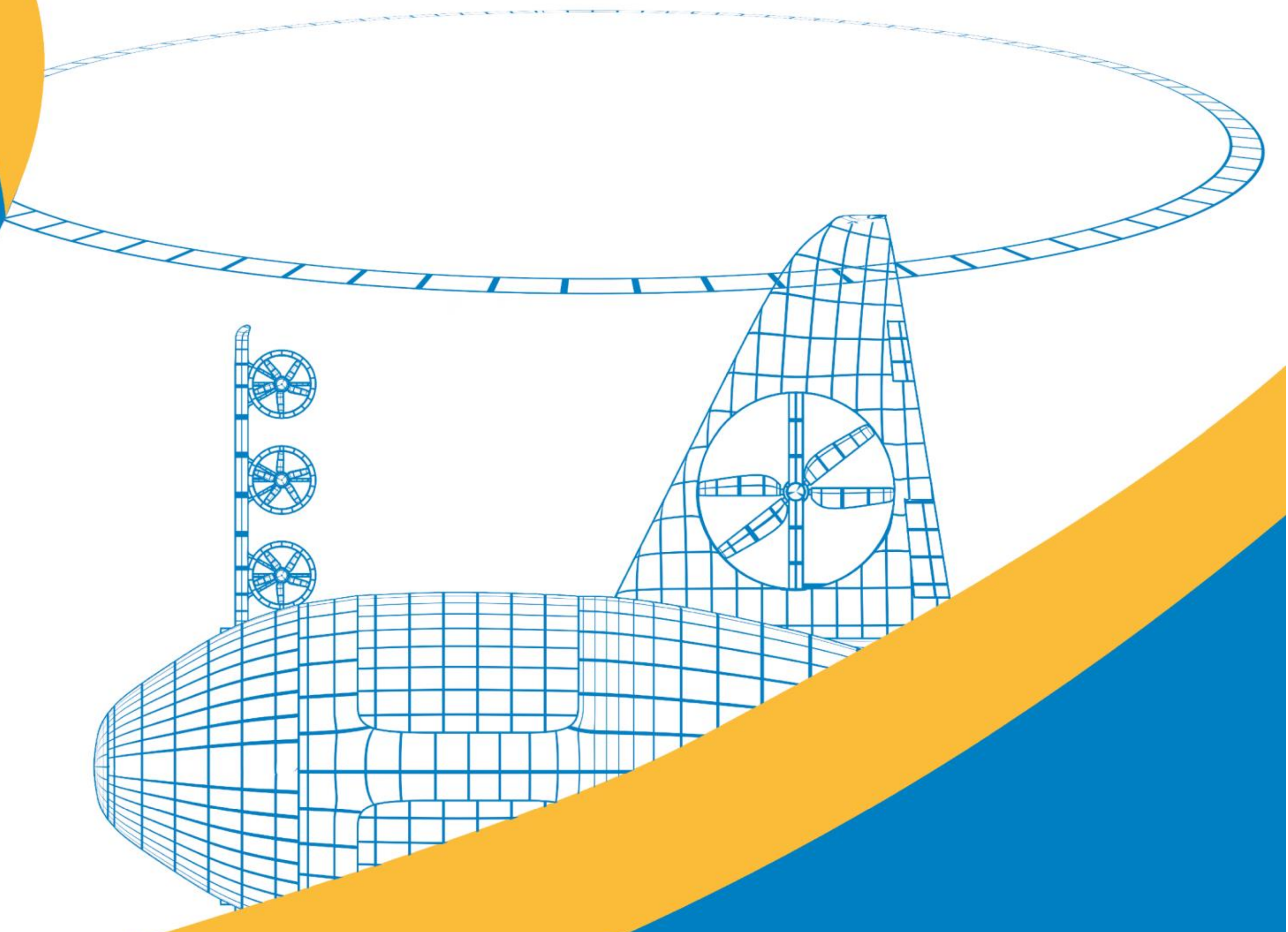
eRules



Small Category VCA

(Revision 0)
(SC + MOC)





Easy Access Rules for small category VCA (SC-VTOL + MOC) (Revision 0)

EASA eRules

EASA eRules: aviation rules for the 21st century

Rules are the core of the EU civil aviation system. The aim of the EASA eRules project is to make them accessible to stakeholders in an efficient and reliable way.

EASA eRules is a comprehensive, single system for structuring, sharing, and storing of rules. It is the single, easy-access online database for all aviation safety rules applicable to persons and organisations subject to Basic Regulation (Regulation (EU) 2018/1139).

The Easy Access Rules (EAR) are the output of the eRules project. The EAR books are consolidated versions of those rules, combining EU regulations with the related EASA Executive Director (ED) decisions in an easy-to-read format with advanced navigation features through links and bookmarks. The EAR books are regularly updated, following the adoption of an official publication.

The EAR books are available:

— in PDF format;

— as dynamic online publications (online format) with a wide range of functionalities, such as filters to obtain regulatory material tailored to one's needs, a search function through the table of contents to quickly access the relevant sections, and easy navigation for computers, tablets, and mobiles; and

— in XML (machine-readable) format that can be easily processed and automated by recipients, producing output that is compatible and can be synchronised with local applications, search databases, etc.

The EASA eRules system is developed and implemented in close cooperation with the Member States and aviation industry to ensure that all its capabilities are relevant and effective.

Published October 2024[1]

[1] The published date represents the date when the consolidated version of the EAR book was generated.

[2] Euro-Lex, Important Legal Notice: http://eur-lex.europa.eu/content/legal-notice/legal-notice.html.

Disclaimer

n/a

This version is issued by the European Union Aviation Safety Agency (EASA), hereinafter also referred to as “the Agency”, in order to provide its stakeholders with an updated, consolidated, and easy-to-read publication. It has been prepared by putting together the officially published Special Condition with the related means of compliance adopted so far. However, this is not an official publication and EASA accepts no liability for damage of any kind resulting from the risks inherent in the use of this document.

LIST OF REVISIONS

n/a

Revision	Published	Reason for revision
0	May 2024	First Easy Access Rules document powered by eRules.

DOCUMENTS INCORPORATED IN REVISION 0

n/a

SC VTOL

Reference	Issue	Publishing Date
SC VTOL Issue 1	Issue 1	15.10.2018
SC VTOL Issue 2	Issue 2	10.06.2024

MEANS OF COMPLIANCE TO SC VTOL

Reference	Issue	Publishing Date
MOC	Issue 1	25.05.2020
MOC	Issue 2	12.05.2021
MOC 2	Issue 1	23.06.2021
MOC 2	Issue 2	29.06.2022
MOC 2	Issue 3	22.12.2022
MOC 3	Issue 1	29.06.2022
MOC 3	Issue 2	21.06.2023

REVISED PARAGRAPHS

n/a

The following list describes the paragraphs in this first consolidated version of the SC-VTOL. It includes the reference documents from which each paragraph originated, and the changes made to it.

REVISION 0

Paragraph	Original Reference	Change Description
Subpart A – General		
VTOL.2000	SC VTOL Issue 2	No change
MOC VTOL.2000	MOC – Issue 2	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023 "EASA" changed to "the Agency"
VTOL.2005	SC VTOL Issue 2	No change
MOC VTOL.2005	MOC – Issue 2	No change
VTOL.2010	SC VTOL Issue 1	"EASA" changed to "the Agency"
MOC VTOL.2010	MOC – Issue 2	"EASA" changed to "the Agency"
Subpart B – Flight		
VTOL.2100	SC VTOL Issue 1	No change
VTOL.2105	SC VTOL Issue 2	corrections regarding text clarity or spelling and to align the requirement wording with ongoing harmonization efforts.
MOC VTOL.2105	MOC 2 – Issue 3	No change
VTOL.2110	SC VTOL Issue 1	No change
VTOL.2115	SC VTOL Issue 1	No change
MOC VTOL.2115	MOC 2 – Issue 3	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023. "EASA" changed to "the Agency"
VTOL.2120	SC VTOL Issue 1	No change
MOC VTOL.2120	MOC 2 – Issue 3	No change
VTOL.2125	SC VTOL Issue 1	No change
VTOL.2130	SC VTOL Issue 1	No change
MOC VTOL.2130	MOC 2 – Issue 3	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023
VTOL.2135	SC VTOL Issue 1	No change
MOC VTOL.2135	MOC – Issue 2	"EASA" changed to "the Agency"
VTOL.2140	SC VTOL Issue 1	No change
VTOL.2145	SC VTOL Issue 1	No change
VTOL.2150	SC VTOL Issue 1	No change
VTOL.2155	SC VTOL Issue 1	No change

VTOL.2160	SC VTOL Issue 1	No change
VTOL.2165	SC VTOL Issue 1	No change
VTOL.2170	SC VTOL Issue 1	No change
Subpart C – Structures		
VTOL.2200	SC VTOL Issue 1	No change
MOC VTOL.2200	MOC – Issue 2	“EASA” changed to “the Agency”
VTOL.2205	SC VTOL Issue 1	No change
MOC VTOL.2205	MOC 2 – Issue 3	“VTOL Aircraft” changed to “VTOL capable Aircraft” as per EASA Opinion No. 03/2023 and corrections regarding text clarity or spelling
VTOL.2210	SC VTOL Issue 1	No change
MOC VTOL.2210	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
VTOL.2215	SC VTOL Issue 1	No change
MOC VTOL.2215	MOC – Issue 2	reference correction: paragraph (g) corrected to paragraph (h)
VTOL.2220	SC VTOL Issue 1	No change
MOC VTOL.2220	MOC – Issue 2	No change
VTOL.2225	SC VTOL Issue 1	No change
MOC VTOL.2225	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
VTOL.2230	SC VTOL Issue 1	No change
MOC VTOL.2230	MOC – Issue 2	No change
VTOL.2235	SC VTOL Issue 1	No change
MOC VTOL.2235	MOC – Issue 2	No change
VTOL.2240	SC VTOL Issue 2	No change
MOC VTOL.2240 (a) and (b)	MOC 2 – Issue 3	“VTOL Aircraft” changed to “VTOL capable Aircraft” as per EASA Opinion No. 03/2023 and corrections regarding text clarity or spelling
MOC VTOL.2240 (d)	MOC 2 – Issue 3	“VTOL Aircraft” changed to “VTOL capable Aircraft” as per EASA Opinion No. 03/2023 and corrections regarding text clarity or spelling
MOC VTOL.2240 (e)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling. “EASA” changed to “the Agency”
VTOL.2245	MOC 2 – Issue 3	No change
VTOL.2250	SC VTOL Issue 2	No change
MOC VTOL.2250 (c)	MOC – Issue 2 MOC 2 – Issue 3	Corrections introduced regarding text clarity or spelling and removing replacement note for (b) from MOC 2 Issue 3 and for (c) from MOC Issue 2
MOC VTOL.2250 (e)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
MOC VTOL.2250 (f)	MOC – Issue 2	“VTOL Aircraft” changed to “VTOL capable Aircraft” as per EASA Opinion No. 03/2023
VTOL.2255	SC VTOL Issue 1	No change
MOC VTOL.2255	MOC 2 – Issue 3	Corrections regarding text clarity or spelling

VTOL.2260	SC VTOL Issue 1	"EASA" changed to "the Agency"
MOC VTOL.2260	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
VTOL.2265	SC VTOL Issue 1	No change
MOC VTOL.2265	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
VTOL.2270	SC VTOL Issue 1	No change
MOC VTOL.2270 (a) and (c)	MOC – Issue 2	No change
MOC VTOL.2270 (b)(1)	MOC – Issue 2	No change
MOC VTOL.2270 (c)	MOC 2 – Issue 3	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023 and corrections regarding text clarity or spelling
MOC VTOL.2270 (e)	MOC – Issue 2	No change
Subpart D – Design and Construction		
VTOL.2300	SC VTOL Issue 1	No change
MOC 1 VTOL.2300	MOC – Issue 2	"EASA" changed to "the Agency"
MOC 2 VTOL.2300	MOC – Issue 2	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023. "EASA" changed to "the Agency"
MOC 3 VTOL.2300	MOC – Issue 2	"EASA" changed to "the Agency"
MOC VTOL.2300 (a)(1)	MOC – Issue 2	No change
MOC VTOL.2300 (a)(2)	MOC – Issue 2	"EASA" changed to "the Agency"
MOC VTOL.2300 (a)(3)	MOC – Issue 2	No change
MOC 4 VTOL.2300	MOC – Issue 2	No change
MOC 5 VTOL.2300	MOC – Issue 2	"EASA" changed to "the Agency"
VTOL.2305	SC VTOL Issue 1	No change
MOC VTOL.2305	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
VTOL.2310	SC VTOL Issue 2	No change
MOC VTOL.2310 (b)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
MOC VTOL.2310 (c)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
VTOL.2315	SC VTOL Issue 2	No change
MOC VTOL.2315 (a)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
VTOL.2320	SC VTOL Issue 1	No change
MOC VTOL.2320 (a)(1)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
MOC VTOL.2320 (a)(2)	MOC – Issue 2	"EASA" changed to "the Agency"
MOC VTOL.2320 (a)(3)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
VTOL.2325	SC VTOL Issue 1	No change
MOC VTOL.2325 (a)(4)	MOC – Issue 2	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023. "EASA" changed to "the Agency"

MOC VTOL.2325 (b)(1) and (b)(2)	MOC – Issue 2 MOC 2 – Issue 3	Corrections regarding text clarity or spelling and removing the note added to paragraph 3 in MOC 2 Issue 3. “EASA” changed to “the Agency”
VTOL.2330	SC VTOL Issue 1	No change
MOC VTOL.2330	MOC 2 – Issue 3	“VTOL Aircraft” changed to “VTOL capable Aircraft” as per EASA Opinion No. 03/2023 and corrections regarding text clarity or spelling. “EASA” changed to “the Agency”
VTOL.2335	SC VTOL Issue 1	No change
MOC VTOL.2335	MOC – Issue 2	No change
VTOL.2340	SC VTOL Issue 1	No change
Subpart E – Lift/Thrust System Installation		
VTOL.2400	SC VTOL Issue 1	No change
MOC VTOL.2400 (b)	MOC – Issue 2	“VTOL Aircraft” changed to “VTOL capable Aircraft” as per EASA Opinion No. 03/2023
MOC VTOL.2400 (c)(3)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
VTOL.2405	SC VTOL Issue 1	No change
VTOL.2410	SC VTOL Issue 1	No change
VTOL.2415	SC VTOL Issue 1	No change
VTOL.2420	SC VTOL Issue 1	No change
VTOL.2425	SC VTOL Issue 1	No change
MOC VTOL.2425 (b)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
VTOL.2430	SC VTOL Issue 1	No change
MOC VTOL.2430 (a)(2)	MOC – Issue 2	No change
MOC VTOL.2430 (a)(3)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
MOC VTOL.2430 (a)(6)	MOC – Issue 2	“VTOL Aircraft” changed to “VTOL capable Aircraft” as per EASA Opinion No. 03/2023
VTOL.2435	SC VTOL Issue 1	No change
MOC VTOL.2435 (f)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
MOC VTOL.2435 (g)	MOC 2 – Issue 3	“VTOL Aircraft” changed to “VTOL capable Aircraft” as per EASA Opinion No. 03/2023 and corrections regarding text clarity or spelling
VTOL.2440	SC VTOL Issue 2	No change
MOC VTOL.2440	MOC 3 – Issue 2	“VTOL Aircraft” changed to “VTOL capable Aircraft” as per EASA Opinion No. 03/2023. “EASA” changed to “the Agency”
VTOL.2445	SC VTOL Issue 1	No change
Subpart F – Systems and Equipment		

VTOL.2500	SC VTOL Issue 1	No change
MOC 1 VTOL.2500 (b)	MOC – Issue 2	No change
MOC 2 VTOL.2500 (b)	MOC – Issue 2	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023. "EASA" changed to "the Agency"
MOC 3 VTOL.2500 (b)	MOC – Issue 2	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023
MOC 4 VTOL.2500 (b)	MOC 2 – Issue 3	Corrections regarding text clarity or spelling. "EASA" changed to "the Agency"
VTOL.2505	SC VTOL Issue 1	No change
VTOL.2510	SC VTOL Issue 2	Corrections regarding text clarity or spelling and to ensure consistency of the safety across the different subparts
MOC VTOL.2510	MOC – Issue 2	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023. "EASA" changed to "the Agency"
MOC VTOL.2510 (a)	MOC 2 – Issue 3	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023 and corrections regarding text clarity or spelling. Take Off Mass changed from 3175kg to 5700kg due to change under VTOL.2005
VTOL.2515	SC VTOL Issue 1	No change
MOC VTOL.2515	MOC – Issue 2	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023and correction of spelling error in standard reference and formula. "EASA" changed to "the Agency"
VTOL.2517	SC VTOL Issue 2	No change
VTOL.2520	SC VTOL Issue 1	No change
MOC VTOL.2520	MOC – Issue 2	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023. "EASA" changed to "the Agency"
VTOL.2525	SC VTOL Issue 1	No change
VTOL.2530	SC VTOL Issue 1	No change
MOC VTOL.2530	MOC 2 – Issue 3	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023 and corrections regarding text clarity or spelling. "EASA" changed to "the Agency"
VTOL.2535	SC VTOL Issue 1	No change
MOC VTOL.2535	MOC 2 – Issue 3	No change
VTOL.2540	SC VTOL Issue 1	No change
VTOL.2545	SC VTOL Issue 1	No change
VTOL.2550	SC VTOL Issue 1	No change
VTOL.2555	SC VTOL Issue 2	No change
MOC VTOL.2555	MOC – Issue 3	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023

Subpart G – Flight Crew Interface and other Information		
VTOL.2600	SC VTOL Issue 1	No change
MOC VTOL.2600	MOC 2 – Issue 3	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023 and corrections regarding text clarity or spelling. "EASA" changed to "the Agency"
VTOL.2605	SC VTOL Issue 1	No change
MOC VTOL.2605	MOC 2 – Issue 3	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023 and corrections regarding text clarity or spelling
VTOL.2610	SC VTOL Issue 1	No change
MOC VTOL.2610	MOC 2 – Issue 3	Corrections regarding text clarity or spelling
VTOL.2615	SC VTOL Issue 1	No change
VTOL.2620	SC VTOL Issue 1	No change
MOC VTOL.2620	MOC 2 – Issue 3	Corrections regarding text clarity or spelling. "EASA" changed to "the Agency"
VTOL.2625	SC VTOL Issue 1	No change
MOC VTOL.2625	MOC 2 – Issue 3	"VTOL Aircraft" changed to "VTOL capable Aircraft" as per EASA Opinion No. 03/2023 and corrections regarding text clarity or spelling. "EASA" changed to "the Agency"

NOTE FROM THE EDITOR

n/a

The content of this document is arranged as follows: the Special Conditions (SC) appear first followed by the Means of Compliance (MOC).

All elements (i.e. SC, MOC) are colour-coded and can be identified according to the illustration below.

Special Condition

Means of Compliance

This document will be updated regularly to incorporate further amendments.

The format of this document has been adjusted to make it user-friendly and for reference purposes. Any comments should be sent to erules@easa.europa.eu.

TABLE OF CONTENTS

PREAMBLE

n/a

Since 2018, EASA published two issues of SC-VTOL and multiple issues of related Means of Compliance documents in a stepwise process. This was done to support the industry with information and clarity on aspects with the most significant safety impact, in a timely manner.

To simplify the use of VTOL capable aircraft (VCA) airworthiness objectives and related MoC, EASA has created this consolidated document, including the already consulted and finally published documents for small category VCAs.

It includes the documents listed under the chapter Revised Paragraphs. While published as Easy Access Rules for VTOL, it is important to note that the content remains still a Special Condition with its related MOC. Feedback on the application of the SC VTOL and its MoC in the context of the certification activities and aircraft operation might result in changes to these documents. Such changes would be introduced by EASA considering first and foremost the safety of the European citizens but also being mindful of the effects on all stakeholders.

The legal basis, the resolution of comments and the final versions of each document are referenced in the original publications on the EASA website.

The types of operations that the Category Enhanced aircraft will perform correspond to the highest operational risk to third parties and/or to passenger transport for remuneration. For this reason, the most stringent system safety objectives are assigned regardless of the number of occupants. This SC applies to VCA with a pilot on board, with a Maximum Take Off Mass of up to 5700kg and up to 9 passengers. The focus is on VFR-Day operations in urban and non-urban environments, and for flights over water, if applicable. Furthermore, it is compatible with various degrees of automation, as well as a future extension of airworthiness criteria to consider the evolution of autonomous operations.

The MOC content has been updated to reflect some of the changes introduced with the latest publication of requirements. The changes are listed under the "Revised Paragraph" chapter and include:

— The increase of the maximum certified take-off mass to 5700 kg

— Introducing the term "VCA" to replace "VTOL" following Commission Implementing Regulation (EU) 2024/1111

— “EASA” changed to "the Agency", to support easier adoption of the content

— Corrections regarding text clarity and spelling

SUBPART A — GENERAL

VTOL.2000

n/a

(a) This Special Condition prescribes airworthiness standards for the issuance of the type certificate, and changes to this type certificate, for a person-carrying vertical take-off and landing (VTOL)-capable aircraft in the small category. This Special Condition is applicable to aircraft with lift/thrust units used to generate powered lift and control and with more than two lift/thrust units used to provide lift during vertical take-off or landing.

(b) For the purposes of this Special Condition, the following definition applies:

(1) 'commercial air transport' means an aircraft operation to transport passengers, cargo or mail for remuneration or other valuable consideration;

(2) 'congested area' means in relation to a city, town or settlement, any area which is substantially used for residential, commercial or recreational purposes;

(3) 'continued safe flight and landing' means an aircraft is capable of continued controlled flight and landing at a vertiport, possibly using emergency procedures, without requiring exceptional piloting skill or strength;

(4) 'controlled emergency landing' means an aircraft is capable of performing a controlled landing, possibly using emergency procedures, without requiring exceptional piloting skill or strength. Upon landing, some aircraft damage may occur;

(5) 'normal flight envelope' means the flight envelope associated with routine operational and/or prescribed conditions;

(6) 'operational flight envelope' means the flight envelope associated with warning onset;

(7) 'limit flight envelope' means the flight envelope associated with aircraft design limits or protection limits;

(8) 'vertiport' means an area of land, water, or structure used or intended to be used for the landing and take-off of VTOL-capable aircraft, and for the movement of VTOL-capable aircraft.

(c) This Special Condition applies to aircraft that are not pressurised.

(d) This Special Condition applies to aircraft with a VNO ≤ 250 knots calibrated airspeed (KCAS).

MOC VTOL.2000 Applicability and definitions

n/a

1. General considerations

When this document quotes CS-27, CS-29, CS-23 or CS-25 paragraphs, unless otherwise indicated, the terms referring to aeroplanes, rotorcraft and their architecture should be replaced by those corresponding to VTOL capable aircraft and their architecture.

Unless otherwise specified, the following replacements should be assumed:

(a) "Rotorcraft" or "aeroplane" should be replaced by "VTOL capable aircraft"

(b) "Engine", "Turbine", "Powerplant" and "Rotor" should be replaced by "Lift/thrust system"

(c) "Autorotation" should be replaced by "Controlled Emergency Landing"

(d) "Fuel" should be replaced by "Energy"

(e) "Fuel tank" should be replaced by "Energy storage device"

VTOL capable aircraft present an intrinsic capability to take-off and land vertically. Some VTOL capable aircraft may additionally be able to take-off or land as conventional aeroplanes, accelerating and/or decelerating on a runway. This mode of operation as conventional aeroplanes, also named CTOL or "conventional take-off and landing", is also specifically addressed, when relevant, in the Means of Compliance described in this document.

2. Continued Safe Flight and Landing

For Category Enhanced aircraft, as detailed in MOC VTOL.2510, the aircraft must be able to perform a continued safe flight and landing after any single failure or combination of failures that are not classified as catastrophic.

All failures directly or indirectly affecting continued safe flight and landing should be considered and evaluated. The lift/thrust system loss is not the only type of failure of this system that could affect safe flight and landing: other types of failures may also be critical, for example a frozen RPM command to a lift/thrust unit or a flight control system actuator failure.

The continued safe flight and landing includes any transition phase between horizontal and vertical flight, if included in the applicable procedure, and the ground phase up to the complete stop of the aircraft and evacuation of the occupants.

It is acceptable to use emergency procedures during the continued safe flight and landing following a failure, for example emergency ratings of the lift/thrust units.

In order to assess the VTOL's ability to perform a continued safe flight and landing, any changes in aircraft performance that affect the capability of the aircraft (e.g. range, expected height loss, remaining rate of climb) to continue the flight and perform a landing after a single failure or combination of failures not extremely improbable should be considered (see section 10 in this MOC, Certified Minimum Performance (CMP)). The characteristics of diversion vertiports that could be used after such failures can differ from the vertiport of intended landing. In this case, the necessary information on the required diversion vertiports should be established and decided prior to the flight to be able to plan the flight accordingly (e.g. distance required for a running landing, load carrying capability, dimensions). Additionally:

(a) The remaining energy reserve following a failure condition should be no less than the sufficient reserve accepted for compliance with VTOL.2430(b)(4).

(b) The performance and obstacle margins should be no less than the minimum accepted for compliance with VTOL.2115, VTOL.2120 and VTOL.2130.

(c) The continued safe flight and landing should not require exceptional piloting skills, alertness, or strength. The Handling Qualities can be evaluated considering the Modified Handling Qualities Rating Method in MOC VTOL.2135.

(d) The procedures for continued safe flight and landing should be designed so as to not injure occupants or people on the ground and should not introduce additional damages to the aircraft due to the landing.

Explanatory Note: The Means of Compliance above mirror CS

27 Category A rotorcraft. It is expected that flight tests will be performed to determine the best repeatable technique(s) for a particular aircraft over the range of mass, centre of gravity, altitude, temperature and other operational limits for which certification is requested. Any landing which results in permanent deformation of the aircraft structure or landing gear beyond allowable maintenance limits is considered an unsatisfactory test point.

3. Controlled Emergency Landing

For Category Basic aircraft, as detailed in MOC VTOL.2510, the aircraft must be able to perform a controlled emergency landing after any single failure or combination of failures not classified as catastrophic. For Category Enhanced, controlled emergency landing procedures could also be published for catastrophic failure conditions.

A controlled emergency landing should be performed under control; in particular it should be possible to steer the aircraft towards a touchdown area with the remaining lift/thrust units. Therefore this objective cannot be met by the use of non-steerable parachutes.

While the objective is similar to a controlled glide or autorotation, some damage to the aircraft to absorb the impact forces can be accepted. Active systems could also be acceptable if they meet the safety requirements of VTOL.2510.

The procedures for a controlled emergency landing should be designed so as to not injure occupants if landing is achieved on a flat solid surface.

The controlled emergency landing includes the transition phase from horizontal to vertical flight, if applicable, and the ground phase up to the complete stop of the aircraft and evacuation of the occupants.

The operational context in which the aircraft is certified should be taken into account when defining the controlled emergency landing: The capability to steer the aircraft should be evaluated based on the gliding distance and the external visual cues necessary in case of a possible loss of instruments or information in the cockpit. In particular, if the aircraft is certified for IFR, the applicant should either demonstrate that the controlled emergency landing can be carried out in IMC, or specify the minimum height required to complete the manoeuvre once the visual references have been regained.

4. Emergency Landing and Survivable Emergency Landing

As opposed to “Continued Safe Flight and Landing” and “Controlled Emergency Landing”, “Emergency Landing” and “Survivable Emergency Landing” do not correspond to design objectives but rather to design cases. They address the ultimate consequences at aircraft level of an uncontrolled landing which would be survivable by the occupants if appropriate design features are incorporated.

These design cases are consequently bound by the physical conditions within which a normal occupant would be reasonably expected to survive after contact of the aircraft with the ground (e.g. impact velocity, time exposure to a given acceleration level, etc.).

Depending on the severity of this ground contact and its consequences, the following definitions are established:

— **Emergency Landing**: Impact (crash) where the occupants are given every reasonable chance of escaping serious injury. The occupants should be able to evacuate the vehicle without assistance. The impact conditions are detailed in VTOL.2270 and associated MOC.

— **Survivable Emergency Landing**: Impact (crash) which is potentially survivable, even with serious injuries to the occupants. The occupants should be protected from post-impact hazards as described in VTOL.2325(a)(4), VTOL.2430(a)(6) and associated MOC.

Accordingly, these design cases should be considered irrespective of their probability of occurrence at least in the definition of: features for the structural protection of occupants (VTOL.2270), means of egress and emergency exits (VTOL.2315), features to minimise the initiation a fire (VTOL.2325) and features to ensure energy retention and minimisation of hazards by the lift/thrust system (VTOL.2430).

Due to their low probability of occurrence, emergency procedures for these design cases are not mandatory and would not need to be demonstrated for compliance with VTOL.2620. Nevertheless, the Agency recommends the definition of such procedures when this would contribute to the survivability of occupants (VTOL.2620).

5. Person-carrying

An aircraft is considered person-carrying if it carries crew, passengers or both.

6. Lift/thrust unit

A lift/thrust unit is considered to be any engine that directly contributes to providing lift or thrust and includes its controller, the connected effector (e.g. rotor, propeller, fan) and any related actuators (e.g. pitch change, tilting, vectoring).

7. Lift/thrust system

The lift/thrust system is composed of the lift/thrust units and their related energy storage, distribution and management systems as well as any other related ancillary systems (e.g. lubrication, cooling or transmission).

8. Flight control system

The flight control system is composed of the pilot controls, computers, wiring, actuators, sensors, and all those elements necessary to control the attitude, speed and flight path (trajectory) of the aircraft. The lift/thrust units can be functionally considered to be actuators of the flight control system and therefore part of the flight control function.

In reference to the lift/thrust unit definition provided in Section 6 of this MOC, any engine directly contributing to providing lift or thrust, its controller, and fans shall comply with applicable engine certification provisions (e.g. SC-EHPS) while the other elements (rotors, propellers, and related actuators) shall comply with SC VTOL.

9. Exceptional piloting skills

The term “exceptional piloting skills” is usually recalled when addressing the Handling Qualities requirements. The Handling Qualities should be such that the aircraft can be operated “without exceptional piloting skills”, which means that the flight crew is expected to have an “average” competency and currency to carry out the task. To ensure that the competency and currency, that will be subjectively evaluated by the applicant, correspond to the expected “average”, the evaluation should be carried out by more than one flight crew with final verification of the compliance finding by the Agency. The Operational Suitability Data (OSD) certification will establish the minimum syllabus of pilot type rating training to ensure that pilots are properly trained to the required level of proficiency.

10. Certified Minimum Performance (CMP)

The Certified Minimum Performance (CMP) is the set of performance data obtained by considering the effect of single failures and combinations of failures that are not extremely improbable on the nominal performance parameters. The CMP should also take into account the effects of the fires that are considered in VTOL.2330.

Depending on the aircraft architecture, the CMP for different performance parameters may be the result of different failures. For example, for a given aircraft, the range may be the most degraded as a result of a battery failure while the best rate of climb may be the most degraded by an electric engine failure. The failure of the battery and of the electric engine would then become, for the respective flight phase and performance parameter, the critical failure for performance (CFP, see section 11 in this MOC).

The CMP is part of the type data and is associated with limitations on the continued safe flight and landing for Category Enhanced and on the controlled emergency landing for Category Basic, to be established in accordance with VTOL.2510 and VTOL.2620.

11. Critical Failure for Performance (CFP)

A critical failure for performance (CFP) is a failure or combination of failures that results in the maximum degradation for a given flight phase and performance parameter. The set of critical failures for performance is used to establish the Certified Minimum Performance and as part of the safety assessment process of VTOL.2510.

VTOL.2005 Certification of small-category VTOL-capable aircraft

n/a

(a) Certification with this small category Special Condition applies to an aircraft with a passenger seating configuration of 9 or less and a maximum certified take-off mass of 5 700 kg or less.

(b) The aircraft must be certified in one or both of the following categories:

(1) Category Enhanced: the aircraft is capable of continued safe flight and landing and meets all applicable requirements. Aircraft intended for operations over congested areas or for Commercial Air Transport operations of passengers must be certified in this category;

(2) Category Basic: the aircraft is capable of a controlled emergency landing and meets all applicable requirements.

MOC VTOL.2005 Certification of small-category VTOL aircraft

n/a

Aircraft can be certified in both categories Basic and Enhanced by using different Aircraft Flight Manual (AFM) supplements and different configurations.

It is also possible to certify an aircraft initially in the Category Basic and later on in the Category Enhanced, subject to the respective compliance demonstration.

The definitions of Continued Safe Flight and Landing and of Controlled Emergency Landing are provided in sections 2 and 3 of MOC VTOL.2000.

VTOL.2010 Accepted means of compliance

n/a

(a) An applicant must comply with this Special Condition using means of compliance accepted by the Agency, which may include consensus standards.

(b) An applicant requesting the Agency to accept a means of compliance must provide the means of compliance to the Agency in an acceptable form and manner.

MOC VTOL.2010 Accepted Means of compliance

n/a

The Means of Compliance (MOC) in this document are a way to facilitate the completion of the necessary certification activities to be conducted by the applicant and verified by the Agency during the compliance demonstration.

Each MOC in this document, when followed in its entirety, is considered an acceptable means for the applicant to demonstrate compliance with the related objectives of the Special Condition for the currently foreseen VTOL architectures and technologies.

The MOC in this document may not yet include appropriate means to demonstrate compliance for the certification of all possible designs and/or technologies, including the new and novel application of existing technologies.

Consequently, for these cases, the MOC in this document cannot be considered by default as being acceptable or appropriate for the certification of a particular design. The use of other means to demonstrate compliance with the special condition may be required to be proposed by the applicant and subsequently accepted by the Agency.

The MOCs in this document may be updated with any necessary complement or modification, while additional MOCs with different objectives in the Special Condition may also be incorporated in this document as required. In the course of these revisions, the Agency may recognise available industry standards as accepted Means of Compliance with the Special Condition VTOL.

The Agency may also accept other means to demonstrate compliance with the objectives contained in the special condition during the certification of a particular design. In doing so, the Agency will thoroughly evaluate all proposals of MOC and analyse their merits and associated justification. Subsequently the Agency will establish whether the proposed MOC will ensure that the relevant safety objective in the special condition can be demonstrated as being fully met by it. The ultimate goal being to provide flexibility in the design of the VTOL whilst ensuring that the objectives of the special condition are satisfied and demonstrated by the applicant.

SUBPART B — FLIGHT

VTOL.2100 Mass and centre of gravity

n/a

(a) The applicant must determine limits for mass and centre of gravity that provide for the safe operation of the aircraft.

(b) The applicant's design must comply with each requirement of this Subpart at critical combinations of mass and centre of gravity within the aircraft's range of loading conditions using acceptable tolerances.

(c) The condition of the aircraft at the time of determining its empty mass and centre of gravity must be well defined and easily repeatable.

VTOL.2105 Performance data

n/a

(a) Unless otherwise prescribed, an aircraft must meet the performance requirements of this Subpart in:

(1) still air and standard atmospheric conditions at sea level for all aircraft; and

(2) ambient atmospheric conditions within the operational flight envelope for:

(i) reserved.

(ii) Category Enhanced.

(b) Unless otherwise prescribed, the applicant must develop the performance data required by this Subpart for the following conditions:

(1) vertiport altitudes from sea level to the maximum altitude for which certification is being sought; and

(2) temperatures above and below standard day temperature that are within the range of operating limitations if those temperatures could have a negative effect on performance.

(c) The procedures used for determining take-off and landing area must be executable consistently by flight crew of average skill in atmospheric conditions expected to be encountered in service.

(d) Performance data determined in accordance with VTOL.2105(b) must account for losses due to atmospheric conditions, cooling needs, installation, downwash considerations, and other demands on power sources.

MOC VTOL.2105 Performance Data

n/a

[RESERVED]

VTOL.2110 Flight Envelopes

n/a

The applicant must determine the normal, operational and limit flight envelope for each flight configuration used in operations. The flight envelopes determination must account for the most adverse conditions for each flight configuration.

VTOL.2115 Take-off performance

n/a

(a) The applicant must determine take-off performance accounting for:

(1) operational flight envelope;

(2) reserved; and

(3) obstacle safety margins.

(b) Reserved.

(c) Reserved.

MOC VTOL.2115 Take-off performance

n/a

Testing of the take-off and landing procedures should take into consideration the "flight crew with average skills" and not be performed in particularly favourable atmospheric conditions. This implies that the performance associated with these procedures should not be determined through a single test, but rather be the result of multiple tests and take into account the normal variability of the results.

1. Introduction to take-off paths:

(a) Helicopter Category A foresees two possible take-off paths, one for Conventional Take-Off (ConvTO) and another for Elevated ConvTO (EConvTO) (Figure 1). The EConvTO differs from the ConvTO operation in that a dropdown below the surface level is allowed provided obstacle clearances (15ft of edge clearance) are maintained until reaching the take-off safety speed V_{TOSS} (defined below). These two take-off paths are applicable to the VTOL capable aircraft with some adaptations for the VTOL flight mechanics.

(b) A third take-off path, Vertical Take-Off (VTO) (Figure 1), is also proposed with the objective of providing an adapted take-off path for VTOL urban environment operations from vertiports (see "Vertical take-off and landing procedure" in section 13):

(1) Obstacle clearance is established from the height h_2, which is set at the top of the vertical climb.

(2) The protection surfaces are established at the height h_2, since the minimum gradients should be determined and demonstrated after reaching VTOSS.

(3) During the vertical segment, it should be possible to perform a Rejected Take-Off (RTO) before reaching the Take-off Decision Point (TDP). Visual or synthetic cues can be used. Examples of synthetic cues include cameras and other trajectory guidance systems. The intended function of the synthetic cues should be clear, and their reliability should meet the safety objectives.

(4) After the TDP it should be possible to perform a Continued Take-off (CTO). The applicant may choose to have a pure vertical or a backup (rearward) take-off trajectory. The maximum deviations from the nominal trajectories should be determined and agreed with the Agency.

(5) The TDP can be placed at any point along the trajectory. Some applicants might elect to have a TDP lower than the top of the vertical segment, if the RTO cannot be performed safely from a given height upwards while meeting the Certified Minimum Performance (CMP) following a Critical Failure for Performance (CFP). Others may set the TDP at the bottom of the vertical segment because the RTO is not a foreseen option.

(c) The differences between the three profiles lie only at the initial portion of the take-off trajectory and acceleration to forward flight, until V_{TOSS} and a positive rate of climb (RoC) are achieved. The trajectories on Figure 1 are depicted considering that a CFP occurs soon after the TDP. A common minimum take-off path definition after V_{TOSS} is possible (Figure 2).

(d) The engine power settings considered are not those already used for conventional turbine engines. For VTOL capable aircraft with electric propulsion, there are at the moment no specific ratings such as the 10 minutes take-off AEO rating, the 30 sec or 2 min. rating, the 2,5 min OEI rating, etc. The power ratings will be defined at project level, as they will depend on the overall configuration (rotor-borne or wing-borne), number of engines, and also failure cases (number of acceptable engine losses). Figure 2 depicts the trajectories and the engine power settings while considering the most critical condition: a Critical Failure for Performance (CFP) during the take-off phase at TDP.

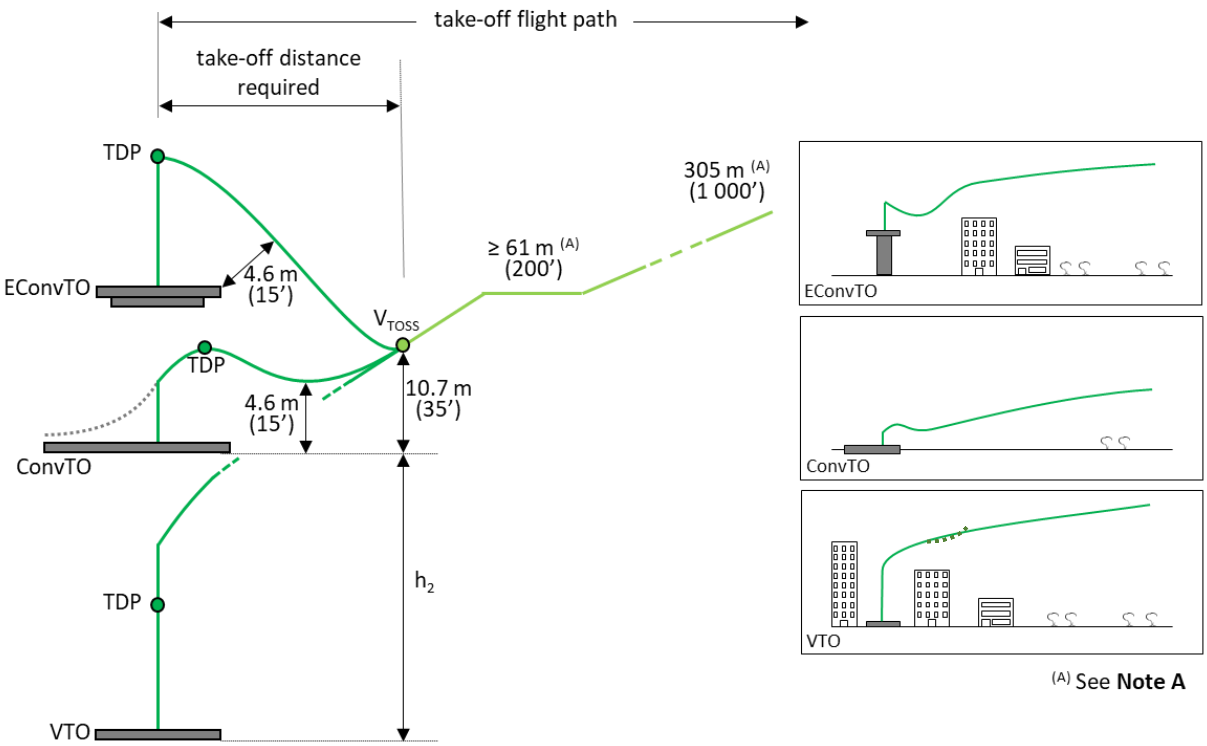


Figure 1: Possible take-off paths

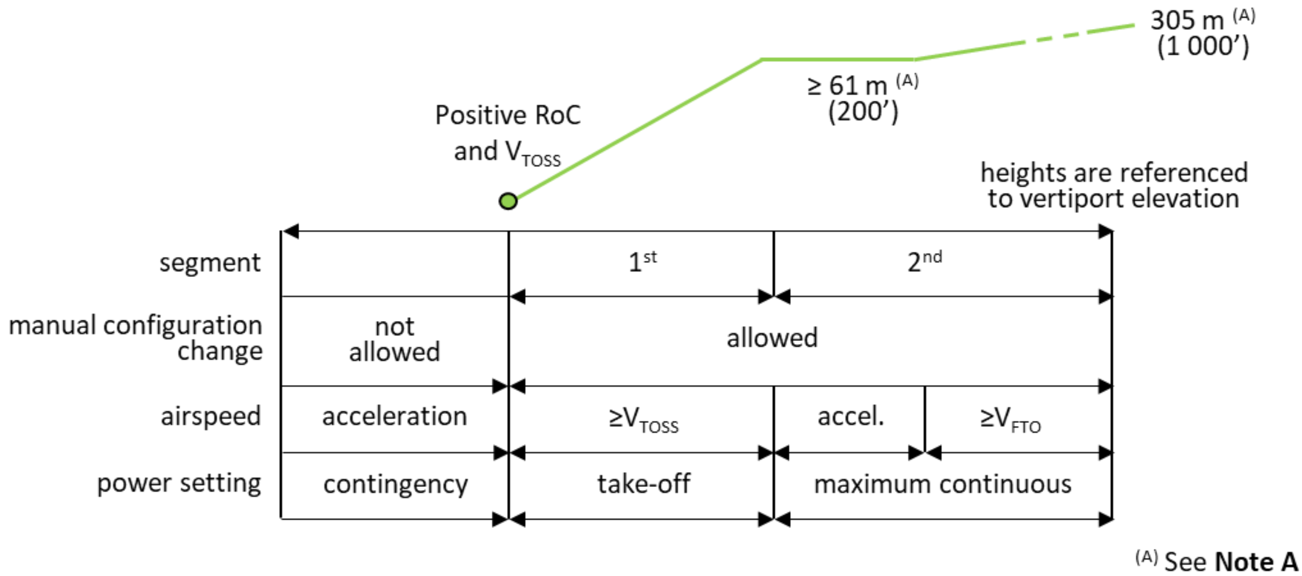


Figure 2: Take-off path segments definitions, after V_{TOSS} is achieved following a CFP at TDP

2. Approved take-off paths

(a) The take-off path extends from the take-off point to a point at which the aircraft is 305 m (1 000 ft) above the take-off elevation at the final take-off configuration.

Note A: The altitudes of 61 m (200 ft) and 305 m (1 000 ft) are proposed in the development of the take-off flight path as currently used for Category A helicopters. Different take-off heights can be considered if compatible with the departure and en-route profile.

(b) The aircraft should be accelerated to V_{TOSS} while clearing any surface by 4.6 m (15 ft).

(c) The aircraft should reach V_{TOSS} and should continue at speeds not less than V_{TOSS}, until it is 61 m (200 ft) above the take-off elevation, with a minimum gradient of climb at each point. The minimum gradients, derived from CS-27 and CS-29, are 4.5 % for the first segment and 2.5 % for the second segment.

(d) For ConvTO, V_{TOSS} should be reached at or before 10.7 m (35 ft) above the take-off elevation. In the dropdown segment, in normal and CFP, not less than 4.6 m (15 ft) clearance to the take-off elevation is allowed.

(e) For the EConvTO, the aircraft may descend below the level of the take-off surface if, in so doing and when clearing the elevated vertiport edge, in normal and CFP, every part of the aircraft clears all obstacles by at least 4.6m (15 ft). The vertical magnitude of any descent below the take-off surface should be determined and published.

(f) For the VTO, V_{TOSS} should be reached at or before 10.7 m (35 ft) above h_2. The Vertical take-off and landing procedure is described in section 13 of this MOC.

(g) The aircraft configuration (e.g. tilt wings/thrust units, flaps, gear) and power settings (contingency/take-off and maximum continuous power) may automatically change along the take-off path. Configuration changes requiring action by the crew are allowed only after the aircraft reaches V_{TOSS}.

(h) Starting at the point at which the aircraft reaches 61 m (200 ft) above the take-off elevation (or above h_2), the aircraft should be accelerated to the Final Take-off Speed (V_{FTO}) and should then be capable of a directional trajectory change with at least 3°/s:

(1) When reaching VFTO while changing directional trajectory, the aircraft should be capable of maintaining at least level flight (no descent).

(2) If the applicant elects to show compliance to the Handling Qualities requirements using the Modified Handling Qualities Rating (MHQRM), specific manoeuvres to replicate this condition should be proposed.

(3) The effect of turn rates on the minimum climb gradients, including a standard turn rate of 3°/s, should be demonstrated and published.

(4) The corresponding maximum turn radius should be measured and published.

(5) The applicant can choose to demonstrate that the aircraft can follow curved approach and take-off climb surfaces as per ICAO Annex 14, volume 2, chapter 4 or better. The effect on the minimum climb gradients should then be demonstrated and published.

3. Take-off Decision Point (TDP)

(a) The TDP is the first point defined by a combination of speed and height from which CTO is demonstrated meeting the CMP, and is the last point in the take-off path from which an RTO is assured.

(b) The Pilot's Intervention Time after a failure, including CFP for take-off, should be set not less than 1 second, and the Pilot's Recognition Time not less than 0.5 second, for a Pilot's Reaction Time after the CFP of not less than 1.5 second. The pilot input, and the decision to CTO or RTO, is expected to happen after the Reaction Time is elapsed. Depending on the aircraft characteristics, cockpit and physical information, the Pilot's Recognition Time and/or the Pilot's Intervention Time might be longer, and therefore need to be evaluated.

Note: The take-off performance should be determined for all associated mass, atmospheric and wind conditions (see MOC VTOL.2105) so that, in case of the occurrence of the CFP event at any time after the start of take-off, the aircraft can either return to, and stop safely on the take-off area, or continue the take-off and climb out.

Note: The Pilot's Reaction time is the sum of the Pilot's Recognition time plus the Pilot's Intervention time. The Pilot's Recognition time is the time counted from the onset of the failure until the pilot is made aware of it. The Pilot's Intervention time is the time elapsed from the moment the pilot is made aware of the failure until an input to the flight controls is made.

4. Take-off Safety Speed (V_{TOSS})

(a) Only primary control inceptors should be used while attaining V_{TOSS} and while establishing the required climb gradient.

(b) V_{TOSS} should be reached without requiring configuration changes commanded by the crew.

(c) V_{TOSS} should be demonstrated for each weight, most critical centre of gravity position, altitude, and temperature for which take-off data are to be determined. It should also include sufficient margin for the limiting (negative) vertical wind velocity and turbulences.

(d) Flying at V_{TOSS} should provide a steady gradient of climb of at least 4.5 % at the power rate setting declared by the applicant for the first take-off segment.

5. Final Take-off Speed (V_{FTO})

(a) Any control can be used while attaining V_{FTO} and while establishing the required climb gradient, however this should not be done before an appropriate pilot's reaction time when considering a CFP condition.

(b) V_{FTO} can be reached and maintained requiring configuration changes, including landing gear retraction, commanded by the flight crew.

(c) V_{FTO} should be determined for each weight, most critical centre of gravity position, altitude, and temperature for which take-off data are to be determined.

(d) Flying at V_{FTO} should provide a steady gradient of climb of at least 2.5 % at maximum continuous power and a manoeuvring capability of not less than 3°/s of turn rate while not descending.

6. Dimension "D"

(a) The diameter 'D' is the diameter of the smallest circle enclosing the VTOL capable aircraft projection on a horizontal plane, while the aircraft is in the take-off or landing configuration, with rotor(s) turning if applicable (Figure 3).

(b) The diameter D should be published in metres and feet, rounded up to the next tenth.

(c) If the VTOL capable aircraft changes its dimensions during taxi or parking (e.g. folding wings), a corresponding D_{taxi} and $D_{parking}$ should also be provided.

7. Hover heights h_1 and h_2

(a) The heights h_1 and h_2 for VTOLs are the equivalent of In Ground Effect (IGE) and Out of Ground Effect (OGE) hover for rotorcraft. Because there could be no actual beneficial "ground effect" on performance of hovering close to the ground for all VTOL designs, the conventional IGE and OGE terms have been considered to be no longer applicable. Applicants may decide to establish h_1 and h_2 values based on other considerations, such as handling qualities or ground clearance following failure conditions. See also Section 13 "Vertical take-off and landing procedure" in this MOC.

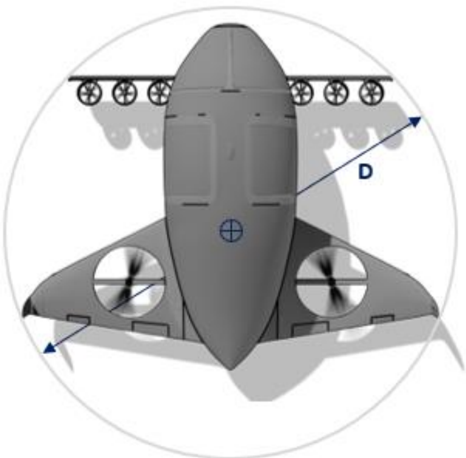


Figure 3: Centre and diameter 'D' of the smallest enclosing circle

8. Centre of the smallest enclosing circle

(a) The location (e.g. STA and BL) of the centre of the smallest enclosing circle used to determine D should be established and published (Figure 3).

(b) If the VTOL capable aircraft changes its dimensions during taxi or parking (e.g. folding wings) and the positions of the centre of the smallest enclosing circle varies, the corresponding locations should also be provided.

9. FATO width required

(a) 'Final approach and take-off area' (FATO) means a defined area over which the final phase of the approach manoeuvre to hover or land is completed and from which the take-off manoeuvre is commenced.

(b) The FATO includes the rejected take-off area.

(c) The FATO width required should be established and published in metres and feet, rounded up to the next tenth.

10. Take-off distance required (TODRV)

(a) 'Take-off distance' (TOD) means the projected horizontal distance from the start of a take-off procedure to:

(1) For ConvTO: the point where the aircraft reaches 10.7 m (35 ft) above the take-off surface with the minimum climb gradient of 4.5 %; or

(2) For EConvTO: after the dropdown segment, the point where the aircraft reaches 10.7 m (35 ft) above the take-off surface with the minimum climb gradient of 4.5%; or

(3) For VTO: the point where the aircraft reaches 10.7 m (35 ft) above h_2 (defined in section 13 of this MOC) with the minimum climb gradient of 4.5 %.

(b) The TOD required for VTOL capable aircraft (TODRV) that provides safe obstacle clearance following a CFP being recognized at TDP should be established and published in metres and feet, rounded up to the next tenth.

11. Rejected take-off distance required (RTODRV)

(a) 'Rejected take-off distance' (RTOD) means the length of the FATO required by the VTOL capable aircraft to complete a rejected take-off in accordance with the Category in which it is operated, Enhanced or Basic. This value is provided in the AFM for comparison with the RTOD available for the FATO.

(b) The RTOD required for VTOL capable aircraft (RTODRV) that provides safe containment following a CFP being recognized at TDP should be established and published in metres and feet, rounded up to the next tenth.

12. TLOF size required

(a) 'Touchdown and lift-off area' (TLOF) means an area on which a VTOL capable aircraft may touch down or lift off.

(b) The TLOF size (length and width) required for approved procedures should be established and published in metres and feet, rounded up to the next tenth.

(c) The minimum dimensions should be the larger of:

(1) the minimum size of the surface to contain the undercarriage;

(2) the aircraft performance scatter during a landing after a Critical Failure for Performance (CFP) to a specific reference point; and

(3) the surface required to provide the minimum suitable visual cues for a landing after a CFP.

13. Vertical take-off and landing procedure

(a) The applicant may provide a procedure for a vertical take-off and landing, with a vertical segment from the ground facilitating clearance of obstacles, for example in the urban environment (Figure 4 and Figure 5).

(b) The AFM should then include the following values:

Parameter	Short description	Minimum/maximum[1]	Reference volume Type 1[2]
h_1	Low hover height	-	3 m (10 ft)
h_2	High hover height	$\geq h_1$	30.5 m (100 ft)
TO_{width}	Width at h_2	≤ 5 D	2 D
TO_{front}	Front distance at h_2	≤ 5 D	1.5 D
TO_{back}	Back distance at h_2	≤ 5 D	1.5 D
$FATO_{width}$	Width of the FATO	≥ 1.5 D	1.5 D
$FATO_{front}$	Front distance on FATO	≥ 0.75 D	0.75 D
$FATO_{back}$	Back distance on FATO	≥ 0.75 D	0.75 D
θ_{app}	Slope of approach surface	≥ 4.5%	12.5 %
θ_{dep}	Slope of departure surface	≥ 4.5%	12.5 %

Note 1: "Minimum/maximum" corresponds to the minimum or maximum values acceptable for certification.

Note 2: See (f)

(c) The published values should represent trajectories obtained with procedures demonstrated to be consistently executable without requiring exceptional piloting skill, alertness, or strength in atmospheric conditions expected to be encountered in service, as required by VTOL.2105(c).

(d) $FATO_{front}$ and $FATO_{back}$ are referenced to the aircraft centre of the smallest enclosing circle (see section 8. of this MOC). TO_{front} and TO_{back} are measured from a vertical line passing through the same point. The values published should ensure the containment of the aircraft during the procedure, for example TO_{back} will be larger for a back-up take-off procedure and $FATO_{front}$ should consider the Rejected take-off distance (RTOD).

(e) The rest of the take-off procedure (e.g. take-off decision point, drop down, climb segments) should be designed with respect to the horizontal plane at h_2

(f) The applicant may develop one or multiple procedures within the maximum/minimum values provided in (b). A specific volume, called "Reference volume Type 1", can also be proposed with standardised values that can be useful for vertiport design in an obstacle rich environment (Figure 6 and Figure 7). Demonstrating during certification that the aircraft can reliably conduct take-off and landings in this volume is offered as a possibility to the applicant to facilitate the integration in corresponding vertiports.

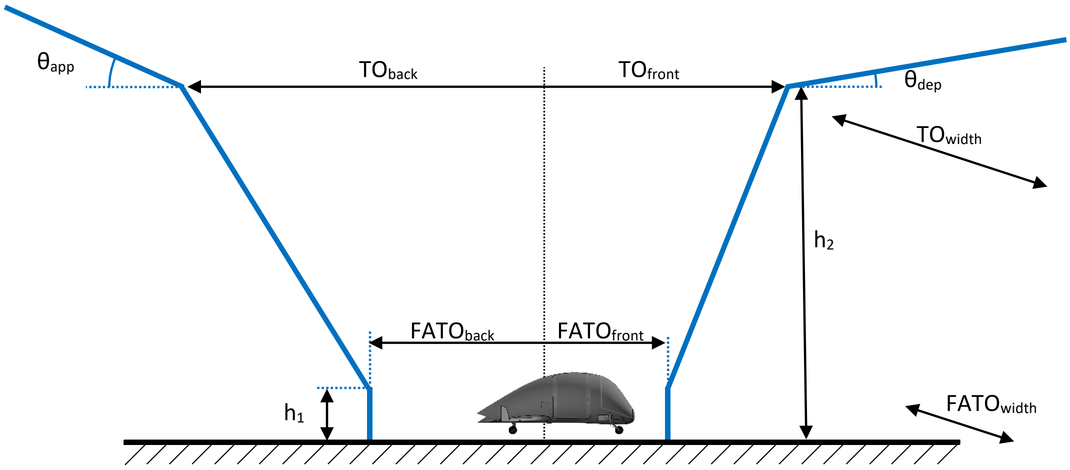


Figure 4: Generic vertical take-off and landing procedure parameters, side view

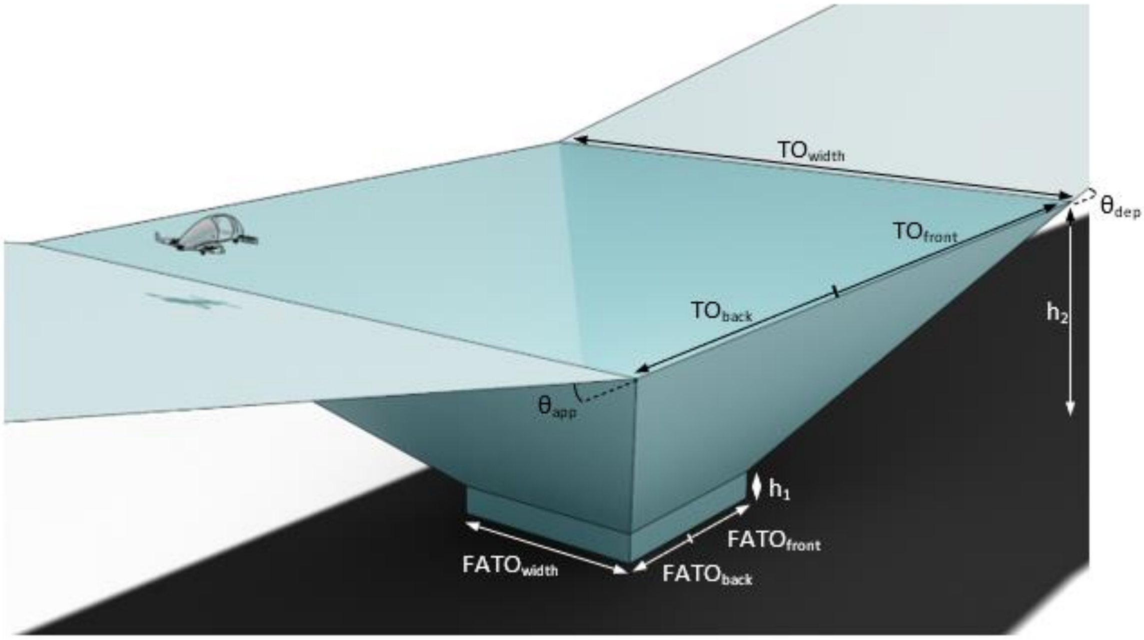


Figure 5: Generic vertical take-off and landing procedure parameters, perspective view

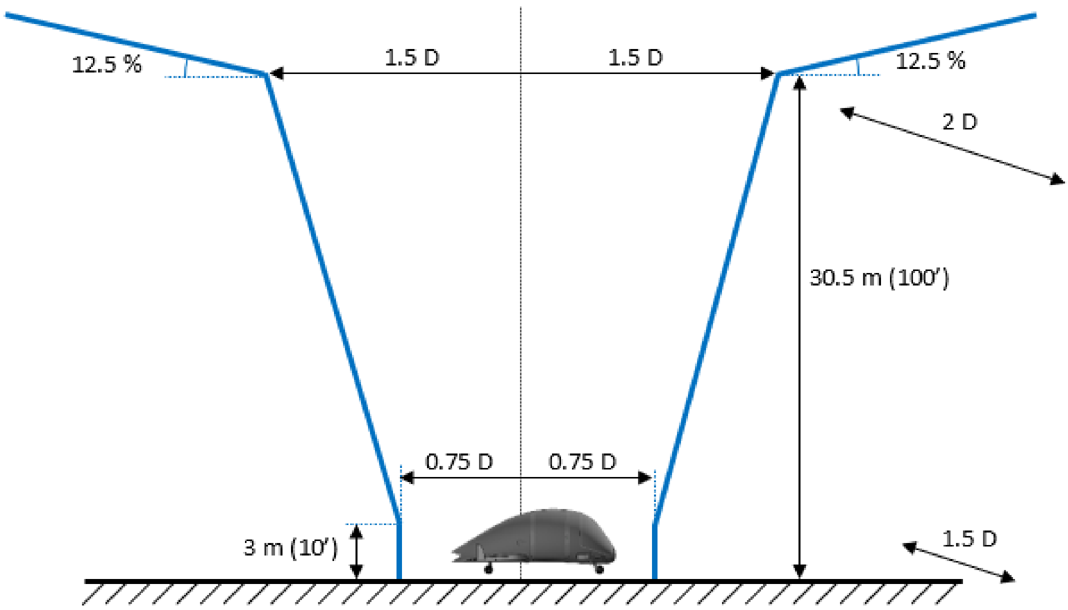


Figure 6: "Reference volume Type 1" vertical take-off and landing procedure parameters, side view

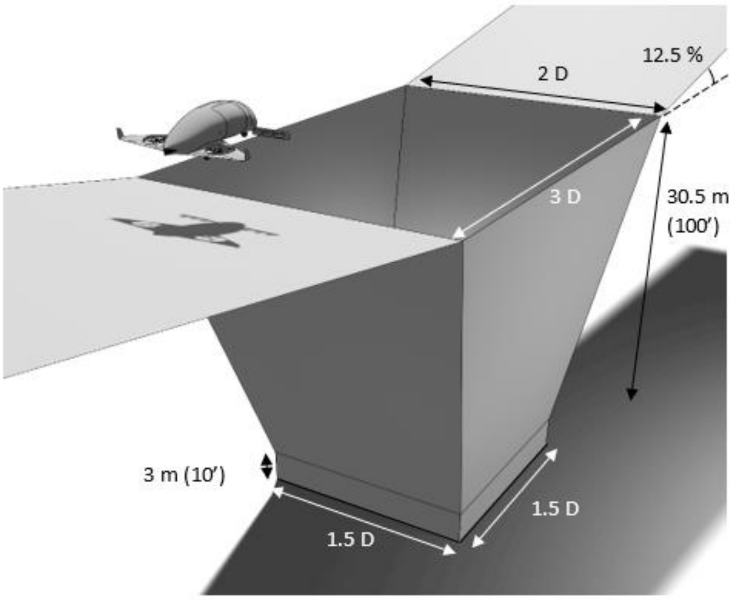


Figure 7: "Reference volume Type 1" vertical take-off and landing procedure parameters, perspective view

14. Overall width

(a) 'Overall width' means the widest lateral width of the VTOL capable aircraft projection on a horizontal plane, while the aircraft is in the take-off or landing configuration, with rotor(s) turning if applicable.

(b) The overall width should be established and published in metres and feet, rounded up to the next tenth.

(c) If the VTOL capable aircraft lateral width changes during taxi or parking (e.g. folding wings), a corresponding overall width during taxi or parking should also be provided.

15. Overall length

(a) 'Overall length' means the longest longitudinal length of the VTOL capable aircraft projection on a horizontal plane, while the aircraft is in the take-off or landing configuration, with rotor(s) turning if applicable.

(b) The overall length should be established and published in metres and feet, rounded up to the next tenth.

(c) If the VTOL capable aircraft length changes during taxi or parking (e.g. retracting tail), a corresponding overall length during taxi or parking should also be provided.

16. Undercarriage width (UCW)

(a) 'Undercarriage width' (UCW) means the width of the undercarriage/landing gear projection on a horizontal plane (Figure 8).

(b) The undercarriage width should be established and published in metres and feet, rounded up to the next tenth.

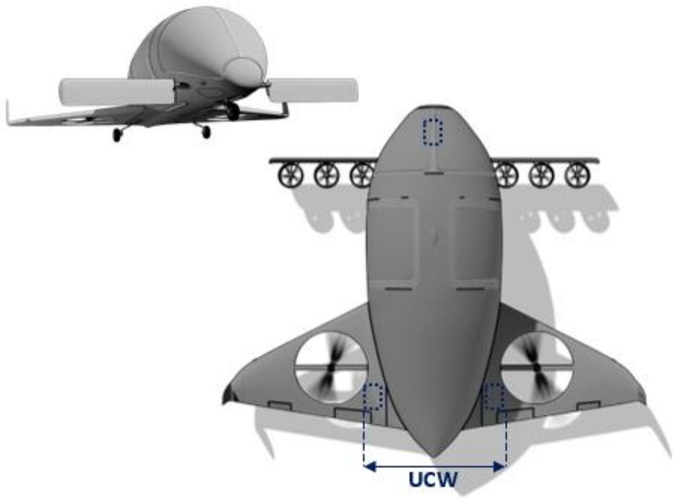


Figure 8: Undercarriage width

17. Undercarriage footprint

(a) 'Undercarriage' footprint means the diameter of the circle containing the landing gear contact area while the aircraft is in the take-off or landing configuration (Figure 9). The undercarriage footprint can be used for the determination of the undercarriage containment area and TLOF (touchdown and lift-off area).

(b) The undercarriage footprint should be established and published in metres and feet, rounded up to the next tenth.

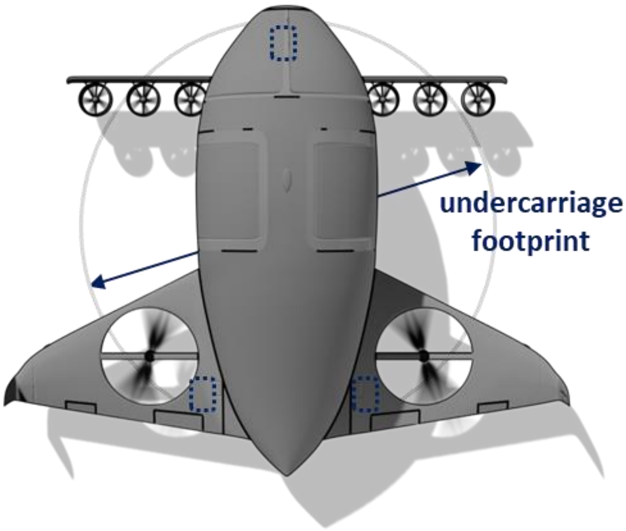


Figure 9: Undercarriage footprint

18. Hover and ground (if applicable) turn diameter required

The diameters of the containment area required to perform a 360-degree turn in a normal operation hover and ground-taxi (if applicable) should be established and published in metres and feet, rounded up to the next tenth.

19. Aircraft Flight Manual Data:

The following data, defined in the previous sections of this MOC, should be included in the AFM:

(a) Approved take-off paths

(b) Take-off decision point

(c) Take-off Safety Speed (V_{TOSS})

(d) Final Take-off Speed (V_{FTO})

(e) Dimension “D”

(f) Hover heights h_1 and h_2 (if applicable)

(g) Centre of the smallest enclosing circle

(h) FATO width required

(i) Take-off distance required for VTOL capable aircraft (TODRV)

(j) Rejected take-off distance required for VTOL capable aircraft (RTODRV)

(k) TLOF size required

(l) Vertical take-off and landing procedure (if applicable)

(m) Overall width

(n) Overall length

(o) Undercarriage width (UCW)

(p) Undercarriage footprint

(q) Hover and ground (if applicable) turn diameter required

VTOL.2120 Climb requirements

n/a

The design must comply with minimum climb performance out of ground effect:

(a) in the normal flight envelope.

(b) for Category Enhanced:

(1) in the operational envelope;

(2) reserved.

(c) reserved.

MOC VTOL.2120 Climb requirements

n/a

(a) For Category Enhanced, the climb gradient without ground effect, at 305 m (1 000 ft) above the take-off surface, should be at least 2.5 %, for each combination of weight and CG, altitude, and temperature for which take-off data are to be determined, and for the duration of the flight:

(1) following a critical failure for performance (CFP) and with the remaining lift/thrust engines at maximum continuous power, if approved, or at take-off power for aircraft for which certification for use of take-off power is requested; and

(2) with the landing gear retracted (if applicable) and the aircraft in cruise configuration; and

(3) at the speed selected by the applicant.

Note: The altitude of 305m (1 000 ft) is proposed as currently used for Category A helicopters. Different cruise altitudes can be considered if compatible with the departure and en-route profile.

See MOC VTOL.2115 and 2130 for specific climb requirements for take-off and balked landing.

(b) For Category Basic, the climb gradient without ground effect, at 305 m (1 000 ft) above the take-off surface, should be at least 2.5 %, for each combination of weight and CG, in nominal conditions (no failure conditions), at ISA SL and for the duration of the flight.

VTOL.2125 Climb information

n/a

(a) The applicant must determine, as applicable, climb and/or descent performance:

(1) in the normal flight envelope;

(2) for Category Enhanced, in the operational envelope;

(3) reserved.

(b) The VTOL ceiling in and out of ground effect, if applicable, must be determined within the operational flight envelope.

VTOL.2130 Landing

n/a

The applicant must determine the following, at critical combinations of flight parameters within the operational limits:

(a) the area required to land and come to a stop, assuming approach paths applicable to the aircraft; and

(b) the approach and landing speeds, configurations, and procedures, which allow a flight crew of average skill to land within the published landing area consistently and without causing damage or injury, and which allow for a safe transition to the balked-landing conditions.

MOC VTOL.2130 Landing

n/a

This MOC does not cover the approach before the landing and starts from a point at which the decision to land, from an operational point of view, has been taken.

1. Landing procedures

(a) The landing can be of two main types: a Conventional Landing (ConvL) or a Vertical Landing (VL):

(1) A ConvL path starts at a Landing Decision Point (LDP, see below) and ends at the point where the aircraft reaches a stop at the FATO on the ground (after which it may taxi). The trajectory may have the most appropriate glide path foreseen by the applicant.

(2) A VL might be required to comply with obstacle separation when landing on a Vertiport in an Urban Air Mobility (UAM) environment. The applicant may choose to have, from a point along the approach after the LDP, a pure vertical trajectory.

(b) The landing procedures should be demonstrated to be consistently executable by flight crew of average skill, as required by VTOL.2105(c).

(c) The landing distance scatter and the maximum deviations from a nominal trajectory should be determined by the applicant.

2. Landing decision point (LDP)

(a) The characteristic point along the landing flight path is the Landing Decision Point (LDP), which is defined as the last point from which a balked landing can be performed. After LDP a balked landing is not assured.

(b) If the aircraft is required to show continued safe flight and landing, then a landing should be possible following a CFP before or after the LDP.

(c) LDP should be identified with a combination of height, vertical speed and airspeed and/or ground speed.

(d) LDP should be reached at a speed equal or lower to V_{REF}.

3. Landing reference Speed (VREF)

The landing reference speed is the speed determined at the flight Glide Path Angle (GPA) for which certification is sought and with all lift/thrust systems operative that:

(a) allows for speed variations during a landing in expected turbulence and all reasonably expected environmental conditions; and

(b) provides enough manoeuvring capability; and

(c) is the initial speed that should be used to determine the area required to land and come to a stop.

4. Landing distance required (LDRV) and touchdown and lift-off area (TLOF) required

(a) The landing distance required is the horizontal distance required to land and come to a stop from a point 15 m (50 ft) above the landing surface (Figure 1). The touchdown and lift-off area (TLOF) required is defined in MOC VTOL.2115 section (12).

(b) The landing distance required for VTOL capable aircraft (LDRV) that provides safe containment following a CFP being recognized at LDP should be established and published in metres, rounded up to the next tenth.

5. Balked landing procedure

(a) The aircraft should be capable of a balked landing following a CFP event without requiring configuration changes commanded by the flight crew until regaining V_{TOSS}. Reaching V_{TOSS} could require continuing the descent, but the minimum height of 35 ft above the vertiport elevation or above h_2, depending on the landing procedure, based on which the take-off distances are calculated, should be respected to ensure obstacle clearance.

(b) Once V_{TOSS} has been regained, configuration changes are permitted, and the minimum climb gradients for the 1st and 2nd segment of the take-off path should be guaranteed (see MOC VTOL.2115).

(c) A representative time to perform a go-around from LDP back to LDP should be provided for the determination of the energy reserve.

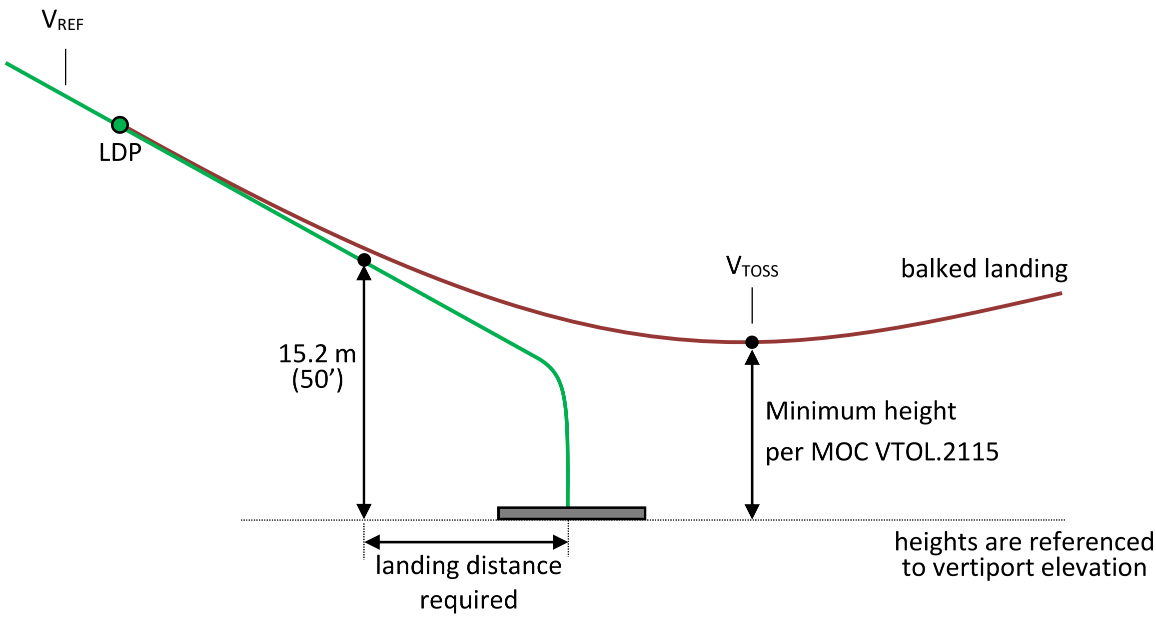


Figure 1: Landing path

6. Aircraft Flight Manual Data:

The AFM should include the following data, defined in the previous sections of this MOC:

(a) Landing procedures

(b) Landing decision point (LDP)

(c) Landing reference Speed (V_{REF})

(d) Landing distance required (LDRH)

(e) Balked landing procedure

VTOL.2135 Controllability

n/a

(a) The aircraft must be controllable and manoeuvrable, without requiring exceptional piloting skills, alertness, or strength, within the operational flight envelope and must be controllable and manoeuvrable within the limit flight envelope:

(1) at all loading conditions for which certification is requested;

(2) during all phases of ground or flight operations;

(3) reserved;

(4) during configuration changes;

(5) in all degraded flight control system operating modes; and

(6) the applicant must demonstrate controllability in wind from zero to a wind limit appropriate for the aircraft type.

(b) Reserved.

(c) Reserved.

(d) It must be possible to make a smooth transition from one flight condition to another without danger of exceeding the limit flight envelope.

MOC VTOL.2135 Minimum Acceptable Handling Qualities Rating

n/a

1. Background and Introduction

The aircraft needs to be controllable and manoeuvrable to cope with adverse weather conditions and to avoid late detected obstacles or traffic appropriate to the type. The control and manoeuvring of the aircraft requires a certain amount of physical and/or mental workload from the crew. Satisfactory Handling Qualities (HQ) give the opportunity for the crew to better manage high workload situations, and allow them to operate safely for longer periods, and to be able to deal with aircraft system failures and contingencies. Degraded HQ lead to an increased crew attentional demand for aircraft control, hence reduced high workload capacity for other tasks and for Situational Awareness.

The following is a method of determining and evaluating, for compliance demonstration, the HQ for VTOLs in the Category Enhanced in normal and abnormal/emergency conditions. The Category Basic VTOLs may also elect to use this method; however, the Minimum Acceptable Handling Qualities Rating section 4 will need to be adapted. The focus is on the crew task of flight path/trajectory control. All the other characteristics of the flight controls such as number of inceptors, size and mechanical forces (friction, breakout etc.) are out of scope of this MOC. These other characteristics however will influence the achievable HQ, so they will be indirectly assessed.

This method is different from CS-23 and CS-27, since in those certification specifications, the HQ of an aircraft are suitably assessed on the addition of the compliance to static or dynamic stability requirements along with other requirements for controllability and average piloting skills. HQ are evaluated without any specific generally recognised method, and are mainly evaluated to measure the workload to determine the minimum crew in respect to the kind of operations. Usually the Cooper Harper Handling Qualities Rating Scale (CHR) is used to measure the Handling Qualities, while the Bedford rating scale (or NASA Task Load Index as alternative) is used to measure the workload. However, each applicant can choose the methodology to determine the HQ and/or workload.

This Modified Handling Qualities Rating Method (MHQRM) is an accepted means of compliance with VTOL.2135, and can also be used to assess compliance, fully or in part, with the following SC VTOL requirements that require a determination of HQ: VTOL.2110 Flight Envelopes, VTOL.2115 Take-off performance, VTOL.2130 Landing, VTOL.2135 Controllability, VTOL.2140 Control forces, VTOL.2145 Flying qualities, VTOL.2150 Stall characteristics and stall warning, VTOL.2160 Vibration, VTOL.2300 Flight control systems and VTOL.2305 Landing gear systems.

This method should not be considered to be the only method. Applicants may propose alternative methods or deviations based on the characteristics of their design, or on their compliance determination strategy. Unless otherwise specified in a special condition, the HQRM does not replace or override any of the systems and equipment requirements of §§ VTOL.2500, VTOL.2505 and VTOL.2510.

2. List of Acronyms

AD	Atmospheric Disturbance
ADQ	Adequate
AFM	Aircraft Flight Manual
CHR	Cooper Harper Rating Scale
CON	Controllable
CONOPS	Concept of Operations
EFCS	Electronic Flight Control System
FC	Failure Conditions
FE	Flight Envelope
FEP	Flight Envelope Protection
FHA	Functional Hazard Assessment
FltC	Flight Condition
GNSS	Global Navigation Satellite System
HQ	Handling Qualities
HQR	Handling Qualities Rating
HQRM	Handling Qualities Rating Method
IMC	Instrument Meteorological Conditions
LFE	Limit Flight Envelope
MHQRM	Modified Handling Qualities Rating Method
MTE	Mission Task Elements
NFE	Normal Flight Envelope
NVIS	Night Vision Imaging System
OFE	Operational Flight Envelope
SAT	Satisfactory
SC	Special Condition
TBD	To be determined
VFR	Visual Flight Rules
VisC	Visual cues
VTOL	Vertical Take Off and Landing

3. MHQRM Process

The overall process is derived from the FAA Advisory Circular 25-7D Appendix E, which was intended mainly to define a method for evaluating Failure Conditions (FCs). In particular, the principle of determining the minimum HQR based on the probability of being in a given Flight Condition (FltC) was adopted. The “tool” to evaluate and show compliance with the minimum acceptable HQR will be derived from ADS-33E. The Mission Task Elements (MTE) manoeuvres of this military standard will be adapted to the SC VTOL based on the Concept of Operations (CONOPS) for VTOL that is being produced by industry. There will be also provisions on the competences of the test pilots (fixed wing or rotary wing background) and on the minimum number of evaluators. This tool is being developed together with industry and research centres, and will be published at a second stage.

This MHQRM starts by determining the minimum acceptable HQR for each phase of the flight and for a given FltC, defined as a combination of the Flight Envelope (FE) and the level of Atmospheric Disturbance (AD), relative to the Nominal State of the aircraft systems, or the probability of the FC being evaluated. A pre-requisite to start the MHQRM process is thus to have Functional Hazard Assessment (FHA) available and have preliminary quantitative assessments for the FCs to be analysed in the MHQRM. If this MHQRM process is intended for validating FC classification in the Aircraft FHA, early coordination with the Agency is advised.

The methodology developed in this MOC is aimed at identifying which FCs need to be considered in the handling quality assessment. One possible outcome of the HQ assessment is that the failure condition classification of a given FC needs to be increased.

To limit the risk of iterations of the FHA content and the subsequent side effects on the MHQRM, early coordination with the Agency on the safety assessment outputs (FHAs, preliminary quantitative analysis) is also advised.

The visual environment, or the quality of the Visual Cues (VisC), is not defined, and the assumption is that the VisC, in terms of external visual environment and displays/sensors feedback, are sufficient to allow the crew to perform their tasks and be able to achieve and assess Desired and Adequate HQ performance criteria. The most conservative external visual environment (Day, Night, IMC, NVIS) should be used for each phase of flight for which certification is requested. For example, if the aircraft is intended to be certified for flight in Night VFR, the climb, cruise, descent and approach phases of flight should be evaluated by using an appropriate external visual environment, while the take-off and landing phase may use a better external visual environment. The VisC will be defined in the evaluation document and should be agreed with the Agency on a case by case basis.

To apply this method it is first necessary to divide the profile of the aircraft into different phases of flight, e.g. taxi (if applicable), take-off (including rejected take-off), climb, cruise, descent, approach and landing (including landing following a failure condition and balked landing). The classification for each phase of flight is done because there could be failure conditions at aircraft level that affect HQs only in one particular phase of flight, as for example the loss of Global Navigation Satellite System (GNSS) could result in a reduced accuracy in the Translational Rate Command FCS mode in low airspeed, or a failure condition (i.e. multiple electric engine failures) could result in less precise turn coordination in cruise.

For each phase of flight, the different FltCs that have a probability of being encountered of greater than 10-9 per hour are then identified. Special care should be given also to the transition between different phases of flight and aircraft configuration changes (if any). The FltCs probability is given by combining (multiplying) the probability of the aircraft being in a specific FE, the probability of the aircraft having a FC that affects HQ (not only flight control system failures, but any other, including lift/thrust system failures) and the probability of an AD being experienced.

When there is an interrelationship between the different probabilities, the FE probability will be adjusted to take this into account. For each FltC, the minimum HQR level is assigned based on the requirements derived from SC VTOL. The applicant should then show compliance by using an approved rating tool in actual flight test, or in a simulator that has been validated and shown to be representative for the test.

4. Minimum ACCEPTABLE HQR

Table 1 describes the different Handling Qualities Rating (HQR) levels and compares them to the System Failure Classification that is contained in MOC VTOL.2510, and to the Cooper Harper Rating Scale.

Exceptional piloting skills should not be required for the achievement of any HQ performance criteria. The evaluation should assess whether Desired or Adequate criteria are met, and the associated workload in terms of physical and/or mental compensation required by the crew.

Table 1: Handling Qualities Ratings definition (Example for Cruise)

Handling Qualities Rating (HQR)	Description	MOC VTOL.2510 Failure Conditions Classifications	Cooper Harper Rating Scale (CHR)
Satisfactory (SAT)	Handling Qualities allow achievement of desired performance criteria without exceptional piloting skills and with no or minimal pilot compensation.	Up to Minor	1-3
Adequate (ADQ)	Handling Qualities allow achievement of desired performance criteria or adequate performance criteria without exceptional piloting skills and with moderate to extensive pilot compensation.	Major	4-6
Controllable (CON)	Handling Qualities DO NOT allow achievement of adequate performance criteria WITHOUT exceptional piloting skills. Allows however continued safe flight and landing, without exceptional piloting skills, after a transient condition or reconfiguration to retain control, if necessary.	Hazardous	7-9

Table 2 is an example for the Cruise phase of flight, and shows the minimum HQR for each FltC, defined as a combination of the FE and the level of AD, relative to the probability of the FC being evaluated. Similar tables could be created for the other phases of flight, as the type of FC, most critical from a HQs point of view, could vary depending on the phase of flight. The minimum HQR for each table will not vary across the different tables, but, since the FC, FE and AD levels may vary depending on the phase of flight, including the probabilities of occurrence, it might be beneficial to have different tables or groups of tables depending on the phase of flight.

The different FE are (Table 3): Normal Flight Envelope (NFE), Operational Flight Envelope (OFE) and Limit Flight Envelope (LFE).

The AD level (Table 4) can be Light, Moderate or Severe.

The FC probabilities (Table 5) are in accordance with the aircraft level MOC VTOL.2510 quantitative probability values. Probability values for Probable up to Remote Failure Conditions have been grouped together for table readability reasons, as the minimum HQR would be the same.

It is important to highlight that NOT every combination of AD, FC and FE should be tested.

Table 2 Minimum Acceptable Handling Qualities Rating

Phase of flight: CRUISE (Example)									
FltC $X_{FE} * X_{FC} * X_{AD}$	Atmospheric Disturbance (AD)								
	Light			Moderate			Severe		
	Flight Envelope (FE)								
Failure Condition (FC)	**NFE**	**OFE**	**LFE**	**NFE**	**OFE**	**LFE**	**NFE**	**OFE**	**LFE**
Nominal Condition	SAT	SAT	CON	SAT	SAT	CON NOTE 1	SAT	ADQ NOTE 1	CON NOTE 1
Probable up to Remote Failure Conditions:	SAT	ADQ	CON	SAT	ADQ NOTE 1	CON NOTE 1	ADQ	CON NOTE 1	CON NOTE 1
Extremely Remote Failure Conditions:	ADQ	ADQ	CON	ADQ	CON NOTE 1	NOTE 2	CON	NOTE 2	NOTE 2

NOTE 1:. This is considered to be a transient condition, and it is expected that better HQR will be achieved when the AD level is decreased. Likewise it should be demonstrated that better HQRs are achieved in the more favourable Flight Envelopes: such transition should be relatively quick and without requiring exceptional piloting skills.

NOTE 2: This FC is shaded in red as it could possibly have a related probability lower than Extremely Improbable, and should not be considered. If the FC probability is greater than Extremely Improbable, then the minimum HQR should be CON.

The probabilities in Tables 3, 4 and 5 apply when they are considered separately. When obvious interrelationships exist due to the design or the intended or expected operation of the aircraft, the way to address this within MHQRM is to modify the FE probability value. For example, for FltCs with Moderate and Severe AD levels in CRUISE and APPROACH, an atmospheric (windshear) event may require an escape operational procedure that results into entry in the LFE, resulting in a LFE probability of 10^0 (i.e. 1 or certain). Similarly, an aircraft flying at the boundaries of the NFE, may experience overspeed due to a gust and fall into the OFE, hence the modified FE would be 10^0 (i.e. 1 or certain). This probability adjustment concept would also apply to FCs where, for example, a loss of warnings or a loss of envelope protection might contribute to excursions outside the NFE or OFE, in which case the flight envelope probability should be increased appropriately. In this latter case, the change of probability will be evaluated case by case and should be agreed with the Agency.

5. Probability definitions and determination

(f) Flight Envelope (FE)

The flight envelope probabilities will depend on the aircraft architecture. The automatic envelope protection provisions (if available) and the cues to the crew will be the determining factors.

The flight crew should operate the aircraft by definition in the NFE. Excursions into the OFE and LFE are determined by AD, by transient conditions due to failures (that can have different probabilities based on the design), or by expected human errors.

These probabilities should be adjusted to account for the interrelationship between AD and FC events (section 4).

Applicants should provide probabilities based on the evidence that they have available to substantiate them, and based on their aircraft characteristics.

Visual and aural warnings, or specific aircraft characteristics at the boundaries of the envelopes (vibrations, noise) could grant credits for increasing the probability of remaining within a given FE.

The probability values proposed by the applicant should be substantiated with actual flight test data.

Table 3: Probability of Occurrence of the Flight Envelope (FE)

Flight Envelope	Notes	Probability X_{FE}
Normal Flight Envelope (NFE)	Generally associated with routine operational and/or prescribed conditions. At the boundaries of this envelope there could be means to raise the awareness of the crew (cautions).	10^0
Operational Flight Envelope (OFE)	The crew should be aware that the operation occurs outside the NFE. At the boundaries of the OFE, warnings and/or EFCS envelope protection means could be present. The Aircraft Flight Manual (AFM) limitations should be consistent with the boundaries of the OFE. When considering airspeed to define the envelope, the high speed boundaries of the OFE would be the current V_{NE}.	TBD
Limit Flight Envelope (LFE)	The crew should never operate in this envelope; a return should be made at least to the OFE. This is the maximum extent in terms of envelope that needs to be investigated from a HQ point of view but should not be included in the AFM. The boundaries of the LFE are associated with aircraft limits.	TBD

(g) Atmospheric Disturbance (AD)

The atmospheric disturbance level ranges from the complete absence of any disturbance up to the atmospheric disturbance level (gusts) that are considered for the structural limits of the aircraft. The AD considered could be different depending on which phase of flight is being evaluated.

Additional steady state relative winds values, for the most critical azimuth, are established to show compliance with the applicable requirements when the aircraft is operating based on ground references (e.g. Take-off, Hover, Landing).

The amplitude of the gusts to be considered for the structural design will be defined in MOC VTOL.2215 "Flight Load Conditions". Non-symmetric gust cases should be considered when evaluating HQ. The shapes of the gusts may also be a critical factor for HQ and should be evaluated.

The steady state relative wind values are derived from the experience from CS-27, and have been identified as being 17 kt. This value is the minimum to be used for airworthiness approval; applicants may choose higher steady wind values based on market requirements.

The steady wind value should be evaluated only in the phases of flight that are close to the ground. The controllability in steady winds should be demonstrated for all FC in Light AD level (without gusts and turbulence).

The exact values of the gusts are currently not defined for each AD level. Even the related probabilities (X_{AD}), which are modified in respect to Appendix E to AC25-7D to account for the Urban Environment, will need to be verified by recorded data which are currently not available.

Table 4: Probability of Occurrence Guidelines of Atmospheric Disturbance (AD)

Atmospheric Disturbance	Notes	Probability X_{AD}
Light:	No appreciable turbulence and steady state winds less than 3 kt with no appreciable gusts.	10^0
Moderate:	Light to moderate turbulence. Changes in altitude and/or attitude occur. Usually causes variations in indicated airspeed.	TBD
Severe:	Turbulence that causes large, abrupt deviations in altitude and/or attitude. Usually causes large variations in indicated airspeeds.	TBD

(h) Aircraft or System Failure Condition affecting HQ (FC)

The Failure Condition probabilities (X_{FC}) relate to the probability of encountering a Failure Condition which affects HQs. This may include, but is not limited to, the FCS or lift/thrust system. The MHQRM should be linked to the Safety Assessment Process at aircraft level. Feedback should be provided into the different Safety Assessment Elements, such as the Functional Hazard Assessment (FHA), Preliminary System Safety Assessment (PSSA), Fault Tree Analysis (FTA), System Safety Assessment (SSA) or Failure Mode and Effect Analysis (FMEA), and vice versa to check if the assumptions of these Safety Assessment Elements in terms of effect (when the driving factor are HQ) are confirmed by the MHQRM evaluation.

Table 5: Probability of Occurrence Guidelines of Failure Condition affecting HQ (FC)

Failure Condition	Notes	Probability X_{FC}
Nominal Operation:	No failures	10^0
Up to Major Failure conditions:	Failures with an effect on HQR not more severe than MAJOR.	NOTE 3
Hazardous Failure conditions:	Failures with a HAZARDOUS effect on HQR.	$\leq 10^{-7}$ NOTE 3
NOTE 3: The applicant may use any value derived from the safety assessment process, provided it meets the safety objectives. Allowable quantitative probabilities for "probable", "remote" and "extremely remote" are defined in MOC VTOL.2510 §8		

VTOL.2140 Control forces

n/a

(a) Reserved.

(b) Reserved.

(c) Residual control forces must not fatigue or distract the flight crew during normal operations of the aircraft and likely abnormal or emergency operations. The trim control, if installed, must not introduce any undesirable discontinuities in control force gradients.

VTOL.2145 Flying qualities

n/a

(a) Within its flight envelopes, the aircraft must show suitable stability and control feel, in all axes.

(b) Within its flight envelopes, no aircraft may exhibit any divergent stability characteristic, so as to require exceptional piloting skills, alertness, or strength or otherwise endanger the aircraft and its occupants.

VTOL.2150 Stall characteristics and stall warning

n/a

(a) If part of the lift is generated by a wing, the aircraft must have controllable stall characteristics in straight flight, turning flight, and accelerated turning flight with a clear and distinctive stall warning that provides sufficient margin to prevent inadvertent stalling.

(b) Reserved.

(c) Reserved.

(d) Reserved.

(e) Reserved.

VTOL.2155 (reserved)

n/a

VTOL.2160 Vibration

n/a

(a) Each part of the aircraft must be free from excessive vibration throughout the limit flight envelope.

(b) Reserved.

(c) Reserved.

(d) Reserved.

VTOL.2165 Flight in icing conditions

n/a

(a) An applicant who requests certification for flight in icing conditions must demonstrate that the aircraft can be safely operated in the icing conditions for which certification is requested.

(b) The applicant must provide a means to detect any icing conditions for which the aircraft is not certified to operate and demonstrate the aircraft's ability to avoid or exit those conditions.

(c) The applicant must develop an operating limitation to prohibit intentional flight, including take-off and landing, into icing conditions for which the aircraft is not certified to operate.

FLIGHT INFORMATION

VTOL.2170 Operating Limitations

n/a

(a) The following flight information must be established:

(1) operating limitations, procedures and instructions necessary for the safe operation of the aircraft; and

(2) essential speeds and performance information.

SUBPART C — STRUCTURES

VTOL.2200 Structural design envelope

n/a

The applicant must determine the structural design envelope, which describes the range and limits of aircraft design and operational parameters for which the applicant will show compliance with the requirements of this Subpart. The applicant must account for all aircraft design and operational parameters that affect structural loads, strength, durability, and aeroelasticity, including:

(a) structural design airspeeds to be considered when determining the corresponding manoeuvring and gust loads must:

(1) if part of the lift is generated by a wing, be sufficiently greater than the stalling speed of the aircraft to safeguard against loss of control in turbulent air, if applicable; and

(2) provide sufficient margin for the establishment of practical operational limiting airspeeds.

(b) flight load conditions to be expected in service;

(c) mass variations and distributions over the applicable mass and centre of gravity envelope, within the operating limitations;

(d) loads in response to all designed control inputs; and

(e) redistribution of loads if deflections under load would significantly change the distribution of external or internal loads.

MOC VTOL.2200 Structural design envelope

n/a

The following design values and limitations should be established to show compliance with the structural requirements of this Subpart, for each aircraft configuration or flight mode, as appropriate:

(Note: Failure conditions need not be taken into account when defining these design values and limitations.)

(a) The design maximum and design minimum weights.

(b) The lift/thrust units design rpm ranges with power on and power off, if applicable. These design values should provide adequate margin to accommodate the variations in rpm speed occurring in any manoeuvre.

(c) Design Airspeeds:

(3) *Maximum level flight speed, V_H*. The maximum level flight speed at maximum continuous power;

(4) Maximum Design speed, V_D.

(5) *Never-Exceed speed, V_{NE}*. V_{NE} should not be greater than 0.9 times V_D.

(6) *Velocity of Normal Operations*, V_{NO} is the maximum structural cruising speed. V_{NO} should be defined by the applicant and should be less than or equal to V_H and V_{NE}

(7) *Maximum design rearward and sideward flight speeds*. The maximum design rearward and sideward speeds should be defined to be no less than 1.11 times the maximum permitted rearward and sideward speeds.

(8) Design speed for maximum gust intensity, V_B (for Category Enhanced). For V_B, the following applies:

(A) V_B should not be less than the speed determined by the intersection of the line representing the maximum positive lift $C_{N\ MAX}$ and the line representing the rough air gust velocity on the gust V-n diagram, or $V_{S1}\sqrt{n_g}$, whichever is less, where –

(a) n_g the positive aircraft gust load factor due to gust, at speed V_{NO}, and at the particular weight under consideration; and

(b) V_{S1} is the stalling speed with the flaps retracted at the particular weight under consideration.

(B) V_B need not be greater than V_{NO}.

(C) If loss of control due to stall is not possible, or definition of V_B in accordance with (A) is not applicable, V_B should be defined according to the VTOL operating limit for flight in turbulent conditions.

(d) The centre of gravity limits corresponding to the configuration of the aircraft.

(e) The rotational speed ratios between each lift/thrust unit and each connected rotating component, as applicable.

(f) The positive and negative limit manoeuvring load factors should be defined based on the maximum capability of the aircraft, taking into account the flight control system (without failure cases), for which:

(9) The probability of being exceeded is shown by analysis to be extremely improbable within the design altitude and temperature range;

(10) The selected values are appropriate to each weight condition between design maximum and minimum weights and associated critical centres of gravity; and

(11) The positive load factor is not less than 2.0 and the negative limit manoeuvring load factor is not less than -0.5.

Note: An absolute maximum positive and negative limit manoeuvring load factor may be proposed for acceptance by the Agency, as appropriate for the aircraft operation and consistent with current Certification Specifications (e.g. CS 23.337 and CS 27.337).

(g) Ranges of altitudes and temperature for which certification is requested.

(h) Ranges of position of adjustable elements of lift/thrust units and control devices, if applicable.

VTOL.2205 Interaction of systems and structures

n/a

For aircraft equipped with systems that affect structural performance, either directly or as a result of failure or malfunction, the applicant must account for the influence and failure conditions of these systems when showing compliance with the requirements of this Subpart.

MOC VTOL.2205 Interaction of systems and structures

n/a

1. General

The following criteria should be used for compliance with VTOL.2205 for aircraft equipped with flight control systems, autopilots, stability augmentation systems, load alleviation systems, flutter control systems, fuel management systems and any other system the failure of which could affect the load condition or aeroelasticity characteristics of the aircraft. If this MOC is used for other systems, it may be necessary to adapt the criteria to the specific system.

(a) The criteria defined herein only address the direct structural consequences of the system responses and performances and cannot be considered in isolation but should be included in the overall safety evaluation of the aircraft. These criteria may in some instances duplicate standards already established for this evaluation. These criteria are applicable to any structure the loading of which may be modified by failure(s) of a system. Specific criteria that define acceptable limits on handling characteristics or stability requirements when operating in the system degraded or inoperative mode are not provided in this MOC.

(b) Depending upon the specific characteristics of the aircraft, additional studies may be required that go beyond the criteria provided in this appendix in order to demonstrate the capability of the aircraft to meet other realistic conditions such as alternative gust or manoeuvre descriptions for an aircraft equipped with a load alleviation system.

(c) The following definitions are applicable to this MOC.

(1) *Structural performance*: Capability of the aircraft to meet the structural requirements of SC-VTOL.

(2) *Flight limitations*: Limitations that can be applied to the aircraft flight conditions following an in-flight occurrence and that are included in the flight manual (e.g., speed limitations, avoidance of severe weather conditions, etc.).

(3) *Operational limitations*: Limitations, including flight limitations, that can be applied to the aircraft operating conditions before dispatch (e.g., fuel, payload and Master Minimum Equipment List limitations).

(4) *Probabilistic terms*: The probabilistic terms (probable, improbable, extremely improbable) used in this MOC are the same as those used in MOC VTOL.2510.

(5) *Failure condition*: The term failure condition is the same as that used in MOC VTOL.2510, however this MOC applies only to system failure conditions that affect the structural performance of the aircraft (e.g., system failure conditions that induce loads, change the response of the aircraft to inputs such as gusts or pilot actions, or lower flutter margins).

2. Effects of Systems on Structures

(a) General. The following criteria will be used in determining the influence of a system and its failure conditions on the aircraft structure. The analysis should be performed for each aircraft configuration or flight mode, as appropriate.

(b) System fully operative. With the system fully operative, the following apply:

(1) Limit loads should be derived in all normal operating configurations of the system from all the limit conditions specified in Subpart C, taking into account any special behaviour of such a system or associated functions or any effect on the structural performance of the aircraft that may occur up to the limit loads. In particular, any significant nonlinearity (rate of displacement of control surface, thresholds or any other system nonlinearities) should be accounted for in a realistic or conservative way when deriving limit loads from limit conditions.

(2) The aircraft should meet the strength requirements of SC-VTOL (Static strength, residual strength), using the specified factors to derive ultimate loads from the limit loads defined above. The effect of nonlinearities should be investigated beyond limit conditions to ensure the behaviour of the system presents no anomalies compared to the behaviour below limit conditions. However, conditions beyond limit conditions need not be considered when it can be shown that the aircraft has design features that will not allow it to exceed those limit conditions.

(3) The aircraft should meet the aeroelastic stability requirements of VTOL.2245

(c) System in the failure condition. For any system failure condition not shown to be extremely improbable, the following applies:

(1) At the time of occurrence. At the time of failure, the aircraft should be evaluated in 1-g level flight and also the most critical flight condition from the usage spectrum defined under MOC VTOL.2240(a)(b). Starting from these flight conditions, a realistic scenario, including pilot corrective actions, should be established to determine the loads occurring at the time of failure and immediately after failure.

Note: Failure scenarios may be excluded from the evaluation, if the probability of occurrence of the failure mode combined with the probability of being in the flight condition is shown to be extremely improbable.

(i) For static strength substantiation, these loads should be multiplied by an appropriate factor of safety that is related to the probability of occurrence of the failure in order to establish theultimate loads to be considered for design. The factor of safety (F.S.) is defined in Figure 1 where 10^{-X} is equal to the probability associated to Extremely Improbable for the aircraft Category and number of passengers in accordance with MOC VTOL.2510.

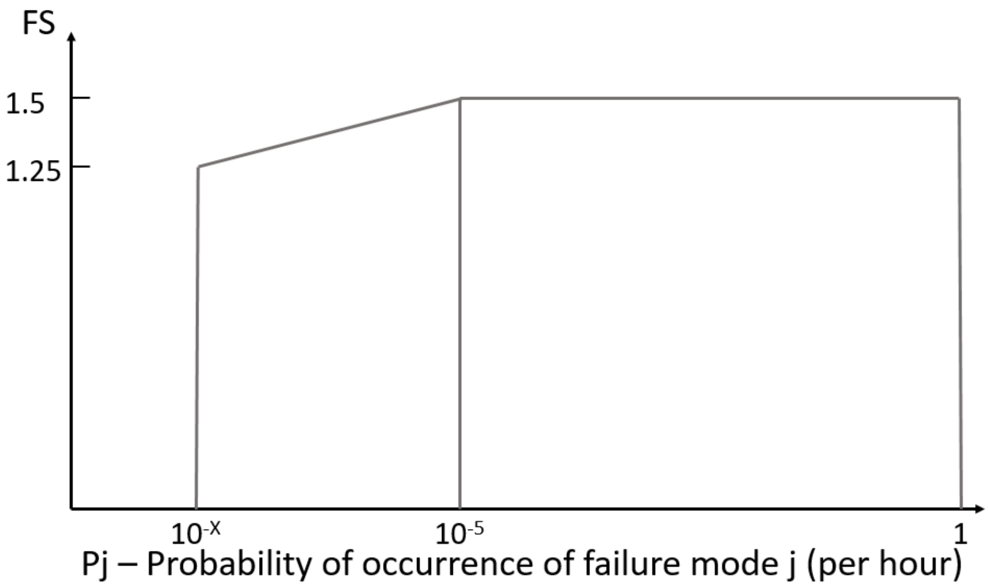


Figure 1: Factor of safety at the time of occurrence

(ii) For residual strength substantiation, the aircraft should be able to withstand two thirds of the ultimate loads defined in subparagraph (c)(1)(i).

(iii) Freedom from aeroelastic instability should be shown up to V_D. The margins intended by MOC VTOL.2245 should be maintained.

(iv) For failure conditions that result in excursions beyond the never-exceed speed, V_{NE}, freedom from aeroelastic instability should be shown to increased speeds, so that the margins intended by MOC VTOL.2245 are maintained. Similarly, any failure condition that results in excursions beyond other operating limitations, such as rpm ranges, freedom from aeroelastic instability should be shown considering these exceedances.

(v) Failures of the system that result in forced structural vibrations (oscillatory failures) should not produce loads that could result in detrimental deformation of primary structure.

(2) For the continuation of the flight. For the aircraft, in the system failed state and considering any appropriate reconfiguration and flight limitations, the following apply:

(i) The loads derived from the following conditions should be determined:

(A) The following limit flight manoeuvring conditions specified in MOC VTOL.2215 should be determined, at speeds up to V_{NE} or the speed limitation prescribed for the remainder of the flight, unless otherwise stated:

(c) Symmetrical flight load conditions

(d) Symmetrical Pull-up and Recovery

(e) Symmetrical Pushover and Recovery

(f) Rolling Flight Conditions

(g) Yawing Conditions (or V_H, whichever is lower)

(h) 50ft/sec gust cases (or V_H, whichever is lower)

(B) The limit ground loads specified in MOC VTOL.2220

(ii) For static strength substantiation, each part of the structure should be able to withstand the loads in subparagraph (2)(i) of this paragraph multiplied by a factor of safety depending on the probability of being in this failure state. The factor of safety is defined in Figure 2 where 10^{-X} is equal to the probability associated to Extremely Improbable for the aircraft Category and number of passengers in accordance with MOC VTOL.2510.

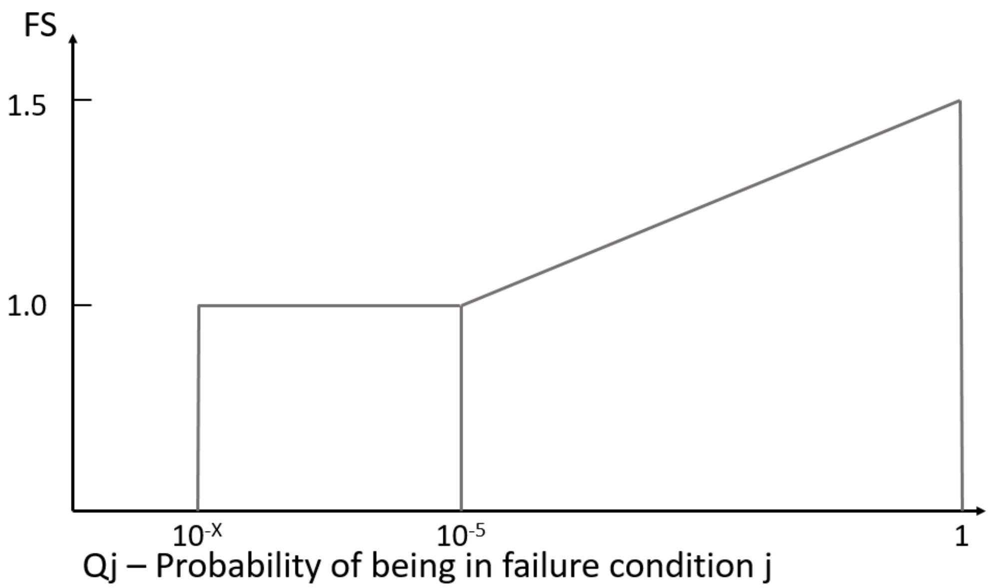


Figure 2: Factor of safety for continuation of flight

$Q_j = (T_j)(P_j)$ where:

T_j = Average time spent in failure condition j (in hours)

P_j = Probability of occurrence of failure mode j (per hour)

Note: If Pj is greater than 10^{-3} per flight hour then a 1.5 factor of safety should be applied to all limit load conditions specified in Subpart C.

(iii) For residual strength substantiation, the aircraft should be able to withstand two thirds of the ultimate loads defined in subparagraph (c)(2)(ii).

(iv) If the loads induced by the failure condition have a significant effect on VTOL.2240(a) and (b) durability then their effects should be taken into account.

(v) Freedom from aeroelastic instability should be shown up to a speed determined from Figure 3. Flutter clearance speeds V' and V'' may be based on the speed limitation specified for the remainder of the flight using the margins defined by MOC VTOL.2245.

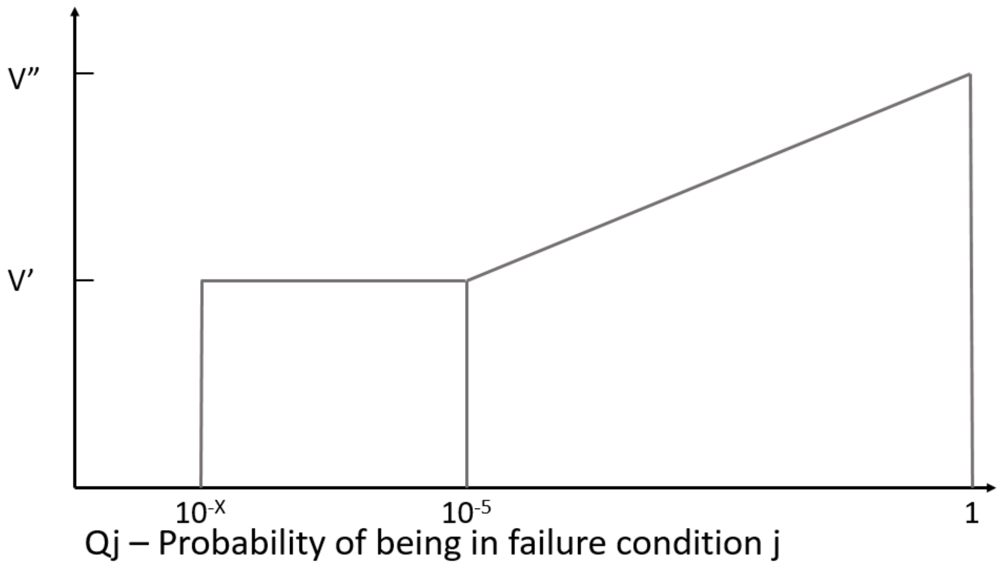


Figure 3: Clearance speed

V' = Clearance speed as defined by maximum permissible speed (V_{NE}) in the failed condition times 1.11

V''= An increase of 20% of V’

Qj = (Tj)(Pj) where:

Tj = Average time spent in failure condition j (in hours)

Pj = Probability of occurrence of failure mode j (per hour)

Note: If Pj is greater than 10^{-3} per flight hour, then the flutter clearance speed should not be less than V''.

(vi) Freedom from aeroelastic instability should also be shown up to V' in Figure 3 above, for any probable system failure condition combined with any damage required or selected for investigation by VTOL.2240

(3) Consideration of certain failure conditions may be required by other paragraphs of SC-VTOL regardless of calculated system reliability. Where the failure analysis shows the probability of these failure to be less than the probability associated to Extremely Improbable for the aircraft Category and number of passengers in accordance with MOC VTOL.2510, criteria other than those specified in MOC VTOL.2510 may be used for structural substantiation to show continued safe flight and landing (for Category Enhanced) or controlled emergency landing (for Category Basic)

(d) Failure indications. For system failure detection and indication, the following applies:

(1) The system should be checked for failure conditions, not extremely improbable, that degrade the structural capability below the level required by SC-VTOL or significantly reduce the reliability of the remaining system. As far as reasonably practicable, the flight crew should be made aware of these failures before flight. Certain elements of the control system, such as mechanical and hydraulic components, the use of special periodic inspections, and daily checks for electronic components maybe proposed , in lieu of detection and indication systems to

achieve the objective of this requirement. These certification maintenance requirements should be limited to component failures that are not readily detectable by normal detection and indication systems and where service history shows that inspections will provide an adequate level of safety.

(2) The existence of any failure condition, that is not extremely improbable, during flight that could significantly affect the structural capability of the VTOL capable aircraft and for which the associated reduction in airworthiness can be minimised by suitable flight limitations, should be signalled to the flight crew. For example, failure conditions that result in a factor of safety between the aircraft strength and the loads of Subpart C below 1.25, or flutter margins below V", should be signalled to the flight crew during flight.

(e) Dispatch with known failure conditions. If the aircraft is to be dispatched in a known system failure condition that affects structural performance, or affects the reliability of the remaining system to maintain structural performance, then the provisions of VTOL.2205 should be met for the dispatched condition and for subsequent failures. Flight limitations and expected operational limitations may be taken into account in establishing Qj as the combined probability of being in the dispatched failure condition and the subsequent failure condition for the safety margins in Figures 2 and 3. These limitations should be such that the probability of being in this combined failure state and then subsequently encountering limit load conditions is extremely improbable. No reduction in these safety margins is allowed if the subsequent system failure rate is greater than 10^{-3} per hour.

STRUCTURAL LOADS

VTOL.2210 Structural design loads

n/a

(a) The applicant must:

(1) determine structural design loads resulting from likely externally or internally applied pressure, force or moment which may occur in flight, ground and water operations, ground- and water-handling, and while the aircraft is parked or moored;

(2) determine the loads required by VTOL.2210(a)(1) at all critical combinations of parameters, on and within the boundaries of the structural design envelope; and

(3) the magnitude and distribution of these loads must be based on established physical principles within the structural design envelope.

MOC VTOL.2210 Structural Design Loads

n/a

1. Loads (General)

CS 27.301(b) and (c) Amdt. 6 is accepted as a means of compliance.

Methods used to determine load intensities and distributions should be validated by flight load measurement unless the methods used for determining those loading conditions are shown to be reliable or conservative.

2. Flight Loads (General)

CS 27.321(a) Amdt. 6 is accepted as a means of compliance.

Note: more detailed MOC on flight loads to be accounted for are available in MOC VTOL.2215.

3. Design Fuel Loads

For aircraft with disposable fuel, the following is applicable:

(a) The disposable load combinations should include each fuel load in the range from zero fuel to the selected maximum fuel load.

(b) If fuel is carried in the wings or other aerodynamic elements, the maximum allowable weight of the aircraft without any fuel in this tank(s) should be established as “maximum zero wing fuel weight” or “maximum zero ‘aerodynamic element’ fuel weight”, if it is less than the maximum weight.

(c) For Category Enhanced, a structural reserve fuel condition, not exceeding the fuel necessary for compliance with VTOL.2430(b)(4), may be selected, considering the most critical fuel distribution. If a structural reserve fuel condition is selected, it should be used as the minimum fuel weight condition for showing compliance with the flight load requirements of MOC VTOL.2215 and:

(1) The structure should be designed to withstand a condition of zero fuel in the wing or aerodynamic element at limit loads corresponding to:

(i) 90 percent of the manoeuvring load factors defined in MOC VTOL.2200, and

(ii) Gust velocities equal to 85 percent of the values prescribed in MOC VTOL.2200.

(2) The durability evaluation of the structure should account for any increase in operating stresses resulting from the design condition of (c)(1).

(3) The flutter, deformation, and vibration requirements should also be met with zero fuel in the wings or aerodynamic elements.

4. Jacking loads

CS 23.507 Amdt. 4 is accepted as a means of compliance

5. Mooring loads

(a) The mooring fittings and its support structure should be analysed for the loads resulting from the maximum permissible mooring wind speed multiplied by 1.11.

(b) The wind should be considered as acting parallel to the ground in any direction to the aircraft. Ground gust conditions should also be considered.

(c) All permissible mooring configurations, i.e. number of mooring lines and their range of angles from the aircraft fitting, should be evaluated.

(d) The maximum wind speed and gust conditions for mooring and the permissible mooring configurations should be published in the Aircraft Maintenance Manual.

6. Towing loads (towbar)

CS 23.509 Amdt. 4 is accepted as a means of compliance for towing an aircraft with the use of a towbar.

7. Towbarless towing (aircraft with wheeled landing gear)

(a) General

Towbarless towing vehicles are generally considered as ground equipment and are as such not subject to direct approval by the certifying agencies. However, these vehicles should be qualified in accordance with the applicable SAE ARP documents. It should be ensured that the nose landing gear and supporting structure is not being overloaded (by static and dynamic (including fatigue) loads) during towbarless towing operations with these vehicles. This should be ensured by the applicant, either by specific investigations as described in (b) and (c) below, or alternatively, by publishing aircraft load limitations in a towbarless towing vehicle assessment document, to allow towbarless towing vehicle manufacturers to demonstrate their vehicles will not overload the aircraft.

(b) Limit static load cases

(1) For the limit static load cases, the investigation may be conducted by rational analysis supported by test evidence.

(2) The investigation should take into account the influence on the towing loads of the tractive force of the towing vehicle including consideration of its weight and pavement roughness.

(3) The investigation should include all towbarless towing operation scenarios.

(4) Operations that are explicitly prohibited need not be addressed.

(c) Durability evaluation

(1) Durability evaluation of the impact of towbarless towing on the airframe should be conducted under the provision of VTOL.2240.

(2) The contribution of the towbarless towing operational loads to the fatigue load spectra for the nose landing gear and its support structure needs to be evaluated.

(3) The impact of the towbarless towing on the certified life limits of the landing gear and supporting structure should be determined.

(4) The fatigue spectra used in the evaluation should:

(i) consist of typical service loads encountered during towbarless towing operations, which cover the loading scenarios noted above for static considerations, and

(ii) be based on measured statistical data derived from simulated service operation or from applicable industry studies.

(d) Other considerations

(1) Specific combinations of towbarless towing vehicle(s) and aircraft that have been assessed as described above and have been found to be acceptable, along with any applicable towing instructions and/or limitations should be specified in the Instructions for Continued Airworthiness and in the Aircraft Flight Manual.

(2) Aircraft braking, while the aircraft is under tow, may result in loads that exceed the aircraft's design load and may result in structural damage and/or nose gear collapse. For these reasons, the aircraft manufacturer should ensure that the appropriate information is provided in the Aircraft Maintenance Manual and in the Aircraft Flight Manual to preclude aircraft braking during normal towbarless towing. Appropriate information should also be provided in the Instructions for Continued Airworthiness to inspect the affected structure should aircraft braking occur, for example in an emergency situation.

8. Ground loads: unsymmetrical loads on multiple-wheel units

(a) *Pivoting loads*. CS 23.511(a) Amdt. 4 is accepted as a means of compliance

(b) *Unequal tyre loads.* The loads established under MOC VTOL.2220 level landing, tail-down and one-wheel landing conditions should be applied in turn, in a 60/40% distribution, to the dual wheels and tyres in each dual wheel landing gear unit.

(c) *Deflated tyre loads.* For the deflated tyre condition –

(1) 60% of the loads established under the MOC VTOL.2220 level landing, tail-down and one-wheel landing conditions should be applied in turn to each wheel in a landing gear unit; and

(2) 60% of the limit drag and sideloads and 100% of the limit vertical load established under the MOC VTOL.2220 sideload, lateral drift and braked roll conditions, or lesser vertical load obtained under (1), should be applied in turn to each wheel in the dual wheel landing gear unit.

VTOL.2215 Flight load conditions

n/a

(a) Critical flight loads must be established for symmetrical and asymmetrical loading from all combinations of flight parameters and load factors at and within the boundaries of the manoeuvre and gust envelope:

(1) at each altitude within the operating limitations, where the effects of compressibility are taken into account when significant;

(2) at each mass from the design minimum mass to the design maximum mass; and

(3) at any practical but conservative distribution of disposable load within the operating limitations for each altitude and weight.

(b) Vibration and buffeting must not result in structural damage

(1) up to dive speed.

(2) within the limit flight envelope.

(c) Flight loads resulting from a likely failure of an aircraft system, component, or lift/thrust unit must be determined.

MOC VTOL.2215 Flight load conditions

n/a

The following flight load conditions specify a set of flight conditions to be evaluated to conservatively cover the most extreme manoeuvring capability of the aircraft. They should be analysed with the aircraft in the most critical flight phases and flight configurations, in accordance with the design limitations as defined in MOC VTOL.2200. The flight load cases may be simulated or defined by combining conservative combinations of parameters, or a combination of these approaches. Full control input ranges should be considered when determining the flight load cases. The limitations imposed by the flight control system, without failure cases, may be taken into account.

Failure conditions need not be considered, except as specified in paragraph (h) of this MOC.

If automation systems, such as autopilot upper modes, or a Detect and Avoid system can generate higher control loads than pilot inputs, the corresponding loads should be taken into account.

Suddenly. For the purposes of this MOC, 'suddenly' is defined as the time interval for complete control input based on a rational analysis, supported by test. For conventional pilot controls, such as stick and pedal, 'suddenly' may be assumed as 0.2 seconds for complete control inputs.

(a) Symmetrical Flight Load Conditions: To produce these flight load conditions, the airspeeds should be set at V_D in forward, rearward and sideward flight. The normal load factor should be unity.

(b) Symmetrical pull-up and recovery: To produce these flight load conditions, with the aircraft in an initial trim condition at forward speeds:

(1) Displace the input control suddenly in order to achieve a nose up motion, to the maximum deflection as limited by the control stops;

(2) Maintain the maximum input control displacement to allow the aircraft to pitch upwards and achieve the specified positive manoeuvring load factor; and

(3) Return the input control suddenly to that required for level flight.

The most critical initial trim forward speeds should be evaluated, up to and including V_D. This flight load condition should be evaluated in both power on and power off rpm ranges, if applicable.

The intention of the symmetric pull-up and recovery manoeuvre is to achieve maximum pitch acceleration, maximum positive normal load factor and maximum aircraft nose-up angle-of attack.

(c) Symmetrical Pushover and Recovery:

To produce these flight load conditions, with the aircraft in an initial trim condition at forward speed :

(1) Displace the input control suddenly, in order to achieve a nose down motion, to the maximum deflection as limited by the control stops;

(2) Maintain the maximum input control displacement to allow the aircraft to pitch downwards and achieve the specified negative manoeuvring load factor; and

(3) Return the input control suddenly to that required for level flight.

The most critical initial trim forward speeds should be evaluated, up to and including V_D.

The intention of the symmetric pushover and recovery manoeuvre is to achieve maximum pitch acceleration, maximum negative normal load factor and maximum aircraft nose-down angle-of attack.

(d) Rolling Flight Conditions (Rolling pull-up and recovery):

To produce these flight load conditions, with the aircraft in an initial trim condition at forward speed:

(1) Displace the input control suddenly, in order to achieve a nose up and rolling moment, to the maximum deflection as limited by the control stops, or that necessary to achieve a positive load factor of not less than two-thirds that specified in paragraph (b);

(2) Maintain the control displacements to allow the aircraft to pitch, roll and achieve a positive manoeuvring load factor of at least two-thirds that specified in (b); and

(3) Return the controls suddenly to those required for level flight.

The maximum rate of roll and the load factor should occur simultaneously. The most critical initial trim forward speeds should be evaluated, up to and including V_D.

The intention of the rolling pull-up and recovery manoeuvre is to achieve maximum pitch acceleration, maximum roll acceleration with two-thirds of the maximum positive normal load factor.

(e) Yawing Conditions:

To produce these flight load conditions, with the aircraft in an initial trim condition, with zero yaw, at forward speeds and in the hover:

(1) Displace the input control suddenly, in order to achieve a yawing motion, to the maximum deflection as limited by the control stops;

(2) Maintain the input control displacement to allow the aircraft to yaw to the maximum transient sideslip angle;

(3) Allow the aircraft to attain the resulting sideslip angle; and

(4) Return the directional control suddenly to neutral.

Both right and left yaw conditions should be evaluated. The most critical initial trim forward speeds should be evaluated, from zero up to and including V_{NE} or V_H, whichever is less.

Yawing conditions in the hover (spot turns) should be evaluated in both in ground effect (IGE) and out of ground effect (OGE).

The intention of the yawing condition is to achieve maximum yaw acceleration and maximum aircraft sideslip angles.

(f) Gust Conditions:

(1) The aircraft should be designed to withstand, at each critical airspeed up to V_D, including hovering, the loads resulting from vertical and horizontal gusts of 9.14 metres per second (30 ft/s).

(2) The aircraft should be designed to withstand, at each critical airspeed up to V_H or V_{NE}, whichever is lower, including hovering, the loads resulting from vertical and horizontal gusts of 15.24 metres per second (50 ft/s).

(3) For Category Enhanced, the aircraft should be designed to withstand, at each critical airspeed up to V_B including hovering, the loads resulting from vertical and horizontal rough air gusts of 20.12 m/s (66 ft/s)

(4) The aircraft should be designed to withstand 100% of the vertical gust condition of (0) acting on one side of the aircraft.

(5) The following assumptions should be made:

(i) For wing structures, the shape of the vertical gust is –

$$U = \frac{Ude}{2}\left(1 - \cos\frac{2\pi s}{25\bar{C}}\right)$$

Where –

s = Distance penetrated into gust (ft);

$\bar{C}$= Mean geometric chord of wing (ft) if applicable, or other dimension rationally derived; and

Ude = Derived gust velocity referred to in paragraphs (1) to (3)

(ii) For other structures, and for horizontal gusts, either sharp-edged (instantaneous) gusts or sharp-edged gusts modified by an alleviation (attenuation) factor may be used for calculating aerodynamic loads for the aircraft and any installed stabilizing surfaces.

(g) Take-off from sloping ground

(1) The aircraft should be designed for take-off from level ground and up to the maximum slope and aircraft orientation combinations permitted for operation

(2) Vertical lift/thrust should be the maximum achievable for the take-off configuration of the aircraft

(3) This condition should be evaluated in both in ground effect (IGE) and out of ground effect (OGE)

(h) Unsymmetrical loads due to lift/thrust unit failure:

(1) The aircraft should be designed for unsymmetrical loads resulting from the failure of the critical lift/thrust unit, including blade release, at speeds up to V_D including hover.

(2) The timing and magnitude of the probable pilot or automated corrective action should be conservatively estimated, considering the characteristics of the particular lift/thrust unit and aircraft combination.

(3) In the case of no corrective action being automatically performed, pilot corrective action, may be assumed to be initiated at the time maximum pitching, rolling or yawing velocity is reached, but not earlier than 2 seconds after the lift/thrust unit failure.

(4) Characterisation of the lift/thrust failure may be considered using analysis in lieu of an instantaneous loss of lift/thrust if appropriate, but should be done in a rational and conservative manner, and appropriately verified by test.

VTOL.2220 Ground and water load conditions

n/a

The applicant must determine the structural design loads resulting from taxi, take-off, landing, and handling conditions on the applicable surface in normal and adverse attitudes and configurations.

MOC VTOL.2220 Ground and water load conditions

n/a

Note: In this issue, this MOC addresses ground conditions only; water load conditions will be defined in a later issue of this MOC.

1. General

(a) *Loads and equilibrium.* For limit ground loads –

(1) The limit ground loads obtained in this MOC should be considered to be external loads applied to the aircraft structure as if it were acting as a rigid body; and

(2) If significant, the structural dynamic response of the airframe should be taken into account considering all critical mass distributions; and

(3) In each specified landing condition, the external loads should be placed in equilibrium with linear and angular inertia loads in a rational or conservative manner.

(b) *Critical centres of gravity.* The critical centres of gravity within the range for which certification is requested should be selected.

2. Ground load conditions and assumptions

(a) For specified landing conditions, all weights should be considered up to the maximum weight. Total lift may be assumed to act through the centre of gravity throughout the landing impact. This lift may not exceed two-thirds of the design maximum weight.

(b) Unless otherwise prescribed, for each specified landing condition, the aircraft should be designed for a limit load factor of not less than the limit inertia load factor substantiated under MOC VTOL.2235 “*Limit drop test*”.

3. Tyres and shock absorbers

CS 27.475 Amdt. 6 is accepted as a means of compliance.

4. Landing conditions

(a) The following landing conditions apply depending on the configuration of the VTOL

(1) The following landing conditions apply to landing gear with two wheels aft, and one or more wheels forward, of the centre of gravity:

(i) The level landing conditions in CS 27.479 Amdt. 6 are accepted as means of compliance.

(ii) The tail-down landing conditions in CS 27.481 Amdt. 6 are accepted as means of compliance.

(iii) The one-wheel landing conditions in CS 27.483 Amdt. 6 are accepted as means of compliance.

(iv) The lateral drift landing conditions in CS 27.485 Amdt. 6 are accepted as means of compliance.

(v) The braked roll conditions in CS 27.493 Amdt. 6 are accepted as means of compliance.

(2) The ground loading conditions for landing gear with tail wheels in subparagraphs (a) to (h) of CS 27.497 Amdt. 6 are accepted as means of compliance.

(3) The ground loading conditions for landing gear with skids in CS 27.501 Amdt. 6 are accepted as means of compliance.

(b) CTOL aircraft should be designed for the additional loading conditions specified in this paragraph. In showing compliance with this paragraph, the following apply:

(1) The level landing conditions in CS 23.479(a) and (b) Amdt. 4 are accepted as a means of compliance.

(2) The tail down landing conditions in CS 23.481 Amdt. 4 are accepted as a means of compliance.

(3) The one-wheel landing conditions in CS 23.483 Amdt. 4 are accepted as a means of compliance.

(4) The sideload conditions in CS 23.485 Amdt. 4 are accepted as a means of compliance.

(5) The braked roll conditions in CS 23.493 Amdt. 4 are accepted as a means of compliance.

(6) The supplementary conditions for tail wheels in CS 23.497 Amdt. 4 are accepted as a means of compliance.

(7) The supplementary conditions for nose wheels in CS 23.499 Amdt. 4 are accepted as a means of compliance.

(8) The supplementary conditions for ski-planes in CS 23.505 Amdt. 4 are accepted as a means of compliance.

(c) The ski landing conditions in CS 27.505 Amdt.6 are accepted as a means of compliance.

5. **Taxiing Condition**

   (a) CS 27.235 Amdt. 6 is accepted as a means of compliance.

   (b) In addition, for aircraft with conventional take-off and landing (CTOL) capability the aircraft should be designed to withstand the loads that would occur when take-offs and landings are performed on unpaved runways having the roughest surface that may be expected in normal operation.

VTOL.2225 Component loading conditions

n/a

(a) The applicant must determine the loads acting upon all relevant structural components, including rotor assemblies, in response to:

   (1) interaction of systems and structures;

   (2) structural design loads;

   (3) flight load conditions;

   (4) ground and water load conditions; and

   (5) limit input torque from lift/thrust units at any rotational speed.

(b) Reserved.

MOC VTOL.2225 Component Loading Conditions

n/a

1. **Engine Torque**

   (a) For turbine engines, CS 27.361(a) Amdt. 6 is accepted as a means of compliance.

   (b) For reciprocating engines, CS 27.361(b) Amdt. 6 is accepted as a means of compliance.

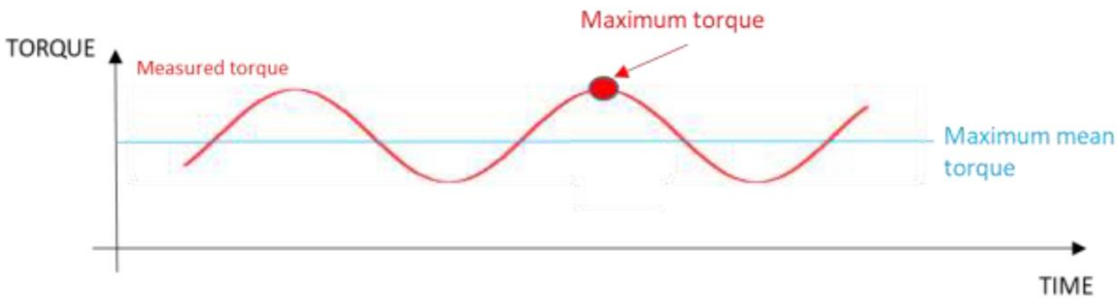
   (c) For electrical engines, the limit torque should not be less than the highest of:

      (1) The torque imposed by sudden engine stoppage due to malfunction or structural failure (such as rotor jamming), and

      (2) The mean torque multiplied by one of the following factors:

         (i) 1.25 for engines for which torque oscillations as a function of time are shown to be negligible, i.e. in the same range as a turbine engine

         (ii) $x + 0.25$ for engines for which torque oscillations as a function of time cannot be considered as negligible. x expresses the amplitude of the torque oscillations around a mean value as shown below:



$$x = \frac{Maximum\ torque}{Maximum\ mean\ torque}$$

2. Unsymmetrical loads for horizontal aerodynamic surfaces

(a) CS 27.427 Amdt. 6 is accepted as a means of compliance for horizontal aerodynamic surfaces that do not have installed lift/thrust units.

(b) In case of a load distribution deviation from CS 27.427 (b) Amdt. 6 and for designs with lift/thrust units installed on the horizontal aerodynamic surface, the applicant is expected to provide the rationale justifying that the selected load distribution conservatively addresses the limit flight load conditions of MOC VTOL.2215. Combinations of unsymmetrical loads, within the design envelope, should be considered including those resulting from asymmetric wing slip-stream effects, lift/thrust unit asymmetric thrust, propeller or lift/thrust unit wake effects and unsymmetrical control surface forces, as applicable. Dedicated flight load and/or wind tunnel measurements should be performed to confirm the suitability of the proposed criteria.

3. Outboard fins or winglets

(a) If outboard fins or winglets are included on the horizontal surfaces or wings, the horizontal surfaces or wings should be designed for their maximum load in combination with loads induced by the fins or winglets and moment or forces exerted on horizontal surfaces or wings by the fins or winglets.

(b) The endplate effects of outboard fins or winglets should be taken into account in applying the flight conditions of MOC VTOL.2215 to the vertical surfaces.

(c) If outboard fins or winglets extend above and below the horizontal surface, the critical vertical surface loading (the maximum load per unit area as determined under MOC VTOL.2215) should be applied as follows:

(1) For configurations where there is no possible influence of the lift/thrust unit wake on the outboard fin or winglet:

(iii) The part of the vertical surfaces above the horizontal surface, with 80% of that loading applied to the part below the horizontal surface; and

(iv) The part of the vertical surfaces below the horizontal surface, with 80% of that loading applied to the part above the horizontal surface;

(2) For configurations with possible influence of the lift/thrust unit wake on the outboard fin or winglet a conservative loading distribution should be determined, supported by flight load and/or wind tunnel measurement.

4. Special Devices

CS 23.459 Amdt. 4 is accepted as a means of compliance.

VTOL.2230 Limit and ultimate loads

n/a

(a) Unless special or other factors of safety are necessary to meet the requirements of this Subpart, the applicant must determine:

(1) the limit loads, which are equal to the structural design loads;

(2) the ultimate loads, which are equal to the limit loads multiplied by a 1.5 factor of safety, unless otherwise provided.

(b) Some strength specifications are specified in terms of ultimate loads only, when permanent detrimental deformation is acceptable.

MOC VTOL.2230 Limit and ultimate loads

n/a

The combination of CS 27.301(a) Amdt. 6 and CS 27.303 Amdt. 6 is accepted as a means of compliance.

STRUCTURAL PERFORMANCE

VTOL.2235 Structural strength

n/a

The structure must support

(a) limit loads without:

(1) interference with the safe operation of the aircraft; and

(2) detrimental or permanent deformation.

(b) ultimate loads.

MOC VTOL.2235 Structural strength

n/a

Note: At this issue, this MOC addresses landing gear drop test requirements only. Additional MOC will be added in future issues to address, for example, allowable damages to the aircraft for the Category Basic controlled emergency landing.

(a) *Shock absorption tests*: CS 27.723 Amdt. 6 is accepted as a means of compliance.

(b) *Limit drop test*: CS 27.725 Amdt. 6 is accepted as a means of compliance.

(c) *Reserve energy absorption drop test:* CS 27.727 Amdt. 6 is accepted as a means of compliance. In addition:

(1) Shock absorbing devices, such as oleos, should not "bottom" during the reserve energy drop test. "Bottoming" occurs when displacement of the device no longer occurs with increasing load. (for further guidance see FAA AC 27.727(a)(3) in FAA AC 27-1B Change 7, which is the EASA AMC as per Book 2 of CS-27 Amdt. 6)

Notes:

(1) The proper attitude for the aircraft after the reserve energy absorption drop test is an attitude which allows for permanent deformation of landing gear elements but provides for adequate egress from the aircraft (for further guidance see FAA AC 27.727A (b)(1) in FAA AC 27-1B Change 7, which is the EASA AMC as per Book 2 of CS-27 Amdt. 6).

(2) External accessories that may not impact the landing surface during drop testing include devices such as externally mounted fuel tanks or accessories that are likely to cause post-landing fires. Cameras, loudspeakers, and search lights may be damaged during deformations resulting from reserve energy drop tests if electrical connections are sufficiently protected to preclude electrical fires and the devices are not likely to penetrate fuel tanks and other energy sources. The expendable accessories, if installed, should also be designed to not have "hard points" that would unacceptably damage the aircraft structure under landing impacts by penetration into the occupied areas or fuel tanks. These expendable accessories should be designed with frangible fittings, frangible devices, or comparable design features. Also, these devices should be designed to not significantly alter the energy absorbing ability or design features of the landing gear (for further guidance see FAA AC 27.727A (b)(2) in FAA AC 27-1B Change 7, which is the EASA AMC as per Book 2 of CS-27 Amdt. 6).

(3) External accessories may not contact a level landing surface after "limit landing load" deflection of the landing gear, i.e. the deflection resulting from the limit drop test described in paragraph A of this MOC.

VTOL.2240 Structural Durability

n/a

(a) The applicant must develop and implement inspections or other procedures to prevent structural failures due to foreseeable causes of strength degradation, which could result in serious or fatal injuries, or extended periods of operation with reduced safety margins. Each of the inspections or other procedures developed under VTOL.2240 must be included in the Airworthiness Limitations Section of Instructions for Continued Airworthiness required by VTOL.2625.

(b) For Category Enhanced, the procedures developed for compliance with VTOL.2240(a) must be capable of detecting structural damage before the damage could result in structural failure.

(c) Reserved.

(d) The aircraft must be designed to minimise hazards due to structural damage caused by high-energy fragments from an uncontained lift/thrust unit or rotating-machinery failure.

(e) For Category Enhanced, provisions for in-service monitoring of parts having an important bearing on safety in operations must be established.

MOC VTOL.2240 (a) and (b) Structural durability

n/a

1. Introduction

VTOL.2240 (a) and (b) requests the applicant to perform all necessary evaluations and actions (inspection, procedures) "*to prevent structural failures due to strength degradation, which could result in serious or fatal injuries, or extended periods of operation with reduced safety margins*."

For the **category Basic**, this comprises of any relevant inspections or other procedures to prevent structural failure (e.g. replacement time for safe life evaluation).

For the **category Enhanced**, this includes any relevant inspections or other procedures to detect structural damages before failure (Damage Tolerance evaluation).

A distinction is thus made between categories Basic and Enhanced concerning durability: while both categories have the same objective to prevent structural failures due to strength degradation, for Enhanced category the detection of structural damage is added to VTOL.2240(a).

Table 1 summarises the accepted means to demonstrate compliance with VTOL.2240 (a) and (b) regarding structural durability and the associated guidance material additionally applicable:

Table 1: Summary of the means of compliance for categories basic and enhanced

Type of Structure	Category Basic	Category Enhanced
Metallic	**Sections 7 and 8 in this MOC,** which include the adaptation of CS 27.571 (Amdt. 6) “*Fatigue evaluation of flight structure*” and of AC 27.571 Instead, it is also accepted to use **Sections 3 and 4 in this MOC** which include an adaptation of CS 29.571 “*Fatigue evaluation of metallic structure*” (Amdt. 6) and of AC 29.571	**Sections 3 and 4 in this MOC,** which include the adaptation of CS 29.571 (Amdt. 6) “*Fatigue evaluation of metallic structure*” and of AC 29.571 (flaw tolerance and crack growth method)
Composite	**Sections 5 and 6 in this MOC**, which include the adaptation of CS 27.573 (Amdt. 6) “*Fatigue evaluation of composite rotorcraft structures*” and of AC 27.573 and AMC 20-29.	
Design precaution for metallic and composite	CS 23.627 (Amdt 4) “*Fatigue strength*” is accepted as means of compliance	

2. Selected Structural Elements (SSE)

Selected Structural Elements (SSE) are parts which carry flight or ground loads, or parts loaded in fatigue the failure of which would reduce the structural integrity of the aircraft.

The following is a non-exhaustive list of SSE examples:

(a) Wing and empennage.

(1) Control surfaces, slats, flaps, and their mechanical systems and attachments (hinges, tracks, and fittings);

(2) Integrally stiffened plates;

(3) Primary fittings;

(4) Principal splices;

(5) Skin or reinforcement around cutouts or discontinuities;

(6) Skin-stringer combinations;

(7) Spar caps; and

(8) Spar webs.

(b) Fuselage.

(1) Frames and adjacent skin;

(2) Door frames;

(3) Pilot-window posts;

(4) Structural bulkheads;

(5) Skin and any single frame or stiffener element around a cutout;

(6) Skin or skin splices, or both,

(7) Door skins, frames, and latches; and

(8) Window frames.

(c) Landing gear and their attachments.

(d) Engine mount/supports

(e) Lift Thrust Units

 (1) Rotors including blades, propeller, hubs

 (2) Rotor drive systems between the engines and the rotor hubs,

 (3) Transmission mounting

(f) Fixed and rotating control system

3. Means of Compliance for structural durability of metallic structures in the category Enhanced:

(a) Each Selected Structural Element (SSE) should be identified, as defined in Section 2 of this MOC.

(b) A fatigue tolerance evaluation of each SSE should be performed, and appropriate inspections and retirement time or approved equivalent means should be established to avoid failure during the operational life of the VTOL.

(c) Each fatigue tolerance evaluation should include:

 (1) In-flight measurements to determine the fatigue loads or stresses for the SSEs identified in (b) in all critical conditions throughout the range of design limitations required in MOC VTOL.2200 (including altitude effects), except that manoeuvring load factors need not exceed the maximum values expected in operations.

 (2) The loading spectra as severe as those expected in operations based on loads or stresses determined under (c)(1), including external load operations, if applicable, and other high frequency power-cycle operations.

 (3) Take-off, landing, and taxi loads when evaluating the landing gear (including skis and floats) and other affected SSEs.

 (4) For each SSE identified in (b), a threat assessment, which includes a determination of the probable locations, types, and sizes of damage taking into account fatigue, environmental effects, intrinsic and discrete flaws, or accidental damage that may occur during manufacture or operation.

 (5) A determination of the fatigue tolerance characteristics for the SSE with the damage identified in (c)(4) that supports the inspection and retirement times, or other approved equivalent means.

 (6) Analyses supported by test evidence and, if available, service experience.

(d) A residual strength determination should be performed that substantiates the maximum damage size assumed in the fatigue tolerance evaluation. In determining inspection intervals based on damage growth, the residual strength evaluation should show that the remaining structure, after damage growth, is able to withstand design limit loads without failure.

(e) The effect of damage on stiffness, dynamic behaviour, loads and functional performance should be considered.

(f) The inspection and retirement times or approved equivalent means established under this Section should be included in the Airworthiness Limitation Section of the Instructions for Continued Airworthiness required by VTOL.2625

(g) If inspections for any of the damage types identified in (c)(4) cannot be established within the limitations of geometry, inspectability, or good design practice, then supplemental procedures, in conjunction with the SSE retirement time, should be established to minimize the risk of occurrence of these types of damage that could result in a failure during the operational life of the VTOL capable aircraft.

(h) Discrete source damage tolerance evaluation. The aircraft should be capable of successfully completing a flight during which likely structural damage occurs as a result of

(1) Uncontained High-Energy Fragments and Sustained Imbalance as specified in VTOL.2240 (d)

(2) Bird impact as specified in VTOL.2250

4. Additional guidance for structural durability of metallic structures in the category Enhanced:

Table 2 below provides the necessary adaptations to use AC 29.571 A and B as additional guidance for the fatigue of metallic structures in the category Enhanced:

Table 2: Adaptations to AC 29.571 A and B for the fatigue of metallic structures in the category Enhanced

AC 29.571A. § 29.571 (Amendment 29-28) FATIGUE TOLERANCE EVALUATION OF STRUCTURE AC 29.571B. § 29.571 (Amendment 29-55) FATIGUE TOLERANCE EVALUATION OF METALLIC STRUCTURE	
Original Text or reference	**General Changes/Adaptations**
“rotorcraft” and “helicopter”	To be replaced by “*VTOL capable aircraft*”
“the FAA” and “the Administrator”	To be replaced by “*EASA*”
“Principal Structural Element” or “PSE”	To be replaced by “*Selected Structural element*” or “*SSE*”
“§ 29.571”	To be replaced by “VTOL.2240 *(a) and (b)*”
“Catastrophic failure”	Concept not applicable to the VTOL durability objective. To be replaced by “*failure*”.
“§ 29.309”	To be replaced by “VTOL.2200”
“§ 29.1529”	To be replaced by “VTOL.2625 *Instructions for Continued Airworthiness*”
AC 29.571A. § 29.571 (Amendment 29-28) FATIGUE TOLERANCE EVALUATION OF STRUCTURE	
Paragraph	**Changes/ Adaptations in addition to the “General changes/adaptations” above**
	Accepted without additional changes
AC 29.571B. § 29.571 (Amendment 29-55) FATIGUE TOLERANCE EVALUATION OF METALLIC STRUCTURE	
Paragraph	**Changes/ Adaptation in addition to the “General changes/adaptations” above**
a. Purpose	To be replaced by the paragraph below: “*This advisory material provides additional guidance with the provisions of VTOL 2240 (a) and (b) dealing with the fatigue tolerance evaluation of VTOL metallic structure. This guidance applies to conventional metallic materials. (Corresponding guidance for composite structure can be found in AC 27.573. The fatigue evaluation procedures outlined in this advisory material are for guidance purposes only and are neither mandatory nor regulatory in nature. Although a uniform approach to*

	fatigue tolerance evaluation is desirable, it is recognized that in such a complex area, new design features and methods of fabrication, new approaches to fatigue tolerance evaluation, and new configurations may require variations and deviations from the procedures described herein."
d.(1) Definitions	Applicable except PSE (xvi), which should be replaced by the definition of SSE provided in Section 2 of MOC VTOL.2240 (a) and (b)
d.(2).(ii)	The sentence below should be removed: *"~~Further mitigation of the sources of damage may be achieved by adoption of a critical parts plan to help ensure that the condition of the part remains as envisaged by the designer throughout its life cycle (see § 29.602).~~ "*
d.(3).(i) ~~Selection of PSE~~ Selected Structural Elements	The text in (i) should be replaced as follows: "Selection of SSE : All SSE, as defined in Section 2 of MOC VTOL.2240(a) and (b), should be identified. Specific areas of interest within the SSE that may require particular attention include the following:" The text in (A) to (G) remains unchanged.
d.(3).(ii)	"§ 29.309" should be replaced by "VTOL.2215"
(f).(2).Identification of PSE SSE	The first sentence is deleted and should be replaced by: *"The fatigue tolerance evaluation should first consider all airframe structure and structural elements, and assemblies susceptible to fatigue loading or fatigue originated from damage."*
(f).(2).(i)	The first sentence is deleted, since the Failure Mode and Effects Analysis is not required for VTOL durability.
(f).(4).(i) Rotorcraft VTOL Usage Spectrum.	The following is added at the end: *"The existing guidance available for flight spectrum determination are based on aeroplane/rotorcraft usage. However, considering the limited experience available on VTOL the applicant should anticipate a realistic and conservative spectrum addressing all flight phases and flight configurations conservatively. The principle to establish a VTOL spectrum can be derived from the existing guidance material"*
(f).(4).(iv)	To be fully replaced by *"The usage spectrum should be presented to the FAA EASA for their concurrence. It should include normal operation over the range of ~~rotorcraft~~ VTOL configurations including a percent time under 'external load' conditions, in all flight phases and configurations.* *These should be distributed conservatively."*
(f).(4).(v)	To be replaced by: *"AC 27-1B MG 11, provides further detail for the development of the rotorcraft usage spectrums used in the fatigue tolerance evaluations.*
(f).(5).(ii).(F)	Should be modified as follows: *"Credit may be given to manufacturing, transport, handling, installation, and maintenance instructions finalized to minimize or avoid damages. Examples of these processes or instructions could be: "frozen manufacturing processes," ~~Flight Critical Parts programs~~, material selection to mitigate intrinsic flaws like inclusions and defects, procedures to reduce deviations from nominal structures, etc."*
(f).(6). Inspectability and Inspection Methods.	*"§ 29.1529 of the regulatory requirements."* should be replaced by "VTOL.2625 *Instructions for Continued Airworthiness*" *The reference to "§ 29.571" should be replaced by "Section 3 (f) in* MOC VTOL.2240(a) and (b)".
(f).(6).(ii).(D)	*"§ 29.1529 of the regulatory requirements."* should be replaced by "VTOL.2625 *Instructions for Continued Airworthiness*"

	The reference to "§ 29.571" should be replaced by "Section 3 (e) in this MOC VTOL.2240(".
(f).(7).(i) Retirement Times	To remove : "*(as required by § 29.571(d)(iii))*"

5. Means of Compliance for structural durability of composite structures in the categories Basic and Enhanced:

(a) Composite aircraft structure should be evaluated under the damage tolerance requirements (d) unless the applicant establishes that a damage tolerance evaluation is impractical within the limits of geometry, inspectability, and good design practice. In such a case, the composite aircraft structure should undergo a fatigue evaluation in accordance with (c).

(b) Damage Tolerance Evaluation:

(1) Damage tolerance evaluations of composite structures should show that failure due to static and fatigue loads is avoided throughout the operational life or prescribed inspection intervals of the VTOL capable aircraft.

(2) The damage tolerance evaluation should include all SSEs, as defined in Section 2 of this MOC.

(3) Each damage tolerance evaluation should include:

(i) The identification of the structure being evaluated;

(ii) A determination of the structural loads or stresses for all critical conditions throughout the range of limits in VTOL.2215 (including altitude effects), supported by in-flight and ground measurements, except that manoeuvring load factors need not exceed the maximum values expected in service;

(iii) The loading spectra as severe as those expected in service based on loads or stresses determined under (b)(3)(ii), including external load operations, if applicable, and other operations including high torque events. The occurrence distribution of all flight phases and flight configurations should be conservatively selected.

(iv) A Threat Assessment for all structure being evaluated that specifies the locations, types, and sizes of damage, considering fatigue, environmental effects, intrinsic and discrete flaws, and impact or other accidental damage (including the discrete source of the accidental damage) that may occur during manufacture or operation;

(v) An assessment of the residual strength and fatigue characteristics of all structure being evaluated that supports the replacement times and inspection intervals established under (b)(4); and

(vi) allowances for the detrimental effects of material, fabrication techniques, and process variability.

(4) Replacement times, inspections, or other procedures should be established to require the repair or replacement of damaged parts to prevent failure. These replacement times, inspections, or other procedures should be included in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by VTOL.2625 Instructions for Continued Airworthiness.

(vii) Replacement times should be determined by tests, or by analysis supported by tests to show that throughout its life the structure is able to withstand the repeated loads of variable magnitude expected in-service. In establishing these replacement times, the following items should be considered:

(A) Damage identified in the Threat Assessment required by (b)(3)(iv);

(B) Maximum acceptable manufacturing defects and in-service damage (i.e., those that do not lower the residual strength below ultimate design loads and those that can be repaired to restore ultimate strength); and

(C) Ultimate load strength capability after applying repeated loads.

(viii) Inspection intervals should be established to reveal any damage identified in the Threat Assessment required by (b)(3)(iv) that may occur from fatigue or other in-service causes before such damage has grown to the extent that the component cannot sustain the required residual strength capability. In establishing these inspection intervals, the following items should be considered:

(A) The growth rate, including no-growth, of the damage under the repeated loads expected in-service determined by tests or analysis supported by tests; and

(B) The required residual strength for the assumed damage established after considering the damage type, inspection interval, detectability of damage, and the techniques adopted for damage detection. The minimum required residual strength is the limit load.

(5) The effects of damage on stiffness, dynamic behaviour, loads and functional performance should be taken into account when substantiating the maximum assumed damage size and inspection interval.

(c) Fatigue Evaluation:

If an applicant establishes that the damage tolerance evaluation described in (b) is impractical within the limits of geometry, inspectability, or good design practice, the applicant should conduct a fatigue evaluation of the particular composite aircraft structure and:

(1) Identify structure considered in the fatigue evaluation;

(2) Identify the types of damage considered in the fatigue evaluation;

(3) Establish supplemental procedures to minimise the risk of failure associated with damage identified in (c)(2); and

(4) Include these supplemental procedures in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness required by VTOL.2625 Instructions for Continued Airworthiness

(d) Discrete damage source evaluation. The aircraft should be capable of continued safe flight and landing (for Category Enhanced) or controlled emergency landing (for Category Basic) with the likely structural damage occurring as a result of

(1) Uncontained High-Energy Fragments and Sustained Imbalance as specified in VTOL.2240 (d)

(2) Bird impact as specified in VTOL.2250

6. Additional guidance for structural durability of composite structures in the categories Basic and Enhanced:

Table 3 below provides the necessary adaptations to use AC 27.573 as additional guidance for fatigue of composite structures in the categories Basic and Enhanced:

Table 3: Adaptations to AC 27.573 for the fatigue of composite structures in the categories Basic and Enhanced

§ 27.573 (Amendment 27-47) DAMAGE TOLERANCE AND FATIGUE EVALUATION OF COMPOSITE ROTORCRAFT STRUCTURES	
Original Text or reference	**General Changes/Adaptations**
"*rotorcraft*" and "helicopter"	To be replaced by "*VTOL capable aircraft*"
"the FAA", "the Administrator", "the Rotorcraft Directorate"	To be replaced by "EASA"
"*Principal Structural Element*" or "*PSE*"	To be replaced by "*Selected Structural element*" or "*SSE*"
"*§ 27.573*"	To be replaced by "VTOL.2240 (a) and (b)"
"*Catastrophic failure*"	Concept not applicable to the VTOL durability objective. To be replaced by "failure".
"*§ 27.309*"	To be replaced by "VTOL.2200"
"*§ 27.1529*"	To be replaced by "VTOL.2625 *Instructions for Continued Airworthiness*"
"*AC 20-107*"	To be replaced by "*AMC 20-29*"
Paragraph	**Changes/ Adaptation in addition to the "General changes/adaptations" above**
d (20) Design Limit loads	"*§ 27.301(a)*" should be replaced by "VTOL.2230"
d (46) Principal Structural Element (PSE).	"PSE" should be replaced by the definition of "SSE" provided in Section 2 of MOC VTOL.2240 (a) and (b)
f. Procedures for Substantiation of Rotorcraft Composite Structure.	This paragraph is modified as follows: *"The composite structures evaluation has been divided into eight basic regulatory areas to provide focus on relevant regulatory requirements. These eight areas are: fabrication requirements; basic constituent, pre-preg and laminate material acceptance requirements, and material property determination requirements; protection of structure; lightning protection; static strength evaluation; damage tolerance and fatigue evaluation; dynamic loading and response evaluation; and special repair and continued airworthiness requirements. Original as well as alternate or substitute material system constituents (e.g., fibers, resins), material systems (combinations of constituents and adhesives), and composite designs (e.g., laminates, cocured assemblies, bonded assemblies) should be qualified in accordance with the methodology presented in the following paragraphs.*

	Each regulatory area will be addressed in turn. It is important to remember that proper certification of a composite structure is an incremental, building block process, which involves phased" *~~FAA/AUTHORITY~~ EASA involvement ~~and incremental approval~~ in each of the various areas outlined herein. ~~It is recommended that an FAA/AUTHORITY certification team approach be used for composite structural substantiation. The team should consist of FAA/AUTHORITY and cognizant members of the applicant's organization. Personnel who are composites specialists (or are otherwise knowledgeable in the subject) should be primary team member candidates. Once selected, it is recommended that team meetings be held periodically (possibly in conjunction with type boards) during certification to ensure the building block certification process is accomplished as intended. The team should assure that permanent documentation in the form of reports or other FAA/AUTHORITY acceptable documents are included in the certification data package.~~* *The documentation includes but is not limited to the structural substantiation reports (both analysis and test), manufacturing processes and quality control, and Instructions for Continued Airworthiness (maintenance, overhaul, and repair manuals). The Airworthiness Limitations Section of the Instructions for Continued Airworthiness is approved by EASA ~~FAA~~ engineering. Engineering practices for many of the areas identified below are available in CMH-17."*
f.(1).(v).	This paragraph is modified as follows: *"Alternate fabrication and process specifications should be approved and must comply with § ~~27.605~~* VTOL.2260. Any alternate specifications should provide at least the same level of quality and safety as the original specification. Any changes should be presented for *~~FAA~~ EASA approval well in advance of the effective date of the production change."*
f.(2). (i) to (vi)	The first sentence is modified as follows: *"The second area is the basic raw constituent, pre-preg and laminate material acceptance requirements, and material property determination requirements of ~~§§ 27.603 and 27.613~~* VTOL.2260."
f.(3)	The first sentence is modified as follows: *"The third area is the protection of structure as required by § ~~27.609~~* VTOL.2255"
f.(4)	This paragraph is modified as follows: *"The fourth area is the lightning protection requirements of § ~~27.610~~* VTOL.2335 Lightning Protection. Protection should be provided and substantiated in accordance with analysis and with tests such as those of *~~AC 20-53, "Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Caused by Lightning" and FAA Report DOT/FAA/CT-86/8~~ paragraph 17.1 of ASTM F3061/F3061M-19 "Standard Specification for Systems and Equipment in Small Aircraft". ~~For composite structure projects involving rotorcraft certificated to earlier certification bases (which do not automatically include the lightning protection requirements of § 27.610), these requirements should be imposed as special conditions.~~ The design should be reviewed early in the certification process to ensure proper protection is present. The substantiation test program should also be established, reviewed and approved early to ensure proper substantiation."*
f(5)	The first sentence is modified as follows: *"The fifth area is the static strength evaluation requirements of ~~§§ 27.305~~ and ~~27.307~~ VTOL.2235 for composite structure."*
f(5).(iii)	The first sentence is modified as follows: *"Allowables should be evaluated and used as specified in ~~§ 27.613~~ VTOL 2260"*

f(5).(v)	The following sentence is modified as indicated: *"If sufficient process and quality controls cannot be achieved, it may be necessary to account for greater variability with special factors ~~(§ 27.619)~~ VTOL.2265 applied to the design"*
f(6).(i). Background.	The first sentence is modified as follows: *"The static strength determination required by ~~§§ 27.305 and 27.307~~ VTOL.2235 establishes the ultimate load capability for composite structures that are manufactured, operated, and maintained with established procedures and conditions. The damage tolerance and fatigue evaluation required by ~~§ 27.573~~ section 5 of the MOC VTOL.2240 (a) and (b) implies procedures that allow the composite structure to retain the intended ultimate load capability when subjected to expected fatigue loads and conditions during its operational life."*
f(6).(iii) Means of compliance	The following sentences are modified as indicated: *"For each ~~PSE~~ SSE, inspections, replacement times, or other procedures must be established as necessary to avoid ~~catastrophic~~ failure. ~~Compliance with the~~ Following ~~requirementsof § 27.573(d b) and (e)~~Section 5 (b) and (c) of MOC VTOL.2240(a) and (b) should be shown by one, or a combination of, the methods described subsequently…."* *"In that case, supplemental procedures must be established and submitted to ~~the FAA~~ EASA for ~~approval~~ acceptance. In any case, ~~the FAA~~ EASA must ~~approve~~agree with the methodology used ~~for compliance to § 27.573~~ in accordance with Section 4 of MOC VTOL.2240(a) and (b)"*
f(6).(iii) (D) Other Procedures.	The first sentence is modified as follows: *"Other procedures are allowed according to ~~§ 27.573(d)~~ Section 5 (b) of MOC 2240(a) and (b)."*
f(6).(iii) (E) Supplemental Procedures	This paragraph is modified as indicated below: *"If the damage tolerant evaluations as described previously cannot be achieved within the limitations of geometry, inspectability, or good design practice, a fatigue evaluation using supplemental procedures may be proposed to the ~~FAA/AUTHORITY~~ EASA per ~~§ 27.573(e)~~ Section 5 (c) of MOC VTOL.2240(a) and (b).* *The applicant must establish that the damage tolerance criteria are impracticable and cannot be satisfied for the specific ~~PSE~~ SSE, locations, and threats considered. In addition, the types of damage considered in the evaluations must be identified. Finally, supplemental procedures must be established to minimize the risk of ~~catastrophic~~ failure with the damages considered."*
f(6).(iv) (B)(1) Identification of Principal Structural Elements Selected Structural Elements.	The complete subparagraph (1) is replaced with Section 2 of MOC VTOL.2240(a) and (b).
f(6).(iv) (B)(1) (i)	This sentence is modified as follows: *"Rotor blades, propellers and attachment fittings."*
f(6).(v).(B).(1)	The final sentences in this paragraph are modified as follows: *"The distribution and number of strain gauges should cover the load spectrum adequately for each part essential to the safe operation of the rotorcraft as identified in ~~§ 27.573(d)(1)~~ Section 5 (b)(1) of MOC VTOL.2240(a) and (b). Other devices such as accelerometers may be used as appropriate."*
f(6).(v).(C)	This paragraph is replaced by the following: *"Parts to be Strain-Gauged: Fatigue critical sections of the Selected Structural Elements (SSE), as defined in Section 2 of MOC VTOL.2240(a) and (b), should be strain-gauged."*

f(6).(vi).(A).(4)	The last sentence is modified as follows: *"A note to this effect should also appear in the rotorcraft VTOL airworthiness limitations section of the maintenance manual prepared in accordance with ~~§§ 27.573 and 27.1529~~ VTOL.2240 and VTOL.2625"*
f(7)	The first sentence is modified as follows: *"The seventh major area is the dynamic loading and response requirements of ~~§§ 27.241, 27.251, and 27.629~~ VTOL.2160, for vibration and resonance frequency determination and separation for aeroelastic stability and stability margin determination for dynamically critical flight structure."*
f(8)	The first sentence is modified as follows: *"The eighth area is the special repair and continued airworthiness requirements of ~~§§ 27.611, 27.1529,~~ VTOL.2625 ~~and 14 CFR part 27 Appendix A~~, for composite structures."*

7. Means of Compliance for structural durability of metallic structures in the category Basic

(a) General. Each SSE, as defined in Section 2 of this MOC, should be identified and evaluated under (b), (c), (d), or (e). The following applies to each fatigue evaluation:

(1) The procedure for the evaluation should be approved.

(2) The locations of probable failure should be determined.

(3) In-flight measurement should be included in determining the following:

(i) Loads or stresses in all critical conditions throughout the range of limitations in VTOL.2200, except that manoeuvring load factors need not exceed the maximum values expected in operation.

(ii) The effect of altitude upon these loads or stresses.

(4) The loading spectra should be as severe as those expected in operation. The loading spectra should be based on loads or stresses determined under (a)(3).

(b) *Fatigue tolerance evaluation*. It should be shown that the fatigue tolerance of the structure ensures that the probability of fatigue failure is extremely remote without establishing replacement times, inspection intervals or other procedures under MOC VTOL.2625.

(c) *Replacement time evaluation*. It should be shown that the probability of fatigue failure is extremely remote within a replacement time furnished under MOC VTOL.2625.

(d) *Fail-safe evaluation*. The following apply to fail-safe evaluation:

(1) It should be shown that all partial failures will become readily detectable under inspection procedures furnished under MOC VTOL.2625.

(2) The interval between the time when any partial failure becomes readily detectable under (d)(1), and the time when any such failure is expected to reduce the remaining strength of the structure to limit or maximum attainable loads (whichever is less), should be determined.

(3) It should be shown that the interval determined under (d)(2) is long enough, in relation to the inspection intervals and related procedures furnished under MOC VTOL.2625, to provide a probability of detection great enough to ensure that the probability of failure is extremely remote.

(e) *Combination of replacement time and fail-safe evaluations.* A component may be evaluated under a combination of (c) and (d). For such component it should be shown that the probability of failure is extremely remote with an approved combination of replacement time, inspection intervals, and related procedures furnished under MOC VTOL.2625.

(f) *Fatigue strength:* The structure should 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.

(g) Discrete source damage evaluation. The aircraft should be capable of successfully completing a flight during which likely structural damage occurs as a result of

(1) Uncontained High-Energy Fragments and Sustained Imbalance as specified in VTOL.2240 (d)

(2) Bird impact as specified in VTOL.2250

8. Additional guidance for structural durability of metallic structures in the category Basic:

Table 4 below provides the necessary adaptations to use AC 27.571 as additional guidance for fatigue of metallic structures in the category Basic

Table 4: Adaptations to AC 27.571 for the fatigue of metallic structures in the category Basic

AC 27.571 FATIGUE EVALUATION OF FLIGHT STRUCTURE AC 27.571. § 27.571 (Amendment 27-26) FATIGUE EVALUATION OF FLIGHT STRUCTURE	
Original Text or reference	**General Changes/Adaptations**
“*rotorcraft*” and “helicopter”	To be replaced by “*VTOL capable aircraft*”
“the FAA” and “the Administrator”	To be replaced by “EASA”
“*Principal Structural Element*” or “*PSE*”	To be replaced by “*Selected Structural element*” or “*SSE*”
“*§ 27.573*”	To be replaced by “VTOL.2240 (a) and (b)”
“*Catastrophic failure*”	Concept not applicable to the VTOL durability objective. To be replaced by “failure”.
“*§ 27.309*”	To be replaced by “VTOL.2200”
“*§ 29.1529*”	To be replaced by “VTOL.2625 Instructions for Continued Airworthiness”
AC 27.571. § 27.571 (Amendment 27-26) FATIGUE EVALUATION OF FLIGHT STRUCTURE	
Paragraph	**Changes/ Adaptation in addition to the “General changes/adaptations” above**
a. (2)	The last sentence is modified as follows: “~~*See Appendix A of FAR Part 27, paragraphs A27.4 and paragraph AC 27.1529 for information*~~ VTOL.2625 *Instructions for Continued Airworthiness*”
a. (3)	To be removed
a. (4)	To be removed

b.(2) (i)	The following sentence should be deleted: "~~(An FAA/AUTHORITY letter for specific test authorization would ordinarily be required.)~~"
b.(5)	*This paragraph should be completely replaced by the following sentence:* *"The Applicant should propose a conservative spectrum that conservatively covers all intended operations of the VTOL capable aircraft. The occurrence distribution of all flight phases and flight configurations should be conservatively selected ."*
AC 27.571A. §27.571 (Amendment 27-33) FATIGUE EVALUATION OF FLIGHT STRUCTURE FOR CATEGORY A CERTIFICATION	
Paragraph	**Changes/ Adaptation in addition to the "General changes/adaptations" above**
a. Explanation	To be removed
b. Procedures	The following introduction text is to be removed: "*~~For Category A certification, the tests specified in paragraph AC 29.571A are required for fatigue tolerance evaluation.~~* *~~Paragraph AC 29.571A is repeated in this section~~*"
b(7) bearing	New section to be added with the following content: "Additional guidance for bearings is provided under MOC VTOL 2250(c)"

MOC VTOL.2240(d) High Energy Fragments – Particular Risk Analysis

n/a

The objective of VTOL.2240(d) and this particular risk analysis applies to lift/thrust unit or rotating-machinery failures, such as propellers, rotors that provide lift, compressor and turbine rotors of turbine engines and APUs and, electric engine rotor and cooling fans. Service experience of conventional aircraft has shown that damages due to high-energy fragments, for example following uncontained compressor and turbine rotor failures, continue to occur. VTOL capable aircraft have no service experience while the introduction of new technology and architectures means that VTOL capable aircraft cannot directly use conventional aircraft service experience to determine the likelihood and effects of failures. For Category Enhanced the failure of a lift/thrust unit or other rotating-machinery should therefore be assumed and the corresponding risk should be assessed, in line with the objective of VTOL.2250(c), with specific considerations for simultaneous or cascading effects presented in this Particular Risk Analysis. For Category Basic, a lower safety objective, in line with VTOL.2510 and the current approach on conventional products, is accepted.

Applicants for either Basic or Enhanced category who wish to utilize a means to shut down or stop individual rotor systems to mitigate hazards considered under this risk analysis should ensure that sufficient and reliable indications, control means and operational procedures are included in the design to allow for correct identification of a failed or hazardous lift/thrust unit and an effective means to meet the analysis assumptions of imbalance exposure herein (see also MOC VTOL.2425(b)).

This MOC does not address the risk to people on the ground, which should be addressed separately.

1. **For Category Basic:**

(a) For Category Basic 1 and Basic 2 aircraft (0 to 6 passengers), no Particular Risk Analysis is requested for high energy fragments.

(b) For Category Basic 3 (7 to 9 passengers) the following methodology should be applied:

(1) For turbine engines, the paths and sizes of fragments described in AMC 20-128A and AMC 25.963(e) in Book 2 of CS-25 Amdt. 24 can be used.

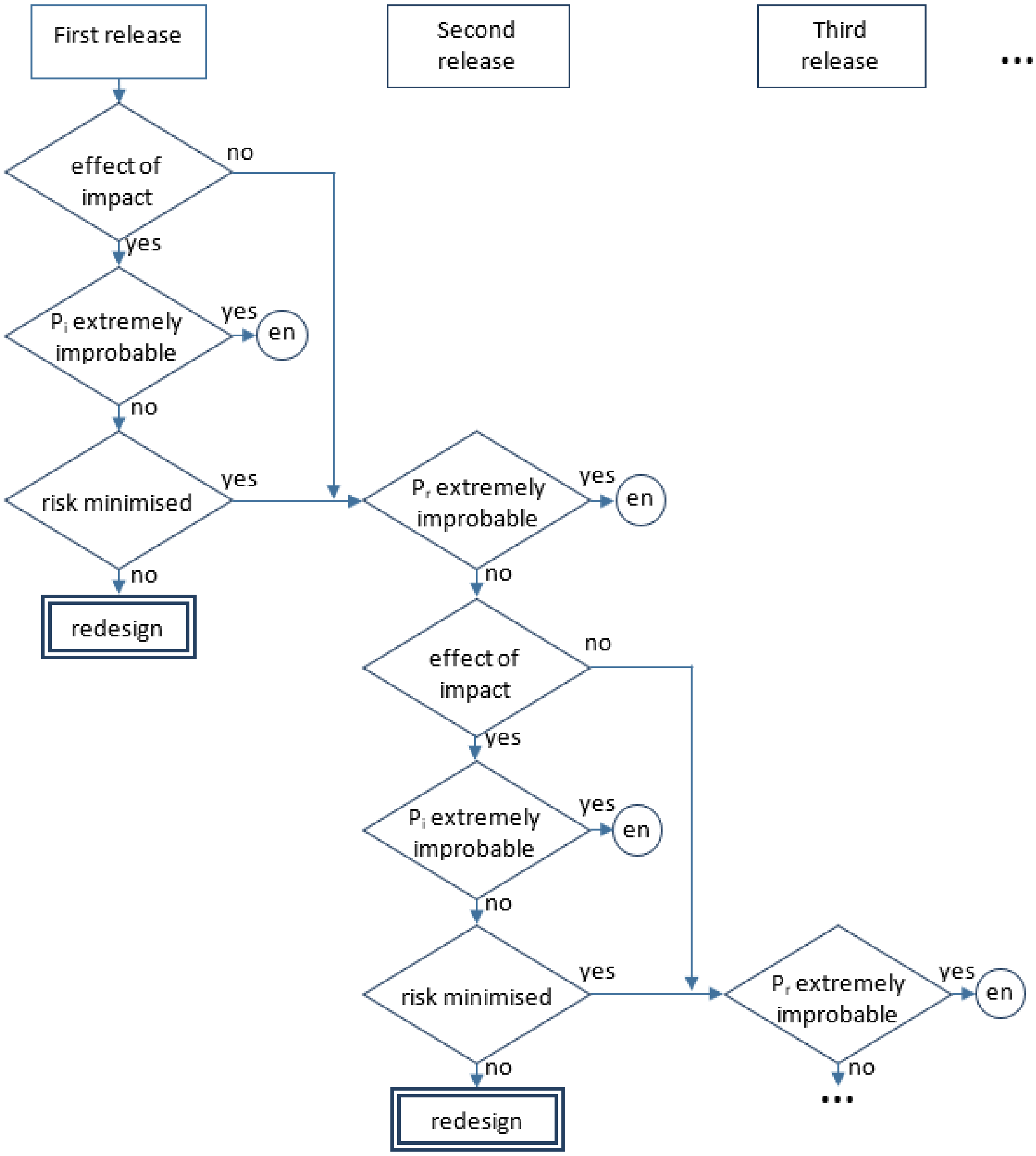
(2) For propellers and other types of fragments, the impact area should be established based on test, analysis, or both. Applicants may use data from propellers with similar physical and operating characteristics to establish the impact area.

(3) The lift/thrust unit or rotating-machinery probability of a Catastrophic effect due to a fragment release should be extremely improbable, in accordance with VTOL.2510, or the risk should be acceptably minimised by the design to the maximum practicable extent.

(i) An applicant may choose to not calculate the probability of a fragment release or impact and demonstrate minimisation directly.

(ii) If the risk is only minimised when impacting a lift/thrust unit, the analysis should be carried further to the next release.

(iii) All consequences of the impact should be considered including possible cascading effects taking into account the overall probability of failure (Figure 1).



P_r = overall probability of the n[th] release occurring
P_i = overall probability of the n[th] impact occurring

Figure 1: Methodology for the cascading failure evaluation for Category Basic 3

2. For Category Enhanced

(a) Fragments to consider:

A failure of a lift/thrust unit or other rotating-machinery should be assumed. The Safety Analysis should consider all fragments that are released with residual energy. For propellers this could be the complete blade from the aerofoil surface to the retention and any component attached to the blade/hub. This could include counterweights, clamps, erosion shields, cuffs, de-ice boots, and pitch change pins.

(b) Path and size of fragments:

For turbine engines, the paths and sizes of fragments described in AMC 20-128A and AMC 25.963(e) in Book 2 of CS-25 Amdt. 24 can be used. For propellers and other types of fragments the impact area should be established based on test, analysis, or both. Applicants may use data from propellers with similar physical and operating characteristics to establish the impact area.

(c) Hazards:

Hazards from the failure of a lift/thrust unit or other rotating-machinery to be considered should include damage due to the impact of the high-energy fragments and the imbalance created by such failure. Further guidance material on engine imbalance, including windmilling considerations, can be found in AMC 25-24. Applicants may utilize design means of control and the stoppage of those lift/thrust units, for which the probability of failure of those control means is shown to be commensurate with the objectives of VTOL.2510, and should rationally consider the environment of operation under the expected imbalance conditions.

(d) Safety Analysis:

(1) It should be assessed that the failure of a lift/thrust unit or rotating-machinery does not have a catastrophic effect as defined in MOC VTOL.2510.

(2) The assessment should include aircraft systems, structures (including energy storage), occupants and other lift/thrust units.

(3) Due to the distributed propulsion, the failure of a lift/thrust unit may, for some architectures, potentially cause other lift/thrust failures in a chain reaction. Specifically, the assessment of simultaneous or cascading failures of lift/thrust units through fragment release should use the following methodology:

(i) The first release shall not have an immediate catastrophic effect, that is:

(A) no catastrophic effect due to the lift/thrust unit failure, and

(B) no catastrophic effect due to a fragment impact into systems, structure, occupants or other lift/thrust units.

(ii) The first release may however have a catastrophic effect by cascading events if extremely improbable. This is determined as follows:

(A) If the first impact can cause a second release of a fragment from a lift/thrust unit, the probability of the second release should be evaluated.

(B) In the determination of the overall probability of the second release, consideration can be given to the probability of occurrence of the first release and the probability of chain reaction (incl. hazardous trajectory probability and associated second release probability).

(C) If this overall probability of the second release (P_r) is less than 10^{-9} per flight hour, the hazards can be considered to have been minimised and the analysis can stop there.

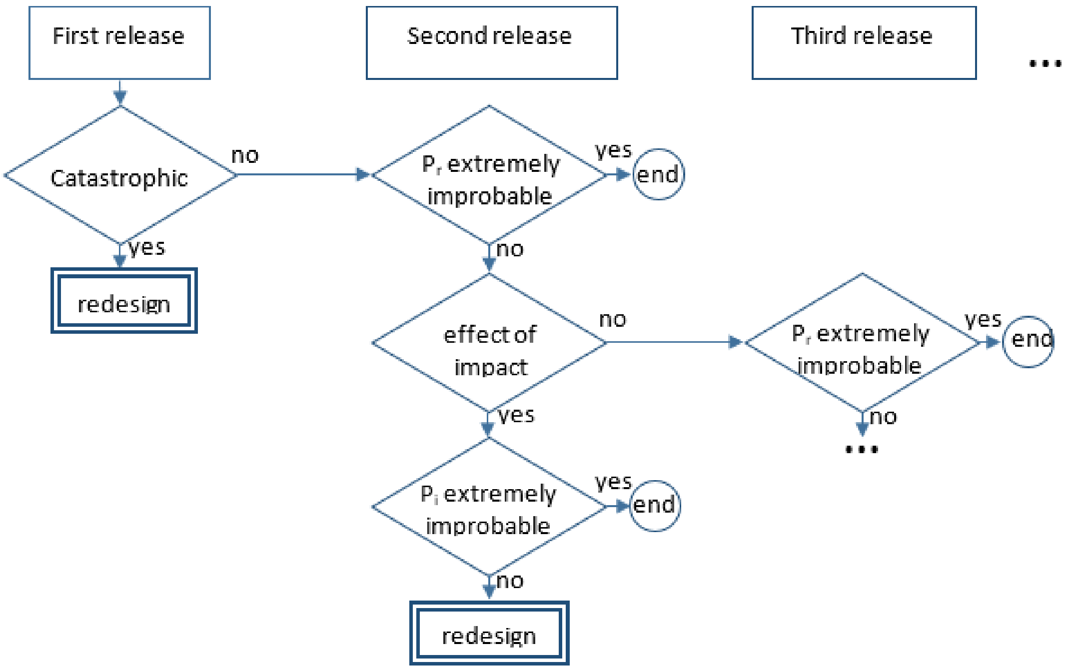
(D) If this overall probability of the second release (P_r) is higher than 10^{-9} per flight hour, the effect of the second impact should be assessed:

(a) If the effect of the second impact is catastrophic, it must be extremely improbable ($P_i < 10^9$ per flight hour).

(b) If the effect of the second impact is not catastrophic, the overall probability of the third release should then be evaluated.

(E) The analysis should continue until the overall probability of the next release (P_r) or impact (P_i) is less than $1 * 10^{-9}$ per flight hour, or all lift/thrust units have been assessed (Figure 2).

(iii) The residual risk for each lift/thrust unit and the whole aircraft should then be quantified to verify that the combined risks do not exceed an acceptable level.



P_r = overall probability of the n^th release occurring
P_i = overall probability of the n^th impact occurring

Figure 2: Methodology for the cascading failure evaluation for Category Enhanced

3. Structural Failure Rate (Category Basic and Enhanced)

(a) The framework outlined in section (b) “Structural Failure Rate” of MOC VTOL.2250(c) may be used to determine the probability of occurrence of the first failure, which is then subsequently used in the cascading scenario.

(b) The qualitative approach of section (b) “Structural Failure Rate” of MOC VTOL.2250(c) cannot be used to justify a Structural Failure Rate lower that 10^{-7} per flight hour. All three aspects should be addressed, i.e. design robustness, quality of the part and in-service continued structural robustness, however not necessarily equally.

MOC VTOL.2240 (e) In-Service Monitoring

n/a

(a) For the purpose of VTOL.2240(e) parts having an important bearing on safety in operations are parts the failure of which has hazardous or catastrophic effects for the aircraft.

(b) The provisions for In-Service Monitoring established in compliance with VTOL.2240(e) should include the necessary means to verify the health and operating conditions to help ensure the continued durability, integrity and functionality of the part. Actions arising from a finding could in the future change the certification approach for similar components or lead to continued airworthiness action.

(c) The applicant should define an In-Service Monitoring programme which should verify the continuity of the effectiveness of design and maintenance provisions, as well other procedures, implemented to comply with VTOL.2240(a) and (b), VTOL.2250(a) and (c) and VTOL.2625 through the life of the type design.

(d) The following means can be used to support the In-Service Monitoring programme:

(1) Analysis of occurrence reports.

(2) Analysis of unscheduled removal rates.

(3) Results of scheduled maintenance.

(4) Strip Reports / Analysis at overhaul.

(5) Post-TC development and maturity tests.

(6) Additional inspection (non-destructive and/or destructive) and testing on selected high time or rejected components.

(7) Feedback from lead customers.

(8) Audits of subcontractors and suppliers of parts.

(9) Statistical process control data of manufacturing processes that are essential to ensure the integrity and/or functionality of the part.

(10) Review of concessions.

(11) Changes in utilization and operating environment.

(12) Operator / applicant working group activities.

(13) Health monitoring data.

(14) Usage monitoring data.

(e) The assessments required by the In-Service Monitoring programme should be performed at suitable periods through the complete life of the subject component types, considering the types of operation, environment and ageing effects expected. In addition, the applicant should consider scheduling early evaluation opportunities to confirm the suitability of the inspection and/or other procedures developed under VTOL.2240. Consideration should be given to adding new samples and revising the programme when changes to the types of operation or environment occur.

(f) A plan defining the tasks and schedule of the In-Service Monitoring programme should be agreed during certification.

(g) Regular reports stating the findings of the In-Service Monitoring programme during service should be furnished to the Agency, assessing all findings made.

VTOL.2245 Aeroelasticity

n/a

(a) The aircraft must be free from flutter, control reversal, and divergence:

(1) at all speeds within and sufficiently beyond the structural design envelope;

(2) for any configuration and condition of operation;

(3) accounting for critical degrees of freedom; and

(4) accounting for any critical failures or malfunctions.

(b) The applicants' design must account for tolerances for all quantities that affect flutter.

MOC VTOL.2245 Aeroelasticity

n/a

(a) General. The aeroelastic stability evaluations referred to in this MOC include flutter, divergence, control reversal and any undue loss of stability and control as a result of structural deformation. The aeroelastic evaluation should include whirl modes associated with any lift/thrust unit or other rotating devices that contribute to significant dynamic forces. Compliance with this paragraph should be shown by analyses and tests.

(b) Aeroelastic stability envelopes. The aircraft should be designed to be free from aeroelastic instability for all configurations and design conditions, including transition phases, within the aeroelastic stability envelopes as follows:

(1) For normal conditions without failures, malfunctions, or adverse conditions, all combinations of altitudes and speeds encompassed by the V_D versus altitude envelope, enlarged at all points by an increase of 20 percent in equivalent airspeed at constant altitude, should be considered. In addition, a proper margin of stability should exist at all speeds up to V_D and there should be no large and rapid reduction in stability as V_D is approached.

(2) For the conditions described in (c) below, for all approved altitudes, any airspeed up to V_D should be considered.

(3) Failure conditions of certain systems should be treated in accordance with VTOL.2205. For these failure conditions, the speed clearances defined in MOC VTOL.2205 Figure 3 apply.

(c) Failures, malfunctions, and adverse conditions. The failures, malfunctions, and adverse conditions which should be considered are:

(1) For aircraft with disposable fuel: critical fuel loading conditions not shown to be extremely improbable which may result from mismanagement of fuel

(2) Single failures, malfunctions, or disconnections, and any combination of these that is not extremely improbable, of elements in the primary flight control system, tab control system, or flutter damper

(3) Failure of any single element of the structure supporting any engine, lift/thrust unit, shaft, or large externally mounted aerodynamic body

(4) Failures of any single element of the lift/thrust unit structure that would affect the aeroelastic characteristics of the aircraft

(5) Any lift/thrust unit or rotating device capable of significant dynamic forces rotating at the highest likely overspeed

(6) Any damage or failure conditions, required or selected for investigation by VTOL.2240 (a) and (b)

(7) Any other combination of failures, malfunctions, or adverse conditions not shown to be extremely improbable.

(d) Flight flutter tests should be made to show that the aircraft is free from flutter, control reversal and divergence and to show by these tests that:

(1) Proper and adequate attempts to induce flutter have been made within the speed range up to V_D;

(2) The vibratory response of the structure during the test indicates freedom from flutter;

(3) A proper margin of damping exists at V_D; and

(4) There is no large and rapid reduction in damping as V_D is approached.

(e) For modifications of the type design which could affect the flutter characteristics, compliance with (a) should be shown, except that analysis alone, which is based on previously approved data, may be used to show freedom from flutter, control reversal and divergence for all speeds up to the speed specified for the selected method.

VTOL.2250 Design and construction principles

n/a

(a) Each part, article, and assembly must be designed for the expected operating conditions of the aircraft.

(b) Design data must adequately define the part, article, or assembly configuration, its design features, and any materials and processes used.

(c) The applicant must determine the suitability of each design detail and part having an important bearing on safety in operations. The applicant must prevent single failures from resulting in a catastrophic effect upon the aircraft.

(d) The control system must be free from jamming, excessive friction, and excessive deflection when the aircraft is subjected to expected limit air loads.

(e) Doors, canopies, and exits must be protected against inadvertent opening in flight, unless shown to create no hazard, when opened in flight.

(f) The aircraft must be designed to ensure that after a likely bird impact the capability remains to conduct:

(1) a controlled emergency landing for Category Basic with a maximum passenger seating configuration of 7 or more; or

(2) continued safe flight and landing for Category Enhanced.

MOC VTOL.2250(c) No catastrophic effect from structural single failures in the Category Enhanced

n/a

The following method is accepted for compliance with VTOL.2250(c) in the Category Enhanced for structural elements and parts:

(a) To demonstrate that no single failure has catastrophic consequences per design, a Safety Assessment should be performed that includes the following steps:

(1) a complete and comprehensive list of structural elements or parts and their interfaces should be provided;

(2) the functions that the structural elements or parts perform should be identified; and

(3) a safety assessment should be performed to identify all structural elements and parts for which failure could lead to Catastrophic consequences. All reasonably anticipated and conceivable failure modes should be taken into account without considering mitigation means, and all the stages of flight and operating conditions should be considered.

(4) The conclusions of the Safety Assessment should demonstrate the non-catastrophic classifications of all single failures and thereby show direct compliance with VTOL.2250 (c).

(5) If any single failure is identified that can lead to a catastrophic consequence:

(i) a structural redesign or vehicle re-configuration should be considered.

(ii) For simply loaded static elements[(1)] that are not involved in a system function, if redesign or reconfiguration is impractical or adds excessive design complexity that would impair the overall safety objective, it should be demonstrated that catastrophic consequences from any single failure are extremely improbable applying a combination of the compensating provisions in accordance with paragraph (b).

Note[(1)]: Simply loaded static elements are typically airframe components. Elements that are high cycle fatigue loaded, rotating and/or complexly loaded such as control surfaces.

(b) Structural Failure Rate

For structural elements or parts and failure modes identified in (a)(5)(ii), if a quantitative assessment is not directly feasible, an acceptable combination of compensating provisions should be implemented that provides sufficient confidence to achieve the safety objective and is appropriate to address the failure mode that could result in catastrophic consequences.

In addition, the framework outlined below may be used to determine the Structural Failure Rate for the MOC VTOL.2240(d) assessment, if a quantitative assessment is not directly feasible.

It should address each of the three following aspects (1) to (3), for which a non-exhaustive list of examples is provided below for each aspect:

(1) Design Robustness:

(i) Larger static safety margins

(ii) Thorough proven understanding of the load distribution

(iii) Natural frequencies far from the forcing frequencies

(iv) Larger fatigue (safe life) margins

(v) Damage tolerance demonstration of larger damages

(vi) Low complexity of the design and a limited number of failure modes

(vii) Design values based on a statistical A-basis (99% probability with 95% confidence) as a minimum

(2) Quality of the part

(i) Identification of key manufacturing parameters and processes that are strictly controlled, the modification of which require OEM validation.

(ii) Regular material batch testing throughout the life of the element or part

(iii) Non-destructive tests (NDT) / Destructive tests (DT) of one sample from every batch throughout the life of the element or part

(iv) Non-destructive acceptance test of every article

(v) Process control specimens or witness coupons

(vi) Special assembly procedures or functional tests to avoid maintenance errors

(vii) Sensitivity to production process variability is low or is taken into account in the design

(3) In-Service Continued Structural Robustness

(i) Regular non-destructive inspections (NDI)

(ii) Limited repairs permitted without TC Holder support

(iii) End of flight reports of relevant parameters, for example, vibration, loads, deflection, temperature, acoustic emission

(iv) Active in-flight monitoring with pilot notification

(v) In-Service Monitoring to verify the health and operating conditions and the effectiveness of design and maintenance provisions, as well as other procedures, throughout the life of the type design., refer to MOC VTOL.2240(e)

(vi) Health and Usage Monitoring System (HUMS), refer to MOC VTOL.2240(e)

(vii) Notification required to the TC Holder of any unusual or unexpected wear or deterioration of parts in service

For some elements the determination of the failure rate could be more appropriately determined using other cycles, such as flight cycles or centrifugal force cycles. A conservative spectrum should then be used to convert the structural failure rate into probability per flight hour.

(c) In the safety assessment in (a)(3) of this MOC related to bearings, as a minimum and when applicable, the following failure modes of bearings should be considered:

(1) rupture of one or several of the bearing constituents

(2) partial or complete seizure of the bearing

(3) advanced spalling of bearings races or rolling elements

(4) advanced wear of bearing rings, rolling elements or cages

(5) loss of bearing preload

(6) permanent deformation

MOC VTOL.2250(e) Doors, canopies and exits

n/a

1. Scope and Definitions

(a) This paragraph applies to: All doors, hatches, openable windows, access panels, covers, etc., on the exterior of the vehicle.

(b) However, this paragraph does not apply if the door requires a specific tool to both open and close the door.

(c) This paragraph also does not apply if the opening of the door, in any flight phase, would not cause an event worse than Minor, as defined in VTOL.2510. The potential of persons inadvertently falling from the vehicle, and the physiological effect on passengers, should be included in the event classification, in addition to any effects on the vehicle structure, systems, controllability etc.

(d) Latches are movable mechanical elements that, when engaged, prevent the door from opening.

(e) Latched means the latches are engaged with their structural counterparts and held in position by the latch operating mechanism.

(f) Structural aspects of Door design, and Emergency Egress from the vehicle are out of scope of this paragraph. Refer to VTOL.2315(a) for emergency egress and Subpart C for the structural aspects.

2. Relevance to ASTM F3061 – 16a

(a) Paragraph 13.11.1 should be applicable, and complements Section 4 below.

(b) Paragraph 13.11.9 could be a means of compliance to Section 4 below, but need not be a separate point.

3. Occupant Retention

A seatbelt, or other occupant retention device, should not be considered an adequate alternative or mitigation against compliance with this paragraph.

4. Door Latching

(a) For all doors within the scope of this paragraph, there should be means for latching and for preventing their opening in flight inadvertently or as a result of mechanical failure.

(b) Acceptable features to prevent inadvertent operation by occupants are, for example:

(1) recessing door handles; and

(2) door handles that are moved/rotated up to open the door and moved/rotated down to close the door.

(c) Means to prevent inadvertent door opening in flight due to "mechanical failure" should be provided through multiple door latches and multiple load path door locking mechanisms so that the door will remain locked after a single failure.

(d) Care should be taken in the design of multiple load path latches and mechanisms to assure independence of all failures to consider the consequences of common-mode failures and errors, and to consider the effort of deflections after failures (if a failure allows deflections into the airstream sufficient to increase aerodynamic loads, the increase in loads should be accounted for; if a failure allows significant movement of latching components, the deflections should be accurately accounted for to assure that disengagement of non-failed latches does not occur).

5. Direct Visual Inspection

There should be means for direct visual inspection of the latching mechanism by flight crew members to determine whether the external doors (including passenger, crew, service, and cargo doors) are fully latched.

6. Flight Crew Indication

There should be visual means (combined with other attention-getters as appropriate, refer to MOC VTOL.2605(b)) to signal to appropriate flight crew members when doors within the scope of this paragraph are not closed and/or not fully latched.

7. Particular Risk Aspects

The door mechanisms should be designed such that the door will not open in case of a bird strike or other Particular Risk effect.

MOC VTOL.2250(f) Aircraft capability after bird impact

n/a

This MOC provides methods to demonstrate the remaining capability of the aircraft after a bird impact as required by VTOL.2250(f).

It is applicable to VTOL capable Aircraft in the Category Basic designed to carry 7 to 9 passengers and in the Category Enhanced.

1. Single bird strike evaluation:

(a) In accordance with VTOL.2250(f), VTOL capable aircraft must be designed to ensure the capability of a controlled emergency landing in the Category Basic with a maximum of 7 or more seats, or of a continued safe flight and landing in the Category Enhanced, after impact of a 1.0-kg (2.2-lb) bird. This should be ensured in the most critical configuration for the corresponding velocity of the VTOL (relative to the bird along the flight path of the vehicle) up to the maximum speed in level flight with maximum continuous power, at operating altitude up to 2438 m (8,000 ft.).

(b) Compliance should be shown by tests or by analysis based on tests carried out on sufficiently representative structures of a similar design.

(c) The following parts should be evaluated for a single bird strike:

(1) The windshield directly in front of occupants and the supporting structures for these panels should be capable of withstanding a bird impact without penetration for maximum speeds above 50kt.

(2) Other structures, systems and equipment should also be evaluated. The selection of the areas to be substantiated should be the result of a comprehensive hazard analysis based on:

(i) Exposed areas of the structure and internal equipment and systems inside of these exposed areas in case of bird penetration or shock loads; and

(ii) Their criticality and their ability to ensure continued safe flight and landing (for Category Enhanced) or controlled emergency landing (for Category Basic).

(d) When performing the hazard analysis, direct and induced effects of a bird strike should be considered:

(1) "Direct Effects": to ensure the integrity of the structure and functionality of systems or equipment (including consideration of shock loads) which are critical for continued safe flight and landing (for Category Enhanced) or controlled emergency landing (for Category Basic).

(2) "Induced Effects": to examine the possible consequences of the ejection of pieces from structures, systems or equipment which are struck by a bird on other structures and systems. For a bird impact on the lift/thrust system, the guidance in MOC VTOL.2240(d) can be followed, when relevant, in the demonstration of compliance mentioned in paragraph (a) of this section.

2. Multiple bird strike evaluation:

(a) VTOLs are generally equipped with redundant systems and structures. To ensure continued safe flight and landing (for Category Enhanced) or controlled emergency landing (for Category Basic) following a multiple bird strike, an evaluation should be performed of the effects of such multiple bird strike in the most critical configurations for the corresponding velocity of the VTOL up to the maximum speed in level flight with maximum continuous power, within the range of airspeed for normal operation up to 4000ft MSL (Mean sea level).

(b) The applicant should consider potentially vulnerable redundant systems and structures and their effective exposed area (wing, lift surfaces, rudder, ailerons…).

(c) An acceptable approach is to show that there is no loss of function of the element that is impacted after a single impact with a medium sized bird of 0.450 kg. Alternatively, scenarios evaluating multiple bird impacts distributed across each structure or system can be proposed by the applicant considering medium birds and small birds according to the MOC VTOL.2400 guidance (see Figure 1). Multiple bird strike evaluation is not required for the windshield.

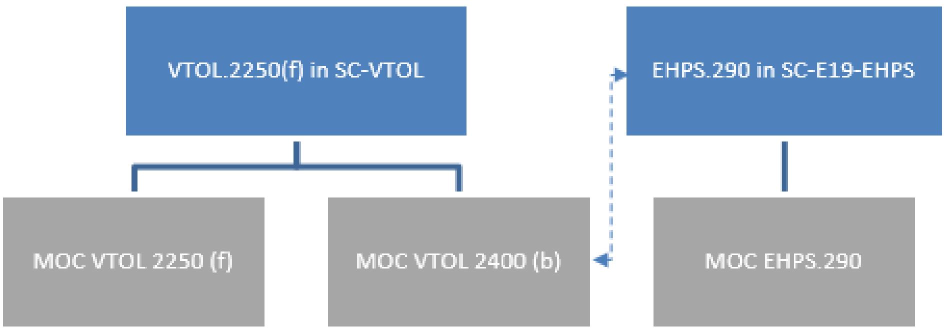


Figure 1- Overview of the Airframe and Propulsion System guidance interaction for compliance to bird strike

VTOL.2255 Protection of structure

n/a

(a) Each part of the aircraft, including small parts such as fasteners, must be protected against deterioration or loss of strength due to any cause likely to occur in the expected operational environment.

(b) Each part of the aircraft must have adequate provisions for ventilation and drainage.

(c) For each part that requires maintenance, preventive maintenance, or servicing, the applicant must incorporate a means into the aircraft design to allow such actions to be accomplished.

MOC VTOL.2255 Protection of structure

n/a

(a) The following combination of CS-27 Amdt. 6 requirements, with their corresponding guidance material, is accepted as a means of compliance with VTOL.2255:

SC VTOL	CS -27 Amdt. 6
VTOL.2255 (a)	CS 27.609 (a) Protection of Structure CS 27.607 (a) Fastener
VTOL.2255 (b)	CS 27.609 (b) Protection of Structure
VTOL.2255 (c)	CS 27.611 Inspection provisions

(b) For composite structures, additional guidance can be found in AMC 20-29 chapter 6.d. and 6.e and in MOC VTOL.2240 (a) & (b).

VTOL.2260 Materials and processes

n/a

(a) The applicant must determine the suitability and durability of materials used for parts, articles, and assemblies, the failure of which could prevent continued safe flight and landing for Category Enhanced, or a controlled emergency landing for Category Basic, accounting for the effects of likely environmental conditions expected in service.

(b) The methods and processes of fabrication and assembly used must produce consistently sound structures. If a fabrication process requires close control to reach this objective, the applicant must define the process with an approved process specification as part of the design data.

(c) Except as provided for in VTOL.2260(f) and (g), the applicant must select design values that ensure material strength with probabilities that account for the criticality of the structural element. Design values must account for the probability of structural failure due to material variability.

(d) If material strength properties are required, a determination of those properties must be based on sufficient tests of material meeting specifications to establish design values on a statistical basis.

(e) If environmental effects are significant on a critical component or structure under normal operating conditions, the applicant must determine those effects.

(f) Design values, greater than the minimums specified by VTOL.2260, may be used, where only guaranteed minimum values are normally allowed, if a specimen of each individual item is tested before use to determine that the actual strength properties of that particular item will equal or exceed those used in the design.

(g) An applicant may use other material design values if specifically approved by the Agency.

MOC VTOL.2260 Materials and processes

n/a

(a) The following combination of CS-27 Amdt. 6 requirements, with their corresponding guidance material, is accepted as a means of compliance with VTOL.2260:

SC-VTOL	CS-27 Amdt. 6
VTOL.2260 (a)	CS 27.603 Material CS 27.613 (c) Material strength properties and design values
VTOL.2260 (b)	CS 27.605 Fabrication methods
VTOL.2260 (c)	CS 27.613 (a) & (b) Material strength properties and design values
VTOL.2260 (d)	CS 27.613 (a) Material strength properties and design values
VTOL.2260 (e)	CS 27.603 (c) Materials
VTOL.2260 (f)	CS 27.613 (e) Material strength properties and design values
VTOL.2260 (g)	CS 27.613 Material strength properties and design values

(b) For composite structures, additional guidance can be found in AMC 20-29 chapter 6 and MOC VTOL.2240 (a) & (b).

(c) For additive manufacturing, additional guidance can be found in the EASA Certification Memorandum CM-S-008.

VTOL.2265 Special factors of safety

n/a

(a) The applicant must determine a special factor of safety for each critical design value for each part, article, or assembly for which that critical design value is uncertain, and for each part, article, or assembly that is:

(1) likely to deteriorate in service before normal replacement; or

(2) subject to appreciable variability because of uncertainties in manufacturing processes or inspection methods.

(b) The applicant must determine a special factor of safety using quality controls and specifications that account for each:

(1) type of application;

(2) inspection method;

(3) structural test requirement;

(4) sampling percentage; and

(5) process and material control.

(c) The applicant must multiply the highest pertinent special factor of safety in the design for each part of the structure by each limit load and ultimate load, or ultimate load only, if there is no corresponding limit load, such as occurs with emergency condition loading.

MOC VTOL.2265 Special factors of safety

n/a

(a) The following combination of CS-27 Amdt. 6 requirements, with their corresponding guidance material, is accepted as a means of compliance with VTOL.2265:

SC-VTOL	CS-27 Amdt. 6
VTOL.2265 (a)	CS 27.619(a) Special factors CS 27.621 Casting factors CS 27.785 (h) & (k)
VTOL.2265 (b)	CS 27.619 Special factors CS 27.621 Casting factors CS 27.623 Bearing factors CS 27.625 Fitting factors CS 27.785 (h)&(k) Seats, berths, safety belts, and harnesses
VTOL.2265 (c)	CS 27.619, applicable to limit (if any) and ultimate load conditions

(b) For items of mass which are subjected to frequent removal: In order to ensure the strength of the components throughout the service life despite the deterioration through frequent removal, an additional factor in accordance with CS 27.619(a)(2) should be applied to all loading conditions. The local attachments for these items should be designed to withstand 1,33 times the specified loads if these items are subject to severe wear and tear through frequent removal.

(c) For composite structure, additional guidance can be found in AMC 20-29.

(d) For additive manufacturing, additional guidance can be found in the EASA Certification Memorandum CM-S-008.

STRUCTURAL OCCUPANT PROTECTION

VTOL.2270 Emergency conditions

n/a

(a) The aircraft, even when damaged in an emergency landing, must protect each occupant against injury that would preclude egress when:

(1) properly using safety equipment and features provided for in the design;

(2) the occupant experiences ultimate static inertia loads likely to occur in an emergency landing; and

(3) items of mass, including lift/thrust unit or auxiliary power units (APUs), within or adjacent to the cabin, that could injure an occupant, experience ultimate static inertia loads likely to occur in an emergency landing.

(b) The emergency landing conditions specified in VTOL.2270(a) must:

(1) include dynamic conditions that are likely to occur in an emergency landing; and

(2) not generate loads experienced by the occupants, which exceed established human-injury criteria for human tolerance due to restraint or contact with objects in the aircraft.

(c) The aircraft must provide protection for all occupants, accounting for likely flight, ground, and emergency landing conditions.

(d) Each occupant protection system must perform its intended function and not create a hazard that could cause a secondary injury to an occupant. The occupant protection system must not prevent occupant egress or interfere with the operation of the aircraft when not in use.

(e) Each baggage and cargo compartment must:

(1) be designed for its maximum loading and for the critical load distributions at the maximum load factors corresponding to the flight and ground load conditions determined under this Special Condition;

(2) have a means to prevent the contents of the compartment from becoming a hazard by impacting occupants or shifting;

(3) protect controls, wiring, lines, equipment, or accessories whose damage or failure would prevent continued safe flight and landing for Category Enhanced, or a controlled emergency landing for Category Basic; and

(4) be designed so that a fire does not preclude continued safe flight and landing for Category Enhanced, or a controlled emergency landing for Category Basic.

MOC VTOL.2270(a) and (c) Emergency landing conditions: General considerations

n/a

This MOC provides a set of general design conditions that, when used in their entirety, are accepted to ensure adequate protection of occupants against injuries that would prevent egress in an emergency landing.

(a) CS 27.561(a) Amdt. 6 is accepted as a means of compliance.

(b) CS 27.561(b) Amdt. 6 is accepted as a means of compliance with the addition under subparagraph (3)(ii) of a 18 g ultimate inertial load factor in the forward direction for CTOL aircraft.

(c) CS 27.561(c) Amdt. 6 is accepted as a means of compliance replacing “rotors, transmissions and engines” by “lift/thrust units, transmissions and energy storage systems”.

(d) CS 27.561(d) Amdt. 6 is accepted as a means of compliance replacing “fuel tanks” by “energy storage systems”.

(e) For CTOL, CS 23.561(d) Amdt. 4 is accepted as a means of compliance.

MOC VTOL.2270(b)(1) Emergency landing dynamic conditions

n/a

This MOC provides a set of general design conditions that, when used in their entirety, are accepted to ensure adequate protection of occupants against injury in dynamic conditions that are likely to occur in an emergency landing.

(a) CS 27.562(a) Amdt. 6 is accepted as a means of compliance.

(b) CS 27.562(b) Amdt. 6 is accepted as a means of compliance under the following conditions:

(1) CS 27.562(b)(1) Amdt. 6 is accepted as a means of compliance, noting that the 30 g at seat attachment level was based upon the typical underfloor structure of a conventional rotorcraft. Therefore the 30 g is only valid if the structure underneath the seats has equal or better damping characteristics than a conventional rotorcraft. If specific design features are integrated, less than 30g at the seat may be acceptable based on analysis supported by tests

(2) CS 27.562(b)(2) Amdt. 6 is accepted as a means of compliance with the following addition: For CTOL peak floor deceleration should occur in not more than 0.05 seconds after impact and should reach a minimum of 26 g. For CTOL seat/restraint systems not being in the first row, peak deceleration should occur in not more than 0.06 seconds after impact and should reach a minimum of 21 g.

(3) CS 27.562(b)(3) Amdt. 6 is accepted as a means of compliance.

(c) CS 27.562(c) Amdt. 6 is accepted as a means of compliance.

(d) CS 27.562(d) Amdt. 6 is accepted as a means of compliance.

MOC VTOL.2270(c) Emergency Landing Conditions

n/a

1. STRUCTURAL PROVISIONS: Ditching, Emergency Flotation and Limited Overwater Operation

VTOL capable aircraft will operate over different water environments, such as inland rivers and lakes, open seas and hostile sea areas. In order to be proportionate to the nature and risk associated to these different operational scenarios, three airworthiness categories are defined: limited overwater operations, emergency flotation and ditching. The air operations rules will specify the airworthiness category necessary for operations over water. The associated design criteria for these airworthiness categories have been developed following a tiered approach with a baseline set of conditions defined for limited overwater operations, additional criteria necessary for emergency flotation and further considerations added for ditching operations.

If certification with ditching provisions, emergency flotation provisions or limited over water operations is requested by the applicant, structural strength should meet the following design criteria.

If certification with emergency flotation or limited over water operations is requested, the loading conditions apply to the buoyancy components that are provided to meet VTOL.2310 and VTOL.2270(c) respectively, and their attachments to the aircraft. Buoyancy components may consist of flotation units of an emergency flotation system (floats), watertight compartments, hull buoyancy, integrated buoyancy or a combination of these.

If certification with ditching provisions is requested, the loading conditions apply to all parts of the aircraft.

(a) Landing conditions:

(1) The conditions considered should be those resulting from an emergency landing into calm water.

(2) Additionally, if certification with ditching provisions or emergency flotation provisions is requested by the applicant, the conditions considered should also be those resulting from an emergency landing into the most severe sea conditions for which certification is requested by the applicant

(3) Unless other rational landing conditions acceptable to the Agency are defined, the following entry conditions apply: a forward ground speed not less than 15.4 m/s (30 knots), and a vertical speed not less than 1.5 m/s (5 ft/s), in likely pitch, roll and yaw attitudes, for each aircraft configuration.

(4) Total lift may be assumed to act through the centre of gravity during water entry. This lift should not exceed two-thirds of the design maximum weight.

(b) Loads:

(1) Aircraft with floats fixed or intended to be deployed before water contact: CS 27.563(b)(1) Amdt. 5 (or later) is accepted as a means of compliance.

(2) Aircraft with floats intended to be deployed after initial water contact: CS 27.563(b)(2) Amdt. 5 (or later) is accepted as a means of compliance.

(3) Aircraft with watertight compartments, hull buoyancy and/or integrated buoyancy: The loads to be considered are those resulting from the aircraft entering the water, in the conditions defined in (a), and in accordance with flight manual procedures.

(c) Procedures:

(1) The buoyancy components and their attachment structure should be substantiated for limit and ultimate loads, as specified in (b).

(2) A review of likely damages to the structure in the vicinity of the buoyancy components should be carried out, including consideration of splintering and sharp edges. The risk from such damage of puncture or improper functioning of the buoyancy components during water entry and flotation should be minimised.

(3) Additionally if certification for ditching is requested by the applicant, any aircraft structure the failure of which would impair flotation, capsize resistance or cabin egress should be substantiated for limit and ultimate ditching loads, unless the effects of these failures are accounted for in the investigation of probable behaviour of the aircraft during water entry, flotation, and the capsize resistance demonstrations.

CS 27 Amdt. 5 (or later): AMC 27.563 provides guidance.

2. Limited Overwater Operations

(a) If certification for only limited overwater operations is requested by the applicant, the aircraft should meet the design criteria defined for MOC VTOL.2310(b) Emergency Flotation, with the exception that capsize resistance of (a)(1)(ii) and (a)(2)(ii) need not be demonstrated.

(b) The following MOC VTOL paragraphs are also applicable:

(1) MOC VTOL.2315(a) Means of egress and emergency exits

(2) MOC VTOL.2430(a)(6) Energy retention capability in an emergency landing

(3) MOC VTOL.2535 Safety Equipment

(4) MOC VTOL.2605(c) Information related to safety equipment

(5) MOC VTOL.2610 Instrument markings, control markings and placard

NOTE: The MOC VTOL applicable to Emergency Flotation and Ditching operations are listed in MOC VTOL.2310(b) and MOC VTOL.2310(c) respectively.

MOC VTOL.2270(e) Cargo and baggage compartments

n/a

The following provisions provide a set of design criteria that, when used in their entirety, are accepted to ensure compliance of the baggage compartment design with VTOL.2270(e):

(a) CS 27.787 Amdt. 6 is accepted as a means of compliance.

(b) CS 27.855(b) Amdt. 6 is accepted as a means of compliance.

(c) For CTOL, in addition to (a) and (b), CS 23.787 Amdt. 4 is accepted as a means of compliance

SUBPART D — DESIGN AND CONSTRUCTION

VTOL.2300 Flight control systems

n/a

(a) The flight control systems must be designed to:

(1) operate easily, smoothly, and positively enough to allow proper performance of their functions;

(2) protect against likely hazards;

(3) allow flight crew to be aware of the control limits.

(b) Trim systems, if installed, must be designed to:

(1) protect against inadvertent, incorrect, or abrupt trim operation;

(2) provide information that is required for safe operation.

MOC 1 VTOL.2300 Fly-by-Wire control systems: Definition and Scope

n/a

The definition of flight control system is provided in MOC VTOL.2000.

Due to the distributed propulsion, most VTOL configurations have a closer integration of engines and flight controls than other types of aircraft. To address this specificity, a number of lift/thrust system and flight control system objectives are included in Subpart F – Systems and equipment objectives.

While some definitions are proposed in this MOC to facilitate common references, they do not imply limits in the scope of analyses. For example, in most configurations, the lift/thrust units play a role in the flight control function and should thus be integrated in any related safety analyses (e.g. MOC VTOL.2510, MOC 4 VTOL.2300).

Scope and certification approach covering both engines and flight controls for each project should be proposed by the Applicant for acceptance by the Agency.

MOC 2 VTOL.2300 Acceptability of ASTM standard F3232/F3232M-20 for Fly-by-Wire flight control systems

n/a

1. Status and comments

The ASTM F3232/F3232M-20 standard is the Standard Specification for Flight Controls in Small Aircraft. As this standard was prepared with the assumption of traditional (i.e. mechanical) primary flight controls, it can only be accepted as a means of compliance with VTOL.2300 for Fly-by-Wire (FbW) control systems with some explanations (see below), adaptations and additions (see Section 2) .

The definitions provided in §3 of ASTM F3232/F3232M-20 are only applicable insofar as the concept exists for VTOL capable aircraft and has not been defined otherwise. For instance: “aircraft type code” is not a valid concept for VTOL and “Continued Safe Flight and Landing” has been specifically defined for VTOL capable aircraft in MOC VTOL.2000.

Similarly, any reference in ASTM F3232/F3232M-20 to standards or methods for the determination of Handling Qualities should be considered to be replaced by a reference to MOC VTOL.2135.

Lastly, while this standard addresses conventional architecture elements such as flaps and stall barrier systems, different considerations may apply for other architectures in VTOL capable aircraft.

The following table provides the status of the acceptability of the ASTM F3232/F3232M-20 standard as a means of compliance with VTOL.2300 for Fly-by-Wire (FbW) control systems. Later revisions of ASTM F3232/F3232M or alternative standards may also be proposed by the applicant and agreed with the Agency as acceptable means of compliance in a particular certification project.

ASTM F3232/F3232M-20	VTOL status/comments
§4.1.1, §4.1.2	Accepted
§4.1.3, §4.1.3.1	Accepted
§4.2	This ASTM standard paragraph is an accepted means of compliance. Nevertheless, additional means of compliance are required for FbW, as proposed in this MOC.
§4.3	Accepted
§4.4	Accepted
§4.5	Accepted
§4.6	Accepted
§4.7	This ASTM § was developed for traditional flight control systems. It is accepted as with some additions, see Section 2 below .
§4.8	Accepted
§4.9	Typo in the ASTM standard: “flight” instead of “light”. Accepted
§4.10	Accepted
§4.11	Accepted
§4.12	Accepted
§4.13	Accepted
§5.1	Accepted
§5.2	Accepted with some additions to address FbW
§5.3 Artificial Stall Barrier System	Accepted

2. Adaptations/additions to ASTM standard F3232/F3232M-20 linked to Fly-by-Wire implementation

(a) Operation tests

To be considered an accepted means of compliance with VTOL.2300(a)(1) and (2), paragraph §4.7 of ASTM standard F3232/F3232M-20 should be adapted and complemented as follows:

(1) Adaptation of ASTM F3232/F3232M-20 standard

4.7 Operation Tests:

4.7.1 It must be shown by operation tests that, when the controls are operated from the pilot compartment with the system loaded <u>to the maximum actuation system forces (i.e. loads and torques)</u>, the system is free from jamming, excessive friction, excessive deflection, or any combination thereof.

NOTES:

(i) It is acceptable to reduce the load slightly to enable movement of the actuator throughout its range.

(ii) This requirement applies to primary and secondary flight controls that move surfaces and flight controls that move or redirect lift/thrust units. It does not apply to fixed propulsion units that vary RPM, blade angle, or thrust for flight control.

(2) Addition to ASTM F3232/F3232M-20 standard

One method, but not the only one, for demonstrating the Operational Tests is as follows:

Conduct the control system operational tests by operating the controls from the pilot's compartment with the entire system loaded so as to correspond to the limit control forces established by the regulations for the control system being tested. The following conditions should be met:

(i) Under limit load, check each control surface/effector for travel and detail parts for deflection. This may be accomplished as follows:

(A) Support the control surface/effector being tested while positioned at the neutral position.

(B) Load the surface using loads corresponding to the limit control forces established in the SC VTOL.

(C) Load the pilot's control until the control surface is just off the support.

(D) Determine the available travel which is the amount of movement of the surface/effector from neutral when the control is moved to the system stop. It is acceptable to reduce the load slightly to enable movement of the actuator throughout its range.

(E) The above procedure should be repeated in the opposite direction.

(F) The minimum control surface/effector travel from the neutral position in each direction being measured should be 10 percent of the control surface travel measured with no load on the surface.

Regardless of the amount of travel of the surface when under limit load, the aircraft should have adequate flight characteristics as specified in Subpart B. Any derivative aircraft of a previous type certificated aircraft need not exceed the control surface travel of the original aircraft; however, the flight characteristics should be flight tested to ensure compliance.

(ii) Under limit load, no signs of jamming or of any permanent set of any connection, bracket, attachment, etc. may be present.

(iii) Friction should be minimised so that the limit control forces and torques specified by the regulations may be met.

MOC 3 VTOL.2300 Validation of Electronic Flight Control Laws (FCL) in Fly-by-Wire flight control systems

n/a

Compliance of the electronic flight control laws should be considered satisfactory when an adequate substantiation of validation activities is shown and formalised in the compliance documents.

(a) Formalisation of compliance demonstration strategy

In order to demonstrate compliance with an adequate level of formalisation, the following should be performed and captured within compliance documents:

(1) Determination of flight control characteristics that require a detailed and specific validation strategy for VTOL.2135, VTOL.2145, VTOL.2300, VTOL.2500, VTOL.2510 compliance and Modified Handling Qualities Rating Method (MHQRM) demonstration;

(2) Substantiation of the proposed validation strategy (e.g. analyses, simulator tests, flight tests) covering the characteristics and features determined above.

(b) Validation activities

For the substantiation of the proposed validation strategy, the applicant should perform the following activities:

(1) Identify the objectives (intended function) of each function.

(2) Check proper integration of each FCL function in the EFCS (Electronic Flight Control System) against objectives (e.g. rig-test, offline/piloted simulation, flight test, …).

(3) Check compatibility of each function with other functions acting on the same control surface/actuator:

(i) Identify potential interface problems with other functions,

(ii) Define test conditions (e.g. rig-test, offline/piloted simulation, flight test, …),

(iii) Particular consideration should be given to actuator limitations and the resulting coupling of the remaining control authority between different control functions.

(4) Check compatibility of each function in all applicable modes with other functions at aircraft level:

(i) Identify potential interface problems with other functions on aircraft level,

(ii) Define test conditions (e.g. rig-test, offline/piloted simulation, flight test, …).

(5) Analyse failure conditions for each function:

(i) Identify failure conditions and classify the severity of failures in accordance with VTOL.2510,

(ii) Define test conditions for verification of failure conditions severities (e.g. rig-test, offline/piloted simulation, flight test, …).

(iii) Where functions are acting on the same control surface/actuators, particular consideration shall be given to coupling of failures in these functions (including control margin dependencies) as well as the overall redundancy management between these functions (including actuator limitations).

(6) Document all steps.

(c) Characteristics

For the validation activities identified by the paragraphs (b) 2 to 5 above, the following should be covered in particular:

(1) Definition of priorities between FCL functions acting on the same control surface / actuator (e.g. priorities, mixing-laws, …),

(2) Multi-objective optimisation (e.g. trajectory, energy consumption, passenger comfort), including trading one criterion (e.g. airspeed) vs others in extreme conditions,

(3) Transition between different FCL modes with and without failures (e.g. blending, fading-in/fading-out, smoothness of transition, …),

(4) Effects of erroneous input data (e.g. air data, aircraft configuration, …),

(5) Discontinuities and non-linearities,

(6) Control law interfaces,

(7) Voting mechanisms,

(8) Protections priorities (e.g. entry/exit logic conditions not symmetrical),

(9) Determination of critical scenario for multiple failures.

The validation strategy should include but should not be limited to operational scenarios. The determination that an adequate level of validation of the FCL design has been achieved should be based on engineering judgment.

(d) Documentation to be provided

The applicant should prepare a checklist with a defined set of test cases based on experience, and provide the FCL Validation methodology and strategy for verification by the Agency.

(e) Auditing

The Applicant should perform adequate auditing and the Agency may define a related Level of Involvement in such audits.

Compliance should be shown in conjunction with the following requirements: VTOL.2135, VTOL.2145, VTOL.2500 and VTOL.2510.

MOC VTOL.2300(a)(1) Function and operation of Fly-by-Wire flight control system

n/a

(a) Flight crew awareness of the modes of operation

(1) If the design of the flight control system has multiple modes of operation (e.g. hover, transition, cruise modes) and/or includes degraded modes following failures, a means should be provided to indicate to the crew any mode that significantly changes or degrades the handling or operational characteristics of the aircraft.

(2) The sub-modes of operation (both in nominal and degraded mode) and the transition between them should be smooth, and should be evaluated to determine whether or not they are intuitive. If these sub-modes or the transition between them are not intuitive, an indication to the flight crew may be required. This indication may be different from the classic “failure alerting”.

(3) In case of several flight control modes, limitations should be clearly annunciated and the definition of a Training Area of Special Emphasis (TASE) in the Flight Crew Data (FCD) may need to be established during the certification of the Operational Suitability Data (OSD).

Compliance should be shown in conjunction with other paragraphs (such as VTOL.2445), where failures could lead to flight control mode degradation.

(b) Flight envelope protection

If Flight Envelope Protection (FEP) features are implemented, then these should follow the following principles:

(1) Onset characteristics of each envelope protection feature should be smooth, appropriate to the phase of flight and type of manoeuvre; and not be in conflict with the ability of the pilot to satisfactorily change the aircraft flight path (e.g. speed, attitude) within the approved flight envelope.

(2) Limit values of protected flight parameters (and if applicable, associated warning thresholds) should be compatible with:

(i) the aircraft structural limits;

(ii) the required safe and controllable manoeuvring of the aircraft;

(iii) the margins to critical conditions;

(iv) dynamic manoeuvring, airframe and system tolerances (both from manufacturing and in-service), and non-steady atmospheric conditions - in any appropriate combination and phase of flight - should not result in a limited flight parameter beyond the nominal design limit value that would cause unsafe flight characteristics;

(v) the rotor rotational speed limits;

(vi) the blade stall limits;

(vii) the engine and transmission torque limits; and/or

(viii) any other operation limitations for the aircraft and lift/thrust system installation.

(3) The aircraft should be responsive to pilot commanded dynamic manoeuvring within a suitable range of the parameter limits that define the approved flight envelope.

(4) The FEP system and any failure condition not shown to be extremely improbable should be analysed per MOC VTOL.2135 MHQRM (including the effect on flight envelope probabilities) and VTOL.2510.

(5) When simultaneous envelope limiting is active this should not result in adverse coupling or adverse priority (e.g. if two or more envelope limitations could exist simultaneously, this consequence should not be a wrong priority).

Adherence to the above principles should be shown in conjunction with the demonstration of compliance with the following requirements: VTOL.2110, VTOL.2425(a), VTOL.2500, VTOL.2510(a)(b) and VTOL.2135 with MOC VTOL.2135.

(c) Flight control and critical displays:

The following apply at all attitudes and in all modes of operation:

(1) The flight control system should be designed to continue to operate and not hinder aircraft recovery from any attitude.

(2) Control systems for essential services should be designed so that when a movement to one position has been selected, a different position can be selected without having to wait for the completion of the initially selected movement, and the system should arrive at the finally selected position without further attention. The movements that 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 aircraft.

(3) Compliance should be shown by evaluation of the closed loop flight control system. This evaluation is intended to ensure that there are no features or unique characteristics (including numerical singularities) which would restrict the pilot's ability to recover from any attitude. The intent is not to limit the use of envelope protection features or other systems that augment the control characteristics of the aircraft.

(4) The following conditions that might occur due to pilot action, system failures or external events should be considered:

(i) Abnormal attitude (including the aircraft becoming inverted;)

(ii) Excursion of any other flight parameter; and

(iii) Flight conditions that may result in higher than normal pitch, roll or yaw rates.

(5) For each of the conditions in (c)(4):

(i) The flight control system should continue to operate;

(ii) The design of the flight control laws, including any automatic protection function should not hinder aircraft recovery; and

(iii) Critical flight displays should continue to provide accurate indications and any other information that the pilot may require to execute recovery from the unusual attitude and/or arrest the higher than normal pitch, roll or yaw rates.

MOC VTOL.2300(a)(2) Protection against likely Hazards for Fly-by-Wire flight control systems

n/a

(a) Control Signal Integrity

Perturbations, as referred to in this MOC, are described as signals that result from any condition that is able to modify the command signal from its intended characteristics. They can be categorised into the following categories:

(1) Internal causes that could modify the command and control signals. These include but are not limited to:

(i) loss of data bits, frozen or erroneous values,

(ii) unwanted transients,

(iii) computer capacity saturation,

(iv) processing of signals by asynchronous microprocessors,

(v) adverse effects caused by transport lag,

(vi) poor resolution of digital signals,

(vii) sensor noise,

(viii) corrupted sensor signals,

(ix) aliasing effects,

(x) inappropriate sensor monitoring thresholds,

(xi) structural interactions (such as control actuator compliance or coupling of structural modes with control modes), that may adversely affect the system operation or structural stability and integrity.

(2) External causes that could modify the command and control signals. These include but are not limited to:

(i) Lightning,

(ii) EMI effects (e.g., electric engine interference, aircraft's own electrical power and power switching transients, smaller signals if they can affect flight control, transients due to electrical failures),

(iii) High Intensity Radiated Fields (HIRF)

(iv) Single Event Effects (SEE)

(3) Spurious signals and/or false data, that are a consequence of perturbations in either of the two categories above, may result in malfunctions that produce unacceptable system responses equivalent to those of conventional systems such as limit cycle/oscillatory failures, runaway/hardover conditions, disconnection, lockups and false indication/warning that consequently present a flight hazard. It is imperative that the command signals remain continuous and free from internal and external perturbations and common cause failures. Therefore special design measures should be employed to maintain system integrity at a level of safety at least equivalent to that which is achieved with traditional hydro-mechanical designs. These special design measures can be monitored through the System Safety Analysis (SSA) process provided specific care is directed to development methods and on quantitative and qualitative demonstrations of compliance.

(4) An evaluation of the following should be conducted:

(i) Theflight control system should continue to perform its intended function (even in a degraded mode)

(ii) Any system in the aerodynamic loop which has a malfunction should not produce an unsafe level of uncommanded motion and should automatically recover its ability to perform critical functions upon removal of the effects of that malfunction.

(iii) Malfunctions of systems in the aerodynamic loop should not adversely affect the ability to perform a safe flight and landing.

(iv) Any disruption to an individual unit or component as a consequence of a malfunction, and which requires annunciation and crew action, should be identified to and approved by the Agency to ensure that:

(A) the failure can be recognised by the crew, and

(B) the crew action can be expected to result in continued safe flight and landing in the Category Enhanced or in a controlled emergency landing in the Category Basic.

(v) An automatic change from a normal to a degraded mode that is caused by spurious signal(s) or malfunction(s) should meet the probability requirements associated with the functional hazard assessment (FHA) established per VTOL.2510(a), (e.g. a failure condition assessed as major should be remote).

(vi) Exposure to a spurious signal or malfunction should not result in a hazard with a probability greater than that allowed by the criteria of VTOL.2510(a) and associated MOC. The impact on handling qualities and structural loads should also be evaluated.

(vii) Interaction of flight control functions and actuator control loops

(viii) The flight control system should operate appropriately when considering other systems. The applicant should ensure the compatibility of automatic functions that may dynamically interact or affect flight control in both normal and anticipated abnormal operating conditions and ensure that such interactions (either by aircraft response or by data transfer) do not result in inappropriate flight control responses. This should include any potential for adverse coupling of the dynamics of one automated flight function with another (e.g., coupling between automated power and flight control functions).

(5) The complexity and criticality of the FbW flight control system (if utilised) necessitates additional laboratory testing beyond that required as part of individual equipment validation and software verification.

(6) It should be shown that either the FbW flight control system signals cannot be altered unintentionally (i.e. what is received by the effector/actuator is what was transmitted by the computer), or that altered signal characteristics meet the following criteria:

(i) Stable gain and phase margins are maintained for all flight control closed loop systems. Pilot control inputs (pilot in the loop) are excluded from this requirement.

(ii) Sufficient pitch, roll, yaw and lift/thrust control power is available to provide control for continued safe flight and landing in the Category Enhanced or for controlled emergency landing in the Category Basic, considering all the FbW flight control system signal malfunctions that are not extremely improbable.

(iii) The effect of spurious signals on the systems which are included in the aerodynamic loop should not result in unacceptable transients or degradation of the aircraft's performance. Specifically, signals that would cause a significant uncommanded motion of a control surface/effector actuator should be readily detected and deactivated or the surface motion should be arrested by other means in a satisfactory manner. Small amplitude residual system oscillations may be acceptable, if justified.

(iv) Establishment of a Validation and Verification process for the development of the flight control monitors, for example following SAE ARP 6539 Validation and Verification Process Steps for Monitors Development in Complex Flight Control and Related Systems.

(7) It should be demonstrated that the output from the control surface closed loop system does not result in any uncommanded, sustained oscillations of flight control surfaces/effectors. The effects of minor instabilities may be acceptable, provided that they are thoroughly investigated, documented, and understood. An example of an acceptable condition would be one where a computer input is perturbed by spurious signals, but the output signal remains within the design tolerances, and the system is able to continue in its selected mode of operation unaffected by that perturbation.

(8) In the context of showing and demonstrating these system characteristics an accepted Means of Compliance includes:

(i) Systematic laboratory validation which includes a realistic representation of all relevant interfacing systems, and associated software, including the control system components which are part of the lift/thrust system. Closed loop aircraft simulation/testing will be necessary in this laboratory validation.

(ii) Laboratory or aircraft testing to demonstrate unwanted coupling of electronic command signals (over the spectrum of operating frequencies) and their effects on the mechanical actuators and interfacing structure.

(iii) Analysis or inspection to substantiate that separation/segregation are utilised to minimize any potential hazards.

(9) A successful demonstration of signal integrity should include all elements, which contribute to command and control signals to the "aerodynamic closed loop" that actuate the flight controls. The "aerodynamic closed loop" should be evaluated for the normal and degraded modes. Elements of the integrated "aerodynamic closed loop" may include for example; digital or analogue flight control computers, power control units, control feedback, major data busses, and the sensor signals including; air data, acceleration, rate gyros, commands to the surface position, and respective power supply sources. Autopilot systems (including feedback functions) should be included in this demonstration if they are integrated with the FbW flight control system.

Compliance should be shown in conjunction with VTOL.2510 and SC EHPS (Electric and Hybrid Propulsion System).

(b) Pre-flight check

A means should be provided to allow a check of full range of movement to their commanded position of all primary lift/thrust controls (i.e. pilot controls, control surfaces) prior to flight, or a means should be provided that will allow the pilot to determine that full control authority is available prior to flight.

Some checks of the engine power and power control (e.g. engine RPM at least at idle thrust) should also be provided.

Compliance should be shown in conjunction with the following requirements VTOL.2425(a), VTOL.2435(f) (g) and VTOL.2615.

(c) Precautions against maintenance error / incorrect assembly

Experience has shown that maintenance errors should be assumed to occur and should be considered in the system design in order to reduce their likelihood.

The flight control system should be designed to physically prevent incorrect assemblies having significant safety effects and/or critical repercussions (i.e. catastrophic, hazardous, or major).

Distinctive and permanent marking should only be used if the prevention of incorrect assembly by design is impractical, and the Agency accepts the justification provided.

Significant safety effects may include an out-of-phase action, reversal in the sense of the control, faults introduced due to improper rigging, interconnection of the controls between two systems where this is not intended and loss of function.

(d) Flight Control Jams

The aircraft, pilot controls and its movable control system and/or surfaces should be designed to prevent a jam from occurring (refer to ASTM F3232/F3232M-20 standard §4.7 and 4.8) and should be tolerant to any jam, as far as practicable, and demonstrate continued safe flight and landing in the Category Enhanced or controlled emergency landing in the Category Basic. This may include the need for jam alleviation means.

The detachment of a part (e.g. control surface) should not be used as an alleviation means.

(1) Definition of Jam:

A jam is a failure or event such that a control (e.g. control surface), pilot control, or component is fixed in one position.

Causes of a jam may include corroded bearings, interference with a foreign or loose object, control system icing, seizure of an actuator, or a disconnection that results in a jam by creating an interference. Jams of this type should be assumed to occur and should be evaluated at positions up to and including the normally encountered positions defined in (2) below.

All other failures that result in a fixed control (e.g. a control surface), pilot control, or component are addressed via the safety analysis process in accordance with VTOL.2300 and VTOL.2510. Depending on system architecture and the location of the failure, some jam failures may not always result in a fixed control surface or pilot control.

(2) Determination of Control System Jam Positions.

The flight phases required to be addressed should cover all flight phases (e.g. vertical takeoff, transition, in-flight (climb, cruise, normal turns, descent, and approach), transition and, vertical landing). Additional phases specific to the aircraft, such as hover should also be considered.

(3) Methodology:

When showing compliance with VTOL.2300(a)(2), the applicant should:

(i) provide a summary of the design features that are intended to prevent a jam from occurring, due to failure or physical interference (jam prevention means),

(ii) provide a summary of the means by which a jam could be alleviated (jam alleviation means),

Note: if credit is taken from a jam alleviation device (e.g. jam breakout or override, disconnect means, alternate surface control, alternate power source, or alternate cable paths), then the conditional probability of failure of the jam alleviation device, given that jam has occurred, should be less than 1×10^{-3}.

(iii) For each axis and flight phase:

(A) determine the 'normally encountered position'.

This 'normally encountered position' is the maximum position resulting from reasonably expected manoeuvres, gust/manoeuvre load alleviation function commands and wind & gust conditions.

As an example, assuming a jam to be approximately 1 x 10^{-6} to 1 x 10^{-7} per flight hour, a reasonable definition of normally encountered positions would represent the range of control surface deflections (from neutral to the largest deflection) expected to occur in 1000 random operational flights, without considering other failures, for each of the flight segments identified in the rule. This assumption should be supported by FMEA/SSA expected failure rates for jams.

NOTE 1: If there is significant uncertainty regarding the control surface positions during 1000 random operational flights, it is acceptable to use the control surface stop or to propose another position based on conservative assumptions for acceptance by the Agency.

NOTE 2: Similarly to NOTE 1 above, the 1000 random operation flights is based on the assumption of a jam to be approximately 1 x 10^{-6} to 1 x 10^{-7} per flight hour. This is actually dependent on the actuator technology, installation, aircraft manufacturer and supplier experience. The Applicant should therefore propose a conservative analysis to cover the risk that is foreseen.

(B) evaluate the jam at positions up to and including the normally encountered position, and demonstrate continued safe flight and landing in the Category Enhanced or controlled emergency landing in the Category Basic including structural strength capability.

NOTE 3: Only the aircraft rigid body modes need to be considered when evaluating the aircraft response to manoeuvres, wind/gust conditions and continued safe flight to landing.

(iv) to identify the remaining possible jamming conditions, and demonstrate to the Agency that all precautions have been taken and that the probability of occurrence is consistent with the hazard classification. If it is needed, it should be discussed with and accepted by the Agency.

NOTE 4: Compliance should be shown in conjunction with MOC VTOL.2215 Flight Load Conditions for wind/gust conditions.

MOC VTOL.2300(a)(3) Control margin awareness

n/a

(a) A suitable annunciation or indication should be provided to the crew for any flight condition in which commands (e.g. control surfaces, engine RPMs) are approaching their limits (whether or not it is pilot commanded) and that returning to normal flight and/or continuation of safe flight requires a specific crew action.

(b) There should be a direct feedback of the control margin to the flight crew at any time in flight, in nominal and in a failure condition. This control margin is the remaining control available, related to the type of control laws (e.g. attitude command) and the means of control (e.g.

torque provided by lift/thrust units). For systems that provide combined thrust and vector control, information should be provided to the crew about which amount of remaining control is available to allow them to take the required actions to fly the aircraft.

(c) In the case of different control margin priorities, they should be clearly indicated to the crew for the current condition (e.g. height hold vs airspeed hold vs bank angle).

(d) It should be taken into account that some pilot-demanded manoeuvres (e.g., rapid roll) are necessarily associated with intended full performance, which may saturate the control. Therefore, simple alerting systems should function in both intended and unexpected flight control-limiting situations and should be properly balanced between the necessary crew-awareness and nuisance alerting. Nuisance alerting should be minimised by proper setting of the warning threshold.

(e) Depending on the application, suitable annunciations may include cockpit flight control position, force, annunciator light, or control position indicators. The term “suitable” indicates an appropriate balance between nuisance and necessary operation. Furthermore, this MOC applies at the limits of flight control authority, not necessarily at the limits of any individual control travel.

Compliance should be shown in conjunction with VTOL.2445 (a), (b), (c), (f) and (g).

MOC 4 VTOL.2300 Common Mode Failures and Errors in Fly-by Wire Flight Control Functions

n/a

To demonstrate compliance with VTOL.2300, in line with VTOL.2510, specific attention should be paid to common mode failures and errors in flight controls. The considerations on common modes in Section 9 (b) of MOC VTOL.2510 apply, supplemented by the following for fly-by-wire flight controls:

(a) Full reliance on Development Assurance and Quality Assurance as sole mitigation of a common mode failure or error leading to a total loss of flight controls function shall be avoided as far as practicable. Additional architectural mitigations that provide functional independence and/or item development independence should be provided.

(b) It is recognized that dissimilarity in the High-level specifications of Flight Control Laws in a Command/Monitoring (COM/MON) architecture may not be easy to implement. Monitoring of the Flight Control Laws may be a possible mitigation means against common mode errors in such case.

MOC 5 VTOL.2300 Hidden Failures in Fly-by-Wire flight control systems

n/a

To demonstrate compliance with VTOL.2300, in line with VTOL.2510, and to reach an acceptable level of safety, specific attention should be paid to latent failures.

The objective is to obtain a design with a minimum number of significant latent failures. Each significant latent failure should be highlighted in the system safety assessment and subject to review by the Agency.

In addition to the general considerations in Section 12 of MOC VTOL.2510, the following applies for fly-by-wire flight control systems:

(a) Definitions:

(1) Latent = dormant = hidden for more than one flight.

(2) A failure is latent until it is made known to the flight crew or maintenance personnel.

(3) A significant latent failure is one, which would in combination with one or more specific failures, or events result in a Hazardous or Catastrophic Failure Condition.

(4) A significant failure condition is one which is classified Hazardous or Catastrophic and contains one or more significant latent failures.

(b) The following approach should be followed:

(1) Double failures, with either one latent, that can lead to a Catastrophic Failure Condition should be avoided as far as practicable in system design. Deviations should be presented and accepted by the Agency.

(2) Latent failures that contribute to Hazardous or Catastrophic effects at aircraft level should be avoided in system design.

(3) The use of periodic maintenance or flight crew checks to detect significant latent failures when they occur is undesirable and should not be used in lieu of practical and reliable failure monitoring and indications.

(4) It is recognised that, on occasion, it would be impracticable to meet (1) and (2). In such cases:

(i) The remaining latent failures should be recorded and justified in the PSSA/SSA and reviewed during the design review process for compliance,

(ii) Compliance should be based on both previous experience and sound engineering judgement and should assess:

(A) the failure rates and service history of each component,

(B) the inspection type and interval for any component whose failure would be latent, and

(C) any possible common cause of cascading failure modes.

(iii) The integrity of the evident part of the significant failure condition should meet a minimum standard:

(A) For Catastrophic failure combinations comprising of only one evident failure, the probability per flight hour of the evident part should be:

a. <= 10^{-5}/Fh for Category Enhanced and Basic 7 to 9 passengers or

b. <= 10^{-4}/Fh for Category Basic below 7 passengers.

(B) For Hazardous failure combinations comprising of only one evident failure, the probability per flight hour of the evident part should be:

a. <= 10^{-4}/Fh for Category Enhanced and Basic 7 to 9 passengers or

b. <= 10^{-3}/Fh for Category Basic below 7 passengers.

(iv) In addition, a Specific Risk calculation should be performed to demonstrate compliance with the presence of a latent failure. For each combination composed of one evident failure and latent failures and leading to a Catastrophic Failure Condition the probability of the latent part of the combination (e.g. "Sum of the products of the failure rates multiplied by the exposure time" of any latent failure) should be on average equal to or less than $1x10^{-3}$ (=1/1000).

(v) The periodic maintenance checks, which may result from the compliance to this Specific Risk criterion in (b)(4)(iv)), should be considered as candidates for required maintenance tasks, in addition to the candidates for required maintenance tasks already selected for compliance to VTOL.2510.

VTOL.2305 Landing gear systems

n/a

(a) The landing gear must be designed to:

(1) provide stable support and control to the aircraft during surface operation; and

(2) account for likely system failures and likely operation environment (including anticipated limitation exceedances and emergency procedures).

(b) The aircraft must have a reliable means of stopping the aircraft with sufficient kinetic energy absorption to account for landing and take-off, in all approved conditions, and of holding the aircraft in position when parked.

(c) For aircraft that have a system that actuates the landing gear, there must be:

(1) a positive means to keep the landing gear in the landing position; and

(2) an alternative means available to bring the landing gear in the landing position when a non-deployed system position would be a hazard.

MOC VTOL.2305 Landing Gear Systems

n/a

1. Scope and Definitions

(a) This MOC applies to

(1) Wheeled landing gear, not to a skid, ski or float design.

(2) Tricycle landing gear arrangements of Nose and Main Landing Gears.

(3) Ground control of the vehicle, for the landing gear, pertains to steering by turning any of the vehicle wheels.

(b) The guidance assumes

(1) Normal take-off and landing is vertical. Forward-speed landings might be made for non-normal (emergency) conditions.

(2) No significant longitudinal engine thrust on ground

(3) Steering system is restricted to low-speed taxi only

(4) Ground resonance addressed separately, at aircraft-level

Note: Running take-off and landing (similar to fixed-wing aircraft) will be considered in a future update of this MOC.

2. Interference with Extension/Retraction

It should be shown that, in any practical circumstances, movement of the pilot's ground control (including movement during retraction or extension or after retraction of the landing gear) cannot interfere with the correct retraction or extension of the landing gear, unless it can be shown that such interference cannot create a consequence worse than Major, as defined in VTOL.2510.

3. Towing

If it is intended to tow the vehicle via the landing gear (either via tow-bar or via direct attachment to the wheel(s)), the ground control system(s), towing attachment(s), and associated elements should be designed or protected by appropriate means such that during ground manoeuvring operations effected by means independent of the vehicle:

(a) Damage affecting the safe operation of the ground control system is precluded, or

(b) A flight crew alert is provided, before taxi commences, if damage may have occurred.

4. Wheels

(a) The wheel should be approved, to ETSO C26d or equivalent

(b) The maximum static load rating of each wheel should not be less than the corresponding static ground reaction with:

(1) Maximum weight; and

(2) Critical centre of gravity.

(c) The maximum limit load rating of each wheel should equal or exceed the maximum radial limit load determined under the applicable ground load requirements of this SC.

5. Tyres

(a) If the landing gear is fitted with a tyre, then it should be a tyre:

(1) That is a proper fit on the rim of the wheel; and

(2) Of a rating that is not exceeded under:

(i) The design maximum weight;

(ii) A load on each main wheel tyre equal to the static ground reaction corresponding to the critical centre of gravity; and

(iii) A load on nose wheel tyres to be compared with the dynamic rating established for those tyres equal to the reaction obtained at the nose wheel, assuming that the mass of the vehicle acts at the most critical centre of gravity and exerts a force of 1.0 g downward and 0.25 g forward, the reactions being distributed to the nose and main wheels according to the principles of statics with the drag reaction at the ground applied only at wheels with brakes. Dynamic elements may be omitted for vehicles which usually take off and land vertically, and for which a running landing is Extremely Improbable.

(b) Each tyre installed on a retractable landing gear system should, at the maximum size of the tyre type expected in service, have a clearance to surrounding structure and systems that is adequate to prevent contact between the tyre and any part of the structure or systems.

(c) ETSO C62 provides the appropriate tyre performance standards. This ETSO accepts the use of a 1.5 factor on the Tyre Rating for helicopters. This factor is also appropriate to be used in VTOL vehicles which take off and land vertically (i.e. equivalent to helicopters).

6. **Brakes**

(a) The brakes should also be adequate to counter any normal unbalanced torque when starting engines or rotors.

(b) A park brake should be included which will hold the vehicle stopped, on a 10 degree slope, on a dry and smooth runway, for whichever is most demanding of the following three cases. In each case a steady wind speed of at least 17 kt, or higher defined by the applicant, from the most adverse direction should be assumed in order:

(1) To allow sufficient time for emergency egress and to secure the vehicle in place via other means

(2) To counter any unbalanced torque when starting or stopping rotating lift/thrust units

(3) To react any element of longitudinal thrust from lift/thrust units, albeit that the take-off and landing will be vertical.

(c) The brakes should have adequate controllability and stopping capacity to bring the vehicle safely to a halt for any emergency running landing (including an immediate re-land). Such a running landing need not be considered if it arises from failure combinations determined to be Extremely Improbable, as defined in VTOL.2510. ETSO-C26c contains minimum performance standards for wheels and wheel-brake assemblies. The relevant rotorcraft section of this ETSO may be used when following this MOC.

(d) Any fatigue or endurance effect of applying the brake during high-speed taxi should be taken into consideration.

(e) Means should be provided for each brake assembly to indicate when the heat sink is worn to the permissible limit. The means should be reliable and readily visible.

(f) Compatibility of the wheel and brake assemblies with the vehicle and its systems should be substantiated.

7. **Landing Gear Warning**

If a retractable landing gear is used, an aural or equally effective landing gear warning device should be provided that functions continuously when the vehicle is in a normal landing mode and the landing gear is not fully extended and locked. A manual shut-off capability should be provided for the warning device and the warning system should automatically reset when the vehicle is no longer in the landing mode.

8. **Landing Gear Position Indication**

If a retractable landing gear is used, there should be a landing gear position indicator (as well as necessary switches to actuate the indicator) or other means to inform the pilot that each gear is secured in the extended (or retracted) position. If switches are used, they should be located and coupled to the landing gear mechanical system in a manner that prevents an erroneous indication of either “down and locked” if each gear is not in the fully extended position, or of “up and locked” if each landing gear is not in the fully retracted position.

9. **Landing Gear Emergency Extension**

If a retractable landing gear is used, emergency means should be provided for extending the gear in the event of :

(a) Any reasonably probable failure in the normal retraction system; or

(b) The failure of any single source of hydraulic, electric, or equivalent energy.

10. Operation Tests

The proper functioning of the extending/retracting mechanism must be shown by operation tests.

11. Landing Gear Lock

There should be a positive means (other than the use of the LG extension power source) to keep the landing gear extended in the landing position.

VTOL.2310 Flotation

n/a

(a) If certification for intended operations on water is requested, the aircraft must:

(1) provide buoyancy of 80 % in excess of the buoyancy required to support the maximum weight of the aircraft in fresh water; and

(2) have sufficient margin so that the aircraft will stay afloat at rest in calm water without capsizing in case of a likely float or hull flooding.

(b) If certification for emergency flotation is requested, the aircraft must:

(1) not rely on any manual action to deploy any installed emergency flotation system;

(2) have watertight compartments, integrated buoyancy or flotation units of the emergency flotation system and their attachments to the aircraft, capable of withstanding the applicable water loads; and

(3) be shown to maintain its intended floating attitude in the sea conditions selected by the applicant; and

(4) be shown not to sink for 15 minutes.

(c) If certification for ditching is requested, the aircraft must:

(1) not rely on any manual action to deploy any installed emergency flotation system;

(2) withstand the applicable water loads;

(3) be shown to have a safe water entry and to maintain its intended floating attitude in the sea conditions selected by the applicant;

(4) be shown not to sink for 15 minutes; and

(5) for Category Enhanced incorporate appropriate post-capsize survivability features.

(d) If certification for limited overwater operations is requested, the aircraft must:

(1) not rely on any manual action to deploy any installed emergency flotation system;

(2) have watertight compartments, integrated buoyancy or flotation units of the emergency flotation system, and their attachments to the aircraft, capable of withstanding the applicable water loads; and

(3) be shown not to sink for 15 minutes.

(e) If certification for operations on floating surfaces is requested, the aircraft must be shown to be able to be safely operated within the surface motion limits selected by the applicant, in addition to meeting the criteria referred to in points (b), (c) or (d).

MOC VTOL.2310(b) Emergency Flotation

n/a

(a) If certification for emergency flotation is requested by the applicant, the aircraft should meet the following design criteria:

(1) For aircraft fitted with an emergency flotation system (floats):

(i) The flotation units of the emergency flotation system and their attachments to the aircraft should comply with the structural provisions for ditching, emergency flotation and overwater operations of MOC VTOL.2270(c)

(ii) The aircraft should be shown to resist capsize, in the intended floating attitude, in the sea conditions selected by the applicant. The probability of capsizing in a 5-minute exposure to the sea conditions should be demonstrated to be less than or equal to 10.0 % with a fully serviceable emergency flotation system, with 95 % confidence. No demonstration of capsize resistance is required for the case of the critical float compartment having failed. Allowances should be made for probable structural damage and leakage.

(iii) For Category Enhanced, it should be shown that the aircraft will not sink following the functional loss of any single complete flotation unit for 15 minutes(1).

(iv) For Category Basic, it should be shown that the aircraft will not sink for 15 minutes(1) with a fully functional emergency flotation system.

(v) An emergency flotation system that is stowed in a deflated condition during normal flight should have a means of automatic deployment following water entry. Automatic deployment should not rely on any manual action during flight.

(2) For aircraft with watertight compartments, hull buoyancy and/or integrated buoyancy:

(i) The buoyancy components of the aircraft and their attachments to the aircraft should comply with the structural provisions for ditching, emergency flotation and overwater operations of MOC VTOL.2270(c).

(ii) The aircraft should be shown to resist capsize, in the intended floating attitude, in the sea conditions selected by the applicant. The probability of capsizing in a 5-minute exposure to the sea conditions should be demonstrated to be less than or equal to 10.0 % with fully functional buoyancy components, with 95 % confidence. No demonstration of capsize resistance is required for the case of the functional loss of the critical buoyancy component. Allowances should be made for probable structural damage and leakage.

(iii) For Category Enhanced, it should be shown that the aircraft will not sink following the functional loss of any single buoyancy component for 15 minutes(1).

(iv) For Category Basic, it should be shown that the aircraft will not sink for 15 minutes(1) with fully functional buoyancy components.

Note (1): 15 minutes is consistent with MOC VTOL.2430(a)(6) “Energy retention capability in an emergency landing”.

(b) CS 27 Amdt. 5 (or later): AMC 27.802 and ‘AMC to CS 27.801(e) and CS 27.802(c)’ provide additional guidance.

(c) If certification with emergency flotation provisions is requested by the applicant, the flight manual should contain the substantiated sea conditions and any associated information relating to the certification obtained with emergency flotation provisions.

(d) The following MOCs are also applicable:

(1) MOC VTOL.2315(a) Means of egress and emergency exits

(2) MOC VTOL.2430(a)(6) Energy retention capability in an emergency landing

(3) MOC VTOL.2535 Safety Equipment

(4) MOC VTOL.2605(c) Information related to safety equipment

(5) MOC VTOL.2610 Instrument markings, control markings and placard

MOC VTOL.2310(c) Ditching

n/a

(a) If certification with ditching provisions is requested by the applicant, the aircraft should meet the following design criteria:

(1) The design criteria defined for MOC VTOL.2310(b) Emergency Flotation

(2) The aircraft should comply with the structural provisions for ditching, emergency flotation and overwater operations of MOC VTOL.2270

(3) Each practicable design measure, compatible with the general characteristics of the aircraft, should be taken to minimise the probability that when ditching, the behaviour of the aircraft would cause immediate injury to the occupants or would make it impossible for them to escape.

(4) The probable behaviour of the aircraft during ditching water entry should be shown to exhibit no unsafe characteristics.

(5) For aircraft fitted with an emergency flotation system:

(i) The aircraft should be shown to resist capsize(1), in the intended floating attitude, in the sea conditions selected by the applicant. The probability of capsizing in a 5-minute exposure to the sea conditions should be substantiated to be less than or equal to 3.0 % with a fully serviceable emergency flotation system and 30.0 % with the critical float compartment failed, with 95 % confidence.

(ii) Allowances should be made for probable structural damage and leakage.

(iii) An emergency flotation system that is stowed in a deflated condition during normal flight should be designed such that the effects of a water impact (i.e. crash) on the emergency flotation system are minimized.

(6) For aircraft with watertight compartments, hull buoyancy and/or integrated buoyancy:

(i) The aircraft should be shown to resist capsize(1), in the intended floating attitude, in the sea conditions selected by the applicant. The probability of capsizing in a 5-minute exposure to the sea conditions should be substantiated to be less than or equal to 3.0 % with fully functional buoyancy components, and 30.0 % with the functional loss of the critical buoyancy component, with 95 % confidence.

(ii) Allowances should be made for probable structural damage and leakage.

(iii) The buoyancy components should be designed such that the effects of a water impact (i.e. crash) on the buoyancy components are minimised.

(7) Unless the effects of the collapse of external doors and windows are accounted for in the investigation of the probable behaviour of the aircraft during ditching and for the capsize resistance demonstration, the external doors and windows should be designed to withstand the probable maximum local pressures.

(8) Additionally, for Category Enhanced: The aircraft design should incorporate appropriate post-capsize[(1)] survivability features to enable all passenger cabin occupants to safely egress the aircraft, taking into account the human breath hold capability.

(i) One method of meeting this post-capsize survivability provision is to create stable floating attitudes which will create an air pocket in the passenger cabin. Passengers can utilise the air in the pocket for continued survival during the time needed for all to make their escape.

(ii) The size and shape of the air pocket should be sufficient to accommodate all passengers. A minimum volume per passenger, in the form of an elliptical column of 70 cm x 50 cm (27 in. x 19 in.) and height of 30 cm (11 in.) relative to the static waterline should be established and demonstrated as fitting into the air pocket, including with the critical float compartment or buoyancy component failed.

(iii) The air pocket should be accessible and immediately available without passengers needing to cross seat backs.

(iv) Emergency breathing systems (EBSs) that are capable of being quickly deployed underwater do exist. This type of personal protective equipment (PPE) may provide a limited level of mitigation for the issues related to human breath hold capability, but it should not be considered alone as being sufficient to meet the post-capsize survivability provisions.

Note [(1)]: Capsize means full or partial capsize, i.e. inability to maintain the intended floating attitude.

(b) CS 27 Amdt. 5 (or later): AMC 27.801 and AMC to CS 27.801(e) and CS 27.802(c) provide additional guidance.

(c) If certification with ditching provisions is requested by the applicant, the flight manual should contain the substantiated sea conditions and any associated information relating to the certification obtained with ditching provisions.

(d) The following MOCs are also applicable:

(1) MOC VTOL.2315(a) Means of egress and emergency exits

(2) MOC VTOL.2430(a)(6) Energy retention capability in an emergency landing

(3) MOC VTOL.2535 Safety Equipment

(4) MOC VTOL.2605(c) Information related to safety equipment

(5) MOC VTOL.2610 Instrument markings, control markings and placard

OCCUPANT SYSTEM DESIGN PROTECTION

VTOL.2315 Means of egress and emergency exits

n/a

(a) The aircraft must be designed to:

(1) Facilitate rapid and safe evacuation of the aircraft in conditions likely to occur following an emergency landing, including on water if an emergency flotation system is included.

(2) Have means of egress (openings, exits or emergency exits) that can be readily located and opened from the inside and outside. The means of opening must be simple and obvious. If an emergency flotation system is included, the means of egress must be above the water in the intended floating attitude. Additionally, if certification for ditching is requested, the means of egress must be usable in all stable floating attitudes.

(i) If certification with emergency flotation provisions or limited overwater operations is requested, there should be an emergency exit accessible to each passenger on each side of the cabin with the aircraft in any stable floating attitude. If submerged, the emergency exit must be identified as an underwater emergency exit and shall be shown by test, demonstration, or analysis to be accessible and operable underwater to give each occupant every reasonable chance of escaping.

(ii) If certification with ditching is requested, underwater emergency exits must be provided and shall be proven by test, demonstration, or analysis to provide for rapid escape with the aircraft in any stable floating attitude.

(3) Have easy access to emergency exits when present.

(b) Reserved.

MOC VTOL.2315(a) Means of egress and emergency exits

n/a

1. Means of egress and emergency exits for Ditching, Emergency Flotation and Limited Overwater Operations[1]

(a) If certification with emergency flotation provisions or limited overwater operations is requested by the applicant, the aircraft should meet the following design criteria:

(1) There should be an emergency exit accessible to each passenger on each side of the cabin with the aircraft in any stable floating attitude.

(2) For aircraft where the proximity of the passenger emergency exits to the flight crew area does not offer a convenient and readily accessible means of evacuation for the flight crew, the following applies:

(i) there should be a flight crew emergency exit on each side of the aircraft, or a top hatch emergency exit in the flight crew area, accessible to the flight crew with the aircraft in any stable floating attitude

[1] For explanation of overwater operations refer to MOC VTOL.2270(c) "Structural Provisions: Ditching, Emergency Flotation and Limited Overwater Operation", MOC VTOL.2310(b) Emergency Flotation and MOC VTOL.2310(c) Ditching.

(ii) each emergency exit should be located to allow rapid evacuation of the flight crew

(3) Each emergency exit should be reasonably protected from becoming jammed as a result of fuselage deformation.

(4) In addition, for flight crew underwater exits: If flight crew emergency exits are submerged in any stable floating position, these exits should meet the following design criteria:

(i) Each exit should be shown by test, demonstration, or analysis to be accessible and operable underwater. Evaluations should consider ranges of size and strength found in the 5th percentile female to the 95th percentile male.

(ii) Each operational device (pull tab(s), operating handle, 'push here' decal, etc.) should be marked with black and yellow stripes.

(iii) The exit should be marked so to be readily located and operated even in darkness, and these markings should remain visible if the cockpit is submerged.

(5) In addition, for passenger underwater exits: If passenger emergency exits are submerged in any stable floating position, these exits should meet the following design criteria:

(i) Each exit should be shown by test, demonstration, or analysis to be accessible and operable underwater to give each occupant every reasonable chance of escaping. Evaluations should consider ranges of size and strength found in the 5th percentile female to the 95th percentile male.

(ii) Each operational marking (pull tab(s), operating handle, 'push here' decal, etc.) should be marked with black and yellow stripes.

(iii) The exit should be provided with a suitable handhold, or handholds adjacently located inside the cabin, to assist occupants in locating and operating the exit, as well as in egressing through the emergency exit.

(iv) The exit should be marked so to be readily located and operated even in darkness, and these markings should remain visible if the cabin is submerged.

(6) Additionally, for aircraft fitted with an emergency flotation system (floats):

(i) Each emergency exit, including underwater exits, should be shown by test, demonstration, or analysis to open without interference from flotation devices, whether stowed or deployed, and with the aircraft in any stable floating attitude.

(b) CS 27 Amdt. 5 (or later): AMC 27.805(c) and AMC 27.807(d) provide additional guidance for certification with emergency flotation provisions or limited overwater operations

(c) If certification with ditching provisions is requested by the applicant, the aircraft should meet the following design criteria:

(1) Each emergency exit, including underwater exits, should be reasonably protected from becoming jammed as a result of fuselage deformation.

(2) Any non-jettisonable doors intended for use after a ditching should have means to enable them to be secured in the open position and remain secure for emergency egress in all sea conditions for which ditching capability is requested by the applicant

(3) For Category Enhanced the following is also applicable:

(i) Ditching emergency exits should be provided such that following a ditching, in all sea conditions for which ditching capability is requested by the applicant and in the intended floating attitude, passengers are able to evacuate the aircraft and step directly into any of the required life raft

(ii) It should be possible for each passenger to egress the aircraft via the nearest underwater emergency exit, when capsized, with any door in the open and secured position;

(iii) Means should be provided to assist cross-cabin escape when capsized

(4) In addition, Flight crew emergency exits should meet the following design criteria:

(i) Each exit should be shown by test, demonstration, or analysis to provide for rapid escape in any stable floating attitude. Evaluations should consider ranges of size and strength found in the 5th percentile female to the 95th percentile male.

(ii) The average load required to operate the exit release mechanism and open the exit should not exceed 222N (50 lbf), and the maximum individual load of a test series should not exceed 245N (55 lbf).

(iii) Each operational device (pull tab(s), operating handle, 'push here' decal, etc.) should be marked with black and yellow stripes and should be shown to be accessible for the range of required flight crew heights and for both the case of an un-deformed seat and a seat with any deformation resulting from the test conditions required by VTOL.2270(b)(1)

(iv) For Category Enhanced: each exit, its means of access and its means of opening, should be provided with highly conspicuous illuminated markings that illuminate automatically and are designed to remain visible in any stable floating attitude and the cockpit flooded.

(v) For Category Basic: The exit should be marked so to be readily located and operated even in darkness, and these markings should remain visible if the cockpit is submerged

(5) In addition, for passenger underwater exits: Underwater emergency exits should be provided in accordance with the following requirements and should be proven by test, demonstration, or analysis to provide for rapid escape with the aircraft in any stable floating attitude:

(i) One underwater emergency exit, providing an unobstructed opening that will admit a 0.48 m by 0.66 m (19 inch by 26 inch) ellipse, should be installed in each side of the aircraft for each unit (or part of a unit) of four passenger seats. However, the seat-to-exit ratio may be increased for underwater emergency exits large enough to permit the simultaneous egress of twopassengers side by side.

(ii) Passenger seats should be located in relation to the underwater emergency exits in a way to best facilitate escape with the aircraft capsized and the cabin flooded

(iii) Underwater emergency exits, including their means of operation, markings, lighting and accessibility, should be designed for use in a flooded and capsized cabin. Evaluations should consider ranges of size and strength found in the 5th percentile female to the 95th percentile male.

(iv) The average load required to operate the exit release mechanism and open the exit should not exceed 222N (50 lbf), and the maximum individual load of a test series should not exceed 245N (55 lbf).

(v) Each operational marking (pull tab(s), operating handle, 'push here' decal, etc.) should be marked with black and yellow stripes.

(vi) The exit should be provided with a suitable handhold, or handholds adjacently located inside the cabin, to assist occupants in locating and operating the exit, as well as in egressing through the emergency exit.

(vii) For Category Enhanced: each exit, its means of access and its means of opening, should be provided with highly conspicuous illuminated markings that illuminate automatically and are designed to remain visible in any stable floating attitude and the cabin flooded.

(viii) For Category Basic: The exit should be marked so to be readily located and operated even in darkness, and these markings should remain visible if the cockpit is submerged

(6) Additionally, for aircraft fitted with an emergency flotation system:

(i) Each emergency exit, including underwater exits, should be shown by test, demonstration, or analysis to open without interference from flotation devices, whether stowed or deployed, and with the aircraft in any stable floating attitude.

(d) CS 27 Amdt. 5 (or later): AMC 27.783, AMC 27.805(c), AMC 27.807(d) and AMC 29.803(c) provide additional guidance for certification with ditching provisions.

VTOL.2320 Occupant physical environment

n/a

(a) The aircraft must be designed to:

(1) allow clear communication between the flight crew and passengers;

(2) protect the occupants against serious injury due to hazards originating from high energy, associated with systems and equipment, including while embarking and disembarking; and

(3) protect the occupants against serious injury due to breakage of windshields, windows, and canopies.

(b) Reserved.

(c) The aircraft must provide each occupant with air at a breathable pressure, free of hazardous concentrations of gases, vapours and smoke during normal operations and likely failures.

(d) Reserved.

(e) If an oxygen system is installed in the aircraft, it must:

(1) effectively provide oxygen to each user to prevent the effects of hypoxia; and

(2) be free from hazards in itself, in its method of operation, and its effect upon other components.

MOC VTOL.2320(a)(1) Clear communication between flight crew and passengers

n/a

(a) CS 23.771(b) Amdt. 4 is accepted as a means of compliance

(b) For those aircraft in which the flight crew members cannot observe the other occupants' seats or in which the flight crew compartment is separated from the passenger compartment

(1) CS 23.791 Amdt. 4 is accepted as a means of compliance, or

(2) A boarding procedure should be introduced together with suitable placarding in the cabin to ensure that the seat belts are fastened during the whole flight.

MOC VTOL.2320(a)(2) Occupant physical environment

n/a

A hazard that originates from high energy should be understood to cover all possible serious injury mechanisms involving one or more of the aircraft's energy sources. This might involve, for example, contact with a high speed rotating part, with a high temperature surface, with a high velocity and/or temperature gas jet, or with an electrically live conductor.

With the aircraft in its normal pre-take-off/post-landing attitude on the ground it should be substantiated that no person in contact with the ground or entering/exiting the aircraft can place any part of their body in a position where serious injury could occur.

This may be achieved by the provision of physical barriers, designed to prevent contact with aircraft parts or reduce the risk of inadvertent movement into dangerous areas, design precautions to prevent the aircraft presenting identified hazards when flight is not intended, or an appropriate combination of both. The complete range of human anthropometry, including children, should be considered.

In the case of physical barrier means, all possible positioning of persons should be considered, without any assumptions of likelihood of a person taking up such a position. However, if full prevention is not feasible, for example against movement into a high velocity and/or temperature gas jet, a partial barrier solution may be acceptable. In such a case, precautions such as highly visible markings, pre-flight briefings to passengers, a requirement for trained ground personnel to be present, etc. might be considered by the Agency to provide a comparable level of safety. Furthermore, the possibility of persons becoming distracted by one potential hazard and moving into another hazardous area, including in the case of darkness, should be considered.

In the case of a design precaution to prevent the presence of high energy at a critical location, the reliability of the precaution should be commensurate with its failure to function as intended being classified as catastrophic. Appropriate mechanical, electrical or software interlocks could form the basis of design precautions, using inputs such as proximity detection of objects around the aircraft, exit locking status, etc. If design precautions based on passivating or shutting down systems are used to protect occupants while entering/exiting the aircraft, these must be supplemented by other design provisions or physical barriers to protect people on the ground.

The chosen means of protection should also cover the case where at the end of flight a passenger immediately opens an exit and egresses the aircraft.

"Serious Injury" should be taken to mean any injury which involves one or more of the following;

(1) hospitalisation for more than 48 hours, commencing within 7 days from the date the injury wasreceived;

(2) a fracture of any bone (except simple fracture of fingers, toes, or nose);

(3) laceration which causes severe haemorrhages, nerve, muscle, or tendondamage;

(4) injury to any internalorgan;

(5) second- or third-degree burns, or any burns affecting more than 5 percent of the body surface; or

(6) verified exposure to infectious substances or harmful radiation.

(Source: ICAO, Annex 13 to the Convention on International Civil Aviation)

MOC VTOL.2320(a)(3) Occupant protection from breakage of windshields, windows, and canopies

n/a

(a) CS 27.775 Amdt. 5 (or later) is accepted as a means of compliance.

(b) In addition, for Category Enhanced and Category Basic with a maximum seating configuration of 7 or more, the windshield should be evaluated for a single bird strike in accordance with VTOL.2250(f).

FIRE AND HIGH ENERGY PROTECTION

VTOL.2325 Fire Protection

n/a

(a) The aircraft must be designed to minimise the risk of fire initiation due to:

(1) anticipated heat or energy dissipation or system failures or overheat that are expected to generate heat sufficient to ignite a fire;

(2) ignition of flammable fluids, gases or vapours; and

(3) fire-propagating or -initiating system characteristics (e.g. oxygen systems).

(4) a survivable emergency landing.

(b) The aircraft must be designed to minimise the risk of fire propagation by:

(1) providing adequate fire or smoke awareness and extinguishing means when practical;

(2) application of self-extinguishing, flame-resistant, or fireproof materials that are adequate to the application, location and certification level; or

(3) specifying and designing designated fire zones that meet the specifications of VTOL.2330.

MOC VTOL.2325(a)(4) Fire Protection - Energy storage crash resistance

n/a

1. Introduction and scope

VTOL.2325 (a)(4) requires that the energy storage system and its installation in the aircraft are designed to minimise the risk of post-crash fires in survivable emergency landings. The ultimate goal is to provide occupants with sufficient time to evacuate or be extracted from the aircraft following such events.

The similarity of VTOL capable aircraft and small rotorcraft justifies the consideration of the design and test criteria as being comparable and therefore applicable. These criteria, mainly contained in CS 27.952 Amdt. 6 and CS 27.561 Amdt. 6, have proven to be successful in a large number of accidents in preventing or delaying the onset of post-crash fires, thus maximising the occupant escape time after survivable emergency landings.

The main concern in small rotorcraft are crash-induced fuel leaks that quickly come in contact with ignition sources during or after impact. It is recognised that there are many possible energy sources in VTOL capable aircraft (fuel, electricity, gas) that require the need to consider other forms of fire initiation. However, they do not invalidate the defined emergency landing conditions for which the design needs to show its capability to minimise the risk of fire initiation.

The following accepted means of compliance with VTOL.2325(a)(4) therefore builds on the design and test criteria contained in CS 27.952 Amdt. 6 and CS 27.561 Amdt. 6, complementing or adapting them, whenever necessary to account for different energy sources.

In addition, this MOC also constitutes an accepted means of compliance with VTOL.2430(a)(6) regarding the energy retention capability of the energy storage and distribution system during a survivable emergency landing on land. Specific considerations for the demonstration of compliance with VTOL.2430(a)(6) of VTOL capable aircraft intended to be used for operations on water, emergency flotation or ditching as per VTOL.2310 or over water are provided in MOC VTOL.2430(a)(6).

2. Energy Storage crash resistance

(a) Unless other means that are acceptable to the Agency are employed to minimise the hazard to occupants caused by energy storage systems following an otherwise survivable impact (crash landing), the energy storage system should incorporate the design features of this MOC

(b) These systems should be shown to be capable of sustaining the static and dynamic deceleration loads of this MOC, considered as ultimate loads acting alone, measured at the system component's centre of gravity without structural damage to the energy storage system or their attachments that could cause any fire other than the contained battery fire allowed in point 3.(f)(2)(ii) of this MOC.

(c) In addition, no harmful amounts of liquids or toxic fumes or gases should enter an occupied area or the evacuation path.

3. Drop test requirements

Each energy storage system, or the most critical energy storage system, should be subject to a drop-test using the following methodology:

(a) the drop height should be at least 15.2 m (50 ft);

(b) the drop impact surface should be non-deforming;

(c) the energy storage system should be charged or filled to its most critical condition expected during a crash;

(d) the energy storage system should be enclosed in a surrounding structure representative of the installation unless it can be established that the surrounding structure is free of projections or other design features likely to contribute to rupture of the energy storage system;

(e) the energy storage system should drop freely in an orientation that is representative of a typical installation on the aircraft and impact in a horizontal position ±10°with regards to the horizontal axis of the VTOL; and

(f) after the drop test there should be no risk of post-crash fire or other harmful release within a time frame compatible with the rescue of seriously injured occupants.

(1) For liquid or gaseous fuels: no leakage of flammable fluids or gases.

(2) For batteries:

(i) structural damage should not lead to a fire, leakage of harmful fluids, fumes or gases; or

(ii) any fire or leakage of harmful fluids, fumes or gases should be contained for at least 15 minutes in non-occupied areas and outside the evacuation path.

(3) Any projectile release should not lead to serious injury to occupants or persons on ground.

4. Energy storage system load factors

(a) Except for energy storage systems located so that structural damage to the energy storage that could cause fire, leakage of harmful or flammable fluids or gases, or toxic fumes in occupied areas or the evacuation path is extremely remote, each energy storage system should be designed and installed to retain its contents under the following ultimate inertial load factors, acting alone.

(b) For energy storage systems in the cabin:

(1) Upward – 4 g.

(2) Forward – 16 g. (18 g for CTOL)

(3) Sideward – 8 g.

(4) Downward – 20 g.

(5) Rearward – 1.5 g.

(c) For energy storage systems located above or adjacent the crew or passenger compartment that, if loosened, could injure an occupant in an emergency landing:

(1) Upward – 1.5 g.

(2) Forward – 12 g.

(3) Sideward – 6 g.

(4) Downward – 12 g.

(5) Rearward – 1.5 g.

(d) For energy storage systems in other areas:

(1) Upward – 1.5 g.

(2) Forward – 4 g.

(3) Sideward – 2 g.

(4) Downward – 4 g.

5. Energy storage system isolation means

(a) For liquid or gaseous fuel systems, self-sealing isolation means should be installed unless hazardous relative motion of energy storage system components to each other or to local aircraft structure is demonstrated to be extremely improbable or unless other means are provided.

(b) The isolations means, such as a fuses, couplings or equivalent devices should be installed where structural deformation could lead to a hazard to the occupants due to high energy release or release of harmful amount of fluids or gases.

(c) For liquid or gaseous fuel systems, the design and construction of the isolation means for fuel tank to fuel line connections, fuel tank to fuel tank interconnects, and other points in the fuel system should incorporate the following design features:

(1) the load necessary to separate a breakaway coupling should be between 25 and 50% of the minimum ultimate failure load (ultimate strength) of the weakest component in the fuel-carrying line. The separation load should in no case be less than 1334 N (300 lb), regardless of the size of the fuel line;

(2) a breakaway coupling should separate whenever its ultimate load (as defined in sub-paragraph 5(c)(1)) is applied in the failure modes most likely to occur;

(3) all breakaway couplings should incorporate design provisions to visually ascertain that the coupling is locked together (leak-free) and is open during normal installation and service;

(4) all breakaway couplings should incorporate design provisions to prevent uncoupling or unintended closing due to operational shocks, vibrations, or accelerations; and

(5) no breakaway coupling design may allow the release of liquid or gaseous fuel once the coupling has performed its intended function.

(d) For electrical energy storage systems:

(1) During a crash landing in which structural damage could lead to the release of high energy, an isolation means should ensure that no energy can be released from the energy storage system which could lead to serious injury to occupants or persons on ground. Its activation should be:

(i) automatic, unless this is demonstrated to be impractical, in which case other means acceptable to the Agency may be employed.

(ii) indicated to the flight crew and rescue personnel.

(2) A manual isolation means has to be safely accessible for the rescue personnel and be clearly marked.

(e) All individual isolation means, such as fuses, emergency stop, breakaway couplings, coupling fuel feed systems, or equivalent means should be designed, tested, installed and maintained so that inadvertent activation in flight is minimised to the maximum extent practicable. It should be ensured that the isolation means are not degrading beyond an acceptable level in accordance with the reliability requirements for systems and the fatigue requirements for structural installations.

(f) Alternatively, for gaseous or liquid fuels, equivalent means to the use of breakaway couplings should not create a survivable impact-induced load on the fuel line to which it is installed greater than 25 to 50% of the ultimate load (strength) of the weakest component of the line and should comply with the fatigue requirements of CS 27.571 Amdt. 6 without leaking.

6. Frangible or deformable structural attachments

(a) Frangible or locally deformable attachments of energy storage system components to local aircraft structure should be used unless hazardous relative motion of energy storage system components to local aircraft structure is demonstrated to be extremely improbable in an otherwise survivable impact.

(b) The attachment of energy storage system components to local aircraft structure, whether frangible or locally deformable, should be designed such that separation or relative local deformation of the attachment of energy storage system components will occur without rupture or local tear-out of energy storage system components that will could cause leakage or high energy release.

(c) The load required to separate a frangible energy storage system components attachment from its support structure, or to deform a locally deformable attachment relative to its support structure, should be between 25% and 50% of the minimum ultimate load (ultimate strength) of the weakest component in the attached system. In no case should the load be less than 1330 N (300 lbs).

(d) A frangible or locally deformable energy storage system components attachment should separate or locally deform as intended whenever its ultimate load (as defined in sub-paragraph 6(c)) is applied in the modes most likely to occur.

(e) All frangible or locally deformable energy storage system components attachments should comply with the fatigue requirements of CS 27.571 Amdt. 6.

7. Separation of flammable fluids or gases and ignition sources

To provide maximum crash resistance, flammable fluids or gases should be located as far as practicable from all occupiable areas and from all potential ignition sources.

8. Other basic mechanical design criteria

Battery system components, electrical wires, and electrical devices should be designed, constructed and installed, as far as practicable, to be crash resistant.

9. Rigid or semi-rigid fuel tanks

Rigid or semi-rigid fuel tank or bladder walls should be impact and tear resistant.

MOC VTOL.2325(b)(1) and (b)(2) Fire Protection: fire extinguishers and design of interiors

n/a

1. Category Basic

(f) Fire Extinguishers: CS 23.851(a), (b)(1), (c) Amdt. 4 are accepted as a means of compliance

(g) Compartment interiors: CS 27.853 Amdt. 6 is accepted as a means of compliance.

(h) Cargo and baggage compartment: CS 27.855 Amdt. 6 is accepted as a means of compliance.

2. Category Enhanced

For Category Enhanced the means of compliance accepted for Category Basic should be completed with the following provisions:

(a) Compartment interiors: CS 29.853(a), (b) and (d) Amdt. 7 are accepted as a means of compliance.

(b) Baggage compartment:

A baggage compartment that is located where the presence of a fire would not easily be discovered by a pilot while at his station should:

(1) Have ceiling and sidewall liners and floor panels constructed of materials that have been subjected to and meet the 45° angle test of Appendix F to CS-23 Amdt. 4. The flame should not penetrate (pass through) the material during application of the flame or subsequent to its removal. The average flame time after removal of the flame source should not exceed 15 s, and the average glow time should not exceed

10 s. The compartment should be constructed to provide fire protection that is not less than that required of its individual panels; or

(2) Be constructed and sealed to contain any fire within the compartment or have a device to ensure detection of fires or smoke by a crew member while at his station and to prevent the accumulation of harmful quantities of smoke, flame, extinguishing agents, and other noxious gases in any crew or passenger compartment.

3. Category Basic and Enhanced: Detection and extinguishing systems in designated fire zones

(a) Detection Systems:

It is accepted that adequate fire or smoke awareness for the designated fire zones is provided by the installation of detection systems that follow Section 3(g) in MOC VTOL.2330.

(b) Extinguishing Systems:

Following CS requirements are accepted as means to comply with VTOL.2325(b)(1) regarding adequate extinguishing means for Designated Fire Zones in accordance with section 1(d) of MOC VTOL.2330:

(1) CS 27.1194 Amdt. 6 “Other surfaces”

(2) CS 29.1195 Amdt. 6 “Fire extinguishing systems”

(3) CS 29.1197 Amdt. 6 “Fire extinguishing agents”

(4) CS 29.1199 Amdt. 6 “Extinguishing agent containers”

(5) CS 29.1201 Amdt. 6“Fire extinguishing system materials”

For extinguishing systems in Fire Withstanding Zones and Explosive Fire Zones (refer to definitions in sections 1(c) and 1(e) of MOC VTOL.2330), specific means of compliance should be agreed with the Agency taking into consideration the intended operation and existing technologies.

VTOL.2330 Fire Protection in designated fire zones

n/a

(a) Flight critical systems, lift/thrust unit mounting, and other structures within or adjacent to designated fire zones must be capable of withstanding the effects of a fire.

(b) A fire or other release of stored energy in a designated fire zone must not preclude continued safe flight and landing for Category Enhanced, or a controlled emergency landing for Category Basic.

(c) Terminals, equipment, and electrical cables used during emergency procedures must be fire-resistant.

MOC VTOL.2330 Fire Protection in designated fire zones

n/a

1. Definitions and Terminology

In accordance with VTOL.2400, the aircraft *lift/thrust system* installation includes each component that is necessary for lift/thrust, affects lift/thrust safety, or provides auxiliary power to the aircraft.

Three *types of Fire Zone* can be found in electric lift/thrust systems. Among them there is the Designated Fire Zone, as defined in CS 29.1181, which should not be confused with the generic term *designated fire zone* used in the Special Condition VTOL encompassing zones of different fire risks.

For the purpose of this MOC, the following definitions are provided:

(a) **Electrical Energy Storage System**

The Electrical Energy Storage System (EESS) consists of the battery necessary for the propulsion of VTOL capable aircraft and its associated management system.

(b) **Fire zones for the lift/thrust system**

(1) Explosive Fire Zone, EFZ

(2) Fire Withstanding Zone, FWZ

(3) Designated Fire Zone, DFZ (reserved)

(c) **Explosive Fire Zone**

The term is related to EESS (Electrical Energy System Storage) supplying an electric engine or powerplant installation and defined by a volume surrounding an EESS including or not an electrical lift/thrust unit. This volume contains the effect of a flame and/or sparks, heat, hot parts ejection, explosive behaviour of accumulated gases and prevents overpressure and its effects.

(d) **Designated Fire Zone**

The Designated Fire Zone encompasses the zones defined in CS 29.1181(a) regarding fires fed by a significant amount of flammable fluids.

(e) **Fire withstanding Zone**

Is a volume surrounding one or several electric lift/thrust units not containing a hazardous quantity of flammable fluids that could be open or closed and able to withstand the effect of a flame and/or sparks, arcing, heat, and hot parts ejection. It is assumed that a lift/thrust unit basically presents a fire hazard, which means that a fire withstanding zone will provide the minimum zonal fire protection.

(f) **Closed Volume**

A closed volume is a volume designed for the complete retention/ containment of fire – it does not preclude from draining or ventilation features that do not impact the fire containment capabilities of the volume or zone.

(g) **Open Volume**

An open volume is a volume designed for the partial retention/ containment of fire. The concept of open volume is applied on the FWZ. It prevents fire propagation by an appropriate choice of materials.

(h) **Fire withstanding capability (Electrical lift/thrust unit fire)**

The fire withstanding capability is the capability required of a Fire Withstanding Zone for electric lift/thrust unit installation, for a fire not confined in a Designated Fire Zone as defined in CS 29.1181(a).

This capability can be shown:

(1) by the test in section 3(e)(4) of this MOC, or

(2) following a fire threat characterisation of the electrical lift/thrust unit proposed by the applicant and accepted by the Agency. This characterisation should be performed using the representative design, material characteristics, power, etc. and should then be used to demonstrate the zone's robustness against a fire threat.

(i) **Explosive fire capability (Electrical Energy Storage System fire)**

The explosive fire capability is the capability required to contain a thermal runaway of the propulsion batteries as defined in the accepted standards or means of compliance.

2. Applicability and Scope

This MOC VTOL.2330 will be developed in an incremental approach according to the following steps:

(a) Step 1: Air cooled engine with rechargeable batteries as electrical energy storage system that are not liquid cooled,

(b) Step 2: Air cooled engine with liquid cooled battery (oil, glycol water, etc…),

(c) Step 3: Other energy storage technologies (e.g. fuel cells, capacitors) or hybrid propulsion. For instance: liquid cooled engine with liquid cooled battery.

The MOC at hand provides guidance and methods for addressing the fire protection of the installation of electric propulsion systems in VTOL using rechargeable batteries as electrical energy storage system that are not liquid cooled [step 1]. Some provisions for steps 2 and 3 have already been included in this step 1 for clarity purpose, especially the definition of Designated Fire Zone in the VTOL context, and will be completed in the subsequent steps. For different energy storage technologies (e.g. fuel cells, capacitors) or hybrid propulsion systems this MOC is not yet applicable and will be completed [steps 2 and 3].

The certification of electric engines and propellers is not part of this MOC.

This MOC does not cover or replace applicable regulations for qualification, handling, storage, transport, and disposal of batteries.

It is applicable to VTOL capable Aircraft in Category Basic and Enhanced.

This MOC can also be followed to demonstrate compliance with VTOL.2325 and VTOL.2440, where applicable.

3. Protection against the effects of fire

(a) **Fire protection of flight controls, lift/thrust unit mounts, and other flight structure:** Flight controls, lift/thrust unit mounts and other flight structure located in the Fire Withstanding Zone, the Designated Fire Zone, the Explosive Fire Zone or in adjacent areas subject to the effects of fire, heat or arc-faults should be constructed of materials or shielded to withstand the effects of fire, so that they can perform their essential function at the most adverse operating condition.

(b) **Areas adjacent to a Fire Withstanding Zone, a Designated Fire Zone or an Explosive Fire Zone:** Components, electrical lines and fittings (including fire detection components, if any), located in an area adjacent to a Fire Withstanding Zone, a Designated Fire Zone or an Explosive Fire Zone should be constructed of such materials and located such that if a portion of the lift/thrust unit or EESS is subject to fire, heat or arc-faults, the following is ensured:

(1) continued safe flight and landing, for Category Enhanced VTOL capable aircraft, or

(2) controlled emergency landing, for Category Basic VTOL capable aircraft.

(c) **Drainage and ventilation of Fire Withstanding Zone, Designated Fire Zone and Explosive Fire Zone:**

(1) There should be a complete drainage of each part of each Fire Withstanding Zone or Explosive Fire Zone if any presence of fluids can occur.

(2) The drainage means should be:

(iii) effective under conditions expected to prevail when drainage is needed; and

(iv) arranged so that no discharged fluids or gases, smoke, soot, particulate will cause an additional hazard.

(3) In the absence of efficient draining, especially in case of a limited amount of fluids in EESS, these fluids can be contained within the zone, which then should be capable of resisting the increased fire threat.

(4) Each Fire Withstanding Zone or Explosive Fire Zone should be ventilated/exhausted to prevent the accumulation of hazardous gases, smoke, soot, particulate.

(5) No ventilation opening may be where it would allow the entry of fluids, of hazardous gases, smoke, soot, particulate or flame from other zones.

(6) The ventilation means should be:

(v) effective under conditions expected to prevail when ventilation is needed, and

(vi) arranged so that no discharge of gases, smoke, soot, particulate or flame will cause an additional hazard or impinge occupants or persons on the ground (refer to Hazard Areas, as defined in paragraph (d) of MOC VTOL.2400(c)(3)).

(d) **Disconnect mechanism**

(1) For each EESS there should be a means to quickly disconnect, either manually by the flight crew or automatically, and isolate the battery from the main electrical circuit during operation.

(2) For each lift/thrust unit there should be a means to quickly disconnect, either manually by the flight crew or automatically, and isolate the engine from the main electrical circuit during operation.

(3) If a manual disconnection means for a lift/thrust unit is implemented, it should be ensured that the connection can be re-established in flight.

(e) **Fire Withstanding Zone**

(1) Each lift/thrust unit, should be isolated by a Fire Withstanding Wall, barrier, shroud, or equivalent means (for example, an air gap), from personnel compartments, structures, flight controls, and any other parts that may be affected by the lift/thrust unit fire and propagate it.

(2) Each element in the Fire Withstanding Zone, including its wall, barrier and shroud should be:

(i) constructed of self-extinguishing materials in order to prevent fire propagation. If an Open Fire Withstanding Volume is chosen, a minimum distance to materials not part of the zone should be established to prevent fire propagation.

(ii) constructed so that no hazardous quantity of fumes, flames, heat, arc or spark, and fluids, including liquid metal, can pass from any lift/thrust unit compartment to other parts of the VTOL capable aircraft, and

(iii) capable of sustaining a fire, spark or arc so that the protected elements essential to perform the remainder of the flight can continue to perform their essential function.

(3) In meeting this paragraph, account should be taken of the probable path of a fire as affected by the airflow in normal flight and vertical take-off and landing.

(4) Fire withstanding wall, barrier, and shroud - including any adhesives, resins, sealer coatings, grommets, bushings or fittings that make up the barrier assembly and installation - should be made of material shown to be flame resistant as per Appendix F of CS-23 Amdt. 4 when exposed to the following tests or their equivalent:

(i) Vertical tests of section (d) for 60 seconds, during which:

(A) the average burn length should not exceed 15cm (6 inches), and

(B) the average flame time after removal of the flame should not exceed 15 seconds, and

(C) drippings from the test specimen should not continue to flame for an average of 3 seconds after falling, and

(D) at no time should the flame penetrate (pass through) the material during application of the flame or subsequent to its removal.

(ii) 45-degree flame tests of section (f), during which the flame should not penetrate (pass through) the material during application of the flame or subsequent to its removal.

(f) **Explosive firewall**

(1) Each EESS should be isolated by an Explosive Firewall, shroud, or equivalent means, from personnel compartments, structures, flight controls, and any other parts that may be affected by fire, heat, sparks, ejected parts and pressure caused by the EES.

(2) Each opening in the Explosive Firewall should be sealed with close-fitting as grommets, bushings, or fittings able to withstand the heat and pressure created by a thermal runaway of the battery.

(3) Each Explosive Firewall and shroud should be:

(i) constructed of materials capable of withstanding the effects of a flame and/or sparks, heat, pressure and hot parts ejection, not allowing backside burning, backside ignition, or significantly high temperatures that can result in additional fire hazard,

(ii) constructed so that no hazardous quantity of fluid, gases, smoke, soot, particulate, liquid metal or flame can pass from any Explosive Fire Zone to other parts of the VTOL capable aircraft, and

(iii) resistant to the heat and pressure created by a thermal runaway of the battery capable of sustaining a fire, spark, arc or heat transfer so that the protected elements essential to perform the remainder of the flight can continue to perform their essential function.

(4) The conditions in (f)(3)(i) and (ii) should be fulfilled for the complete duration of an accepted Thermal Runaway Test as per MOC VTOL.2440.

(5) In meeting this paragraph, account should be taken of the probable path of a fire as affected by the airflow in normal flight and vertical take-off and landing.

(g) **Detection systems**

(1) Detection systems include but are not limited to: quick-acting fire, gases, overtemperature / undervoltage / overpressure sensors.

(2) For each EESS and lift/thrust unit, approved, quick-acting detectors should be provided in numbers and locations to ensure prompt detection of faults potentially leading to fire.

(3) Each detector should be constructed and installed to withstand any loads to which it would be subjected in operation.

(4) No detector should be affected by any oil, water, other fluids, or fumes, soot and corrosive gas that might be present.

(5) There should be a means to allow flight crew members to check the functioning of each detector system electrical circuit.

(6) The wiring and other components of each detector system in an electrical energy storage system compartment should have appropriate characteristics for the associated fire zone.

(7) No detector system component for any fire zone (FWZ, DFZ or EFZ) should pass through any other fire zone, unless–

(i) It is protected against the possibility of false warnings resulting from fires in zones through which it passes; or

(ii) The zones involved are simultaneously protected by the same detector and extinguishing systems.

VTOL.2335 Lightning Protection

n/a

Unless it is shown that exposure to lightning is unlikely, the aircraft must be protected against catastrophic effects of lightning.

MOC VTOL.2335 Lightning Protection

n/a

(a) In order to demonstrate that the exposure to lightning is "unlikely", the same operational limitations as defined in MOC VTOL.2515 "Electrical and electronic system lightning protection" are accepted.

(b) CS 27.610 Amdt. 6 is accepted as a means of compliance.

(c) As an alternative to CS 27.610 Amdt. 6, paragraph 17.1 of ASTM F3061/F3061M-19 "Standard Specification for Systems and Equipment in Small Aircraft" is also accepted as a means of compliance.

VTOL.2340 Design and construction information

n/a

The following design and construction information must be established:

(a) operating limitations, procedures and instructions necessary for the safe operation of the aircraft;

(b) the need for instrument markings or placards;

(c) any additional information necessary for the safe operation of the aircraft; and

(d) inspections or maintenance to assure continued safe operation.

SUBPART E — LIFT/THRUST SYSTEM INSTALLATION

VTOL.2400 Lift/thrust system installation

n/a

(a) For the purpose of this Subpart, the aircraft lift/thrust system installation must include each component that is necessary for lift/thrust, affects lift/thrust safety, or provides auxiliary power to the aircraft.

(b) Each aircraft engine, propeller and auxiliary power unit (APU) must be type certified, or meet accepted specifications.

(c) The applicant must construct and arrange each lift/thrust system installation to account for:

(1) all likely operating conditions, including foreign object threats;

(2) sufficient clearance of moving parts to other aircraft parts and their surroundings;

(3) likely hazards in operation, including hazards to ground personnel; and

(4) vibration and fatigue.

(d) Hazardous accumulations of fluids, vapours or gases must be isolated from the aircraft and personnel compartments and must be safely contained or discharged.

(e) Installations of lift/thrust system components that deviate from the component limitations or installation instructions must be shown to be safe.

(f) For the purposes of this Subpart, 'energy' means any type of energy for the lift/thrust unit, including, for example, fuels or any kind of electric current.

MOC VTOL.2400(b) Accepted Specifications for Electric/Hybrid Lift/Thrust Units

n/a

EASA Special Condition E-19 on Electric/Hybrid Propulsion System is an accepted specification to be met by electric/hybrid lift/thrust units that are installed in VTOL capable aircraft.

MOC VTOL.2400(c)(3) Lift/thrust system installation – likely hazards in operation

n/a

The likely hazards in operation, including hazards to ground personnel, that the applicant should account for, include:

(a) Risk of inadvertent electric engine start (if applicable):

The aircraft controls should prevent inadvertent sudden motor operation when not commanded by the pilot, in particular during the aircraft supply power-on.

(b) Rotor/propeller disk conspicuity during landing, take-off and ground operations (if applicable):

CS 27.1565 Amdt. 6 is accepted as a means of compliance for rotors, propellers and other rotating parts that could hit and injure ground personnel. Considerations for night conditions should also be included if night operations are authorised.

(c) Downwash effect on third parties:

The downwash of the aircraft should be characterised and reported to allow safe operation and minimisation of hazards to ground personnel.

The following method can be followed to test and report aircraft downwash:

(1) Preliminary assessment:

The applicant should assess whether the test as described in this section can be conducted safely for his aircraft.

(2) Test:

While the aircraft is in a low hover, the radial component of the downwash (outwash) is measured around the aircraft on a circle of diameter 2 D.

(3) Reporting:

The maximum measured speed is reported in km/h to the nearest multiple of 5, as well as the measurement standard (here "§(c) in MOC VTOL.2400(c)(3)"), in the performance section of the aircraft flight manual.

If the downwash temperature on the 2 D-diameter circle is more than 10°C above ambient temperature, this should also be characterised and reported.

Note: 'D' is reported as part of MOC VTOL.2115.

(4) Test specification:

Parameter	Description	Value	Tolerance
Conditions	density altitude	≤ 2000 ft	-
	ambient wind, throughout each test run, measured 2 m above the ground within 200 m of the circle centre. Location should be representative of the test condition.	≤ 3 kt	-
	no precipitations	-	-
Surface	Smooth pavement, e.g. concrete or asphalt, surrounded by clear area, e.g. grass (Figure 1)		
	diameter pavement	≥ 3 D	-
	diameter clear area	≥ 6 D	
	naturally occurring height discontinuity on pavement (excluding measuring equipment and operator, e.g. joint between concrete slabs)	≤ 2 cm	-
	naturally occurring height discontinuity on clear area (e.g. grass)	≤ 20 cm	-
	pavement level (locally and overall)	0°	± 2°
	clear area level (locally and overall)	0°	± 5°
Aircraft position	Hovering in a normal take-off and landing configuration, holding height or a power datum. Up to 8 poles can be used to assist in visually positioning the aircraft.		
	height (from the bottom of the landing gear)	1 m	(2)
	heading	-	(2)
	lateral and longitudinal position	-	(2)
	mass	MTOM	-0.1%
	diameter of poles	≤ 3 cm	-

Measurement positions	Measuring at discrete locations on the 2 D circle[(1)] - option 1: While the aircraft is maintained on a fixed heading, successive measurements are taken around the 2 D circle (Figure 2) - option 2: The aircraft is yawed facing successive aiming points while measurements are taken at 4 fixed cardinal positions on the 2 D circle to compensate for residual ambient wind (Figure 3). The measurement intervals at the 4 positions should be synchronised (within ± 1 sec).		
	distance between successive measurement positions (option 1) or aiming points (option 2)	≤ 2 m	-
	heights (Figure 4)	0.5 m and 1.5 m	± 5 cm
	lateral and longitudinal position	-	± 10 cm
	measure in the radial direction	-	± 5°
	measure the horizontal wind component	-	± 5°
	measure the maximum over time (for each measurement)	≥ 10 s	-
Measuring support	An operator and up to 4 poles, or a tripod, can be used to assist in positioning the measuring equipment. The operator and poles should not be located directly in front or behind the measuring equipment.		
	diameter of poles or tripod legs	≤ 3 cm	-
	position of operator laterally of measuring equipment	≥ 2 m	-
Measuring equipment	For example vane anemometer		
	accuracy wind speed	≤ ± 4.5 km/h	-
	accuracy temperature (if applicable)	≤ ± 3°C	-
	resolution wind speed	≤ 1 km/h	-
	wind speed reporting interval	≤ 3 sec [(3)]	-

(1) The 2 D circle should be centred on the centre of the smallest enclosing circle (refer to MOC VTOL.2115 Section 8).

(2) The accuracy of the hover should meet the accuracy expected in operations. Height, heading and lateral/longitudinal position accuracy values could be the "desired" values used to evaluate the handling qualities in hover as per Eurocae ED-295 standard.

(3) or "maximum" reporting function

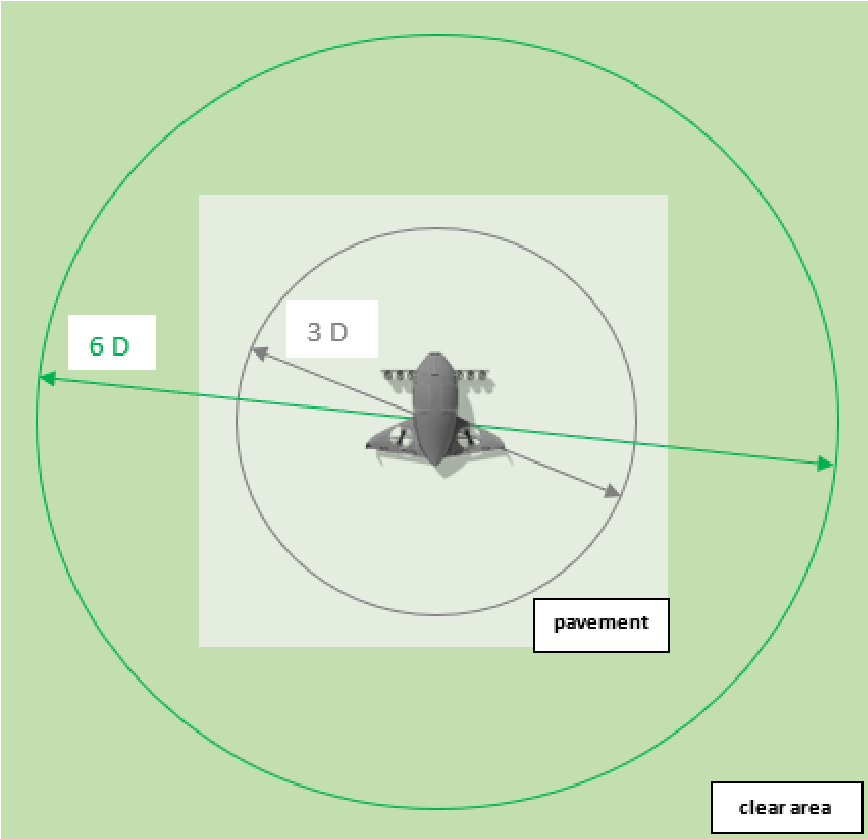


Figure 1: Test surfaces

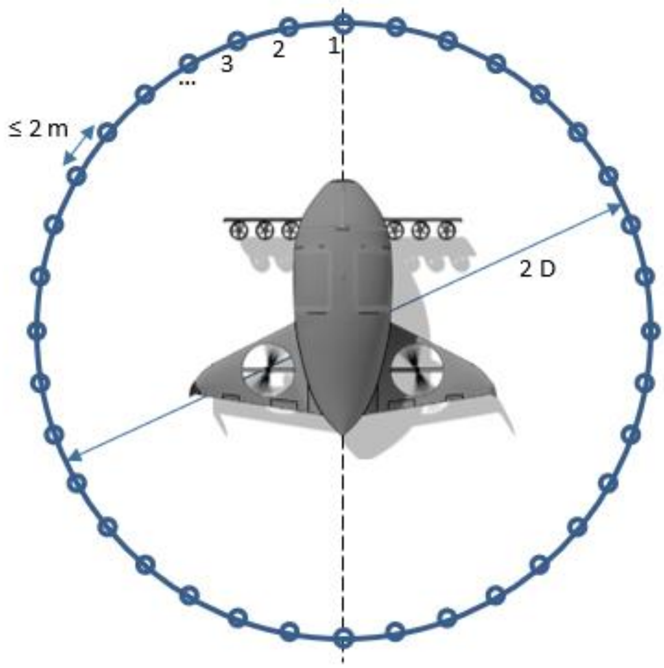


Figure 2: Option 1 – Measurement positions

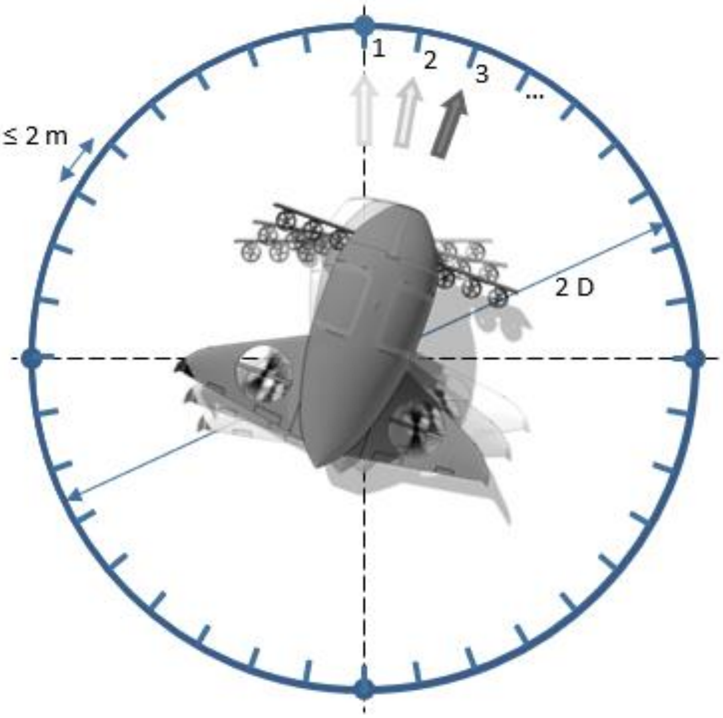


Figure 3: Option 2 – Measurement positions and aiming points

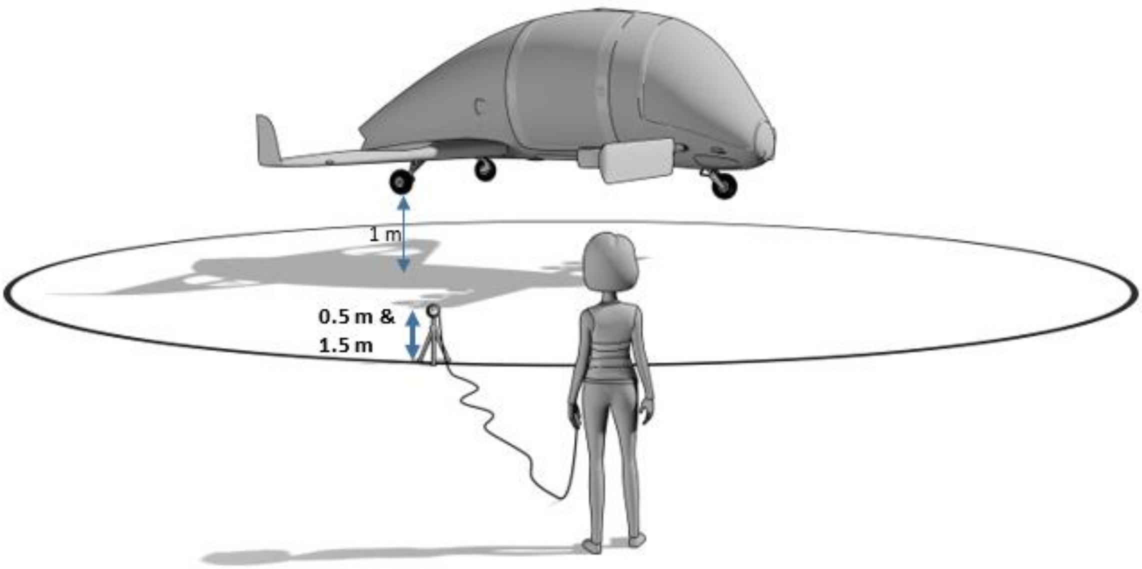


Figure 4: Measurement heights

(d) Hazard areas:

Areas around the aircraft where a hazard to persons or equipment may exist, for example due to moving surfaces, engine exhaust or battery venting in case of fire, should be identified and depicted in the AFM (see example Figure 5). Corresponding hazard markings should be present on the aircraft.

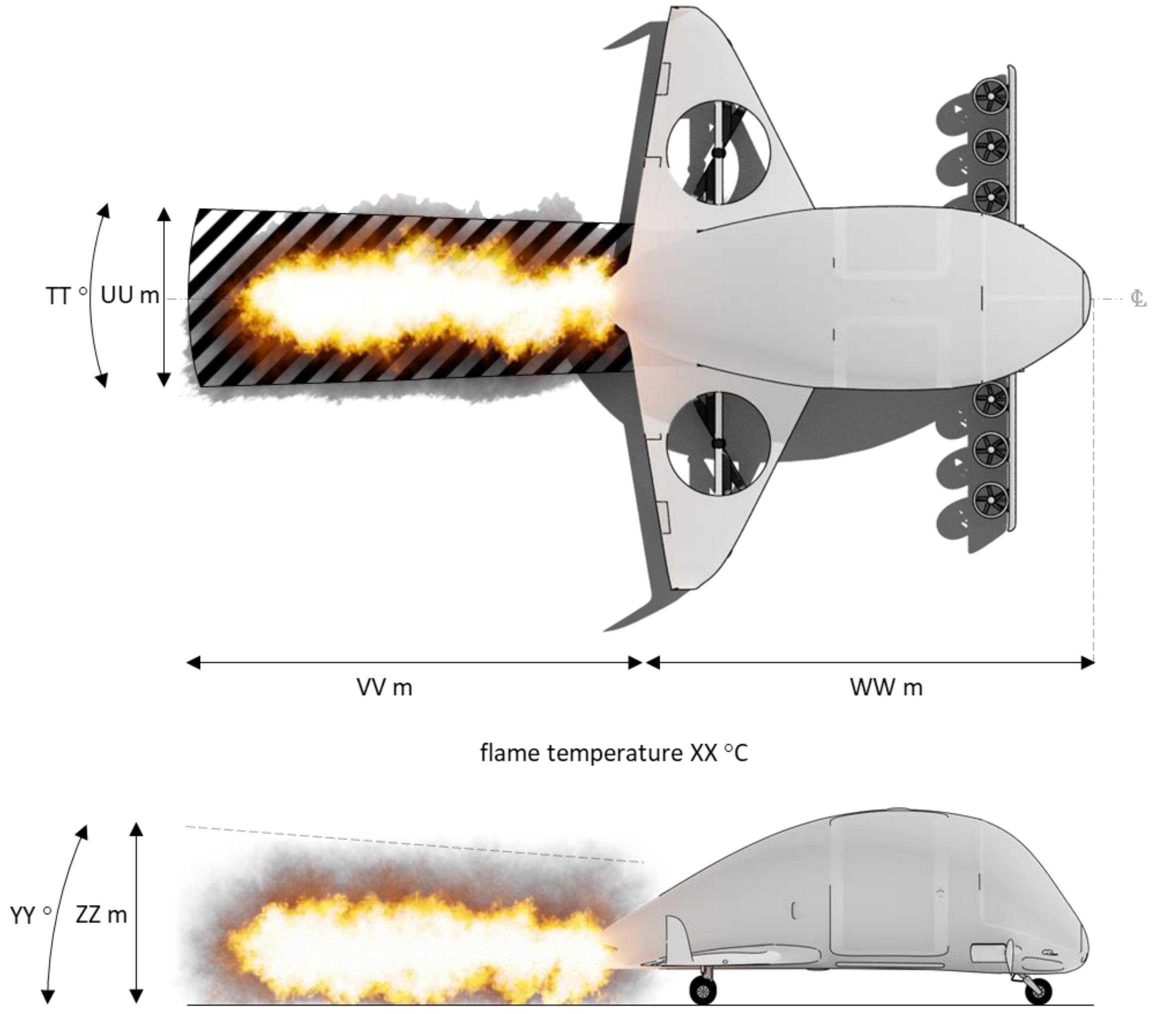


Figure 5: Example of battery fire flame venting hazard area depiction

(e) High Voltage:

Eurocae ED-290 “Guidance on High Voltage definition and Consideration for Personal Safety” is accepted as a means to determine the likely hazards related to High Voltage to be accounted for in VTOL.2400 (c)(3)

VTOL.2405 (reserved)

n/a

VTOL.2410 (reserved)

n/a

VTOL.2415 Lift/thrust system installation ice protection

n/a

(a) The aircraft and lift/thrust system installation design must prevent any accumulation or shedding of ice or snow that would adversely affect lift/thrust system operation.

(b) Reserved.

VTOL.2420 (reserved)

n/a

VTOL.2425 Lift/thrust system operational characteristics

n/a

(a) The installed lift/thrust system must operate without any hazardous characteristics during normal and emergency operation within the range of operation limitations for the aircraft and lift/thrust system installation.

(b) If the safety benefits outweighs the hazard, the design must allow the shutdown and restart of a lift/thrust unit in flight within an established envelope.

MOC VTOL.2425(b) Shutdown and Restart of a Lift/Thrust Unit in Flight

n/a

A lift/thrust unit may be shut down during VTOL operation in some particular failure cases (overspeed condition, erratic operation…) or in the event of energy starvation. In the event of failure, this shutdown can be automatically triggered by the control system or manually triggered by the flight crew as a result of the application of an emergency operating procedure. The shutdown can affect several whole lift/thrust units or only one of its sub-systems, e.g. one electric engine.

(a) In any case, there should be means to isolate the lift/thrust system as requested per VTOL.2440.

(b) Special care should be taken of distributed propulsion systems incorporating a large number of lift/thrust units. Human error, such as the shutdown of the wrong lift/thrust unit by the pilot, should be avoided by adequate design solutions and an appropriate human factors evaluation.

(c) The phrase "if the safety benefit outweighs the hazard" employed in VTOL.2425(b) is related to the capability to restart (or relight in the case of an internal combustion engine) a lift/thrust unit.

It is often worthwhile that the aircraft system allows the restart or the relight (in case an internal-combustion engine is part of the lift/thrust system) of the lift/thrust unit that has been shut down.

However, this restart/relight capability should not be systematically the safest option to offer to the flight crew as it could also create hazards to the aircraft. The applicant should therefore establish an associated failure scenario to determine if it is in the interest of safety to perform a restart and relight.

(d) In performing the assessment in (c), the applicant should take into account the following elements:

(1) The aircraft performances and handling qualities:

Is a continued safe flight and landing possible without restarting/relighting the lift/thrust unit that has been shut down? If not, there should be means to restart/relight the shutdown lift/thrust unit (automatically or by the flight crew).

(2) The associated hazards:

Does the restart/relight of the shutdown lift/thrust unit allow a continued safe flight and landing? The following two examples are provided for clarification:

(i) One electric engine is shut down on a VTOL equipped with several electric engines. On the one hand, the aircraft flight control system detects the engine shutdown and adjusts the flight control laws in order to perform a continued safe flight and landing. On the other hand, a restart of the shutdown electric engine is performed automatically, which may lead to aircraft transient attitude changes due to the flight control system adjustments. This may surprise the flight crew which could be detrimental in situations such as the final approach. In such situations, if automatic engine restart/relight capabilities are provided to the VTOL, the system capability should enable the crew to make a final decision whether to activate this function or not.

(ii) An electric engine is shut down due to friction caused by a bearing damage. Vibrations are detected and the engine is shutdown. The restart of such engine may lead to sparks (with the associated fire risk), high vibration levels or other phenomena that could impair the safety of the aircraft. Such severe bearing damage should be detectable so as to prevent from restart/relight.

(3) Human factors

VTOL concepts are often designed around a significant number of lift/thrust units. The applicant should assess if manual operating procedures to restart or relight a shutdown lift/thrust unit are compatible with the workload of the flight crew or if the procedures should be automated, and what are the possibilities of erroneous manipulation of the lift/thrust unit controls during a restart/relight performed by the flight crew, as well as possible ways of mitigating them by design.

Note: Standard systems safety assessment and flight crew error assessment contain specific methodologies to identify and mitigate hazards presented by restarting a lift/thrust unit in flight.

VTOL.2430 Lift/thrust system installation, energy storage and distribution systems

n/a

(a) Each system must:

(1) be designed to provide independence between multiple energy storage and supply systems so that a failure, including fire, of any one component in one system will not result in the loss of energy storage or supply of another system.

(2) be designed to prevent catastrophic events due to lightning strikes taking into account direct and indirect effects for aircraft unless it is shown that exposure to lightning is unlikely.

(3) provide energy to the lift/thrust system installation with adequate margins to ensure safe functioning under all permitted and likely operating conditions, and accounting for likely component failures.

(4) provide the relevant information established in VTOL.2445 to the flight crew and provide uninterrupted supply of that energy when the system is correctly operated, accounting for likely energy fluctuations.

(5) provide a means to safely remove or isolate the energy stored within the system.

(6) be designed to retain the energy under all likely operating conditions and minimise hazards to the occupants and people on the ground during any survivable emergency landing. For Category Enhanced, failure due to overload of the landing system must be taken into account.

(7) prevent hazardous contamination of the energy supplied to each lift/thrust unit installation.

(b) Each storage system must:

(1) withstand the loads under likely operating conditions without failure, accounting for installation;

(2) be isolated from personnel compartments and protected from likely hazards;

(3) be designed to prevent significant loss of stored energy due to energy transfer or venting under likely operating conditions;

(4) provide energy for a sufficient reserve based on a standard flight; and

(5) be capable of jettisoning energy safely if this functionality is provided.

(c) Each energy-storage-refilling or -recharging system must be designed to:

(1) prevent improper refilling or recharging;

(2) prevent contamination of the stored energy during likely operating conditions; and

(3) prevent the occurrence of any hazard to the aircraft or to persons during refilling or recharging.

(d) Likely errors during ground handling of the aircraft must not lead to a hazardous loss of stored energy.

MOC VTOL.2430(a)(2) Protection of the fuel system against lightning

n/a

For the protection of a conventional fuel system against lightning:

(a) CS 27.954 Amdt. 6 is accepted as means of compliance

(b) As an alternative to CS 27.954, the paragraph 17.2 of ASTM F3061/F3061M-19 “Standard Specification for Systems and Equipment in Small Aircraft” is also accepted as a means of compliance.

MOC VTOL.2430(a)(3) and (a)(4) Accessible energy in electrical energy storage systems

n/a

(a) Eurocae ED-289 "Guidance on the determination of accessible energy in battery systems for eVTOL applications" is accepted as a means to determine the adequate margins of an electrical energy storage system required by VTOL.2430(a)(3).

(b) Eurocae ED-289 "Guidance on the determination of accessible energy in battery systems for eVTOL applications" is accepted as a means to define the reliability of the relevant information of an electrical energy storage system to be provided to the flight crew as required by VTOL.2430(a)(4) and established in VTOL.2445(g).

MOC VTOL.2430(a)(6) Energy retention capability in an emergency landing

n/a

1. General

MOC VTOL.2325(a)(4) provides an accepted means of compliance with VTOL.2430(a)(6) regarding the energy retention capability of the energy storage and distribution system during a survivable emergency landing on land.

2. Specific considerations for VTOL capable aircraft with an electrical energy storage and distribution system

In addition to Section 1 of this MOC, the following applies for VTOL capable aircraft with an electrical energy storage and/or distribution system:

(a) For VTOL capable aircraft that are certified as per VTOL.2310 for intended operations on water, for emergency flotation or for ditching, MOC VTOL.2325(a)(4) with the following changes constitutes an accepted means of compliance with VTOL.2430(a)(6) regarding the energy retention capability of the energy storage and distribution system during a survivable emergency landing on water:

(1) In Section 3(b) of MOC VTOL.2325(a)(4): the drop impact surface should be water. Conservatively a non-deforming surface may be used.

(2) In Section 5 (d)(1) of MOC VTOL.2325(a)(4): persons on ground include all persons in contact with the VTOL, including persons in the water. The electrical energy storage and distribution system should retain the stored electrical energy for at least 15 minutes.

(b) For VTOL capable aircraft certified for continued operations over water without meeting the flotation categories under VTOL.2310, MOC VTOL.2325(a)(4) with the following change constitutes an accepted means of compliance with VTOL.2430(a)(6) regarding the energy retention capability of the energy storage and distribution system during a survivable emergency landing on water:

(1) In Section 3(a) of MOC VTOL.2325(a)(4): the drop height may be reduced to 6 m

VTOL.2435 Lift/thrust installation support systems

n/a

(a) Reserved.

(b) Reserved.

(c) Reserved.

(d) Reserved.

(e) Reserved.

(f) Likely foreign object damage that would be hazardous to the lift/thrust unit must be prevented.

(g) The flight crew must be aware of the lift/thrust configuration.

(h) Reserved.

MOC VTOL.2435(f) Prevention of likely foreign object damage to the lift/thrust unit

n/a

(a) The demonstration of compliance with VTOL.2435(f) should consider any foreign object of a nature such that it could impair the proper functioning of the lift/thrust system, both in flight and on the ground.

(b) It should be substantiated that the strike and ingestion effects of foreign objects such as plastic bags, papers, cleaning cloths, hand tools, rivets, bolts and screws are not hazardous to the aircraft. This can be achieved by demonstrating that such threat cannot affect more than a critical number of lift/thrust units and ensuing

— continued safe flight and landing for Category Enhanced

— controlled emergency landing for Category Basic

(c) Design precautions should be taken to avoid the clogging of cooling holes by foreign objects.

MOC VTOL.2435(g) Flight crew awareness of the lift/thrust unit configuration

n/a

This MOC is applicable in case that several configurations of the lift/thrust system are part of the VTOL type design definition.

It is a common practice in the rotorcraft industry that turbines are equipped with different kinds of air intakes depending on the mission. In accordance with VTOL 2435 (g) the flight crew must be aware of the associated configuration in order to apply the proper procedures and to adequately calculate the performances.

(a) The term “configuration” of the lift/thrust system mentioned in VTOL.2435 (g) refers only to “physical” configuration. It does not consider the different aerodynamic conditions that a lift/thrust system may be subject to within the certified envelope. For example, a lift/thrust unit mounted on a tilting element is considered as a single configuration even though the aerodynamic conditions in which the lift/thrust unit operate depend on the tilting angle.

(b) The intent of VTOL.2435(g) is therefore to provide the flight crew through the relevant VTOL capable aircraft systems, with the necessary information concerning any lift/thrust configuration that has an impact on:

(1) the lift/thrust performances

(2) the lift/thrust operating procedures

The applicant should assess the impact of any lift/thrust configuration change with regards to these criteria.

(c) If it is determined that VTOL performances and/or operating procedures should be adapted depending on the lift/thrust configuration:

(1) The flight crew should have a clear and easily interpretable means to know which configuration of the lift/thrust system is mounted

(2) Operating procedures impacted by the configuration should be provided in the flight manual

(3) The impact of the different configurations on the VTOL capable aircraft performances should be established by a combination of analysis, bench tests and flight tests. Following their determination, they should be published in the flight manual

(4) VTOL capable aircraft systems which use the configuration status of the lift/thrust system automatically (without human intervention), should receive this status also automatically.

VTOL.2440 Lift/thrust system installation fire protection

n/a

There must be means to isolate and mitigate hazards in the event of a lift/thrust system fire or overheat in operation.

MOC VTOL.2440 Propulsion Batteries Thermal Runaway for VTOL category enhanced

n/a

1. Introduction

Compliance with VTOL.2440, but also with VTOL.2330, VTOL.2400(d), VTOL.2425(a), VTOL.2430 (a)(1)(5), (b)(2), (c)(3), (d), VTOL.2510, and VTOL.2525 requires demonstrating that the hazards from a fire in the propulsion battery system will be appropriately prevented and mitigated.

The latest rechargeable lithium battery systems minimum operational performance standard RTCA DO-311A is a useful baseline for developing and testing propulsion battery systems. However, its "Thermal runaway containment test", in section 2.4.5.5, was developed for lithium batteries that provide power to other aircraft systems or equipment. Therefore, the standard did not necessarily consider the particularities of battery systems intended to be used for electric and hybrid aircraft propulsion.

That containment test, when applied to propulsion battery systems, may lead to decrease their energy/weight ratio unduly and substantially, because of placing the focus on the containment of an unprecedented thermal runaway event instead of considering the implementation of different protection layers and the containment of a realistic worst-case thermal runaway event. While this test could be accepted as means of compliance, provided that other requisites are also met, it should not alleviate the implementation of appropriate protective layers/measures.

In this Means of Compliance, the Agency proposes an alternative test method for propulsion lithium batteries, to promote best industry practices, robust designs, and protection layers strategies for the entire propulsion battery system. Moreover, this alternative intends to foster innovation and development of new solutions for these battery system protection layers, instead of relying only on containment mitigations.

The main reasons for this alternative method to RTCA DO-311A section 2.4.5.5. “Thermal Runaway Containment Test” are:

(a) The amount of additional external energy put into the battery system for this test is far in excess of energies used in service, which are limited by fail-safe protection layers and proper design, manufacturing, installation, operation, and maintenance.

  (1) Depending upon the chemistry, rechargeable lithium batteries can accept overcharging levels that lead to double the normal energy before reaching a point of chemical and thermal instability.

  (2) Heating the whole battery could compromise the validity of the test results due to mechanical and thermal effects created by pre-heating the whole battery structure, materials, and components to high temperatures.

(b) In some cases, overcharging (if feasible) or overheating the whole battery can drive a near-simultaneous failure of all cells in the battery, which would not represent a realistic in-service field failure, but an extreme condition not encountered in service, even in batteries where reliable and tested protection layers were not implemented.

(c) However, in other cases, this test may lead to undertest the propulsion battery containment, since:

  (1) Only one test article is tested.

  (2) There is no characterisation of thermal runaway behaviour at cell level for different parameters.

  (3) The variability in the characteristics of the cells, or the possibility of having defective cells within the battery system, may lead to trigger very few cells at temperatures lower than the thermal runaway initiation temperature of most of the cells.

  (4) As the power to the heating device may be removed once a thermal runaway has initiated, it could lead to have only those very few cells into thermal runaway.

  (5) If a thermal runaway occurs in at least two cells, the objective of the test is already met.

  (6) Degradation of the propulsion battery containment due to aging and environmental conditions during operation is not considered.

(d) The design of electronics for critical aviation applications has been practiced for decades in the industry and demonstrated as highly effective for the safe operation of aircraft when consistent with appropriate industry practices. Therefore, as for any other system in the aircraft, if designed protections are shown to be reliable, the overall risk testing should consider these protections and their reliability.

Considering this, two acceptable approaches are proposed in this Means of Compliance to address the demonstration of an adequate mitigation of battery system thermal runaway conditions for VTOL capable aircraft in the category enhanced.

This Means of Compliance is neither addressing nor superseding other tests and considerations needed for the certification of propulsion battery systems (i.e., external short circuit, available system capacity and energy, protections testing, battery system crashworthiness tests, HV signage…).

This Means of Compliance is predicated on battery technologies and chemistries that are currently known and ready for use. Future technologies and chemistries might require additional or alternative considerations that should be first established at project level.

2. Reference Documents

The following references have been used as a source of information or to provide accepted methods and practices:

(a) RTCA DO-311A "Minimum Operational Performance Standards for Rechargeable Lithium Batteries and Battery Systems", December 19, 2017.

(b) RTCA DO-160G/EUROCAE ED-14G "Environmental Conditions in Airborne Systems and Equipment".

(c) ED-289 "Guidance on Determination of Accessible Energy in Battery Systems for EVTOL Applications".

(d) ED-312 "Guidance on Determining Failure Modes in Lithium-Ion Cells for eVTOL Applications".

(e) RTCA DO-227A "Minimum Operational Performance Standards for Non-Rechargeable Lithium Batteries".

(f) EASA AMC 20-115 "Airborne Software Development Assurance Using EUROCAE ED-12 and RTCA DO-178".

(g) EASA AMC 20-152 "Development Assurance for Airborne Electronic Hardware (AEH)".

(h) SAE ARP 4761 "Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment".

(i) EASA MOC VTOL.2330 "Fire Protection in designated fire zones".

3. Definitions

For the purpose of this MOC:

(a) "Battery" is used as a generic term for an electrochemical energy storage system.

(b) "Battery Cell" means a single electrochemical unit which exhibits a voltage across its two terminals and is used as the elementary unit of a battery module or battery system.

(c) "Battery Module" means a group of electrically interconnected cells in series and/or parallel arrangement contained in a single enclosure that ensures that no fluids, flames, gasses, smoke, or fragments enter other modules, and that no thermal runaway is propagated from one module to the others during normal operation or failure conditions.

(d) "Battery system" means an assembly of electrically interconnected battery modules (modularized battery) or cells in series and/or parallel, plus any protective, monitoring, alerting circuitry or hardware inside or outside of the battery, its packaging, and the designed venting provisions.

(e) “Propulsion battery (system)” means a battery or battery system used primarily for electric and hybrid propulsion applications.

(f) “Cell Thermal Runaway” is a rapid self-sustained heating of a battery cell driven by exothermic chemical reactions of the materials within the cell. Examples of objective evidence or unambiguous markers that demonstrate that a cell achieved thermal runaway are:

(1) A sharp increase in temperature and pressure and a drop in cell voltage.

(2) Measured peak temperature at least 80% of the typical peak temperature reached during thermal runaway for a given chemistry, per test or per literature reports.

(3) Melted metallic components of cells (other than lithium).

(4) Decomposed active materials / Oxidized metallic lithium.

(5) Pyrolyzed (charred) cell contents.

(g) “Battery Thermal Runaway” is defined as:

(1) Thermal runaway of two cells that thermally affect at least one common adjacent third cell within the same battery or, for modularized batteries, within the same module.

(2) Thermal runaway of any three or more cells within the same battery or, for modularized batteries, within the same module.

Explanatory Note:

This Means of Compliance applies only to battery systems intended to be primarily used for electric and hybrid propulsion in VTOL capable aircraft in the category enhanced. Therefore, the terms “Propulsion Battery (System)” and “Battery (System)” are used interchangeably throughout this MOC and are equivalent to the term “Electrical Energy Storage System” in EASA SC-VTOL.

4. Prerequisites

Propulsion battery systems should successfully demonstrate the implementation of multiple layers of mitigation mechanisms against unsafe conditions, such as thermal runaway, by providing the following:

(a) Evidence that RTCA DO-311A section 2.1 “General Requirements” have been considered and successfully implemented and that section 3 “Installation Considerations” has been evaluated.

(b) Evidence that critical functions including control and protective functions that include software have been designed and validated, as per the applicable revision of EASA AMC 20-115, to an appropriate design assurance level.

(c) Evidence that critical functions, including control and protective functions with airborne electronic hardware, have been designed and validated as per the applicable revision of EASA AMC 20-152 to an appropriate design assurance level.

(d) Evidence that a safety assessment of the propulsion battery system has been performed as per the applicable revision of SAE ARP 4761, addressing the hazards leading to, during, and following a thermal runaway. This safety assessment should include:

(1) Functional Hazard Assessment (FHA).

(2) System Safety Assessment (SSA) including a qualitative and quantitative analysis of the failure condition (e.g., Fault Tree Analysis (FTA/DD/MA)).

(i) The System Safety Assessment (SSA) should demonstrate that the safety objectives associated to identified failure conditions are fulfilled.In particular, any catastrophic failure condition should be extremely improbable and not result from a single failure of the propulsion battery system, including control and protective functions inside or outside of the battery.

(3) Failure Modes and Effects Analysis (FMEA).

(4) Common Cause Analysis (CMA, PRA and ZSA).

(e) Evidence that propagation prevention mechanisms are successfully implemented when the propulsion battery system is tested in accordance with thermal runaway Non-Propagation Tests guidelines defined in section 7.(a).

Note 1:

Demonstrating compliance with one of the test approaches defined in this MOC does not alleviate the classification of the failure condition “battery thermal runaway” (as defined in 3.(g)), which is considered catastrophic**.**

The safety of the propulsion battery is based in a multi-layer approach, where the reliability of the cells and the control and protective functions play a key role and should not be alleviated, since:

— Propulsion batteries are not comparable to other aircraft equipment/systems, due to their novel use, criticality, significant fire hazard and lack of service experience.

— Thermal runaway tests are not comparable to other qualification tests, due to the variability in the outcome of the tests (due to cell variability, TR initiation criteria, temperature, SOC..) and their novelty and lack of testing experience.

Therefore, this safety requirement should be used by the applicants to specify the reliability requirement for the cell failure, as well as the safety objectives of the control and protective functions.

5. Approach #1: RTCA DO-311A Section 2.4.5.5. Battery Thermal Runaway Containment Test

Propulsion battery systems are considered to properly fulfil verification aspects of propulsion battery system thermal runaway conditions when:

(a) Section 4. “Prerequisites” of this document is followed, and

(b) They are tested in accordance with RTCA DO-311A section 2.4.5.5 Battery Thermal Runaway Containment Test in accordance with the requirements of RTCA DO-311A section 2.2.2.4, and

(c) At least 20% of the cells in the battery system achieved thermal runaway in the test referenced in previous point 5.(b).

6. Approach #2: Battery Thermal Runaway Containment for Continued Safe Flight and Landing (CSFL)

Propulsion battery systems are considered to properly fulfil verification aspects of propulsion battery system thermal runaway conditions when they are tested following:

(a) Section 4. “Prerequisites” of this document, <u>and</u>

(b) The Thermal Runaway Containment for CSFL time tests guidelines defined in section 7.(b).

Note 2:

Since propulsion battery systems have much higher capacity and size than conventional battery systems, it may not be feasible to design a battery system that complies with the previous test approaches with a reasonable weight penalty. The applicant may propose a modularized battery system composed out of battery modules to comply at battery module level, instead of at battery system level, with any of the test approaches defined in this document.

7. Test Guidelines

(a) Thermal Runaway Non-Propagation Tests:

(1) Latent manufacturing cell defects should be minimized, as stated in RTCA DO-311A section 2.1.7 “Mitigation of cells failures” and in ED-312 “Guidance on Determining Failure Modes in Lithium-Ion Cells for eVTOL Applications” section 2.1.3 “Manufacturing considerations”. However, even using the most reliable cells from the most robust suppliers, and applying proper incoming inspection and testing, these manufacturing defects cannot be totally prevented. Consequently, having an internal short circuit at cell level in propulsion battery systems with thousands of cells becomes a likely scenario for a thermal runaway. For that reason, propagation to adjacent cells in the battery should be properly prevented to avoid a chain reaction.

(2) The applicant should define, in coordination with the Agency, a set of tests at battery system level to demonstrate that the propagation prevention mechanisms have been successfully implemented.

(3) The following guidelines should be considered for the development of Thermal Runaway Non-Propagation tests:

(i) Aging and environmental conditions during operation may result in degradation of the electrochemical properties and protection layers for each battery. Therefore, to test the worst-cases conditions during the life of the propulsion battery system, these tests should also be performed with battery systems that have experienced loading that could lead to such degradation, i.e., vibrations, thermal and electrical cycling, either on separate test articles or sequentially on the same test articles. Battery systems used for RTCA DO-160/EUROCAE ED-14 environmental tests and aging cycle tests (iaw. EUROCAE ED-289) can be used as test samples when the applicant demonstrates a proper aging and degradation. Alternatively, battery systems that have gone through equivalent accelerated life tests can also be used.

(ii) A full characterisation of thermal runaway behaviour at cell level should be performed by the applicant to identify, and include at battery system level tests, the potential worst-cases for cell-to-cell propagation at battery system level tests, combining the following parameters:

(A) Thermal Runaway Trigger Method. When it is possible to overcharge the cell to force a thermal runaway, the behaviour of the cell between overcharging and overheating may lead to different outcomes.

(B) State of Charge (SOC). In some cases, low SOC leads to more material remaining in the cell, hence increasing the probability of cell-to-cell propagation. However, higher SOC usually leads to a more explosive and energetic thermal runaway with more material expelled outside the cell.

(C) Positions of the internal short-circuit relative to the cell venting mechanism. Different positions of the heater on the cell may lead to different outcomes in the way the cell is venting or even cause side or bottom ruptures of the cell case.

(D) Heating rates. Different heating rates (i.e., between 5°C/min and 20°C/min) have demonstrated different behaviours of the thermal runaway at cell level, with flames or smoke development depending on the heating rate.

(iii) For this characterization, at least the following parameters should be determined during the test:

(A) Initial State of Charge.

(B) Trigger time for the thermal runaway.

(C) Maximum temperature.

(D) Average total thermal energy release expressed in joules.

(E) Initiation temperature.

(F) Temperature rise rate.

(G) Quantification of mass ejected.

(iv) Due to the high variability in cell level tests, the applicant should define, in coordination with the Agency, an appropriate number of replicates to ensure a representative sample for the cell thermal runaway characterization in (ii). This sample should represent all expected cell variabilities that are anticipated in the life of the product, and should include cell replicates from different lots, manufactured on different dates and from different manufacturing sites (if applicable).

(v) A thermal runaway in a cell in the propulsion battery system should be caused by the worst-case combinations of test conditions determined in the cell characterisation in (ii).

(vi) The triggered cell should be selected as follows:

(A) To maximize the potential for propagation to other cells, the spacing and heat transfer characteristics between cells should be assessed.

(B) The battery system configuration, location of the cell within the battery system, and point 7.(a)(3)(ii) should be assessed to justify the selection of cells with the potential to become worst cases to be tested (e.g. centre, wide face, narrow face, corner, edge…).

(vii) The tested battery system should be representative of the type design configuration, and should include the installation into the aircraft, designated venting provision, installation orientation, and any other design configuration or variable that could impact the test outcome.

(viii) In case there are battery systems with different installations within the aircraft that could impact the test outcome, these different installations should be tested, or if properly justified, at least the worst-case installation.

(ix) The tested battery system should not be modified to such an extent that the method of propagation is not anymore representative of that for a non-modified battery system. Wires for heating, voltage, and temperature monitoring should be passed through the housing and any openings should be sealed to retain internal pressure. Suitable sealant may be high temperature RTV silicone rubber or equivalent.

(x) The cells should not be modified in any way that changes their composition or mechanical properties (including the external cell case).

(xi) The temperature of the battery system before triggering the cell should be always stabilized at 55°C or the maximum operating high temperature, whichever is higher.

(xii) The trigger mechanism may be deactivated once thermal runaway has been initiated in the triggered cell.

(xiii) If a thermal runaway in the targeted cell does not occur, the objective of the test has not been met.

(xiv) The following parameters should be recorded during the test:

(A) The voltage of at least the cell being triggered.

(B) The temperature of the cell being triggered.

(C) The temperatures of the cells nearest to the cell being triggered.

(D) The temperature of the external surface of the battery system and/or Explosive Fire Zone (including the venting provisions).

(E) The volume at standard temperature and pressure, rate of release, and temperature of gasses that exit the battery system and/or Explosive Fire Zone.

(xv) The battery system tested should be monitored for a minimum of 8 hours after the initial thermal runaway event, and during this time it should comply with the following:

(A) No propagation to other cells.

(B) No rupture of the battery system and/or Explosive Fire Zone.

(C) No release of fragments outside the battery system and/or Explosive Fire Zone.

(D) No escape of flames or emissions outside of the battery system and/or Explosive Fire Zone, except through the designed venting provisions.

(E) No compromise of warning signals and safety functions (e.g., battery automatic disconnect function).

(b) Thermal Runaway Containment for CSFL time Tests

(1) Experience has demonstrated that, although very unlikely, more than a cell could go into thermal runaway due to an unforeseen failure mode. Therefore, the applicant should define in coordination with the Agency, a set of tests to demonstrate that realistic worst-cases of thermal runaway in more than a cell can be managed at propulsion battery system level and installation level (Battery Explosive Fire Zone) ensuring continued safe flight and landing in accordance with EASA MOC VTOL.2330 “Fire Protection in designated fire zones”.

(2) The following guidelines should be considered for the development of Thermal Runaway Containment for CSFL time Tests:

(i) Aging and environmental conditions during operation may result in degradation of the electrochemical properties and protection layers for each battery. Therefore, to test the worst-cases conditions during the life of the propulsion battery system, these tests should also be performed with battery systems that have experienced loading that could lead to such degradation, i.e., vibrations, thermal cycling and electrical cycling, either on separate test articles or sequentially on the same test articles. Battery systems used for RTCA DO-160/EUROCAE ED-14 environmental tests and aging cycle tests (iaw. EUROCAE ED-289) can be used as test samples when the applicant demonstrates a proper aging and degradation. Alternatively, battery systems that have gone through equivalent accelerated life tests can also be used.

(ii) All the parameters identified in Section 7.(a)(3)(ii) (Guidelines for development of Thermal Runaway Non-Propagation Tests) for the full characterisation of thermal runaway behaviour at cell level should be also considered to determine the potential worst-cases for Thermal Runaway Containment tests.

(iii) A thermal runaway in at least 20% of the cells in the propulsion battery system should be caused by the worst-cases of combinations of test conditions as determined in the previous point 7.(b)(2)(ii).

(iv) Triggered cells should be selected as follows:

(A) To maximize the potential for propagation to other cells, the spacing and heat transfer characteristics between cells should be assessed.

(B) The battery system configuration, the location of the cells within the battery system, and point 7.(b)(2)(ii) should be assessed to justify the selection of cells that have potential to be worst cases to be tested (e.g. centre, wide face, narrow face, corner, edge, subgroup of triggered cells in different sides, ...)

(v) The tested battery system should be representative of the type design configuration, and should include the installation into the aircraft, designated venting provision, installation orientation, and any other design configuration or variable that could impact the test outcome.

(vi) In case there are battery systems with different installations within the aircraft that could impact the test outcome, these different installations should be tested, or if properly justified, at least the worst-case installation.

(vii) The tested battery system should not be modified to such an extent that the method of propagation is not anymore representative of that for a non-modified battery system. Wires for heating, voltage, and temperature monitoring should be passed through the housing and any openings should be sealed to retain internal pressure. Suitable sealant may be high temperature RTV silicone rubber or equivalent.

(viii) The cells should not be modified in any way that changes their composition or mechanical properties (including the external cell case).

(ix) The temperature of the battery before triggering the cells, should be always stabilized at 55°C or the maximum operating temperature, whichever is higher.

(x) The trigger mechanism may be deactivated once a thermal runaway has been initiated in all the targeted cells.

(xi) It should be proven for each test that:

(A) The trigger method setup aims to trigger all targeted cells at the same time.

(B) All triggered cells have entered into thermal runaway within a reasonable amount of time (approximately 1 minute).

(xii) If a thermal runaway in the targeted cells does not occur, the objective of the test has not been met.

(xiii) If propagation to all cells is prevented, the number and locations of cells that entered thermal runaway should be reported.

(xiv) The following parameters should be recorded during the test:

(A) The voltages of at least the cells being triggered.

(B) The temperatures of the cells being triggered.

(C) The temperatures of the cells nearest to the cells being triggered.

(D) The temperature of the external surface of the battery system and/or Explosive Fire Zone (including the venting provisions).

(E) The volume at standard temperature and pressure, rate of release, and temperature of gasses that exit the battery system and/or Explosive Fire Zone.

(xv) During the test it should be demonstrated that the thermal runaway can be managed at propulsion battery system level and at installation level (Battery Explosive Fire Zone) ensuring continued safe flight and landing in accordance with EASA MOC VTOL.2330 Fire Protection in designated fire zones.

VTOL.2445 Lift/thrust system installation information

n/a

The following lift/thrust system installation information must be established:

(a) Operating limitations, procedures and instructions necessary for the safe operation of the aircraft;

(b) the need for instrument markings or placards;

(c) any additional information necessary for the safe operation of the aircraft;

(d) inspections or maintenance to assure continued safe operation;

(e) information related to the lift/thrust configuration;

(f) techniques and associated limitations for lift/thrust unit starting and stopping; and

(g) energy level information to support energy management, including consideration of a likely component failure within the system.

SUBPART F — SYSTEMS AND EQUIPMENT

VTOL.2500 General requirements on systems and equipment function

n/a

(a) Requirements VTOL.2500, VTOL.2505 and VTOL.2510 are general requirements applicable to systems and equipment installed in the aircraft, and should not be used to supersede any other specific SC VTOL requirement.

(b) Equipment and systems required to comply with type certification requirements, airspace requirements or operating rules, or whose improper functioning would lead to a hazard, must be designed and installed so that they perform their intended function throughout the operating and environmental limits for which the aircraft is certified.

MOC 1 VTOL.2500(b) Intended function of systems and equipment

n/a

1. Considerations on Safety Assessment and Development Assurance

(a) Compliance with VTOL.2500(b) is intrinsically linked with VTOL.2510 and should therefore be addressed simultaneously.

(b) In particular, the safety assessment and development assurance processes described in paragraph §9 and §10 of MOC VTOL.2510 are part of the accepted means of compliance with VTOL.2500(b).

2. Operating and environmental conditions

VTOL.2500(b) covers the equipment and systems installed to meet a regulatory requirement, or whose improper functioning would lead to a hazard. Such systems and equipment are required to "be designed and installed so that they perform their intended function throughout the operating and environmental limits for which the aircraft is certified". The aircraft operating and environmental conditions include:

(c) the full normal envelope of the aircraft, as defined by the Aircraft Flight Manual, with any modification to that envelope associated with abnormal or emergency procedures;

(d) any anticipated external aircraft environmental conditions:

(1) external environmental conditions such as atmospheric turbulence, HIRF, lightning, and precipitation, which the aircraft is reasonably expected to encounter, with severities limited to those established by certification standards and precedence;

(e) any anticipated internal aircraft environmental conditions:

(1) the environmental effects within the aircraft, including vibration and acceleration loads, variations in fluid pressure and electrical power, and fluid or vapour contamination due to either the normal environment or accidental leaks or spillage and handling by personnel; and

(f) any additional conditions where equipment and systems are assumed to "perform their intended function."

For lift/thrust system, compliance with VTOL.2400 can be used to support the compliance demonstration with VTOL.2500(b) regarding the Electric Hybrid Propulsion System (EHPS) scope defined in the Special Condition E-19 EHPS.

MOC 2 VTOL.2500(b) Electromagnetic compatibility

n/a

1. Introduction and scope

This MOC provides an accepted means of compliance related to Electromagnetic Compatibility (EMC) between different equipment and also between equipment and its interconnecting cabling. It is applicable to VTOL capable Aircraft in Categories Basic and Enhanced.

2. Electromagnetic compatibility

Electromagnetic compatibility tests should be conducted on the ground and in- flight as necessary. Any electromagnetic interference (EMI) noted on the ground should be repeated in-flight at the frequency at which the EMI occurred on the ground, unless the problem could be analysed and resolved beforehand. Since some systems are difficult to operate on the ground (e.g. air data system, etc.), the effects of EMI should be evaluated with all systems operating in-flight to verify that no adverse effects are present in the engine, energy supply system control, battery management, brake antiskid and other systems.

When electromagnetic interference and radio frequency interference (EMI and RFI) protection is required, special attention should be paid to the termination of individual and overall shields. Back shell adapters that are designed for shield termination, connectors with conductive finishes, and EMI grounding fingers are available for this purpose as are many other suitable solutions.

Electromagnetic interferences can exist between systems, but also between wires, and between wires and systems. Electromagnetic interference can be introduced into aeroplane systems and wiring by coupling between electrical cables or between cables and coaxial lines or other aeroplane systems. The correct functioning of systems should not be affected by EMI generated by adjacent wires. EMI between wiring which is a source of EMI and wire susceptible to EMI increases in proportion to the length of parallel runs and decreases with greater separation. Wiring of sensitive circuits that may be affected by EMI should be routed away from other wiring interference or provided with sufficient shielding to avoid system malfunctions under operating conditions. Regardless of the function performed, the equipment and its interconnecting wiring will unavoidably generate and be exposed to various types of electrical transients, electrical and magnetic fields, and spurious noise, spanning over a wide range of frequencies and amplitudes. For sure, EMI should be limited to negligible levels in wiring related to systems that are necessary for continued safe flight, landing and egress. A comprehensive victim and source testing is typically expected to ensure the proper functioning of the systems on the aircraft (unless another way is agreed with the Agency). The following sources of interference should be considered:

(a) Conducted and radiated interference caused by electrical noise generation from apparatus connected to the busbars.

(b) Coupling between electrical cables or between cables and aerial feeders.

(c) Parasitic currents and voltages in the electrical distribution and grounding systems, including the effects of lightning currents or static discharge.

(d) Different frequencies between electrical generating systems and other systems.

EUROCAE ED-248 is an accepted means of compliance with VTOL.2500(b) concerning electromagnetic compatibility, except that the note in its Table 3, paragraph 6.2, for helicopters or small aircraft with HF radio transmitters installed does not apply to VTOL capable aircraft.

MOC 3 VTOL.2500(b) Airworthiness Security in the Category Enhanced

n/a

Airworthiness Security is the protection of the airworthiness of an aircraft from intentional unauthorised electronic interaction: harm due to human action (intentional or unintentional) using access, use, disclosure, disruption, modification, or destruction of data and/or data interfaces. This also includes the consequences of malware and forged data and of access of aircraft systems from ground systems but does not include physical attacks or electromagnetic disturbance.

Improper functioning of equipment and systems can be caused by intentional unauthorised electronic interaction (IUEI). The applicant should consider cybersecurity threats as possible sources of 'improper functioning' of equipment and systems:

(a) The equipment, systems and networks of Category Enhanced VTOL capable aircraft, considered separately and in relation to other systems, should be protected from intentional unauthorised electronic interactions that may result in catastrophic or hazardous effects on the safety of the aircraft. Protection should be ensured by showing that the security risks have been identified, assessed and mitigated as necessary.

(b) When required by paragraph (a), the applicant should make procedures and instructions for continued airworthiness (ICA) available that ensure that the security protections of the aircraft equipment, systems and networks are maintained.

AMC 20-42 – Airworthiness Information Security Risk Assessment is an accepted means of compliance with VTOL.2500(b) for Airworthiness Security aspects.

MOC 4 VTOL.2500(b) Certification credit for simulation and rig tests

n/a

1. Scope of this MOC

This MOC provides methods and guidance when using simulation benches and test rigs in the substantiation of compliance with different system requirements of the SC-VTOL (for example: VTOL.2500(b), VTOL.2510, VTOL.2135, etc.).

In this MOC:

(a) 'simulation bench' refers to a simulator with pilot in the loop capability, when "Simulation" has been agreed in the Certification Programme as the means to demonstrate compliance with a requirement in the SC-VTOL (See Appendix A to AMC 21.A.15(b)).

(b) 'test rig' refers to a laboratory test bench, when "Laboratory test" has been agreed in the Certification Programme as the means to demonstrate compliance with a requirement in the SC VTOL (See Appendix A to AMC 21.A.15(b)).

Other uses of simulation benches and test rigs are out of scope from this particular MOC, in particular with different purposes than defined under (a) and (b) (e.g. when supporting an assessment if "Calculation/Analysis" has been agreed in the Certification Programme to demonstrate compliance with a requirement in the SC VTOL, or when they are not in connection with the type certification exercise). Moreover, this MOC does not apply to the compliance demonstration of structural requirements of Subparts C and D.

This MOC is intended as a general guideline that should be applied to any rig tests or simulations when fulfilling the purposes defined under (a) and (b). Additional and specific guidelines for using rig tests to show compliance with specific requirements (e.g. VTOL.2520) may be available in the MOCs associated to these requirements.

2. Introduction

For most aircraft, simulator benches and test rigs commonly used to support aircraft integration tests may also support some certification tests. This requires particular attention on complex, highly integrated aircraft: simulators and test rigs are efficient and powerful means that enable the evaluation of failure cases which sometimes could even not be tested by flight test. Indeed, traditional verification methods are usually effective for loss of function, but additional effort is often needed for more complex aspects (e.g. malfunction, unintended behaviour, cascading failures/faults, propagation effects, common mode errors). Furthermore, simulator benches and test rigs also offer flexibility to perform the evaluations with different scenarios and enable to check the impact of parameters' variability. Tests on simulators and test rigs may be agreed in the Certification Programme to show compliance with some certification requirements, particularly for Handling Qualities (HQ), Performance, Flight Controls and other systems, as well as for Human Factors (HF). This MOC may thus apply to any simulator or rig test facilities when proposed to be used as a means of compliance or to support a means of compliance (e.g. failure case evaluation to support a safety analysis) for certification requirements.

To ensure that credit can be taken from simulators and test rigs tests, simulators and test rigs should be adequately representative of aircraft systems and flight dynamics. At the same time, the limitations for using simulators and test should be established. This objective can be achieved by a combination of a controlled development process of simulators and test rigs, simulator configuration management, system models behaviour validation (crosschecked when necessary with partial system development bench or flight test results, analysis, desktop simulation) and engineering/operational judgment.

3. Means of Compliance

To qualify simulation benches and test rigs so that they can be used to substantiate compliance for certification, the following aspects should be addressed by the applicant:

(a) Identify/list all simulator benches and test rigs proposed in the Certification Programme to be used for "simulation" and "laboratory test" compliance demonstrations (as per Appendix A to AMC 21.A.15(b)).

(b) Controlled development process:

Simulation benches and test rigs usually integrate numerous real aircraft systems or components, and modelled systems or components. Although simulation benches and test rigs are not subject to certification, the design of such devices for use as a certification means is deemed of sufficient complexity to stipulate a formalized and structured development process.

(1) Simulation benches and test rigs specifically developed to support a given certification project should have a formalized and structured development process to achieve the applicant's own objectives for the scope and intended use.

This development process should include the usage of problem reports to record identified issues and their associated corrections (see Section 3(c)(2))

(2) When simulation benches and test rigs are re-used from another project, the applicant should propose justifications to ensure the correctness/appropriateness of the rigs for the intended purpose.

(c) Configuration management:

(1) Simulation benches and test rigs configuration should be managed similarly to the test aircraft configuration with a traceability that covers all relevant systems and models as well as the human machine interface (HMI). A change control process should also be implemented.

(2) A detailed status of simulation benches and test rigs should be established for all certification tests (including tests performed without Agency participation) and briefed along with each test order before the certification tests:

(i) The configuration management of simulation benches and test rigs should include the relevant elements for the test objectives (e.g. version of the flight control laws/software, flightcrew alerting system and the electronic check list (ECL)

(ii) Problem reports should be established and assessed at system test level for their effects on the representativeness in all relevant aspects (e.g. Human Factor, Handling Qualities, System Performances). This would typically include deficiencies, process deviations and errors in definition or implementation of simulation benches or test rigs.

(3) The tracking and impact assessment of the models' limitations (see section 4 below) and any simulation bench problem reports should be part of the configuration management process.

(4) Consistency of the simulation benches and rig tests design with aircraft design:

As part of the configuration management process, the consistency of the aircraft design with simulation benches and test rigs should be guaranteed. The objective is to ensure:

(i) The representativeness of the benches with respect to the expected certification configuration; In case modifications are performed once the certification tests have started, the simulation benches or test rigs modification impact analysis should assess the need for additional/modified testing (e.g. new/updated tests, regression tests).

(ii) The identification of the impact of post-test evolutions of the aircraft design on the validity of the certification tests performed on the simulation benches and test rigs.

(iii) The repeatability of the tests later on

(d) Representativeness:

(1) The applicant should provide an overview of the general verification strategy applied for the integration of the different systems and models in simulation benches and test rigs:

Integration testing should begin with item-by-item integration building to intra-system, inter-system and aircraft level integration, using verification at each stage. The intent is not for the Agency to verify each step of the integration or over-formalise this process but to share an understanding of this process (and where it is documented) in order to obtain confidence in the representativeness of the simulation bench.

(i) Similarly, for each major simulation bench configuration change, an integrated verification is necessary and should also follow a similar controlled process.

(ii) The intent of the bench should be defined (e.g. test(s) intended to be performed, validation of a procedure) and depending on the intent, the representativeness for the part/scope that is required should be demonstrated.

(2) For an agreed “Simulation” compliance demonstration: the certification evaluations performed in the simulation bench are typically with an aircraft-level view, they cover not only the aircraft behaviour or a single item or system but possibly multiple systems as well as the flight crew procedures and the workload. The demonstration of the representativeness and limitations of the simulator bench should, therefore, also be at aircraft-level, that is inter--systems. Representativeness of simulated failure cases should also be demonstrated. The representativeness and limitations should match the test objectives and be synthetised in a single document.

(3) For an agreed “Laboratory test” compliance demonstration: the certification evaluation performed on a test rig may be with a system, multi-system, or aircraft-level view. The representativeness and limitations should match the test objectives and be synthetized in a single document.

(4) The representativeness demonstration:

(i) Should cover the steady state and the transient phases and should be based on flight test data when available, as proposed by the applicant.

(ii) Where (i) is not possible, for instance for hazardous or catastrophic failure cases, the demonstration should also include analysis (for example, matching of system behaviour expected by the design office with the simulator bench/test rig behaviour) and comparison with partial or segmented demonstration of a failure case performed in flight when relevant.

(iii) For the system part, qualification test data, partial system bench or flight test results combined with analysis and/or engineering judgement could also be used to assess the system response compared to the related models embedded in the simulation bench.

(5) The representativeness and limitations assessment should also cover the dynamics of data exchanges between systems during the failures and the potential dynamics (including time delays) introduced by the specific hardware and model architecture of the simulation bench and test rig, when the timing may influence the sequence of events and the system/aircraft behaviour.

(6) Models' representativeness and limitations:

(i) For system models, when used instead of the real aircraft systems:

(A) the representativeness and limitations of these models should be established and presented before the evaluation, and

(B) this status in (A) should include the functional and/or operational impacts due to the lack of representativeness or the limitations, and

(C) these pieces of information in (B) should be part of the configuration management mentioned in Section 3.(c) of this MOC.

(ii) The representativeness and limitations (in terms of flight domain for instance) of the simulated aircraft dynamics and the aerodynamic models (including on aircraft the control surfaces hinge moments and free-float positions):

(A) should be demonstrated (by comparison to flight test data when available) and documented, and

(B) relevant tolerances specified in the applicable certification specification for flight simulation training devices may be used as a guideline, and

(C) sound engineering judgment should be exercised to determine whether tolerances of the models are adequate.

(iii) When used to support VTOL.2510 compliance demonstration, the simulation bench:

(A) should be capable of monitoring structural loads during tests through a model, and

(B) if no real time monitoring is available, the simulation bench test data could be post-processed when high load level are suspected, and

(C) the representativeness and the limitations of aircraft loads models used should be established.

(iv) Aircraft on the ground model representativeness and limitations should be part of this status.

Note: This status on models' representativeness and limitations should be established and briefed before the certification tests.

(7) When the performance impact is an expected output of a failure case assessment in the simulation bench,

(i) the representativeness and limitations should be documented (e.g. ground effect, ground reaction and braking models), and

(ii) point (i) should be supported by a combination of flight test results, analysis, desktop simulation and engineering/operational judgment to provide a qualitative/reasonable assessment of the performances' representativeness, and

(iii) depending on the intended evaluation, the most appropriate simulator bench configuration (i.e., using models versus real systems) may vary. This choice should be justified, documented, and briefed before the evaluation.

(8) For Human Factors assessments,

(i) the representativeness of systems and simulation means is not a key driver in the early stages of the development and should not necessarily prevent simulation bench usage as long as the nature of the limitations does not compromise the validity of the data to be collected.

(ii) partial certification credit may still be granted while using a non-conformed test article, provided that the item to be evaluated is simulated with an adequate level of representativeness.

(9) When the simulation bench is used for purposes of Human Factors and Handling Qualities evaluation certification,

(i) the simulation bench should be designed to maximise the subject pilots' immersive environment to demonstrate and validate the Human Factor data."

(ii) it is recommended to ensure a sterile environment (no outside noise or visual perturbation), with realistic simulation of ATC communications, subject pilots wearing headsets, etc.

(10) For Human Factors (HF) and Handling Qualities (HQ) evaluation certification tests, the applicant should present the list of problem reports and simulation bench limitations. Their related cockpit effects with an assessment of their impacts on the representativeness of the certification exercise should be presented to the Agency. Problem reports that are considered to not affect the HF and HQ evaluations by either comparison to Flight Test data, Analysis or Engineering Judgement do not need to be presented to the Agency. Regardless of Agency attendance or not to HF or HQ evaluations, this data is expected to be directly visible in the certification data package, for example data could be included in the evaluations test reports.

(e) Recognition of the simulation bench in the design organisation manual (or equivalent) as a certification means:

If the simulation bench is planned to be used to generate compliance data (this applies for instance if some certification tests are planned to be performed on the simulation bench or test rigs):

(1) For any test facility used to produce deliverables (e.g. certification reports), the personnel and the processes should be managed via procedures under the control of the Design Organization.

(2) The simulation bench should be recognized as an asset of the applicant Design Organization.

(3) The applicant should document:

(i) how the simulation bench is recognized in the Design Organisation Manual (or equivalent) as a certification mean;

(ii) which processes of the Design Organization are in place that are related to the aspects and considerations discussed in this MOC.

(f) Automatic testing and analysis tools

(1) Automatic testing and analysis tools, if used, should be subject to a controlled development process (see Section 3.(b)) and configuration management (see Section 3.(c)). This includes automatic testing and analysis tools that are not considered to be part of the simulation and test rigs but are used to process the associated verification data.

(2) Pass/fail criteria should be reviewed and

(i) should take care of the bench and system dynamics, and

(ii) special care should be taken if static or quasi-static criteria are used, and

(iii) a manual review of the critical cases (e.g. safety-critical monitors, reconfigurations after failure) should still be performed to identify if the dynamic of the parameters used to compute the pass/fail criteria are correct, or to detect unexpected behaviours outside the direct parameters under analysis.

(3) If the automatic testing or analysis tool eliminates, reduces, or automates processes for this simulation bench, then the tool should be qualified to a way acceptable to the Agency. For example, guidance from ED-215/DO-330 Software Tool Qualification Considerations for TQL-5 may be followed.

(4) Limitations and problem reports should be recorded, and

(i) their impact should be assessed as part of the configuration management process, and

(ii) a process to address these limitations needs to be established and could include identification of temporary corrective actions (e.g. manual review) pending correction.

VTOL.2505 General requirements on equipment installation

n/a

(a) Each item of installed equipment must be installed according to limitations specified for that equipment.

(b) Reserved.

VTOL.2510 Equipment, systems, and installations

n/a

(a) The equipment and systems identified in SC VTOL.2500, considered separately and in relation to other systems, must be designed and installed such that:

(1) each catastrophic failure condition is extremely improbable and does not result from a single failure;

(2) each hazardous failure condition is extremely remote; and

(3) each major failure condition is remote.

(b) The operation of equipment and systems not covered by SC VTOL.2500 must not cause a hazard throughout the operating and environmental limits for which the aircraft is certified.

(c) For Category Enhanced, provisions for in-service monitoring of equipment and systems which failure may have hazardous or catastrophic consequences must be established.

MOC VTOL.2510 Equipment, systems, and installations

n/a

1. Purpose

This MOC describes an accepted means for showing compliance with the requirements VTOL.2510(a) and VTOL.2510(b). These means are intended to supplement the engineering and operational judgement that should form the basis of any compliance demonstration.

Whilst this MOC details "what" should be addressed for showing compliance with the requirement VTOL.2510(a), it does not provide detailed guidance on the implementation of development assurance and safety assessment processes. Detailed guidance and recommended practices may be found in the standards that are recognised through the list of reference documents in §3 below.

In general, the extent and structure of the analyses required to show compliance with VTOL.2510(a) and VTOL.2510(b) will be greater when the system is more complex and the effects of the Failure Conditions are more severe.

2. Applicability

As specified in VTOL.2500(a), paragraph VTOL.2510 is intended as a general requirement that should be applied to any equipment or system as installed, in addition to specific systems requirements, considering the following:

(a) General - If a specific SC VTOL requirement exists which predefines systems safety aspects (e.g., redundancy level or criticality) for a specific type of equipment, system, or installation, then the specific SC VTOL requirement will take precedence. This precedence does not preclude accomplishment of a system safety assessment. For example, requirement VTOL.2430 predefines a required level of redundancy in the energy storage and distribution systems.

(b) Subpart B, C and D - While VTOL.2510 does not apply to the performance and flight characteristics of Subpart B and structural requirements of Subparts C and D, it does apply to any system on which compliance with any of those requirements is based. For example, it does not apply to an aircraft's inherent stall characteristics, but it does apply to a stall warning system used to enable compliance with VTOL.2150.

(c) Subpart E - In certain VTOL configurations, the lift/thrust system is closely integrated with other systems, such as the flight control system, and will also affect "continued safe flight and landing" or the "controlled emergency landing". Therefore the "lift/thrust control systems" and "lift/thrust system installation hazard assessment" will be addressed through the requirements VTOL.2500 and VTOL.2510 of Subpart F.

This MOC does not cover "Airworthiness Security" aspects. Interactions and interfaces between the system safety assessment process and the security assessment process exist however. Therefore, should a function be implemented or a system/equipment installed on the aircraft as a result of the airworthiness security assessment process, this function or system/equipment needs to undergo the system safety assessment process.

3. Reference Documents

The following references are quoted in different sections of this MOC as a source of additional guidance:

(a) EUROCAE ED-79A/ARP4754A, Guidelines for development of civil aircraft and systems

(b) SAE ARP4761, Guidelines and methods for conducting the safety assessment process on civil airborne systems and equipment.

(c) AMC 20-115( ), Airborne Software Development Assurance Using EUROCAE ED-12 and RTCA DO-178.

(d) AMC 20-152( ), Development Assurance in Airborne Electronic Hardware (AEH)

(e) AMC 20-189( ), Management of Open Problem Reports.

(f) AMC 25-19 Amdt. 24, Certification Maintenance Requirements

4. Definitions

(a) Complexity: An attribute of functions, systems or items which makes their operation, failure modes or failure effects difficult to comprehend without the aid of analytical methods. (Source: ED-79A/ARP4754A).

(b) Continued Safe Flight and Landing: see MOC to VTOL.2000 Applicability and definitions.

(c) Controlled emergency landing: see MOC to VTOL.2000 Applicability and definitions.

(d) Commercial-Off-The-Shelf (COTS) software: Commercially available applications that are sold by vendors through public catalogue listings. COTS software is not intended to be customised or enhanced. Contract-negotiated software developed for a specific application is not COTS software (Source: ED-12C/DO-178C).

(e) Derived requirements: Additional requirements resulting from design or implementation decisions during the development process which are not directly traceable to higher-level requirements and/or specify behaviour beyond that specified by the higher level requirements (Source: adapted from ED-79A/ARP4754A and ED-12C/DO-178C).

(f) Development Assurance: All of those planned and systematic actions used to substantiate, at an adequate level of confidence, that errors in requirements, design and implementation have been identified and corrected such that the system satisfies the applicable certification basis. (Source: ED-79A/ARP4754A).

(g) Development Assurance Level (DAL): the level of rigor of development assurance tasks necessary to demonstrate compliance with paragraphs VTOL.2500 and VTOL.2510 (Source: adapted from ED79A/ARP4754A). The DALs are determined by the system safety assessment process.

Two types of development assurance levels are identified in this document:

(1) FDAL: Development Assurance Levels for aircraft functions, systems and equipment

(2) IDAL: Development Assurance Levels for software and electronic hardware items

(h) Error: An omission or incorrect action by a flight crew member or maintenance personnel, or a mistake in requirements, design, or implementation.

Note: Errors may cause failures, but are not considered to be failures (Source: adapted from AMC 25.1309 in Book 2 of CS-25 Amdt. 24).

(i) Event: An occurrence which has its origin distinct from the aircraft, such as atmospheric conditions (e.g. gusts, temperature variations, icing and lightning strikes) , runway conditions, conditions of communication, navigation, and surveillance services, bird-strike, payload fire. The term is not intended to cover sabotage. (Source: adapted from AMC 25.1309 in Book 2 of CS-25Amdt. 24)

(j) Failure: An occurrence that affects the operation of a component, part, or element such that it can no longer function as intended (this includes both loss of function and malfunction). (Source: adapted from AMC 25.1309 in Book 2 of CS-25 Amdt. 24)

(k) Failure Condition: A condition having an effect on the aircraft, its occupants and/or third parties, either direct or consequential, which is caused or contributed to by one or more failures or errors, considering flight phase and relevant adverse operational or environmental conditions, or external events. (Source: adapted from AMC 25.1309 in Book 2 of CS-25 Amdt. 24)

(l) Latent failure: A failure is latent until it is made known to the flight crew or maintenance personnel. (Source: adapted from AMC 25.1309 in Book 2 of CS-25 Amdt. 24)

(m) Malfunction: Failure of a system, subsystem, unit, or part to operate in the normal or usual manner. The occurrence of a condition whereby the operation is outside specified limits. (Source: AC 23.1309-1E)

(n) Open-source software: describes software that comes with permission to use, copy and distribute, either as is or with modifications, and that may be offered either free or with a charge. The source code should be available. (Source: Gartner)

(o) Significant latent failure: A significant latent failure is one, which would in combination with one or more specific failures, or events result in a Hazardous or Catastrophic Failure Condition. (Source: adapted from AMC 25.1309 in Book 2 of CS-25 Amdt. 24).

5. Abbreviations

(a) AEH – Airborne Electronic Hardware

(b) COTS – Commercial Of The Shelf

(c) CMA – Common Mode Analysis

(d) (F)/(I)DAL – Function / Item Development Assurance Level

(e) PRA – Particular Risk Analysis

6. Principles of Fail-Safe design concept

The requirements of SC-VTOL 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.

(a) The following basic objectives pertaining to failures apply:

(1) 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.

(2) Subsequent failures of related systems during the same flight, whether detected or latent, and combinations thereof, should also be considered.

(b) 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:

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

(2) 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.

(3) Isolation and/or Segregation of Systems, Components, and Elements so that the failure of one does not cause the failure of another.

(4) Proven Reliability so that multiple, independent failures are unlikely to occur during the same flight.

(5) Failure Warning or Indication to provide detection.

(6) Flight Crew Procedures specifying corrective action for use after failure detection.

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

(8) Designed Failure Effect Limits, including the capability to sustain damage, to limit the safety impact or effects of a failure.

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

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

(11) Error-Tolerance that considers adverse effects of foreseeable errors during the VTOL capable aircraft’s design, test, manufacture, operation, and maintenance.

7. Failure conditions classifications and probability terms

(a) Failure Conditions Classifications.

Failure Conditions are classified according to the severity of their effects as follows:

(1) No Safety Effect: Failure Conditions that would have no effect on safety; for example, Failure Conditions that would not affect the operational capability of the aircraft or increase crew workload.

(2) Minor: Failure Conditions which would not significantly reduce aircraft safety, and which involve crew actions that are well within their capabilities. Minor Failure Conditions may include, for example, a slight reduction in safety margins or functional capabilities, a slight increase in crew workload, such as routine flight plan changes, or some physical discomfort to passengers.

(3) Major: Failure Conditions which would reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in crew workload or in conditions impairing crew efficiency, physical distress to occupants, possibly including injuries, or physical discomfort to the flight crew.

(4) Hazardous: Failure Conditions, which would reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be:

(i) a large reduction in safety margins or functional capabilities, or

(ii) physical distress or excessive workload such that the flight crew's ability is impaired to where they could not be relied on to perform their tasks accurately or completely, or

(iii) for Category Enhanced, possible serious injury to an occupant other than the flight crew, but no fatality reasonably expected, or

(iv) for Category Basic, serious or fatal injury to an occupant other than the flight crew.

(5) Catastrophic:

(i) For Category Enhanced, failure conditions, which are expected to result in one or more fatalities, or incapacitation of a flight crew member, usually with the loss of the aircraft. Failure conditions that would prevent continued safe flight and landing of the aircraft are also considered catastrophic.

(ii) For Category Basic, failure conditions, which are expected to result in multiple fatalities, or incapacitation or fatal injury to a flight crew member, usually with the loss of the aircraft. Failure conditions that would prevent a controlled emergency landing of the aircraft are also considered catastrophic.

Explanatory Note: The Categories Basic and Enhanced were introduced in the Special Condition to allow proportionality in safety objectives. The highest safety levels of Category Enhanced apply for the protection of third-parties when flying over congested areas or when conducting commercial air transport of passengers. Different levels of performance are also requested through the performance objectives of Continued Safe Flight and Landing and of Controlled Emergency Landing. This issue of the MOC adds considerations for incapacitation, serious injuries and fatalities in the definitions of Hazardous and Catastrophic failure conditions. For Category Basic, the definitions are similar to AC 23.1309-1E. For Category Enhanced fatalities are excluded in the definition of Hazardous failure conditions due to the high number of operations anticipated and the public safety expectations in the air taxi/urban air mobility context. This also aligns with the expected approach for RPAS where a fatality (on the ground) would be classified Catastrophic.

When referring to "fatalities": passengers, flight crew and people on ground are considered.

(b) Qualitative Probability Terms.

When using qualitative analyses to determine compliance with VTOL.2510(a), the following descriptions of the probability terms used in VTOL.2510 and this MOC have become commonly accepted as aids to engineering judgment:

(1) Probable Failure Conditions are those that are anticipated to occur one or more times during the entire operational life of each aircraft.

(2) Remote Failure Conditions are those that are unlikely to occur to each aircraft during its total life, but which may occur several times when considering the total operational life of a number of aircraft of the type.

(3) Extremely Remote Failure Conditions are those that are not anticipated to occur to each aircraft during its total life but which may occur a few times when considering the total operational life of all aircraft of the type.

(4) Extremely Improbable Failure Conditions are those so unlikely that they are not anticipated to occur during the entire operational life of all aircraft of one type.

8. Safety Objectives

The objective of VTOL.2510(a) is to ensure an acceptable safety level for equipment and systems as installed on the aircraft. A logical and acceptable inverse relationship must exist between the average probability per flight hour and the severity of failure condition effects.

(a) Safety Objectives per aircraft category and failure condition classification:

The safety objectives for each failure condition are:

Table 5: Safety Objectives

		Failure Condition Classifications			
	Maximum Passenger Seating Configuration	**Minor**	**Major**	**Hazardous**	**Catastrophic**
		Allowable Qualitative Probability			
		Probable	Remote	Extremely Remote	Extremely Improbable
		Allowable Quantitative Probability (Note C and D) **Development Assurance Level**			
Category Enhanced	-	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-7}$ FDAL B	$\leq 10^{-9}$ FDAL A
Category Basic	**7 to 9 passengers** **(Basic 3)**	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-7}$ FDAL B	$\leq 10^{-9}$ FDAL A
	2 to 6 passengers **(Basic 2)**	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-7}$ FDAL C (see Note A)	$\leq 10^{-8}$ FDAL B (see Note A)
	0 to 1 passenger **(Basic 1)**	$\leq 10^{-3}$ FDAL D (see Note B)	$\leq 10^{-5}$ FDAL C	$\leq 10^{-6}$ FDAL C (see Note A)	$\leq 10^{-7}$ FDAL C (see Note A)

[Quantitative safety objectives are expressed per flight hour]

Note A: no considerations of the system architecture for a DAL reduction are acceptable, as the FDAL classification already constitute a proportionate approach.

Note B: Alleviation in software development assurance for IDAL D as per section 10(c) is possible.

Note C: It is recognised that, for various reasons, component failure rate data may not be precise enough to enable accurate estimates of the probabilities of Failure Conditions. This results in some degree of uncertainty. When calculating the estimated probability of each Failure Condition, this uncertainty should be accounted for in a way that does not compromise safety.

Note D: The applicant is not expected to perform a quantitative analysis for minor failure conditions.

Note E: An average flight profile (including flight phases duration) and an average flight duration should be defined.

(b) Single failure and common cause failure considerations:

According to VTOL.2510(a)(1), 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. Common-cause failures (including common mode failures) and cascading failures should be evaluated as dependent failures from the point of the root cause or the initiator. Errors in development, manufacturing, installation, and maintenance can result in common-cause failures (including common mode failures) and cascading failures. They should, therefore, be assessed and mitigated in the frame of the common –cause and cascading failures consideration.

Protection from multiple failures should be provided when the first failure would not be detected during normal operations of the aircraft, which includes pre-flight checks.

Sources of common cause and cascading failures include development, manufacturing, installation, maintenance, shared resource, event outside the system(s) concerned, etc. The ARP4761 describes types of common cause analyses, which may be conducted, to ensure that independence is maintained (e.g. particular risk analyses, zonal safety analysis, common mode analyses), see also Section 9(b).

While single failures should normally be assumed to occur, experienced engineering judgment and relevant service history may show that a catastrophic failure condition by a single failure mode is not a practical possibility. The logic and rationale used in the assessment should be so straightforward and obvious that the failure mode simply would not occur unless it is associated with an unrelated failure condition that would, in itself, be catastrophic.

Analyses should always consider the application of the fail-safe design concept as described in section 6, 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

Early coordination with the Agency on these aspects is advised.

9. Safety assessment process

(a) Overview

The Safety Assessment process aims at demonstrating that systems and components are designed and installed in a way that occurrence probabilities of failure conditions are commensurate with their classification and that no catastrophic failure condition results from a single failure. It consists of several objectives, listed below in no particular order:

(1) Examine aircraft and system functions to identify potential functional failures and classify the hazards associated with specific failure conditions.

(2) Establish the safety requirements for the aircraft, its systems and items and validate these safety requirements.

(3) Verify that system architecture and design meets the corresponding safety requirements and the safety objectives, including the single failure criterion.

(4) Establish and verify physical and functional separation, isolation and independence requirements between systems and items, and verify that these requirements have been met.

Guidance on how to perform the Safety Assessment process can be found in ED-79A/ARP4754A and ARP4761. The applicant may propose other guidance for the Safety Assessment process, which should be agreed with the Agency in conjunction with the overall proposed Development Assurance process.

The depth and scope of the analyses are dependent on the system criticality and/or complexity.

The safety assessment process is an iterative process, requiring preliminary assessment steps to ensure that the proposed system architecture(s) can reasonably be expected to meet the safety objectives, as well as regular coordination with the Agency on the different process steps.

When identifying the aircraft and system functions and classifying the hazards associated with the Failure Conditions, the applicant will have to substantiate the effects of failure conditions with consideration to operational conditions and events. Guidance on the handling qualities assessment can be found in MOC VTOL.2135.

Any assumptions made during the safety assessment process need to be justified and validated.

(b) Common mode considerations

Common mode analysis (CMA) is an analytical method to define independence principles and associated requirements, and verify that those independence requirements have been implemented sufficiently. The CMA serves also as a tool to identify any lack of independence and to develop mitigation means to reduce the likelihood or the effect of a common mode failure resulting from a lack of independence.

The CMA should be performed early in the safety assessment process, because it has an impact on the definition of the safety requirements as well as on the system architecture.

Sources of common mode failures include development, manufacturing, installation, maintenance, shared resource, event outside the system(s) concerned, etc. When identifying mitigation means for specific common modes, the means should be appropriate to the common mode failure/error.

It is important to note that even Items that are developed to IDAL A may be subject to development error. Such error may simultaneously affect several instances of the same item with potential functional or safety consequences. EASA has experienced cases, where a development error in IDAL A item has even resulted in simultaneous failures of all affected equipment. Therefore, it should not be assumed that IDAL A items are protected from such development errors and consequently they should be included in the scope of the common mode analysis irrespective of the FDAL/IDAL of the system/item.

The following structured approach is accepted to accomplish a common mode analysis:

(1) Establish program-specific checklists (for common mode types, sources, and resulting failures/errors). ARP4761 paragraph K.3.1 can be followed for this purpose. These checklists should be used to detect elements that may defeat the redundancy or independence principles within the design.

The following Common Modes are examples of common mode types, sources, and resulting failures/errors to be considered:

(i) Software development errors

(ii) Hardware development errors

(iii) Hardware failures

(iv) Production/repair flaws

(v) Stress related events (e.g., abnormal flight conditions, abnormal system configurations)

(vi) Installation errors

(vii) Requirement errors

(viii) Environmental factors (e.g., temperature, vibration, humidity, etc.)

(ix) Cascading faults

(x) Common external source faults

(xi) General Common Modes are further detailed in the ARP4761 table K1.

(2) Identify the independence principles and requirements. ARP4761 paragraph K.3.2 can be followed for this purpose.

These Failure Conditions should cover both the availability (i.e. loss) and integrity of functions and protections.

(3) Analyse the design to ensure it meets the principles and requirements identified in paragraph (2) above. ARP4761 paragraph K.3.3 can be followed for this purpose.

The analysis of the design:

(i) should be conducted not just at system level but also at item level (Airborne Electronic Hardware items including architecture and Software items including architecture), and

(ii) should address both the availability (i.e. loss) and integrity of functions and protections.

(4) Document the results of the above steps of the CMA process. ARP4761 paragraph K.4 can be followed for this purpose.

Additional considerations may be appropriate for some specific systems and functions. In particular for Fly-by-wire Flight Control Functions, MOC 4 VTOL.2300 applies.

10. Development Assurance process

Any analysis necessary to show compliance with VTOL.2510(a) should consider the possibility of development errors.

For simple systems, which are not highly integrated with other aircraft systems, errors made during the development of systems may still be detected and corrected by exhaustive tests conducted on the system and its components, by direct inspection, and by other direct verification methods capable of completely characterising the behaviour of the system. Such items may be considered as meeting the DAL A rigor when they are fully assured by a combination of testing and analysis, however requirements for these items should be validated with the rigor corresponding to the FDAL of the function. Systems which contain software and/or complex electronic hardware items, cannot be considered simple.

For more complex or highly integrated systems, exhaustive testing may either be impossible because all of the system states cannot be determined or impractical because of the number of tests which should be accomplished. For these types of systems, compliance may be shown by the use of development assurance. The level of development assurance should be commensurate with the severity of the failure conditions the system is contributing to.

(a) Development Assurance Level (DAL) allocation

The development assurance level of a function or of an item is assigned depending on the classification of the failure conditions it contributes to.

Initial FDAL allocation is performed in accordance with Section 8(a) in this MOC.

Guidelines, which may be further used for the allocation of development assurance levels to aircraft and system functions (FDAL) and to items (IDAL), are described in the document ED-79A/ARP4754A, section 5.2.

In the absence of agreed guidelines on FDAL/IDAL allocation, the FDAL should be commensurate with those applicable to the category of aircraft as per Sectionn8(a) in this MOC and the IDAL of all components contributing to a given function should be equal to the FDAL of that function.

(b) Aircraft/System development assurance

For the aircraft and for systems of FDAL A, B, C or D, this MOC recognises the ED-79A/ARP4754A as acceptable guideline for establishing a development assurance process from aircraft and systems levels down to the level where software/ Airborne Electronic Hardware (AEH) development assurance is applied.

The extent of application of ED-79A/ARP4754A to substantiate functional development assurance activities may vary depending on the complexity of the systems and on their level of interaction with other systems. Early concurrence with the Agency is essential.

(c) Software development assurance

This MOC recognises AMC 20-115( ) as an accepted means of compliance with requirement VTOL.2510(a).

For Commercial-Off-The-Shelf (COTS) software items and open-source software, in addition to the provisions of AMC20-115(), this MOC recognises guidance from DO-278A/ED-109A section 12.4 as an alternative that could be generally applied beyond the limits of CNS/ATM systems. In this case, the association between ED-12C/DO-178C software level and ED-109A/DO-278A AL (Assurance Level) can be found in DO-278A / ED-109A table 2-2 of section 2.3.3 'Assurance Level Definitions'.

Alleviation for software items of IDAL D contributing to Minor Failure Conditions:

(1) For Category Basic 1 and Basic 2 (c.f. Table 1: Safety Objectives), it is possible to alleviate the software-level development assurance, relying on system-level development assurance processes, provided that:

(i) the equipment is one piece of equipment; and

(ii) the equipment is developed with an acceptable development assurance process.

(2) For Category Basic 3 (see Table 1: Safety Objectives) and Enhanced, the software-level development assurance may be alleviated provided that:

(i) the software high-level requirements are defined and are verified to be captured in the systems requirements as described in ED-79A/ARP4754A section 5.4; and

(ii) if some are 'derived requirements', a mechanism is in place to properly identify, validate and verify those derived software high-level requirements as described in ED-79A/ARP4754A section 5.4.

Note: In both cases, the system-level processes are not considered to be software development assurance processes.

(d) Airborne Electronic Hardware development assurance

This MOC recognises AMC 20-152( ) as accepted means of compliance for requirement VTOL.2510(a).

(e) Open Problem Report management

This MOC recognises AMC 20-189( ) as accepted means of compliance for establishing an open problem report management process for the system, software and AEH domains.

(f) Considerations on derived requirements

ED-79A/ARP4754A section 5.3.1.4 adequately addresses the concerns related to potential for errors introduced by derived requirements while designing and implementing the systems

However, if ED-79A/ARP4754A section 5.3.1.4 defines the derived requirements as those that "may not be uniquely related to a higher-level requirement ", the definition could create an ambiguity as it is limited to "Additional requirements resulting from design or implementation decisions during the development process which are not directly traceable to higher-level requirements".

Requirements that trace to a higher-level requirement and add a behaviour that is not specified at a higher level should also be considered as derived.

As a consequence, the definition from ED-79A/ARP4754A is superseded by the definition provided in Section 4 of this document.

11. Considerations for highly integrated systems

(a) Generic guidance

(1) When aircraft functions are provided by a combination of systems, the relevant requirements of those systems should be validated together, including the following activities:

(i) Analysis of the potential interactions and interferences between systems,

(ii) Planning of dedicated activities at system and aircraft levels to ensure validation of those requirements that are affected by interactions or interference.

(2) When incorporating multiple functions into the same system or equipment, applicability of AMC 20-170 should be considered. For architectures with no partitioning, particular care should be taken in the analysis of interactions between functions.

(b) Additional Considerations for the Lift/Thrust system

For most VTOL capable aircraft designs, the Flight Control System and the Lift/Thrust system are highly integrated, i.e. the propulsion system directly contributes to the controllability of the aircraft. Therefore the development of the Lift/Thrust system should take into consideration the safety objectives of Section 8 and should follow the provisions of VTOL.2510 and associated guidance.

12. Latent failure considerations

The use of periodic maintenance or flight crew checks to detect significant latent failures when they occur is undesirable and should not be used in lieu of practical and reliable failure monitoring and indications. Significant latent failures are latent failures that would, in combination with one or more specific failure(s) or event(s), result in a Hazardous or Catastrophic failure condition and should be avoided in system design.

Within the frame of the no single failure criterion, dual failure combinations, with either one latent, that can lead to a Catastrophic Failure Condition should be avoided in system design. Any such combinations should be highlighted in the relevant SSA and discussed with the Agency as early as possible after identification.

Additional considerations may be appropriate for some specific systems and functions. In particular for Fly-by-wire Flight Control Functions, MOC 5 VTOL.2300 applies.

13. Flight Crew and Maintenance considerations

(a) Flight Crew actions

When assessing the ability of the flight crew to cope with a failure condition, the information that is provided to the flight crew and the complexity of the required action should be considered. If the evaluation indicates that a potential failure condition can be alleviated or overcome during the time available without jeopardizing other safety related flight crew tasks and without requiring exceptional pilot skill or strength, credit may be taken for correct and appropriate corrective action for both qualitative and quantitative assessments. Similarly, credit may be taken for correct flight crew performance if overall flight crew workload during the time available is not excessive and if the tasks do not require exceptional pilot skill or strength. Unless flight crew actions are accepted as normal airmanship, the appropriate procedures should be included in the Agency-approved AFM or in the AFM revision or supplement. The AFM should include procedures for operation of complex systems such as integrated flight guidance and control systems. These procedures should include proper pilot response to cockpit indications, diagnosis of system failures, discussion of possible pilot-induced flight control system problems, and use of the system in a safe manner.

(b) Maintenance actions

Credit may be taken for the correct accomplishment of maintenance tasks in both qualitative and quantitative assessments if the tasks are evaluated and found to be reasonable. Required maintenance tasks, which mitigate hazards, should be provided for use in the Agency-approved ICA. Annunciated failures that will be corrected before the next flight or a maximum duration should be established before a maintenance action is required. If the latter is acceptable, the analysis should establish the maximum allowable interval before the maintenance action is required. A scheduled maintenance task may detect latent failures. If this approach is taken, and the failure condition is hazardous or catastrophic, then a maintenance task should be established. The process for the identification and selection of these scheduled maintenance tasks requires early coordination and agreement with the Agency. Guidance may be found in AMC 25-19.

Credit could be given to tests performed due to mean time between failures (MTBF) to detect the presence of hidden failures, if it can be ascertained that the equipment is removed and inspected at a rate much more frequent than the safety analysis requires. This credit should be substantiated in the relevant SSA. The means of detection of the hidden failures should be clearly identified, either at the opportunity of the acceptance tests performed before the equipment enters service or leaves the manufacturer, or at the opportunity of test of system integrity when it is installed back on the aircraft. This substantiation should be recorded in the relevant SSA. In case of double failures, with either one or both hidden, that can lead to Catastrophic or Hazardous Failure Condition, no credit should be taken from MTBF for failure detection, and the maintenance task enabling detection of the hidden failure should be identified as a required maintenance task.

MOC VTOL.2510(a) Aircraft Parachute Rescue System

n/a

1. Scope of this MOC

(a) This MOC provides guidance and methods for addressing the installation and operation of Aircraft Parachute Rescue Systems (APRS). An APRS is intended to prevent serious injuries to the occupants and third parties, during an impact onto the ground while the aircraft is suspended beneath a fully inflated parachute system, following a serious in-flight incident.

(b) The MOC is applicable to VTOL capable aircraft in the Categories Basic and Enhanced.

(c) The purpose of this MOC is to offer a path for demonstrating compliance with SC-VTOL of an APRS installation intended as a last resort following a failure classified as catastrophic and already meeting the corresponding probability target as per MOC

VTOL.2510, without taking any credit for the APRS. Therefore, APRS installations cannot be:

(1) used for substantiation or relief of requirements defined in SC-VTOL,

(2) part of the minimum equipment,

(3) compensation for any deviation from SC-VTOL.

2. Background

Aircraft Parachute Rescue Systems (APRS) are designed to provide a last safety resort in case of a partial or full loss of aircraft controllability. A variety of system concepts are available, a number of them have been tested successfully, and some have eventually been certified together with the aircraft design.

Common to all of them are parachute canopies made from textile fabric, lines, connecting bridles and a deployment system. Textile decelerators, parachutes are a sub-group of them, have a longstanding and successful history. The current technology covers the range of any combination from very low speed to high Mach numbers, light payload to tons of heavy payload and from low to high altitude [1].

Nevertheless, the engineer's task remains challenging as the design needs to be tailored to the specific use. Furthermore, the interaction between the forebody wake and parachute system in all phases from deployment to landing depends highly on the design of the aircraft. Last, but not least, parachutes are made from fabric, the behaviour of which changes each time the same sample is tested.

Thusly, a certain margin in performance and reliability needs to be taken into account.

Furthermore, an efficient APRS requires two further elements, the suspension system and the crashworthiness of the aircraft fuselage. The suspension system connects the aircraft structure to the bridle line. It should assure a predefined attitude for touchdown, despite reasonably expectable damages to the aircraft structure. The crashworthiness of the aircraft fuselage is intended to dissipate and consume the impact energy such that the occupants suffer no serious injuries. It is obvious, that the effectivity of the crashworthiness depends on the correct attitude at initial touchdown with the ground.

Last, but not least, the demonstration of the function under realistic conditions is required. The APRS can be demonstrated for a certain Capability Category. The four available categories ⋆, ⋆⋆, ⋆⋆⋆, ⋆⋆⋆⋆ depend on the scope of the demonstrated scenarios and to what extent this has been shown by flight or ground test (see Chapter 5., Table 2).

This MOC VTOL.2510(a) is based on research data, existing standards (see Chapter 3.) and certification of parachute systems (see Chapter 4., Table 1) for General Aviation aircraft. It is applicable for SC-VTOL up to the maximum certified take-off mass of 5 700 kg or less.

3. Reference documents

[1] Parachute Recovery Systems Design Manual; T.W. Knacke, January 1992, ISBN: 0-915516-85-3

[2] ASTM F3408/F3408M-20, © ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, U.S.A.

[3] Vorläufige Ergänzungsforderungen für den Einbau von Gesamtrettungssystemen in Segelflugzeugen und Motorseglern; Luftfahrt-Bundesamt, October1994

[4] OSTIV Airworthiness Standards for Sailplane Parachute Rescue Systems, October 1996, P. Kousal for OSTIV

[5] Entwicklung von Nachweisverfahren für die Verkehrssicherheit von Segelflugzeugen und Motorseglern;
W. Röger et al., February 2002, FE-Nr. L-1/98-50169/98, FH Aachen for German Ministry of Transport

[6] Untersuchungen des Insassenschutzes bei Unfällen mit Segelflugzeugen und Motorseglern;
M. Sperber et al., 1998, L-2/93-50112/92, TÜV Rheinland for German Ministry of Transport

[7] Verbesserung der Insassensicherheit bei Segelflugzeugen und Motorseglern durch integrierte Rettungssysteme; W. Röger et al., April 1994, FE-Nr. L-2/90-50091/90, FH Aachen for German Ministry of Transport

[8] Insassensicherheit bei Luftfahrtgerät; W. Röger et al., December 1996, FE -L-4/94-50129/94, FH Aachen for German Ministry of Transport

4. EASA/FAA Publications

These MOCs have been issued as part of certification projects (in chronological order):

Table 1: EASA/FAA Publications

Number, Date, Authority	Title	Code, Aircraft	Seats, MTOM, Speed, Altitude
23–ACE–88 November 1997 FAA[1]	Ballistic Recovery Systems Cirrus SR–20 Installation	Part 23 Model SR-20	4 seats, 1 428 kg V_c 155 KTAS, 17 500 ft
CSTMG01 SC 02 May 2008 EASA[2]	CSTMG01 Special Condition 02 in accordance to Part 21.A.16B (a) (1): Sailplane Parachute Rescue System	CS-22 generic (not model specific)	2 seats, 900 kg V_c 270 km/h EAS
SC-OVLA.div-01 March 2010 EASA[2]	Installation of Ballistic Recovery System (BRS)	CS-VLA generic (not model specific)	2 seats, 750 kg
23-16-01-SC August 2016 FAA[1]	Cirrus Design Corporation, Model SF50; Whole Airplane Parachute Recovery System	Part 23 Model SF50	5/7 seats, 6 000 lb V_c 250 kt, 28 000 ft

5. Means of Compliance

For the demonstration of compliance with the Special Condition VTOL, the following Means of Compliance are accepted:

(a) ASTM standard 'F3408/F3408M – 20, Standard Specification for Aircraft Emergency Parachute Recovery Systems', reference [2], together with the additional requirements in (b),

(b) Supplemental requirements based on references [3] and [4], substantiated by references [5] through [8]. These are listed in Table 2 and Table 3 below:

[1] See: https://www.federalregister.gov/

[2] See: https://www.easa.europa.eu/document-library/product-certification-consultations

Table 2: Flight and Deployment Tests		Basic only	Basic and Enhanced		
Nr.	**Test requirement fulfilled**	*	**	***	****
i.	Flight test deployment at v_{NE}				X
ii.	Flight test deployment in a stabilised turn at the most critical of the following combinations of bank angle and speed: - the maximum permissible bank angle at its maximum permissible speed - v_H or v_{NE}, whichever is lower, and its associated maximum bank angle			X	X
iii.	Flight test deployment during stabilised hover			X (see Note 1)	X (see Note 1)
iv.	Flight test deployment at maximum permissible vertical rate of descent (at zero forward speed)		X	X	X
v.	Parachute drop test at maximum design altitude		X	X	X
vi.	Parachute drop test at v_{NE}	X	X	X	
vii.	Ground test deployment at lowest temperature			X	X
viii.	Ground test deployment at highest temperature		X	X	X
ix.	Ground deployment/extraction test (zero height and speed), with increased mass of the rescue system according to maximum limit load factor n	X	X		
x.	Static strength test of parachute attachment to the airframe up to ultimate load, considering flight speed up to v_D.	X	X	X	X

Color legend: Colour coding in Table 2 means, blue for an additional requirement, and orange for a no-longer applicable requirement when moving to the next higher Capability Category.

Note 1: Unless test requirement (iii) is shown to be less severe than (iv), both tests (iii) and (iv) should be performed for Capability Category *** and Capability Category ****.

Table 3: Supplemental requirements based on references [3] and [4]
Compliance with requirements in 'non-activated' condition
The airworthiness requirements for the basic type design should be complied with to the full extent, as long as the aircraft rescue system is not activated.
Opening shock
Oscillation caused by the opening force should be sufficiently damped.
Strength of the parachute system
At critical aircraft masses the parachute system should comply correspondingly with the applicable requirements of ETSO-C23f, or any equivalent acknowledged requirement.
Application of opening shock into the aircraft structure

Table 3: Supplemental requirements based on references [3] and [4]
All textile components of a suspension system should have at least a safety factor of 2 against failure. A possibly asymmetric loading of the suspension system should be taken into account. Precautions should be taken to prevent possible damages of the APRS due to aircraft structure damages such as sharp edges or splintering.
Activation of the rescue system
The design should provide sufficient margin to prevent malfunction caused by stacking up of tolerances (due to manufacturing and installation processes), temperature effect, g-load or any other conditions encountered in the operational domain.
a) Manual operation of the rescue system should comply with VTOL.2510(a) and in addition should satisfy the following conditions:
1) The release should be done by a handle which is pulled for activation.
2) The handle should be (also under the expected acceleration conditions) well reachable and operable by pilots of differing size, by either right or left hand.
3) The handle should be conspicuously colour coded and clearly marked from the other operating knobs of the aircraft.
4) The handle should be large enough so that the necessary operating forces can be safely applied by the whole hand, even when gloves are worn.
Example: A handle which
- is located in a central position between the inceptor(s) (such as control stick or wheel) and the pilot,
- has a colour coding by yellow-black rings,
- is like a stiff loop handle (analogue to an ejection seat),
is considered compliant with the above-mentioned requirements.
b) Automatic operation of the rescue system should comply with VTOL.2510(a).
c) For the activation, a combination of points a) and b) is acceptable. Nevertheless, each paragraph needs to be fully complied with.
d) For points a) and b) the Flight Manual should describe in detail the required sequence of activation, the criteria for activation, the procedures to reconfigure the propulsion system in a secure manner and any related limitations and procedures, as applicable.
Assessment of normal and unintended/spurious activation
A safety assessment should be performed to assess the effect of system normal function and functional failures. It should not only address potential hazards to the occupants and people on the ground during normal activation, but also following unintended/spurious activations. All failure conditions and their severity should be identified in line with VTOL.2510. On most aircraft, unintended/spurious activation is likely to have catastrophic effects in some phases of operation. Suitable precautions taken to ensure the system meets the safety objectives associated to these failure conditions should include all realistic conditions which occur during the
- operation
- rescue by first-aiders
- storage
- maintenance
- transportation
of the aircraft.
b) The status 'secured'/'armed' should be simply and unequivocally verifiable from the inside and outside of the cockpit.
Control forces and travel for the activation of the release mechanism
a) The operating force necessary for the release of the system should be: - higher or equal to 10 daN, and, - lesser or equal to 20 daN.
b) For the activation of the release mechanism, a defined positive travel of the release handle should be required
Mechanical integration of the rescue system into the aircraft

Table 3: Supplemental requirements based on references [3] and [4]
The integration of all components required for the successful functioning of the rescue system should be done in an area of the aircraft, the damaging of which is improbable in case of mid-air collisions and aerial disintegration.
Precautions against twisting of the parachute system
Suitable means should ensure that no twisting of the parachute lines occurs due to rotation.
Emissions
Emissions produced by the use of the rescue system should neither lead to severe health impairment of the occupants, nor to break-out of a fire.
Compliance with other requirements
Compliance with these requirements should not relieve from compliance of other related requirements. For instance, regulations for handling explosives must be observed.
Operating limitations and information
Operating information should be furnished which define the handling of the system during
- operation,
- rescue by first-aiders,
- storage,
- maintenance,
- transportation.

VTOL.2515 Electrical and electronic system lightning protection

n/a

Unless it is shown that exposure to lightning is unlikely:

(a) each electrical or electronic system that performs a function, the failure of which would prevent continued safe flight and landing for Category Enhanced, or a controlled emergency landing for Category Basic, must be designed and installed such that:

(1) the function at the aircraft level is not adversely affected during and after the time the aircraft is exposed to lightning; and

(2) the system recovers normal operation of that function in a timely manner after the aircraft is exposed to lightning unless the system's recovery conflicts with other operational or functional requirements of the system.

(b) each electrical and electronic system that performs a function, the failure of which would reduce the capability of the aircraft or the ability of the flight crew to respond to an adverse operating condition, must be designed and installed such that the system recovers normal operation of that function in a timely manner after the aircraft is exposed to lightning.

MOC VTOL.2515 Electrical and electronic system lightning protection

n/a

1. Unlikely Exposure to Lightning

It is stated in VTOL.2515 that sub paragraphs (a) and (b) are applicable "unless it is shown that the exposure to lightning is unlikely". The demonstration on this condition should be based on reliable meteorological reports and/or on-board means to detect lightning, directly or indirectly (e.g. Lightning Detector, Weather Radar). Therefore, an accepted means to avoid the compliance demonstration with electrical and electronic system lightning protection requirements is to establish the following operational limitations:

(a) VFR Day with reliable weather reports stating the absence of significant clouds before and/or during the flight for departure, enroute, terminal and diversion vertiports, or

(b) VFR with means to detect lightning or storm cells via a certified onboard system, and/or ground base support plus appropriate communication with the pilot. The qualification of such ground-based system should be ensured by the operator.

When VTOL.2515 (a) and (b) are applicable, this MOC proposes simplified methods for addressing the Indirect Effects of Lightning (IEL) compliance demonstration on VTOL capable aircraft. These methods vary depending on the VTOL capable Aircraft categories; Basic 1 (0 to 1 passenger), Basic 2 (2 to 6 passengers), Basic 3 (7 to 9 passengers) and Enhanced.

2. Reference Documents

The following references are quoted in different sections of this MOC as a source of additional information or to provide accepted methods and practices:

(a) Industry Standards

(1) ASTM

F3061/F3061M	Specification for Systems and Equipment in Small Aircraft
F3230	Standard Practice for Safety Assessment of Systems and Equipment in Small Aircraft
F3309	Standard Practice for Simplified Safety Assessment of Systems and Equipment in Small Aircraft

(2) EUROCAE/SAE/RTCA

ED-81/ARP5413A	Certification of an Aircraft Electrical/Electronic Systems for the Indirect Effect of Lightning
ED-84/ARP5412B	Aircraft Lightning Environment and Related Test Waveforms
ED-91/ARP5414B	Aircraft Lightning Zoning
ED-105/ARP5416A	Aircraft Lightning Test Methods
ED-158/ARP5415B	User/s Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effect of Lightning
ED-14()/DO-160()	Environmental Conditions and Test Procedures for Airborne Equipment

(b) Authorities Guidance

(1) FAA

PS-ACE-23-10	HIRF/Lightning Test Levels and Compliance Methods for 14 CFR Part 23 Class I, II, and III Aircraft *Note: only partially recognised by EASA*
AC 23.1309-1E	System Safety Analysis and Assessment for Part 23 Aircraft
AC 20-136B	Aircraft Electrical and Electronic System Lightning Protection

(2) EASA

MOC VTOL.2515	Acceptable Means of Compliance for VTOL System Safety Analysis and Assessment
AMC 20-136	Aircraft Electrical and Electronic System Lightning Protection

3. Definitions

For the purpose of this MOC the following definitions apply:

(a) **Actual Transient Level (ATL):** The level of transient voltage or current that appears at the equipment interface circuits due to the external environment. This level may be less than or equal to the transient control level, but should not be greater.

(b) **Adverse Effect:** A response of a system that results in an undesirable and/or unexpected operation of an aircraft system, or undesirable and/or unexpected operation of the function performed by the system.

(c) **Ceiling And Visibility are OK (CAVOK):** statement in meteorological report indicating that there are no clouds below 5000 ft AGL (or Minimum Sector Altitude whichever is greater), no presence of Towering Cumulus (TCU) and/or Cumulonimbus (CB) and visibility above 10 km.

(d) **Equipment:** A component of an electrical or electronic system with interconnecting electrical conductors.

(e) **Equipment Transient Design Level (ETDL):** The peak amplitude of transients to which equipment is qualified.

(f) **Hazard related to lightning exposure:** Comparison between the probability to be struck by Lightning and the failure from another internal cause.

(g) **IEL Group:** Group of VTOL categories having the same methodology for their Indirect Effects of Lightning compliance demonstration. 3 Groups have been identified; Group I for VTOL Category “Basic 1” (0-1 passenger), Group II for VTOL Category “Basic 2” (2-6 passengers) and Group III for VTOL Categories “Basic 3” (7-9 passengers) and Enhanced.

(h) **Immunity:** Capacity of a system or piece of equipment to continue to perform its intended function, in an acceptable manner, in the presence of an electrical transient.

(i) **Indirect effects:** Electrical transients induced by lightning in aircraft electrical or electronic circuits.

(j) **Internal environment:** The potential fields and structural voltages inside the aircraft that are produced by the external environment.

(k) **Lightning Certification Level (LCL):** Level of an electrical or electronic system performing a function whose most critical Failure Condition is catastrophic, hazardous or major.

(l) **Margin:** The difference between the equipment transient design levels and the actual transient level.

(m) **No Significant Cloud (NSC):** statement where CAVOK information is not met but ensures no presence of Towering Cumulus (TCU) and/or Cumulonimbus (CB).

(n) **Normal Operation:** A status where the system is performing its intended function. When addressing compliance with VTOL.2515 (a) (2), the function whose failure would prevent the continued safe flight and landing for Category Enhanced or a controlled emergency landing for Category Basic should be in the same undisturbed state than before exposure to the Lightning threat. Other functions, performed by the same system, subject to VTOL.2515 (b), are not required to be recovered.

(o) **System:** An electrical or electronic system includes all electrical and electronic equipment, components and electrical interconnections that are required to perform a particular function.

(p) **Transient Control Level (TCL):** The maximum allowable level of transients that appear at the equipment interface circuits because of the defined external environment.

(q) **Upset:** Impairment of system operation, either permanent or momentary. For example, a change of digital or analogue state that may or may not require a manual reset.

4. Means of Compliance:

(a) Minimum Design Considerations

(1) In order to utilise the methods described in this practice, the following minimum design considerations should be addressed. If deviations from these minimum design considerations are desired, the acceptability of the methods described should be agreed by the Agency.

(2) The airframe should incorporate low impedance electrical conductors to allow lightning current to flow through the aircraft. The low impedance conductors should be incorporated into the basic structure of the aircraft.

(i) For aircraft with primarily metal structure, the metal skin provides a low impedance electrical conductor. Standard rivets and bolts should provide adequate electrical bonding between permanent structural joints. Electrical bonding straps or jumpers should be installed on moving parts or for removable panels or parts.

(ii) For aircraft with primarily carbon fibre or fiberglass structure, metal mesh, metal foil, or expanded metal foil should be incorporated onto the external surfaces of the aircraft composite structure. This mesh or foil should be joined together electrically and provide a continuous electrical conductor between the extremities of the aircraft. Metallic components that are internal to the structure of the aircraft may also be used to provide similar shielding for equipment and its wiring.

(iii) For aircraft constructed of tube and fabric, the tube skeleton can be considered to be the low impedance electrical path through the aircraft. The bonding also may be achieved by the use of bonding straps or jumpers where required to electrically bond other metallic sub-structure that might be relied upon to provide bonding for equipment.

(3) Electrical bonding specifications and verifications should be developed and implemented on the production drawings and instructions for continued airworthiness.

Additional considerations for wiring protection can be found in ED-158 A (User's Manual for certification of aircraft electrical/Electronic Systems for the Indirect Effect of Lightning).

(b) IEL Group Determination

The IEL Group should be identified by using Table 1; the relevant Group will determine the IEL Compliance Verification method given in paragraph (d).

	VTOL Categories			
	Basic (max passenger seating configuration)			Enhanced
	0-1	2-6	7-9	
IEL Group	**I**	**II**	**III**	**III**

Table 1 – IEL Group Allocation

(c) IEL Safety Assessment

(1) Aircraft systems that require an IEL Safety Assessment should be identified. The elements of the system that perform a function should be defined, considering redundant and/or backup equipment that constitutes the system. The process used for identifying these systems should be similar to the process used for showing compliance with VTOL.2510. This requirement addresses any system failure that may cause or contribute to an effect on the safety of flight of an aircraft. The effects of a Lightning Strike should be assessed to determine the degree to which the aircraft and its systems safety may be affected. The operation of the aircraft systems should be assessed separately and in combination with, or in relation to, other systems. This assessment should cover:

(i) All normal aircraft operating modes, stages of flight, and operating conditions;

(ii) All failure conditions and their subsequent effect on aircraft operations and the flight crew; and

(iii) Any corrective actions required by the flight crew.

(2) A safety assessment related to IEL should be performed to establish and classify the equipment or system failure condition. Table 2 provides the corresponding Failure Condition classification and system IEL certification level for VTOL.2515. The IEL safety assessment determines the consequences of failures, due to IEL, for the aircraft functions that are performed by the system. The Lightning Certification Level (LCL) classification assigned to the system and functions can be different from the Design Assurance Levels assigned for equipment function and/or item (software, and complex electronic hardware). This is because operation in Lightning environment can cause common cause effects. The term 'Design Assurance Level' should not be used to describe the Lightning Certification Level because of the potential differences in assigned classifications for software, complex electronic hardware, and equipment function

IEL Requirements VTOL.2515	**MOST CRITICAL FAILURE CONDITION OF THE FUNCTION**	**SYSTEM LIGHTNING CERTIFICATION LEVEL (LCL)**
Unless it is shown that exposure to lightning is unlikely: (a) Each electrical or electronic system that performs a function, the failure of which would prevent continued safe flight and landing for Category Enhanced, or a controlled emergencylanding for Category Basic, must be designed and installed such that: (1) The function at the aircraft level is not adversely affected during and after the time the aircraft is exposed to lightning; and (2) The system recovers normal operation of that function in a timely manner after the aircraft is exposed to lightning unless the system's recovery conflicts with other operational or functional requirements of the system.	Catastrophic	A
(b) The Each electrical and electronic system that performs a function, the failure of which would reduce the capability of the aircraft or the ability of the flight crew to respond to an adverse operating condition, must be designed and installed such that the system recovers normal operation of that function in a timely manner after the aircraft is exposed to lightning.	Hazardous/Major	B/C

Table 2 – IEL Failure Conditions and System Lightning Certification Level

(i) The IEL safety assessment should consider all potential adverse effects due to system failures; loss, malfunctions or misleading information caused by IEL threat. The IEL safety assessment may show some systems have different failure conditions in different phases of flight; therefore, the LCL corresponds to the most critical Failure Condition

(ii) In addressing the Failure Condition in Table 2, the nature of IEL should be considered. The potential for common cause of failures across multiple equipment/systems performing the same or different functions due to the simultaneous exposure to the IEL threat should be considered. Additionally, the inherent immunity of mechanical systems with no electrical circuitry should also be considered.

(iii) In addressing the Failure Condition in Table 2, the indirect effects of lightning should not be combined with random failures that are not the result of the IEL threat.

(iv) Due to the similar approach in the safety assessment process related to IEL and HIRF, the System Certification Levels for HIRF and Lightning are usually the same.

(d) IEL Compliance Verification

(1) Unless operational limitations are implemented to only allow operation in VFR Day with reliable weather reports on the absence of significant clouds, or the Operation in VFR is permitted with certified VTOL systems to detect the lightning strike or storm cells, then the likelihood of exposure to lightning in VMC condition has to be

considered (see Figures 1 and 2 in Section 5). Nevertheless, the Hazard related to this exposure on VTOL capable aircraft could be assessed by comparing the Rate of lightning strike to Aircraft and the Safety objectives at Aircraft Level (see Table 3 in Section 5); in some cases, the probability of having a lightning strike to an aircraft is lower than the probability of having a failure from another technical cause. In such cases, the Hazard associated with a lightning strike can be considered to be unlikely and therefore for lower IEL Groups and the IEL Groups operating in VFR, VTOL.2515 (b) is not applicable for Level B and/or C systems that can be removed from the verification (see Section 6).

(2) IEL Group I

(i) For level A Systems (Display and Non-Display)

(A) Follow the AMC 20-136; or

(B) Conduct Equipment/System testing using the following categories:

(a) According to the VTOL capable aircraft primary structure and wiring type, choose the appropriate Category/Waveform at Level 3 in EUROCAE ED-14G section 22.

(b) Fail/Pass Criteria: when subjected to the Lightning Environment, it could be acceptable that equipment is/are subject to adverse effect, provided that the Level A function is maintained at the aircraft level and all the Equipment/Systems that are required in normal operation recover manually or automatically, in a timely manner, this function after the threat.

(ii) For Level B Systems on aircraft approved for IFR Operation

Conduct Equipment/System testing using the following categories:

(A) According to the VTOL capable aircraft primary structure and wiring type, choose the appropriate Category/Waveform at Level 2 in EUROCAE ED-14G 22.

(B) Fail/Pass Criteria; when submitted to the Lightning Environment, it could be acceptable that redundant equipment is/are subject to adverse effect, provided that the Level B function is recovered manually or automatically, in a timely manner, after the threat.

(3) IEL Group II

(i) For level A Systems (Display and Non-Display)

(A) Follow the AMC 20-136; or

(B) Conduct Equipment/System testing using the following categories:

(a) According to the VTOL capable aircraft primary structure and wiring type, choose the appropriate Category/Waveform at Level 3 in EUROCAE ED-14G section 22.

(b) Fail/Pass Criteria; when submitted to the Lightning Environment, it could be acceptable that equipment is/are subject to adverse effect; provided that the Level A function is maintained at the aircraft level and all the Equipment/System, required in normal operation, recover manually or automatically, in a timely manner, this function after the threat.

(ii) For Level B Systems

Conduct Equipment/System testing using the following categories:

(A) According to the VTOL capable aircraft primary structure and wiring type, choose the appropriate Category/Waveform at Level 2 in EUROCAE ED-14G 22.

(B) Fail/Pass Criteria; when submitted to the Lightning Environment, it could be acceptable that redundant equipment is/are subject to adverse effects, provided that the Level B function is recovered manually or automatically, in a timely manner, after the threat.

(4) IEL Group III

(i) For Level A Non-Display Systems:

(A) Follow the AMC 20-136; or

(B) Determine the aircraft Actual Transient Level (ATL) (by test, analysis, combination of both or by similarity); and

(C) Conduct Equipment/System testing using the following categories:

(a) According to the VTOL capable aircraft primary structure and wiring type, choose the appropriate Category/Waveform at Level 3 or 4 in EUROCAE ED-14G section 22.

(b) Fail/Pass Criteria; when submitted to the Lightning Environment, it could be acceptable that equipment is/are subject to adverse effect, provided that the Level A function is maintained at the aircraft level and all the Equipment/Systems that are required in normal operation, recover manually or automatically, in a timely manner, this function after the threat.

(c) Verify the positive margin between the default levels applied during the Equipment/System testing (EDTL as defined in (a)) and the Transient Control Level (TCL, maximum expected aircraft ATLs). If a positive margin is not established, corrective measures should be implemented in line with AMC 20-136.

(ii) For level A Display Systems:

(iii) Conduct Equipment/System testing using the following categories:

(A) For VTOL capable aircraft with primarily metal structure, EUROCAE ED-14G section 22 category A3J3L3.

(B) For VTOL capable aircraft with primarily carbon fibre, fiberglass or non-conductive material structure, EUROCAE ED-14G section 22 category B3K3L3.

(C) Fail/Pass Criteria; when submitted to the Lightning Environment, it could be acceptable that equipment is/are subject to adverse effect, provided that the Level A function is maintained at the aircraft level and all the Equipment/Systems required in normal operation recover manually or automatically, in a timely manner, this function after the threat.

(iv) For level B Systems:

(v) Conduct Equipment/System testing using the following categories:

(A) For VTOL capable aircraft with primarily metal structure, EUROCAE ED-14G 22 category A2J2L2.

(B) For VTOL capable aircraft with primarily carbon fibre, fiberglass or non-conductive material structure, EUROCAE ED-14G section 22 category B2K2L2.

(C) Fail/Pass Criteria; when submitted to the Lightning Environment, it could be acceptable if redundant equipment is/are subject to adverse effect, provided that the Level B function is recovered manually or automatically, in a timely manner, after the threat.

(vi) For Level C Systems on aircraft approved for IFR Operation:

(vii) Conduct Equipment/System testing using the following categories:

(A) For VTOL capable aircraft with primarily metal structure, EUROCAE ED-14G 22 category A1J1L1.

(B) For VTOL capable aircraft with primarily carbon fibre, fiberglass or non-conductive material structure, EUROCAE ED-14G section 22 category B1K1L1.

(C) Fail/Pass Criteria; when submitted to the Lightning Environment, it could be acceptable that redundant equipment is/are subject to adverse effect, provided that the Level C function is recovered manually or automatically, in a timely manner, after the threat.

(5) IEL Testing for Level A Systems considerations;

(i) The Test Levels for upper IEL Group could also be used for lower IEL Group; for instance, the use of the level for Level A Non-Display System for IEL Group III can be used for Level A System of IEL Groups I/II.

(ii) Equipment testing is acceptable when it is shown that the interdependencies between equipment performing a function are understood and each equipment is tested and monitored to verify there is no unacceptable upset of the function.

(iii) If similar equipment are used to perform the same function, the test can be limited to a single equipment.

(6) Level A System architecture consideration: when a level A system is composed of redundant channels/equipment that perform the same level A function, it is permitted to limit the system to the channels/equipment that are required in normal operation provided that they are not susceptible when they comply with VTOL.2515(a); for instance if it is demonstrated that the primary channels comply with VTOL.2515(a) without the support of the back-up channel, the equipment of this channel is/are not required to be qualified to Level 3/4, however this back-up channel should be considered to be as a level B system (Level 2).

5. Rate of Lightning strike to small aircraft and Failure Condition Likelihood

(a) Rates of Lightning strike in General Aviation

Research on lightning strikes to aircraft has shown that the rate of lightning strikes per flight cycle is closely correlated to several parameters: the size, the cruise altitude and the ratio of VMC/IMC conditions. This correlation provides a method for estimating the likelihood of lightning strikes to smaller aircraft.

Table 3 provides estimated small aircraft lightning strike rates based on this correlation.

A/C Class	Class I	Class II	Class III
Percentage of operations in instrument meteorological conditions	10%	27%	38%
Rate of lightning strikes per flight cycle	$7.\ 10^{-6}$	2.10^{-5}	7.10^{-5}
Hours per flight cycle	0.73	0.80	1.41
Rate of lightning strikes per flight hour	10^{-5}	3.10^{-5}	5.10^{-5}

Table 3 - Estimated small aircraft lightning strike rates

(b) Environmental Condition and Aircraft Position

A Lightning strike database has been established for the FAA; it compiles all the lightning strikes reports involving small aircraft.

Figure 1 shows, from this Lightning Strike database shows the position of the aircraft when it was struck by lightning. It can be seen from this figure that this mainly occurs when the aircraft is in clouds where intra-clouds flashes are intercepted by the Aircraft. In a few cases, below clouds, it is possible that Cloud-to-ground Lightning strikes are intercepted or triggered by the Aircraft.

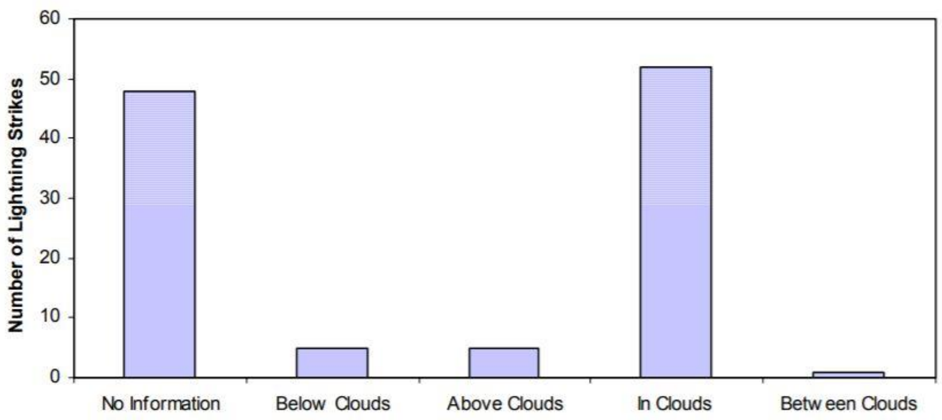


Figure 1 - Number of Lightning Strikes vs Aircraft Position

Figure 2 shows, from this Lightning strike database, the environmental conditions of the aircraft when it was struck by lightning. It can be seen from this figure that Lightning Strike mainly occurs under rain or hail conditions but in 30% of the cases there was no precipitation.

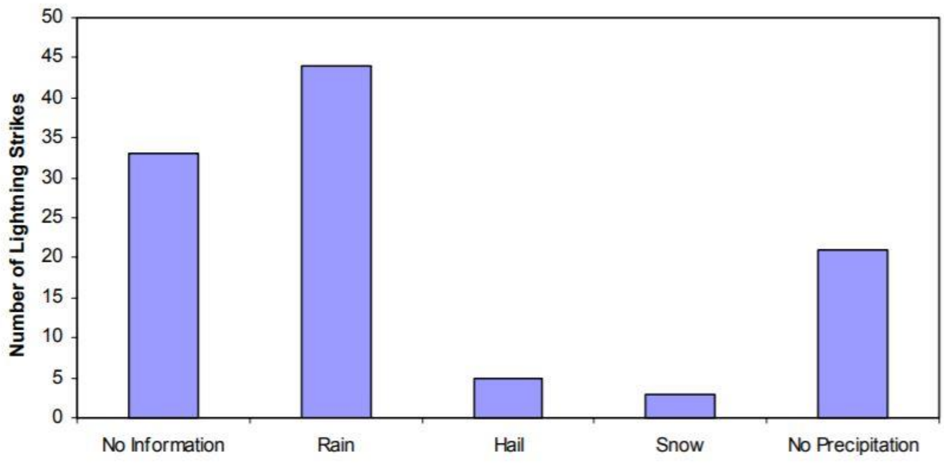


Figure 2 - Number of Lightning Strikes vs Environmental Conditions

Table 4 presents the Rates of lightning strike to Aircraft according to the IEL Group; these Rates are the results of the data from the Table 1 and Figures 1 and 2 extrapolated to VTOL Groups.

A/C Group	IEL Group I VFR (1)(2)	IEL Group I IFR (1)(2)	IEL Group II VFR (1)(2)	IEL Group II IFR (1)(2)	IEL Group III VFR (1)(2)	IEL Group III IFR(1)(2)
$R_{\text{Lightning Strike}}$ /FH	5.10^{-6}	5.10^{-5}	8.10^{-6}	8.10^{-5}	10^{-5}	10^{-4}

Table 4 - IEL Group Lightning Strike Rates

(1) For simplification it has been assumed that aircraft flying under VFR are in VMC and aircraft flying under IFR are in IMC for 50% and VMC for 50% of the flight time (so same order of magnitude between IMC and IFR)

(2) A factor 10^{-1} has been applied to the Rate of Lightning Strike to aircraft between IFR and VFR operations (according to data from Figures 1 and 2).

(c) Hazard on VTOL capable aircraft

By comparing the Rate of Lightning Strike and the Safety Objective at Aircraft Level, we can determine its associated Hazard category.

Table 5 provides the likelihood of the Hazard due to Lightning Strike for a given IEL Group.

Failure Condition A/C Group	**Catastrophic (Level A)**	**Hazardous (Level B)**	**Major (level C)**
IEL Group I VFR	Likely (Safety Objectives 10^{-6})	Unlikely (Safety Objectives 10^{-5})	Unlikely (Safety Objectives 10^{-4})
IEL Group I IFR	Likely (Safety Objectives 10^{-6})	Likely (Safety Objectives 10^{-5})	Unlikely (Safety Objectives 10^{-4})
IEL Group II VFR	Likely (Safety Objectives 10^{-7})	Likely (Safety Objectives 10^{-6})	Unlikely (Safety Objectives 10^{-4})
IEL Group II IFR	Very Likely (Safety Objectives 10^{-7})	Likely (Safety Objectives 10^{-6})	Unlikely (Safety Objectives 10^{-4})

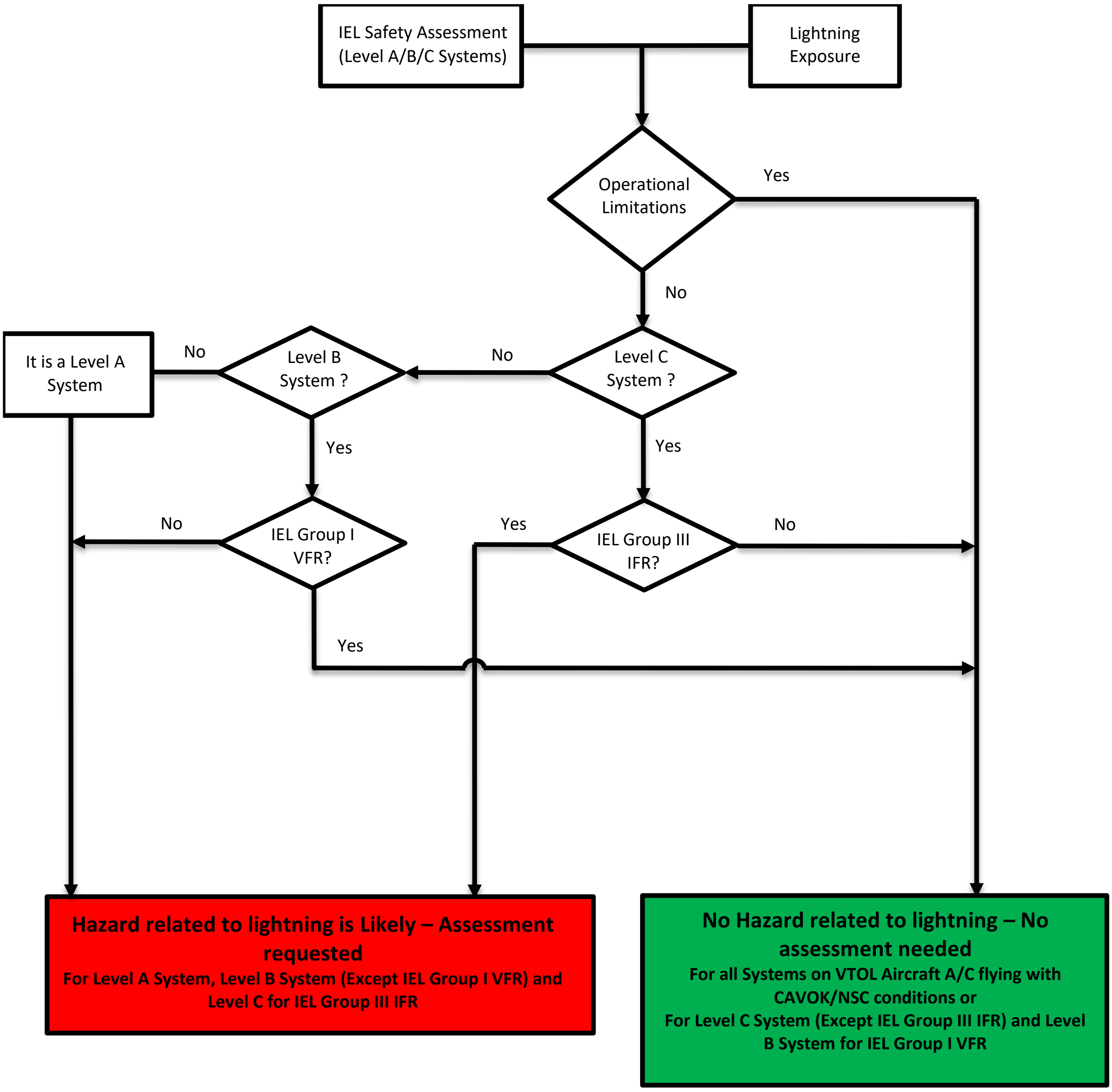
IEL Group III VFR	Very Likely (Safety Objectives 10^{-8})	Likely (Safety Objectives 10^{-6})	Unlikely (Safety Objectives 10^{-4})
IEL Group III IFR	Very Likely (Safety Objectives 10^{-8})	Likely (Safety Objectives 10^{-6})	Likely (Safety Objectives 10^{-4})

Table 5 - Likelihood of Hazard due to Lightning Strike

$P_{Hazard} = R_{Lightning\ Strike} / S_{Safety\ Objective}$

$P_{Hazard} < 1$: Hazard is Unlikely, $1 \leq P_{Hazard} \leq 10^2$: Hazard is Likely, $P_{Hazard} > 10^2$: Hazard is Very Likely

6. Decisional Flow Chart on the Hazard related to Lightning Exposure to Aircraft



VTOL.2517 Electrical wiring interconnection system (EWIS)

n/a

(a) EWIS means any wire, wiring device, or combination of these, including termination devices, installed in any area of the aircraft for the purpose of transmitting electrical energy, including data and signals between two or more intended termination points.

(b) EWIS must be considered an integral part of the system and must be considered in showing compliance with all applicable SC VTOL requirements.

VTOL.2520 High-intensity radiated fields (HIRF) protection

n/a

(a) Each electrical and electronic system that perform a function, the failure of which would prevent continued safe flight and landing for Category Enhanced, or a controlled emergency landing for Category Basic, must be designed and installed such that:

(1) the function at the aircraft level is not adversely affected during and after the time the aircraft is exposed to the HIRF environment; and

(2) the system recovers normal operation of that function in a timely manner after the aircraft is exposed to the HIRF environment, unless the system's recovery conflicts with other operational or functional requirements of the system.

(b) Each electrical and electronic system that performs a function, the failure of which would reduce the capability of the aircraft or the ability of the flight crew to respond to an adverse operating condition, must be designed and installed such that the system recovers normal operation of that function in a timely manner after the aircraft is exposed to the HIRF environment.

MOC VTOL.2520 High-intensity radiated fields (HIRF) protection

n/a

1. Scope of this MOC

This MOC proposes simplified methods for addressing High Intensity Radiated Fields (HIRF) compliance demonstration on VTOL capable aircraft. These methods depend on the VTOL capable Aircraft Category; Basic 0 to 1 passenger, Basic 2 to 6 passengers, Basic 7 to 9 passengers and Enhanced.

The topics covered within this MOC are: Minimum Design Requirements, HIRF Group Determination, HIRF Safety Assessment and HIRF Compliance Verification.

2. Reference Documents

The following references are quoted in different sections of this MOC as a source of additional information or to provide accepted methods and practices:

(a) Industry Standards

(1) ASTM

F3061/F3061M	Specification for Systems and Equipment in Small Aircraft
F3230	Standard Practice for Safety Assessment of Systems and Equipment in Small Aircraft
F3309	Standard Practice for Simplified Safety Assessment of Systems and Equipment in Small Aircraft

(2) EUROCAE/SAE/RTCA

ED-107A/ARP 5583A	Guide to Certification of Aircraft in a High Intensity Radiated Field (HIRF) Environment
ED-14()/DO-160()	Environmental Conditions and Test Procedures for Airborne Equipment

(b) Authorities Guidance

(1) FAA

PS-ACE-23-10	HIRF/Lightning Test Levels and Compliance Methods for 14 CFR Part 23 Class I, II, and III Airplanes *Note: only partially recognised by EASA*
AC 23.1309-1E	System Safety Analysis and Assessment for Part 23 Airplanes
AC 20-158A	The Certification of Aircraft Electrical and Electronic Systems for Operation in the High-intensity Radiated Fields (HIRF) Environment

(2) EASA

MOC VTOL.2510	Means of Compliance for VTOL Equipment Systems and installations
AMC 20-158	Aircraft Electrical and Electronic System High-intensity Radiated Fields (HIRF) Protection

3. Definitions

For the purpose of this MOC the following definitions apply:

(a) Adverse Effect: A response of a system that results in an undesirable and/or unexpected operation of an aircraft system, or undesirable and/or unexpected operation of the function performed by the system.

(b) Attenuation: Term used to denote a decrease in electromagnetic field strength in transmission from one point to another. Attenuation may be expressed as a scalar ratio of the input magnitude to the output magnitude or in decibels (dB).

(c) Equipment: Component of an electrical or electronic system with interconnecting electrical conductors.

(d) External High-intensity Radiated Fields Environment: Electromagnetic RF fields at the exterior of an aircraft.

(e) Field Strength: Magnitude of the electromagnetic energy propagating in free space expressed in volts per meter (V/m).

(f) High-intensity Radiated Fields (HIRF) Environment: Electromagnetic environment that exists from the transmission of high power RF energy into free space.

(g) High-intensity Radiated Fields (HIRF) Test level: The level of Field Strength applied during the Equipment/System Test, it may vary according the RF Band.

(h) HIRF Certification Level (HCL): The level of an electrical or electronic system that performs a function whose worst Failure Condition classification is catastrophic, hazardous or major.

(i) HIRF Group: Group of VTOL categories having the same methodology for their HIRF compliance demonstration. 3 Groups have been identified; Group I for VTOL Category “Basic 1” (0-1 passenger), Group II for VTOL Category “Basic 2” (2-6 passengers) and Group III for VTOL Categories “Basic 3” (7-9 passengers) and Enhanced.

(j) Immunity: The capacity of a system or piece of equipment to continue to perform its intended function, in an acceptable manner, in the presence of RF fields.

(k) Internal HIRF Environment: RF environment inside an airframe, equipment enclosure, or cavity. The internal RF environment is described in terms of the internal RF field strength or wire bundle current.

(l) Normal Operation: A state of the system where the system is performing its intended function. When addressing compliance with VTOL.2520 (a) (2), the function whose failure would prevent the continued safe flight and landing for Category Enhanced or a controlled emergency landing for Category Basic should be in the same undisturbed state than before exposure to the HIRF threat. Other functions, performed by the same system, subject to VTOL.2520 (b), are not required to be recovered.

(m) Radio Frequency (RF): Frequency useful for radio transmission. The present practical limits of RF transmissions are roughly 10 kilohertz (kHz) to 100 gigahertz (GHz). Within this frequency range, electromagnetic energy may be detected and amplified as an electric current at the wave frequency.

(n) System: The piece of equipment connected via electrical conductors to another piece of equipment, both of which are required to make a system function. A system may contain pieces of equipment, components, parts, and wire bundles.

(o) Transfer Function: The ratio of the electrical output of a system to the electrical input of a system, expressed in the frequency domain. For HIRF, a typical transfer function is the ratio of the current on a wire bundle to the external HIRF field strength, as a function of frequency.

(p) Upset: An impairment of system operation, either permanent or momentary. For example, a change of digital or analogue state that may or may not require a manual reset.

4. Means of Compliance

(a) Minimum Design Considerations

(1) In order to utilise the methods described in this practice, the following minimum design considerations should be addressed. If deviations from these minimum design considerations are desired, the acceptability of the methods described should be agreed to by the Agency.

(2) The airframe should incorporate low impedance electrical conductors to allow induced current to flow through the aircraft. The low impedance conductors should be incorporated into the basic structure of the aircraft.

(i) For aircraft with primarily metal structure, the metal skin provides a low impedance electrical conductor. Standard rivets and bolts should provide adequate electrical bonding between permanent structural joints. Electrical bonding straps or jumpers should be installed on moving parts or for removable panels or parts.

(ii) For aircraft with primarily carbon fibre or fiberglass structure, metal mesh, metal foil, or expanded metal foil should be incorporated onto the external surfaces of the aircraft composite structure. This mesh or foil should be joined together electrically and provide a continuous electrical conductor between the extremities of the aircraft. Metallic components that are internal to the structure of the aircraft may also be used to provide similar shielding for equipment and its wiring.

(iii) For aircraft constructed of tube and fabric, the tube skeleton can be considered to be the low impedance electrical path through the aircraft. The bonding also may be achieved by the use of bonding straps or jumpers where required to electrically bond other metallic sub-structure that might be relied upon to provide bonding for equipment.

(3) Electrical bonding specifications and verifications should be developed and implemented on the production drawings and instructions for continued airworthiness.

(b) HIRF Group Determination

The HIRF Group should be identified by using Table 1; the relevant Group will determine the HIRF Compliance Verification method given in paragraph (d).

<table>
<tr><td rowspan="3"></td><td colspan="4">VTOL Categories</td></tr>
<tr><td colspan="3">Basic (max passenger seating configuration)</td><td rowspan="2">Enhanced</td></tr>
<tr><td>0-1</td><td>2-6</td><td>7-9</td></tr>
<tr><td>HIRF Group</td><td>I</td><td>II</td><td>III</td><td>III</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 1 – HIRF Group Allocation

(c) HIRF Safety Assessment

(1) The VTOL capable aircraft systems that require a HIRF Safety Assessment should be identified. The elements of the system that perform a function should be defined, considering the use of redundant and/or backup equipment that constitutes the system. The process used for identifying these systems should be similar to the process used for showing compliance with VTOL.2510. This requirement addresses any system failure that may cause or contribute to an effect on the safety of flight of a VTOL capable aircraft. The effects of a HIRF encounter should be assessed to determine the degree to which the aircraft and its systems safety may be affected. The operation of the aircraft systems should be assessed separately and in combination with, or in relation to, other systems. This assessment should cover:

(i) All normal VTOL capable aircraft operating modes, stages of flight, and operating conditions;

(ii) All failure conditions and their subsequent effect on VTOL capable aircraft operations and the flight crew; and

(iii) Any corrective actions required by the flight crew

(2) A safety assessment related to HIRF should be performed to establish and classify the equipment or system failure condition. Table 2 provides the corresponding Failure condition classification and system HIRF certification level for VTOL.2520. The HIRF safety assessment determines the consequences of failures, due to HIRF, for the aircraft functions that are performed by the system. The HIRF Certification Level (HCL) classification assigned to the system and functions can be different from the Design Assurance Levels assigned for equipment function and/or item (software, and complex electronic hardware). This is because HIRF is an environment that can cause common cause effects. The term 'Design Assurance Level' should not be used to describe the HIRF Certification Level because of the potential differences in assigned classifications for software, complex electronic hardware, and equipment function

HIRF Requirements VTOL.2520	MOST CRITICAL FAILURE CONDITION OF THE FUNCTION	SYSTEM HIRF CERTIFICATION LEVEL (HCL)
(a) Each electrical and electronic system that performs a function, the failure of which would prevent continued safe flight and landing for Category Enhanced, or a controlled emergency landing for Category Basic, must be designed and installed such that: **(1) The function at the aircraft level is not adversely affected during and after the time the aircraft is exposed to the HIRF environment; and** **(2) The system recovers normal operation of that function in a timely manner after the aircraft is exposed to the HIRF environment, unless the system's recovery conflicts with other operational or functional requirements of the system.**	Catastrophic	A
(b) Each electrical and electronic system that performs a function, the failure of which would reduce the capability of the aircraft or the ability of the flight crew to respond to an adverse operating condition, must be designed and installed such that the system recovers normal operation of that function in a timely manner after the aircraft is exposed to the HIRF environment.	Hazardous/Major	B/C

Table 2 – HIRF Failure Conditions and System HIRF Certification Level

(3) The HIRF safety assessment should consider all potential adverse effects due to system failures; loss, malfunctions or misleading information caused by a HIRF threat. The HIRF safety assessment may show some systems have different failure conditions in different phases of flight; therefore, the HCL corresponds to the most critical Failure Condition.

(4) In addressing the Failure Condition in Table 2, the nature of HIRF should be considered. The potential for common causes of failures across multiple equipment/systems performing the same or different functions due to the simultaneous exposure to the HIRF threat should be considered. Mechanical systems can be considered inherently immune to HIRF and may be used in the safety assessment.

(5) In addressing the Failure Condition in Table 2, the effects of HIRF should not be combined with random failures that are not the result of the HIRF threat.

(6) Due to the similar approach in the safety assessment process related to IEL and HIRF, the System Certification Levels for HIRF and Lightning are usually the same.

(d) HIRF Compliance Verification

(1) By applying the 'Net Safety Benefit' approach[1] on the lower HIRF Group, VTOL.2520 (b) is not applicable for level C system of HIRF Groups I and II, it could be removed from the Compliance Verification.

(2) HIRF Groups I and II

(i) For Level A Non-Display Systems:

(A) Follow AMC 20-158; or

(B) Conduct Equipment/System testing using the following default levels:

(a) Conducted susceptibility testing with the Generic transfer function for aircraft (according to VTOL shape and size) extrapolated to the HIRF Environment III (as defined in Section 5) corresponding to the EUROCAE ED-14G section 20 categories Y or W.

(b) Radiated Susceptibility testing with Generic attenuation curves (depending on equipment location) extrapolated to the HIRF Environment III (as defined in Section 5) corresponding to the EUROCAE ED-14G section 20 categories L, G or F

(c) Fail/Pass Criteria; when subjected to the HIRF Environment, it could be acceptable that redundant equipment is/are subject to adverse effects, provided that the Level A function is maintained at the aircraft level and all the Equipment/Systems that are required in normal operation recover manually or automatically, in a timely manner, this function after the threat.

[1] For additional information, refer to the EASA Proposed Certification Memorandum CM-SA-001 published in the EASA Website: Proposed Certification Memorandum CM-SA-001 - Net Safety Benefit - Issue 01 | EASA (europa.eu)

(ii) For Level A Display Systems:

(A) Follow the AMC 20-158; or

(B) Conduct Equipment/System testing using the following default levels:

(a) Conducted susceptibility testing ?with the Generic transfer function for aircraft (according to VTOL shape and size) extrapolated to the HIRF Environment I (as defined in Section 5) corresponding to the EUROCAE ED-14G section 20 categories O or M.

(b) Radiated Susceptibility testing with Generic attenuation curves (depending on equipment location) extrapolated to the HIRF Environment I (as defined in Section 5) corresponding to the EUROCAE ED-14G section 20 categories G, F or D.

(c) Fail/Pass Criteria; when subjected to the HIRF Environment, it could be acceptable that redundant equipment is/are subject to adverse effects, provided that the Level A function is maintained at the aircraft level and all the Equipment/Systems that are required in normal operation recover manually or automatically, in a timely manner, this function after the threat.

(iii) For Level B Systems:

(A) Follow the AMC 20-158 (by using Equipment HIRF Test Levels 1 or 2 as defined in Section 5); or

(B) Conduct Equipment/System testing as defined in (d) (2) (ii) (B) (a) and (b); when submitted to the HIRF Environment, if the Equipment/System subject to adverse effects does not to recover its level B function after the threat, the method proposed by the AMC 20-158 for Level B systems in (d) (2) (iii) (A) can be used as an alternatively.

(3) HIRF Group III

(i) For Level A Non-Display Systems:

(A) Follow the AMC 20-158; or

(B) Conduct Equipment/System testing using the following default levels:

(a) Conducted susceptibility testing with the real transfer function of the aircraft (determined by Low Level coupling test, analysis, combination of both or similarity) extrapolated to the HIRF Environment III (as defined in Section 5).

(b) Radiated Susceptibility testing with real attenuation curves (determined by Low level Testing, analysis, combination of both or similarity) extrapolated to the HIRF Environment III (as defined in Section 5).

(c) Fail/Pass Criteria; when submitted subjected to the HIRF Environment, it could be acceptable that redundant equipment is/are subject to adverse effects, provided that the Level A function is maintained at the aircraft level and all the

Equipment/Systems that are required in normal operation recover manually or automatically, in a timely manner, this function after the threat.

(ii) For Level A Display Systems:

(A) Follow the AMC 20-158; or

(B) Conduct Equipment/System testing using the following default levels:

(a) Conducted susceptibility with the Generic transfer function for aircraft (according to VTOL shape and size) extrapolated to the HIRF Environment I (as defined in Section 5) corresponding to the EUROCAE ED-14G section 20 categories O or M.

(b) Radiated Susceptibility with Generic attenuation curves (depending on equipment location) applied HIRF Environment I (as defined in Section 5) corresponding to the EUROCAE ED-14G section 20 categories G, F or D.

(c) Fail/Pass Criteria; when subjected to the HIRF Environment, it could be acceptable that redundant equipment are subject to adverse effect, provided the Level A function is maintained at the aircraft level and all the Equipment/Systems required in normal operation recover manually or automatically, in a timely manner, this function after the threat.

(iii) For Level B Systems:

(A) Follow the AMC 20-158 (by using Equipment HIRF Test Levels 1 or 2 as defined in Section 5); or

(B) Conduct Equipment/System testing as defined in(d) (3) (ii) (a) and (b); when submitted to the HIRF Environment, if the Equipment/System, subject to adverse effects, does not to recover to its level B function after the threat, the method proposed by the AMC 20-158 for Level B systems in (d) (3) (iii) (A) can be used as an alternative.

(iv) For Level C Systems:

(A) Follow the AMC 20-158 (by using Equipment HIRF Test Level 3 as defined in Section (5); or

(B) Conduct Equipment/System testing as defined in (d) (3) (ii) (a) and (b); when submitted to the HIRF Environment, if the Equipment/System, subject to adverse effects, does not to recover to its level C function after the threat, the method proposed by the AMC 20-158 for Level C systems in (d) (3) (iv)(A) can be used as an alternative.

(4) HIRF Testing for Level A systems considerations;

(i) The Test Levels for upper HIRF Group can also be used for lower HIRF Groups; for instance the use of real transfer function and attenuation curves and/or more severe External HIRF Environment can be used for Level A Systems of HIRF Groups I/II.

(ii) Equipment testing is acceptable when it is shown that the interdependencies between equipment performing a function are understood and each equipment is tested and monitored to verify that there are no unacceptable upsets of the function.

(iii) If similar equipment are used to perform the same function; the test can be limited to a single equipment.

(5) Level A System architecture consideration; when a Level A system comprises redundant channels/equipment that perform the same level A function, it is permitted to limit the system to the channels/equipment that are required in normal operation provided that they are not susceptible when they comply with VTOL.2520(a); for instance if it is demonstrated that the primary channels comply with VTOL.2520(a) without the support of the back-up channel, this channel is not requested to be exposed to the HIRF Environment I/III, however this back-up channel should be considered to be a level B system.

5. HIRF Environments and Equipment HIRF Test Levels

This Section specifies the HIRF environments and equipment HIRF test levels for electrical and electronic systems under VTOL.2520.

(a) HIRF environment I is specified in the following Table 3:

Table 3 — HIRF Environment I

FREQUENCY	FIELD STRENGTH (V/m)	
	PEAK	AVERAGE
10 kHz - 2 MHz	50	50
2 MHz - 30 MHz	100	100
30 MHz - 100 MHz	50	50
100 MHz – 400 MHz	100	100
400 MHz – 700 MHz	700	50
700 MHz - 1 GHz	700	100
1 GHz - 2 GHz	2000	200
2 GHz - 6 GHz	3000	200
6 GHz - 8 GHz	1000	200
8 GHz - 12 GHz	3000	300
12 GHz - 18 GHz	2000	200
18 GHz - 40 GHz	600	200

In this table, the higher field strength applies at the frequency band edges.

(b) HIRF environment II is specified in the following Table 4:

Table 4 — HIRF Environment II

FREQUENCY	FIELD STRENGTH (V/m)	
	PEAK	AVERAGE
10 kHz – 500 kHz	20	20
500 kHz - 2 MHz	30	30
2 MHz - 30 MHz	100	100
30 MHz – 100 MHz	10	10
100 MHz – 200 MHz	30	10
200 MHz - 400 MHz	10	10
400 MHz - 1 GHz	700	40

1 GHz - 2 GHz	1300	160
2 GHz - 4 GHz	3000	120
4 GHz - 6 GHz	3000	160
6 GHz - 8 GHz	400	170
8 GHz - 12 GHz	1230	230
12 GHz – 18 GHz	730	190
18 GHz - 40 GHz	600	150

In this table, the higher field strength applies at the frequency band edges.

(c) HIRF environment III is specified in the following Table 5:

Table 5 — HIRF Environment III

FREQUENCY	FIELD STRENGTH (V/m)	
	PEAK	AVERAGE
10 kHz – 100 kHz	150	150
100 kHz - 400 MHz	200	200
400 MHz - 700 MHz	730	200
700 MHz – 1 GHz	1400	240
1 GHz - 2 GHz	5000	250
2 GHz - 4 GHz	6000	490
4 GHz - 6 GHz	7200	400
6 GHz - 8 GHz	1100	170
8 GHz - 12 GHz	5000	330
12 GHz – 18 GHz	2000	330
18 GHz - 40 GHz	1000	420

In this table, the higher field strength applies at the frequency band edges.

(d) Equipment HIRF Test Level 1.

Equipment Level Test ED-14G (or later Revision) Cat R for both conducted and radiated susceptibility.

(e) Equipment HIRF Test Level 2.

Equipment HIRF test level 2 is HIRF environment II in table 4 of this Section reduced by acceptable generic aircraft transfer function and attenuation curves. Testing should cover the frequency band of 10 kHz to 8 GHz.

(f) Equipment HIRF Test Level 3.

Equipment Level Test ED-14G (or later Revision) Cat T for both conducted and radiated susceptibility.

VTOL.2525 System power generation, energy storage, and distribution

n/a

The power generation, energy storage, and distribution for any system, as applicable, must be designed and installed to:

(a) supply the power required for operation of connected loads during all intended operating conditions;

(b) reserved;

(c) reserved.

VTOL.2530 External and cockpit lighting

n/a

(a) All lights must be designed and installed to minimise any adverse effects on the performance of flight crew duties.

(b) Any position and anti-collision lights, if required by operational rules, must have the intensities, flash rate, colours, fields of coverage, and other characteristics to provide sufficient time for another aircraft to avoid a collision.

(c) Any position lights, if required by operational rules, must include a red light on the left side of the aircraft, a green light on the right side of the aircraft, spaced laterally as far apart as practicable, and a white light facing aft, located on an aft portion of the aircraft fuselage or on the wing tips.

(d) Taxi and landing lights, if required, must be designed and installed so they provide sufficient light for night operations.

(e) If certification for intended operations on water is requested, riding lights must provide a white light visible in clear atmospheric conditions.

MOC VTOL.2530 External and Cockpit Lighting

n/a

1. Instrument lights

CS 23.1381 Amdt. 4 is accepted as means of compliance with VTOL.2530 (a) for the instrument lights.

2. Taxi and landing lights

Depending on the aircraft configuration, either CS 23.1381 Amdt. 4 or CS 27.1383 Amdt. 6 is accepted as means of compliance with VTOL.2530 (a) and VTOL.2530 (d) for taxi and landing lights. The applicability of CS 23.1381 or CS 27.1383 as means of compliance should be agreed with the Agency based on the configuration of the aircraft in order to ensure that the objective of VTOL.2530 is fully met.

3. Position light

Depending on the aircraft configuration, either paragraphs from CS 23.1385 to CS 23.1397 Amdt. 4, both inclusive, or paragraphs from CS 27.1385 to CS 27.1397 Amdt. 6, both inclusive, are accepted as means of compliance with VTOL.2530 (a), (b) and (c) for the position lights. The applicability the aforementioned CS-23 or CS-27 requirements as means of compliance should be agreed with the Agency based on the configuration of the aircraft in order to ensure that the objective of VTOL.2530 is fully met.

4. Riding lights

CS 27.1399 Amdt. 6 is accepted as means of compliance with VTOL.2530 (a) and VTOL.2530 (e) for riding lights.

5. Anti-collision lights

(a) The anti-collision lights are intended to attract attention to the aircraft and they should be designed and installed to ensure minimum performances in terms of intensities, flash rate, colours and fields of coverage, in order to be capable to provide sufficient visibility in a timely manner for another aircraft to avoid a collision. CS 23.1401 Amdt. 4 is accepted as means of compliance with VTOL.2530 (b) and meets this intent.

(b) In order to show compliance with VTOL.2530 (a), any potential adverse effects of the lights operations on the satisfactory performance of the flight crew duties should be assessed, for instance cockpit reflections or any possible effects of rotor or propeller blade strobing.

(c) Other means than (a) may be proposed and agreed with the Agency to comply with VTOL.2530(a) and (b). They may be based either on the outcome of the assessment in (b) or on a different rationale. For instance, they could also have the purpose to comply with operational or local regulations in the intended operational environment by preventing harmful dazzle to outside observers, reducing light pollution, etc. The following examples provide methods that can be acceptable upon agreement with the Agency:

(1) Installation of red anti-collision lights compliant with CS 27.1401 Amdt. 6. The applicant has to justify that the performances of the lights (intensities, flash rate, colour and fields of coverage) are sufficient to satisfy the intent of VTOL.2530 (b) for the specific VTOL capable aircraft design and operations;

(2) Installation of anti-collision lights compliant with CS 23.1401 Amdt 4 with additional provisions aimed to adapt and make compatible the intensity of the lights with certain operational conditions or environments, e.g. by providing means for the flight crew to reduce the intensity of the lights and switch them off;

(3) Installation of an anti-collision lighting system comprising a combination of lights compliant with (1) and lights compliant with (2).

VTOL.2535 Safety equipment

n/a

Safety and survival equipment, required by the operating rules, must be reliable, readily accessible, easily identifiable, and clearly marked to identify its method of operation.

MOC VTOL.2535 Safety Equipment

n/a

[MOC 2 - Issue 3]

CS27.1411 Amdt. 5 (or later) is accepted as a means of compliance.

For overwater operations, the combination of CS27.1415 Amdt. 5 (or later) and CS29.1415(d) Amdt. 5 (or later) is accepted as a means of compliance for the installation of additional safety equipment as required by any applicable operating rule.

Each emergency locator transmitter, including sensors and antennae, required by the applicable operating rule, should be installed so as to minimise damage that would prevent its functioning following an accident or incident. (See AMC 27.1470 Amdt. 5 (or later))

VTOL.2540 (reserved)

n/a

VTOL.2545 Pressurised systems elements

n/a

Pressurised systems must withstand appropriate proof and burst pressures.

VTOL.2550 (reserved)

n/a

VTOL.2555 Installation of flight recorders

n/a

The aircraft must be equipped with an approved flight recorder or recorders that:

(a) is installed so as to ensure accurate recording for at least 5 hours and appropriate safeguarding of the data supportive for accident investigation;

(b) is powered by the most reliable power source and remains powered for as long as possible without jeopardising service to essential or emergency loads and emergency operation of the aircraft;

(c) has a high proportion of its outer surface area coloured in bright orange; and dimensions that are adequate for visually locating it on an accident scene;

(d) is installed so that it automatically records prior to the aircraft being capable of moving under its own power and stops automatically following lift/thrust units powering off; and

(e) except for some data approved by EASA to be transmitted and recorded remotely, records in an accepted digital data, audio or image format, and with reference to a timescale:

  (1) information that is sufficient to determine the flight path and speed;

  (2) communications with air traffic services;

  (3) audio from the flight crew compartment for installations intending to support multicrew and VEMS operations;

(4) information provided to the crew and necessary for the safe operation of the aircraft.

(f) If the installation has an erasure device or function, the installation must be designed to minimise the probability of inadvertent operation and actuation of the erasure device or function during crash impact.

MOC VTOL.2555 Installation of recorders

n/a

This MOC is applicable to each recorder installed to comply with VTOL.2555.

(a) General:

The recorder should have an ETSO authorisation against one of the following ETSOs or a later equivalent:

(1) ETSO-C123b; or

(2) ETSO-C124b; or

(3) ETSO-2C197

(b) Recorder installation:

The container of the recording medium should be located and mounted so as to minimise the probability of the container rupturing or the recording medium being destroyed as a result of impact with the Earth's surface or of heat damage caused by a post-impact fire.

The structural provisions within the aircraft for the mounting of the recorder should be able to withstand the loads resulting from severe vibration (such as those resulting from rotor imbalance). In addition, the strength of the local attachments should be able to withstand the crash safety loads in CS 27.561(b)(3).

If the recorder has an erasure device or function, the installation must be designed to minimise the probability of inadvertent operation and actuation of the erasure device or function during crash impact.

(c) Recorder identification:

A high proportion of the area of the outer surfaces of the container of the memory medium should be coloured bright orange.

The height, width and depth of the container of the memory medium must each be 4 cm (1.5 inches) or greater

(d) Recorder characteristics:

The recorder should:

(1) Permit quick downloading of the flight parameters without having to remove the recorder;

(2) Be capable of retaining the flight parameters that are recorded during at least the preceding 5 hours and the audio recording during at least the preceding 2 hours;

(3) Automatically start to record as early as possible after power-on and in any case prior to the aircraft being capable of moving under its own power;

(4) Continue to record until the termination of the flight when the aircraft is no longer capable of moving under its own power;

(5) If the recorder has a recording duration of less than 25 hours, have a means for the flight crew to stop the recording upon completion of the flight in such a way that re-enabling the recording is only possible by a dedicated manual action.

(e) Flight Parameters and audio recording:

The recorder, or the combination of recorders installed to comply with VTOL.2555, should:

(1) Record the flight parameters required to accurately determine the flight path, speed, attitude, engine power, operation and configuration of the VTOL capable aircraft. The minimum list of flight parameters to be recorded is provided in paragraphs (j) and (l). All recorded parameter values should be accurately time-stamped according to a common time reference and be recorded at a rate not below 4 Hz;

(2) For aircraft with a minimum flight crew of two pilots, simultaneously record, on separate channels and with reference to a timescale:

(i) The aural environment of the cockpit (area microphone;)

(ii) Pilots' headset audio, including but not limited to voice communications, audio signals for navigation aids, aural alerts.

(f) Maintenance instructions:

(1) When developing the ICA for the recorder systems, the applicant should address all the failures that may affect their correct functioning or the quality of the recorded information.

Note: 'Recorder systems' designates the recorders and their dedicated equipment (e.g. dedicated sensors or transducers, dedicated data busses, dedicated power source…).

(2) Examples of failures (indicative and non-exhaustive list):

(i) Loss of the recording function or of the acquisition function of the recorder;

(ii) Failure of a means to facilitate the finding of the recording medium after an accident (e.g. an underwater locating device or an emergency locator transmitter attached to the recorder);

(iii) Failure of a means to detect a crash impact (for the purpose of stopping the recording after a crash impact, or for the purpose of deploying the recorder if it is deployable);

(iv) Failure of any power source dedicated to the recorder (e.g. dedicated battery);

(v) Failure of the start-and-stop function;

(vi) Failure of a sensor dedicated to the recorder system;

(vii) For flight parameters recording, when any required parameter is missing, or is not correctly recorded;

(viii) For audio recording (if applicable):

(ix) Any required audio signal is missing, or is recorded with an audio quality that is rated 'poor' (refer to the example of audio quality rating provided in Section 9 of AMC 25.1459);

(x) Failure of a transducer or amplifier dedicated to the recorder system (e.g. failure of the cockpit area microphone).

(g) Data transmission & ground recording: [Reserved]

(h) The following flight parameters should as a minimum be recorded with a recording resolution at least as high as specified in EUROCAE Documents ED-155 or ED-112:

(1) Time

(2) Altitude

(3) Latitude

(4) Longitude

(5) Indicated airspeed or calibrated airspeed

(6) Groundspeed

(7) Outside Air Temperature (OAT)

(8) Heading (magnetic or true)

(9) Track

(10) Vertical speed

(11) Pitch attitude

(12) Roll attitude

(13) Longitudinal acceleration (body axis)

(14) Normal acceleration

(15) Lateral acceleration

(16) Roll rate or Roll acceleration

(17) Pitch rate or Pitch acceleration

(18) Yaw rate or yaw acceleration

(19) If electric engines are used:

(i) Electric Engines: rotation speed of each rotor (in RPM)

(ii) Electric Engines: health status of each electric engine controller

(iii) Electric Engines: temperature of each electric engine

(iv) Electric Engines: temperature of each electric engine controller

(v) Electric Engines: measured electrical current for each electric engine

(vi) For liquid cooled electric engines: pressure and temperature of the cooling liquid

(20) Flight controls

(i) Pilot input positions on all axis and corresponding flight control,

(ii) Outputs (e.g. target RPM for each electric engine, flight surface positions, …)

(21) Status of each flight control computer

(22) Wings angle (if applicable)

(23) Nacelles angles (if applicable)

(24) Propeller pitch (for each variable pitch propeller)

(25) Air-Ground status such as Weight on Wheels or equivalent parameter

(26) Alerts (including master warning and master caution status)

(27) Manual voice transmission keying (if voice communications are used)

(28) For each battery used for propulsion and/or flight controls:

(i) Health status, State Of Charge (SOC), voltage, temperature, current flow,

(ii) if available:

(A) State of Power (SOP); or

(B) Calculated remaining flight time.

(29) Health status of each electrical distribution unit (e.g. distribution units, converters) contributing to the propulsion and/or flight controls

(30) Status of the battery management system (if any)

(31) If combustion engine(s) are used:

(i) Fuel parameters;

(ii) Oil pressure and oil temperature;

(iii) Parameters required to determine propulsive thrust or power delivered;

(iv) Turbine RPM (if applicable);

(v) FADEC health status (if applicable);

(vi) Aircraft inputs used by the FADEC (if applicable);

(vii) Any electrical current generation; and

(viii) Any other parameter subject to a limitation

(i) In addition, the following flight parameters should be recorded if they are used by the aircraft systems or are available for use by the pilot to operate the aircraft. They should be recorded with a recording resolution at least as high as specified in EUROCAE Documents ED-155 or ED-112:

(1) Active AFCS mode

(2) Radio altitude or terrain elevation

(3) Current navigation source,

(4) Vertical and lateral deviation with respect to current active navigation path

(5) DME 1 & 2 distances

(6) Drift angle

(7) Wind speed

(8) Wind direction

(9) Landing gear position

(10) Ice: ice detection, status of de-icing or anti-icing system

(11) Electric Engine: vibration level

(12) Traffic advisories or alerts, if installed (e.g. ADS-B IN, ACAS…)

(13) Obstacle and terrain alerts, if installed (e.g. TAWS, …)

(j) If the VTOL capable aircraft has datalink communication capabilities, the following should be recorded:

(1) data link communication messages to and from the aircraft, including messages applying to the following applications:

(i) data link initiation and termination,

(ii) controller-pilot communication,

(iii) addressed surveillance,

(iv) flight information, including weather data (if required for operation),

(v) aircraft broadcast surveillance,

(vi) aircraft operational control data, and

(vii) graphics.

(2) information that enables correlation to any associated records related to data link communications and stored separately from the helicopter; and

(3) information on the time and priority of data link communications messages, taking into account the system's architecture.

SUBPART G — FLIGHT CREW INTERFACE AND OTHER INFORMATION

VTOL.2600 Flight crew compartment

n/a

(a) The flight crew compartment arrangement, including flight crew view, and its equipment must allow the flight crew to perform their duties within the flight envelopes of the aircraft, without excessive concentration, skill, alertness, or fatigue.

(b) The applicant must install flight, navigation, surveillance, and lift/thrust system installation controls and displays so that a qualified flight crew can monitor and perform defined tasks associated with the intended functions of systems and equipment. The system and equipment design must account for flight crew errors, which could result in additional hazards.

(c) For Category Enhanced, the flight crew interface design must allow for continued safe flight and landing after the loss of vision through any one of the windshield panels.

MOC VTOL.2600 Flight crew compartment

n/a

1. External flight crew view

The following material is intended to serve as a guide, highlighting the elements to be considered when developing and assessing the external flight crew view of a VTOL capable aircraft. It offers a possible method to show compliance with VTOL.2600 for this design element.

The function of the external flight crew view in a piloted VTOL capable aircraft remains the same as assumed for any other aircraft in their respective Certification Specifications.

In the design phase of the pilot compartment, when considering the external flight crew view, applicants may therefore choose to start by using the guidance already available in AMC and AC material relevant to CS 27.773 “Pilot compartment view”, while keeping in mind the differences related with VTOL capable aircraft and Innovative Air Mobility (IAM) Operations. The AMC available for the different Certification Specifications include also Human Factors considerations.

(a) Functions of the external flight crew view:

The external field of view should fulfil the following functions:

(1) Provide sufficient external view so that the flight crew can perform their task of safely controlling the aircraft flight path.

(i) The external field of view, or visual cues, will need to be assessed depending on the Flight Controls Laws, Kind of Operations and expected Meteorological Conditions (VMC or IMC)

(ii) The external visual cues necessary to safely control the aircraft might differ depending on the phase of flight, as i.e. in the VTOL phase the flight crew may focus on ground details (“chin bubbles”) to fly a given trajectory or hold a position, while in forward flight they might only need to have a visible horizon.

(iii) Depending on the design, the external view may be used for hazard awareness and/or mitigation, by showing that, by having parts of the aircraft visible by the crew, abnormal conditions can be identified to take proper actions and operate the aircraft safely.

(2) Provide sufficient external view to see and avoid:

(i) Traffic

(ii) Ground obstacles

(b) External field of view characteristics:

(1) Optical distortions in the windshield or canopy, especially in the prime viewing areas should be avoided.

(2) The design should allow for sufficient external field of view free of obstruction. Account can be taken of aircraft specific features (as “chin bubbles”) that provide the flight crew with sufficient visible external cues, in all day/night and weather conditions expected in operation.

(3) The need for demisting devices/features should be considered during the development. Recent experience in electrically powered aircraft, where the amount of heated air that can be accessed and needs to be dissipated, has shown that the external view can get heavily impacted by fogging, and that the installation of an additional device/feature could be required for that purpose.

(4) The area of the pilot compartment field of view that according with FAA AC 27.773[1] should be free from obstruction should be used as starting point for the design: years of experience show that this obstruction free area has ensured the functions listed in (a).

(i) when using this material, applicants should consider the differences between the VTOL expected trajectories and flight attitudes envelope compared to conventional aircraft, and the CONOPS that will be carried out by the flight crew in terms of traffic/obstacle “see and avoid”.

(ii) deviations from the current material can be justified by the reasons in (i) but also by design characteristics of the VTOL capable aircraft (canards, lift/thrust systems forward of the flight crew compartment view).

(iii) any obstructions should be assessed, and the suitability of the external field of view evaluated, in the entire flight test domain against its intended functions in the CONOPS.

(5) If, for design reasons, the available external field of view does not allow the flight crew to perform their duties, the applicant may show compliance by using synthetic cues displayed to the flight crew. These synthetic cues should be designed to a high level of integrity and precision, in order to meet the intended function. They should be introduced as soon as possible in the design and be thoroughly assessed during the complete flight test campaign.

[1] AC 27.773 from FAA AC 27-1B Change 7 constitutes the EASA AMC with CS 27.773

(c) Loss of vision through windshield panel:

According to VTOL.2600 (c), for category Enhanced, the flight crew interface design must allow for continued safe flight and landing after loss of vision through any one of the windshield panels. The applicant should demonstrate by flight test, in case of a complete loss of vision through any panel, the remaining external field of view with the use of particular procedure (e.g., flight with sideslip) will allow for continued safe flight and landing.

(d) Flight in precipitation[1] and operation in other environmental hazards:

(1) The external field of view should be sufficient in day/night, and not impaired by precipitation conditions and other environmental hazards.

(2) Precipitation conditions include, but are not limited to, rain, hail and snow.

(3) While (e) provides specific guidance on evaluating the external vision obstruction resulting from a certain continuous exposure to snow conditions, no specific requirement applies for the obstruction when flying into inadvertent snow or rain.

(4) Flight into hail should be considered taking into account the damage that can result from windshield structural integrity considerations as referred in (c), rather than concerning the expected obstruction due to its accumulation.

(5) Other environmental hazards include, but are not limited to, operations into sand, dust and saline environment.

(6) There is no specific requirement to determine any external vision impairment resulting from the exposure to environmental hazards.

(7) The effect of operating into other environmental hazards should be taken into account during the aircraft systems qualification, including their effects on windshield wipers efficiency or the degradation of performance of any other alternative precipitation removing devices (i.e. hydrophobic coating or blowers), if installed.

(e) Flight into known snow conditions:

CS-27 and AMC-27 contain no specific requirement or guidance for flight in precipitation conditions. In particular, no reference to falling and blowing snow is made in CS 27.773. There are no external vision requirements for flight into inadvertent snow.

This section intends to address the protection against potential accumulation of snow on windshield and windows when flying into known falling and blowing snow.

So far, the pilot view obstruction in snow conditions has been addressed by the European Light Helicopter Manufacturers and the European Airworthiness Authorities during flight test demonstration for a turbine engine installation, as requested by the CS 27.1093(c). During these flight tests for helicopters powered by turbine engine, snow accretion was sometimes observed on the helicopter windshield, leading to a dangerous reduction in the pilot view. In these instances, only the use of wipers was able to restore acceptable visibility.

The Standardised European Rules of the Air establish in SERA.5010 the conditions under which an ATC unit can authorise a helicopter to operate within a control zone under

[1] Flight into known icing conditions is out of the scope of this MOC.

Special VFR clearance, including certain weather minima. Therefore, it is assumed that a helicopter certified for day and night VFR can perform hover flights in re-circulating snow, take-off and land under snow falls, and fly with falling snow compatible with the Special VFR limit visibility.

Since the SERA Special VFR rules could still be applicable for VTOL capable aircraft, it is necessary to consider the pilot view of the flight path during a flight in snow fall that is compatible with these weather minima.

(1) The external field of view should be sufficient in day/night, and not impaired by snow conditions.

(2) If certification for flight in snow conditions is requested, it should be demonstrated that snow, both falling and blowing, does not accumulate on the VTOL windshield and windows so that flight crew external view of the flight path and surroundings is not unduly impaired during taxiing, hover flight, take-off, level flight and landing. Normal operations with no hazardous reduction in the pilot's view of the flight path should be demonstrated under the following:

(i) **Conditions to ensure VTOL operation in falling and blowing snow without restriction:**

(A) **Visibility**: ½ mile as limited by snow, which represents a moderate/heavy snowstorm and is also consistent with the weather minima compatible with Special VFR. This value is a test parameter rather than an operational limitation to be imposed on the VTOL after the tests are completed.

(B) **Temperature**:

(a) Unless other temperatures are deemed more critical, -4°C to +1°C (25°F to 34°F) being -2°C to +1°C desirable (28°F to 34°F) should be used, as conducive to wet snow conditions, which tends to accumulate on unheated surfaces subject to impingement.

(b) Company development testing or experience with similar VTOL may be adequate to determine other critical ambient conditions for certification testing.

(C) **Operations**:

Operation	Minimum Test Duration
Ground operations	20 minutes
IGE hover	5 minutes
Level flight	1 hour
Descent and landing	-

(a) Ground running, taxiing, and IGE hover operations are generally the most critical since the VTOL may be operating in recirculating snow. Twenty-five minutes, or the maximum allowed time in relation the aircraft limitations, under these extreme conditions is considered a reasonable maximum, both from the view of pilot stress and the maximum expected taxi time prior to take off in bad weather.

(b) One hour of level flight operation, or maximum expected flight duration, under ½-mile visibility snow conditions is deemed to provide ample opportunity for accumulation to begin to build. Go-arounds and transitions to and back to wingborne flight, if applicable, should be included in these flight operations.

(c) The durations reported in the table above are minimum test duration times based on experience with rotorcraft operations, to ensure that the snow accretion on the aircraft and windshield is representative of a worst-case scenario. Different durations can be agreed with the Agency depending on the actual aircraft limitations or the expected operations.

(D) **Provisions in the Aircraft Flight Manual:**

(a) Visibility restrictions or limitations, based on which falling and blowing snow operations can be allowed, are not considered appropriate, as visibility may fluctuate rapidly in snowstorms. It is affected by the presence of fog or ice crystals, is not measured or controlled by the flight crew, and is difficult to estimate.

(b) Time limitations, other than possibly for ground and hover operations, are not considered appropriate:

1. Since during cruise in snow conditions the aircraft is likely to be in and out of heavy snowfall, it is not practical for the flight crew to measure the time spent in snow in level flight conditions. Thus, it is not appropriate to include time limitations in the AFM for level flight snow operations.

2. A practical ground and IGE hover time limitation of less than 25 minutes, or the maximum allowed time in relation the aircraft limitations, in recirculating snow may be considered. The expected action at the expiration of this specified time would be landing or transition to a safe flight condition where it has been shown that snow accumulations will not intensify or shed and so not cause unacceptable reduction in pilot visibility.

(ii) **Artificially produced snow** should not be used as the sole means of showing compliance. While it is an excellent development tool, artificial snow production devices are usually restricted to use for hover and ground evaluations, and the snow pellets produced by these machines are not sufficiently similar to natural snowflakes to justify the use of artificial snow as the sole basis of certification.

(3) **Other test conditions:**

(i) The windshield and windows should remain free of excessive snow accumulation. Excessive accumulation is defined as accumulation that may cause hazardous reduction in flight crew's view of the flight path.

(ii) Actual flight demonstration should be performed in natural snow. The ground operations and IGE hover test conditions assume operation in recirculating snow. Blowing snow, resulting from rotor airflow recirculation, can be expected to be more severe than natural blowing snow if the VTOL capable aircraft continues to move slowly over freshly fallen snow. Thus, the blowing snow operational capability should be demonstrated by the taxi and hover operations in recirculating snow.

(iii) Airspeeds:

(A) For VFR VTOL capable aircraft, the airspeeds for the level flight test condition should include the maximum consistent with the visibility conditions.

(B) For IFR operations, the airspeed should range from the minimum IFR speed or the minimum for snow operations up to the maximum cruise speed or the maximum speed specified for snow operations in the flight manual limitations, unless other airspeeds are deemed more critical. VTOL seeking VFR certification may later be IFR certified with a possible increase in airspeed in snow conditions. This factor should be considered if IFR certification is anticipated.

(iv) Visibility measurements:

(A) The specified visibility assumes that visual measurements are made in falling snow in the absence of fog or recirculating snow by an observer at the test site outside the tests VTOL capable aircraft's area of influence.

(B) An accepted equation for relating this measured visibility to snow concentration is $V = 374.9/C^{0.7734}$ where C is the snow concentration (grams/metre^3) and V is the visibility (metres).

(a) This equation can be reasonably applied to all snowflake type classifications and is credited to J.R. Stallabrass, National Research Council of Canada.

(b) Other equations may be applied if they are shown to be accurate for the particular snowflake types for the test programme.

(v) The likelihood that the desired concentration will exist for the duration of the testing is even more remote. Because of these testing realities, it is very likely that exact target test conditions will not be achieved. Those involved in certification should exercise good judgment in accepting alternate approaches. However, the applicant should strive to perform the test in conditions as close as practicable to ½ mile visibility.

(vi) If it becomes apparent that snow accumulations in ground and IGE hover operations in recirculating snow are much more severe than in the level flight test, it is reasonable to accept prolonged IGE operations in recirculating snow and to accept durations of less than 1-hour level flight, or maximum expected flight duration. Best efforts should be made to ensure that at least some level flight time is accomplished at ½-mile visibility to assure that the spectrum is covered.

(vii) For the level flight portion, if after a reasonable time it is noticed that there is no snow accumulation that would impair the pilot visibility, the duration of the level flight may be reduced accordingly.

(viii) It should be determined that the visibility established at the test site is limited by snow and not by fog or poor lighting (twilight) conditions.

(ix) Recirculation is necessarily a qualitative judgment by the test pilot. For test purposes, recirculation should be the highest snow concentration attainable in the manoeuvre, or that corresponding to the lowest visibility at which (in the pilot's judgment) control of the VTOL is possible in the IGE condition. The visibility specification of ½ mile outside of the recirculation influence becomes inconsequential provided that fresh, loose snow is continually experienced during the ground operation and IGE hover testing phase. However, since it is intended that the test phases be accomplished sequentially to assure that transition to take off and other transients are considered, the conditions at take-off, level flight, and descent and landing should approximate the ½-mile visibility criteria.

2. Controls and displays for use by the flight crew:

CS 27.1302 Amdt. 8, as per the guidelines defined in its AMC 27.1302, is accepted as a means of compliance with VTOL.2600 regarding the design and approval of installed equipment that is intended for use by the crew members from their normal seating positions in the cockpit with the following considerations:

(a) CS 27.1302 and its AMC 27.1302 apply to the flight crew interfaces and system behaviour for all the installed systems and equipment used by the flight crew in the cockpit while operating the VTOL capable aircraft in normal, abnormal/malfunction and emergency conditions.

(b) The functions that the flight crew members are able to perform from the cabin need to be considered if they can interfere with the ones under the responsibility of the cockpit flight crew, or if dedicated airworthiness requirements are included in the rules.

(c) CS 27.1302 and its AMC do not apply to flight crew training, qualification, or licensing requirements.

(d) The extent of the compliance demonstration necessary for each design may vary and not all the material contained in this MOC has to be systematically followed. The proportionate application of AMC 27.1302 will depend on criteria such as the VTOL category (Enhanced and Basic) and the maximum passenger seating configuration.

Explanatory Note:

The Categories Basic and Enhanced were introduced in the Special Condition to allow proportionality in safety objectives.

It is considered that the safety objectives for CS-25 and CS-27/29 aircraft should be maintained as a minimum for VTOL capable aircraft in the Category Enhanced, i.e. intended for operations over congested areas or for commercial air transport of passengers.

The same approach is followed in the implementation of Human Factors during the design and certification processes of VTOL cockpits.

For the Category Basic, proportionality is allowed in the application of AMC 27.1302 as defined in this MOC VTOL.2600.

(e) The following proportional approach in the application of AMC 27.1302 supersedes AMC 27.1302 paragraph **3.2.9 "Proportional approach in the compliance demonstration":**

	Maximum Passenger Seating Configuration	**Proportionality**
Category Enhanced	-	Applicants for a VTOL capable aircraft should follow all provisions in AMC 27.1302.
Category Basic	7 to 9 passengers	Applicants for a VTOL capable aircraft should follow all provisions in AMC 27.1302.
	2 to 6 passengers	Applicants for a VTOL capable aircraft are: i. not required to develop a dedicated **HFs test programme** and ii. allowed to **use single occurrence of a test** for compliance demonstration;
	0 to 1 passenger	Applicants for a VTOL capable aircraft are: i. not required to develop a dedicated **HFs test programme**; ii. allowed to **use single occurrence of a test** for compliance demonstration; iii. allowed to **use a single crew** to demonstrate the HFs scenario based assessments.

VTOL.2605 Installation and operation information

n/a

(a) Each item of installed equipment related to the flight crew interface must be labelled, if applicable, as for its identification, function, or operating limitations, or any combination of these factors.

(b) There must be a discernible means of providing system operating parameters required to operate the aircraft including warnings, cautions, and normal indications, to the responsible crew member.

(c) Information concerning an unsafe system operating condition must be provided in a timely manner to the crew member responsible for taking corrective action. The information must be clear enough to avoid likely crew member errors.

(d) Information related to safety equipment must be easily identifiable and its method of operation must be clearly marked.

MOC VTOL.2605 Installation and operation information

n/a

(a) CS 27.1322 Amdt 6, as per the guidelines established in AC 27.1322, and with further advice provided in AMC 25.1322, is accepted as a means of compliance with VTOL.2605(b) regarding the design of warnings, cautions and advisory lights.

(b) CS 27.1302 Amdt. 8, as per the guidelines established in AMC 27.1302, is accepted as a means of compliance with VTOL.2605(b) and (c) regarding the design of flight crew interfaces and behaviour of installed systems and equipment used by the flight crew in the cockpit while operating the VTOL capable aircraft in normal, abnormal abnormal/malfunction and emergency conditions.

(1) The functions that the flight crew members perform from the cabin should be considered if they can interfere with the ones under the responsibility of the cockpit flight crew, or if dedicated airworthiness requirements apply.

(2) CS 27.1302 and its AMC 27.1302 do not apply to flight crew training, qualification, or licensing requirements.

(3) The extent of the compliance demonstration necessary for each design may vary and not all the material contained in this MOC has to be systematically followed. The proportionate application of AMC 27.1302 will depend on criteria such as VTOL category (Enhanced and Basic) and the maximum passenger seating configuration.

Explanatory Note:

The Categories Basic and Enhanced were introduced in the Special Condition to allow proportionality in safety objectives.

It is considered that the safety objectives for CS-25 and CS-27/29 aircraft should be maintained as a minimum for VTOL capable aircraft in the Category Enhanced, i.e. intended for operations over congested areas or for commercial air transport of passengers.

The same approach is followed in the implementation of Human Factors during the design and certification processes of VTOL cockpits.

For the Category Basic, proportionality is allowed in the application of AMC 27.1302 as defined in this MOC VTOL.2605.

(4) The following proportional approach in the application of AMC 27.1302 supersedes AMC 27.1302 paragraph **3.2.9 "Proportional approach in the compliance demonstration"**:

	Maximum Passenger Seating Configuration	**Proportionality**
Category Enhanced	-	Applicants for a VTOL capable aircraft should follow all provisions in AMC 27.1302.
Category Basic	7 to 9 passengers	Applicants for a VTOL capable aircraft should follow all provisions in AMC 27.1302.
	2 to 6 passengers	Applicants for a VTOL capable aircraft are: ii. not required to develop a dedicated HFs test programme and iii. allowed to use single occurrence of a test for compliance demonstration;
	0 to 1 passenger	Applicants for a VTOL capable aircraft are: iv. not required to develop a dedicated HFs test programme; iv. allowed to use single occurrence of a test for compliance demonstration; v. allowed to use a single crew to demonstrate the HFs scenario based assessments.

(c) CS 27.1561 Amdt. 5 (or later) is accepted as a means of compliance with VTOL.2605(d) regarding the identification of information related to safety equipment and the marking of its method of operation.

VTOL.2610 Instrument markings, control markings and placards

n/a

(a) Each aircraft must display in a conspicuous manner any placard and instrument marking necessary for operation.

(b) The design must clearly indicate the function of each cockpit control, other than primary flight controls.

(c) The applicant must include instrument marking and placard information in the Aircraft Flight Manual.

MOC VTOL.2610 Instrument markings, control markings and placards

n/a

(a) The following are accepted as a means of compliance with VTOL.2610(a):

(1) Markings or placards should be placed close to or on (as appropriate) the instrument or control with which they are associated.

(2) The terminology and units used should be consistent with those used in the Aircraft Flight Manual.

(3) The units used for markings and placards should be those that are read on the relevant associated instrument.

(4) Publications which are considered to provide appropriate standards for the design substantiation and certification of symbolic placards may include, but are not limited to, 'General Aviation Manufacturers Association (GAMA) Publication No. 15 — Symbolic Messages', Initial Issue, 1 March 2014.

(5) AMC 1 to CS 23.2610 Amdt. 5 is accepted as additional MOC with VTOL.2610(a)

(b) CS 27.1555 (a), (b)(1) and (2), and (e) Amdt.6 are accepted as means of compliance with VTOL.2610(b).

(c) If certification with ditching provisions, emergency flotation provisions or limited over water operations is requested by the applicant, each emergency control that may need to be operated underwater should be marked with the method of operation and be marked with yellow and black stripes.

VTOL.2615 Flight, navigation, and lift/thrust system instruments

n/a

(a) Installed systems must provide the flight crew member who sets or monitors parameters for the flight, navigation, and lift/thrust system the information necessary to do so during each phase of flight. This information must:

(1) be presented in a manner that the crew members can monitor the parameters and trends, as needed to operate the aircraft; and

(2) include limitations, unless the limitation cannot be exceeded in all intended operations.

(b) Indication systems that integrate the display of flight or lift/thrust system parameters required to safely operate the aircraft, or required by the operating rules, must:

(1) not inhibit the primary display of flight or lift/thrust system parameters needed by any flight crew member in any normal mode of operation;

(2) reserved.

VTOL.2620 Aircraft Flight Manual

n/a

The applicant must provide an aircraft flight manual that must be delivered with each aircraft and contains the following information:

(a) operating limitations and procedures;

(b) performance information;

(c) loading information;

(d) instrument marking and placard information; and

(e) any other information necessary for the safe operation of the aircraft.

MOC VTOL.2620 Electronic Aircraft Flight Manual

n/a

1. INTRODUCTION AND SCOPE

This MOC presents guidelines for obtaining approval of an electronic version of an Aircraft Flight Manual (eAFM). These guidelines also apply to eAFM appendices and supplements. The guidelines are applicable to eAFM applications running on hardware platforms which may or may not be included in the aircraft type design definition.

(a) These guidelines cover:

(1) The definitions of the eAFM and its constituents, as well as its relationship with the EFB world;

(2) The expected process for airworthiness approval of the eAFM;

(3) The acceptable means to ensure:

(i) completeness and integrity of the eAFM, as well as the means for ensuring control of its configuration and of the information thereby provided;

(ii) management of supplemental information regarding specific aircraft configurations and removable kits;

(iii) approval of post-TC eAFM revisions, either stand alone or design change related, including those done by third parties and those resulting from continuing airworthiness processes.

(b) These guidelines do not cover:

(1) Systems that provide input to other aircraft systems or equipment;

(2) Supplementary software or software functions used to prepare documentation suitable for use in the operation of the aircraft under the applicable operating rules (e.g. airport analysis software).

(c) Similarly to a paper AFM, eAFM software application is not certified as part of the aircraft type design, however it is approved by the Agency for showing compliance with VTOL.2620 and becomes part of the type certificate.

(d) The operational rules (Commission Regulation (EU) No 965/2012 and subsequent amendments) include provisions for the use of an eAFM. However, from an airworthiness approval standpoint, the showing of compliance of the aircraft eAFM with the TC basis requirements should be based on this MOC.

(e) When the eAFM is hosted and used in flight on non-installed equipment (not part of the type design definition), such as on a tablet device, it is considered to be an Electronic Flight Bag (EFB) application. In this case the operational rules apply, which address the use of EFB, including the operational risk assessment, paperless operations, environmental testing, administration, Human-Machine Interface and Human Factors considerations, and pilot procedures and training.

2. Definitions

The primary purpose of the AFM required by VTOL.2620 is to provide an authoritative source of information necessary for the safe operation of the aircraft. In this aim, it is based in the first place on source technical data files from which all required AFM information should be gathered, classified, organized, and prioritized. These data files need to be processed by a specific software application to allow interactive display of the information in a given format and structure. The eAFM software application may run on different kinds of host platforms with various hardware and operating systems.

The following definitions apply:

(a) *Electronic AFM (eAFM)*: Set of data files and a software application used to provide interactive display of AFM information on an authorised host platform.

(b) *Software Application*: The software program(s), installation information and operating guide to be used by the end user in conjunction with the data files to display the eAFM information.

(c) *Host Platform*: The hardware and basic software (e.g. Operative System (OS), input/output software) environment that enables the operation of the software application to input, process and output the eAFM information to the end user.

(d) *Authorised host platform configuration*: Host platform configuration with characteristics (e.g. input/output hardware characteristics, Operating System version, Central Processing Unit (CPU) type, CPU frequency, memory) for which the eAFM performance and integrity are guaranteed.

Note: Particular cases of authorised host platform configuration are the "worst case authorised host platform configurations" that correspond to the configurations with minimum characteristics ensuring the eAFM performance and integrity.

3. eAFM scope of approval and deliverable data package

The approved constituent elements of an eAFM are the **data files** and the **software application(s)**. The host platform is not part of the approved eAFM. If it is not part of the type design definition (e.g. in the case of non-installed equipment such as portable COTS equipment), the list of host platform configuration characteristics and their authorised range will be identified as conditions for the eAFM approval.

Therefore, the following information should be clearly identified and made available with each aircraft:

(a) The eAFM data files applicable to that aircraft, i.e. name, format, version, and date.

(b) The eAFM software application(s), i.e. name, version, part or build number, installation information (including verification procedure, see Section 5(b)(3) in this MOC) and operating guide.

(c) If the host platform is non-installed equipment (not part of the type design definition), the list of authorised host platform configuration characteristics and the range in which those characteristics may evolve while ensuring the correct performance of the eAFM.

4. Compliance demonstration

(a) The following eAFM aspects should be addressed in the demonstration of compliance with VTOL.2620:

(1) The technical content of the approved AFM information (e.g. Limitations, Normal and Emergency procedures, Performance data, etc.);

(2) The structure of this technical content, i.e. the way the different sections, subsections and single information of the eAFM are ordered and structured in relation with each other;

(3) The eAFM information format, i.e. the way the technical content and structure of the eAFM are displayed.

(b) The software application(s) should ensure at any time segregation and clear distinction of the approved data from non-approved ones, in particular when interactive functions of the software are in use. The software should always show if any information is approved (by indication of the approval status and approving organisation/authority) or belongs to the non-approved part of the AFM.

(c) Identification of the approval status of the eAFM (data file version, SW application version, etc.) should be made readily available to the end user via a dedicated function or permanently displayed. The eAFM should be under configuration management control and a unique identifier covering all the eAFM constituents should be available.

(d) Practical access to, and readability and usability of, the eAFM information on ground, in flight, and during any foreseeable normal and emergency operating condition should be also demonstrated.

5. Software considerations

(a) The integrity and reliability of the eAFM software application(s) running on an authorised host platform should be commensurate with the safety objectives defined for their identified failure conditions.

(b) Software running on non-installed equipment:

(1) If the software application is intended to be installed on non-installed equipment, not part of the type design definition, such as Commercial Off-the-Shelf (COTS) platforms and possibly under control by the operator, the lack of development assurance of the platform should be compensated for by at least the following:

(iv) Development assurance activities at application level; and

(v) Verification at eAFM end user level (operator).

(2) A software development assurance process for the eAFM software application(s) should be defined and implemented. It should include in particular extensive[1] verification of the eAFM functionality, including robustness test cases, in a repeatable and standardised manner and for the worst-case authorised platform configurations. This could be achieved by means of development assurance processes (e.g. DO-178()/ED-12(), DO-330/ED-215...) or other appropriate means to be agreed by the Agency.

(3) An additional verification procedure should be developed and provided to end users, as part of the eAFM installation information, for them to ensure adequate verification of the eAFM functionality on their final host platform configuration(s). It should also provide information on how to ensure the absence of regression in

[1] "Extensive" means that all possible eAFM functionalities have been covered by the verification.

case of new or updated host platforms (e.g. Operating System update) or when new software application versions are released.

(c) eAFM data files: The integrity of the eAFM information should be ensured, e.g. by means of CRC protection of the data files.

(d) Identification of the authorized host platform characteristics

(1) The host platform will not be part of the Agency approved eAFM.

(2) The host platform can consist of COTS equipment, without software or hardware qualification, whose technological and performance features as available on the market may change very rapidly. Therefore, the specifications of the host platform configuration characteristics for which the eAFM performance and integrity are guaranteed should be provided.

(3) The eAFM host platform may be an EFB (as defined in the Air Operations Regulation).

(e) Software running on installed equipment: If the eAFM is intended to be hosted in installed equipment (part of the type design definition), the host platform characteristics are fully defined (at the time of its certification); therefore the development assurance at application level can be performed on the final target platform alleviating the need for verification at end user level.

6. eAFM supplements

The eAFM may contain supplements or may propose to embed them in the basic eAFM structure.

In the latter case, the eAFM software application should have a safeguarded feature for selection and de-selection of eAFM for kits, optional equipment, or supplemental information. For this purpose, it should be demonstrated that:

(a) The selection of eAFM supplements for kits is restricted by design only to the people/organizations holding proper rights and responsibilities for making such changes;

(b) The risk of inadvertent changes to the aircraft configuration is properly mitigated, e.g. by means of disclaimers and warning messages displayed on the screen and/or confirmation actions to be performed in order to implement the change;

(c) The selection of eAFM supplements for kits is always readily accessible from any view of the eAFM;

(d) Simultaneous selection of eAFM supplements for incompatible kits is not possible;

(e) Information regarding eAFM supplements for kits whose operation is optional is properly tagged as “if operated”;

(f) Information regarding eAFM supplements for kits that may be removable is properly tagged as “if installed”;

(g) The eAFM provides a log of all selectable supplements for kits or supplemental information.

7. Performance computation

(a) Software assurance

(1) If the eAFM includes a performance computation function, by which the flight crew can calculate and display the aircraft performance both during the flight preparation and in flight, the following additional considerations apply.

(i) The applicant should perform a safety assessment of the performance computation function in order todefine the safety objectives as prescribed by VTOL.2510. A software development assurance process should then be defined and implemented in accordance with AMC 20-115()

(ii) Considering the nature of an eAFM software application, certain adaptations to the DO-178()/ED-12() objectives may be necessary. The rationale for any objective alleviation should be documented. It should be demonstrated that any objective removal can only cause at worst eAFM availability problems and cannot lead to data integrity problems (i.e. production of erroneous data).

(iii) The following adaptations to ED-12C (or later revisions) objectives are provided as examples:

Ref.	Rationale
6.3.4.f	This objective remains applicable except for the worst-case execution timing, stack usage, resource contention, task or interrupt conflict. Worst case execution is not an issue for an eAFM software application execution as it only impacts eAFM availability. Stack usage is not an issue. Resource contention is not an issue since it will only cause availability problems. Task or interrupt conflict is not an issue as it only impacts availability of the function, not its integrity.
6.3.5	The analysis of the linking and loading data and memory map is not requested, as the eAFM is not integrated into aircraft systems.
6.4.2.2 b	This objective could be potentially alleviated. Any system initialization problems will likely be obvious and result in temporary or permanent eAFM unavailability or the need to restart the eAFM. Also, the abnormal conditions will likely be obvious.
6.4.2.2 c	This objective could be alleviated. There is no data coming from external systems. Input data are recorded by the user and output data is computed by the core computation software. eAFM is not a system, but an application running on a COTS operating system.
6.4.2.2 e	This objective could be alleviated. The operating system is performing real time management, and time frame exceeded should only lead to temporary or permanent unavailability of the eAFM. It should not impact data integrity produced by the eAFM.
6.4.2.2 f	This objective could be alleviated. eAFM generally does not have real time constraints. It is an application running on an operating system, which has its own time and task management schemes. Problems in this area should only lead to temporary or permanent unavailability of the eAFM.
6.4.3.a	This objective is applicable. Nevertheless, activities that lead to check real time properties, memory overflow and hardware failure check like detection of failure to satisfy execution time requirements, inability of built-in test to detect failures and stacks overflow are not applicable.

(b) Database Assurance: Databases used for performance calculation should be produced using standard industry processes such as the provisions of DO-178()/DE-12() for Parameter Data Item verification, configuration and change controls or the processes of.DO-200()/ED-76(), as applicable, to a level commensurate with the failure effects identified in the safety assessment.

(c) Software Usage Aspects: The applicant should substantiate that the eAFM performance computation function is designed to:

(1) Provide a generated output containing all the information required to be in the AFM by VTOL.2620. This includes all relevant information (e.g. variables used for a specific condition) to determine operating condition and applicability of the generated output.

(2) Provide equivalent or conservative results to that obtained by performance charts otherwise approved (e.g. in paper/pdf format) for the AFM.

(3) Preclude calculations that would generate results identified as EASA approved by:

(iv) Extrapolating data beyond computational bounds agreed to by the Agency and the applicant; or

(v) Using unapproved flight test analysis or AFM expansion methods.

(4) Provide a satisfactory level of transparency (e.g. understanding of performance relations and limitations).

(d) Interface Aspects: The applicant should substantiate that the eAFM performance calculation function is designed to minimise mistakes or misunderstanding by a trained user during data input and interpretation of output. For this purpose, guidance on Air Operations Regulation for Human Machine Interface and Human Factors aspects of Electronic Flight Bags, such as AMC1 SPA.EFB.100(b)(2) and paragraph (f) of AMC5 SPA.EFB.100(b)(3), may be considered.

8. eAFM Approval Process

(a) The Agency will approve the initial version of the “envelope” eAFM, i.e. the full set of all approved AFM content. Any subsequent revision will be also approved, either directly by the Agency or by means of a DOA privilege.

(b) TC holders may have the privilege, under the Authority of their DOA/POA, to define the content of each individual aircraft eAFM (customised eAFM), by selecting the appropriate approved parts from the envelope eAFM, according to the known configuration of this individual aircraft, and, if needed, the particular requests of the Authority of the country of registration of the aircraft, and distribute this eAFM to the operator.

9. eAFM Customization

Customised eAFM may be built for specific operators’ configurations and managed under the DOA/POA responsibility. With this regard, the following apply:

(a) If the approved eAFM is intended to be the one applicable to all fleet and incorporating all kits, clear instructions on how to customize this eAFM application(s) should be available for operators.

(b) As some eAFM information (e.g. limitation, procedures, etc.) may be applicable to a single or limited number of aircraft only, it should be specified how this information will be managed and conveyed into the customized eAFM, clarifying also in which cases such information may take precedence and replace the one of the basic eAFM.

10. Printed copies and excerpts of the eAFM

(a) Printed copies or excerpts of the eAFM could lead to use incorrect or obsolete data, which could endanger the conduct of the flight. Therefore, excerpts or copies under any format (printed, .pdf, .jpg, .xps, .png, etc) of any part of or of the entire eAFM directly from the software application(s) should be either not allowed or considered and marked as uncontrolled. In particular, if permitted, the extraction of information for building up operational documentation should not impair or corrupt the technical content, the structure and the presentation format of the approved eAFM.

(b) Moreover, the following objectives apply:

(1) The segregation of the data, as well as separation of the approved from unapproved data should be maintained in the pdf or printed copy.

(2) The pdf or printed copy should clearly identify the issue or version of the eAFM and the specific aircraft configuration to which it refers.

11. Design organization processes

It is recommended that the applicant's approved design organization ensures that it identifies and implements all needed processes specific to the eAFM, covering in particular aspects such as electronic authoring and distribution of the eAFM, normal revisions, third party changes (such as resulting from Supplemental Type Certificates), and urgent content or software revisions resulting from Airworthiness Directives requirements.

VTOL.2625 Instructions for Continued Airworthiness

n/a

(a) The applicant must prepare Instructions for Continued Airworthiness that are appropriate for the certification level and performance level of the aircraft.

(b) If Instructions for Continued Airworthiness are not supplied by the manufacturer of an appliance or product installed in the aircraft, the Instructions for Continued Airworthiness for the aircraft must include the information essential to the continued airworthiness of the aircraft.

(c) The Instructions for Continued Airworthiness must contain a Section titled 'Airworthiness limitations' that is segregated and clearly distinguishable from the rest of the document. This Section must set forth each mandatory maintenance action required for type certification. This Section must contain a legible statement in a prominent location that reads: 'The Airworthiness limitations Section is approved and variations must also be approved'.

(d) The applicant must develop and implement procedures to prevent structural failures due to foreseeable causes of strength degradation, which could result in serious or fatal injuries, loss of the aircraft, or extended periods of operation with reduced safety margins. The Instructions for Continued Airworthiness must include procedures developed under SC VTOL.2255.

MOC VTOL.2625 Instructions for Continued Airworthiness

n/a

1. General

The holders of type certificates are responsible for ensuring that there is sufficient and accurate information in the ICA and that they are delivered in a timely manner to maintain the continued airworthiness of the product. ICA is one of the key elements to keep the product airworthy.

ICA provide documentation of necessary methods, inspections, processes, and procedures.

This Means of Compliance (MOC) provides a set of general guidance that, when used in their entirety, are accepted to ensure adequate preparation of Instructions for Continued Airworthiness (ICA).

CS 27.1529 Amdt. 6 and referenced CS-27 Appendix A is accepted as means of compliance together with additional associated guidelines given in FAA AC 27-1B Change 7 Appendix A and complemented by those elaborated below.

In regard to FAA AC 27-1B Change 7 Appendix A chapter 4 “Airworthiness Limitation Section” paragraph 1.(a)(2) the regulatory reference (i.e. CS 27.571) should read VTOL.2240(a).

2. List of abbreviations

Abbreviation	Meaning
	Airworthiness Limitations Section
	Aircraft Maintenance Manual
	AeroSpace and Defence Industries Association of Europe
	Air Transport Association (now Airlines for America (A4A))
	Component Maintenance Manual
	Certification Specifications
	European Union Aviation Safety Agency
	European Technical Standard Orders
	Instructions for Continued Airworthiness
	Standard Practices Manual
	Type Certificate Holder
	Trouble Shooting Manual
	Vendor Service Bulletin
	Wiring Diagram Manual

3. Format and content

ICA can be published in documents or in a manner that is outside the traditional understanding of a document, for example, as a series of web pages, or in a publishing format linked to tasks or data modules rather than pages. The data containing the instructions is itself the ICA, not any particular type of publication.

Adapted to the VTOL requirements, applicants may apply the latest ATA or ASD standards (e.g. ATA iSpec 2200 or ASD S1000D), which are recommended to be used by EASA for a clear structure. Basic manuals are defined by using those standards. However, manufacturers may arrange differently the range of manuals and their content.

There is no requirement for any specific format or arrangement of the manual or manuals. However, the specific arrangement and format chosen by the applicant should be used in a uniform manner.

The ICA content should be provided in English (Simplified Technical English, as e.g. in accordance with ASD Specification ASD-STE100). If manuals are produced in different languages, master copies in English should be provided to the Agency.

4. Timely availability of ICA

The EASA Certification Memorandum CM-ICA-001 “Completeness and timely availability of Instructions for Continued Airworthiness” provides guidance on the completeness and timely furnishing of ICA to the operator/owner and any other person required to comply with any of those instructions. This CM is deemed applicable to VTOL capable aircraft as well.

From 18 May 2022 (c.f. Art. 3 Regulation (EU) 2021/699) Point 21.A.7 of Annex I to Regulation 748/2012, along with the associated AMC1 21.A.7(c), will become applicable to cover this aspect of timely availability of ICA.

5. ICA Provided by Suppliers for an appliance

The ICA for the VTOL capable aircraft should include the information essential to the VTOL capable aircraft’s continued airworthiness. When parts of the ICA are produced by a supplier, there should be clear agreements between TCH and suppliers established to ensure the availability of the relevant ICA.

Certain information from the suppliers and their interfaces should be considered ICA.

Either this information is directly integrated in the TCH VTOL capable aircraft-, Lift/thrust unit- or ETSO-“top-level” ICA, if applicable in accordance with the technical standard applied, or it is provided in the supplier documentation (as for example Component Maintenance Manuals (CMM), Vendor Service Bulletins (VSB)).

The supplier documentation which is integrated in the “top-level” ICA of the TCH, or is referenced in there, is considered part of the complete ICA package.

If “top-level” ICA contains “discard” or “remove and replace” instructions for certain components (including system testing and other instructions ensuring that the product will be put in an airworthy state by such replacement), and do not refer to supplier documentation for necessary airworthiness actions, then the VTOL capable aircraft airworthiness is maintained by discard/replacement action, and the supplier documentation is not part of the ICA.

6. Multiple Manuals

It is not the intent of the Agency to enforce a specific selection/range of manuals, names and their abbreviations, apart from manuals/sections, which are referenced in requirements, like the “Airworthiness Limitations” in VTOL.2625(c). The selection of manuals, names and their abbreviations used in this MOC should be considered as examples only.

In case of segregation of information dedicated to a specific subject from a principal manual (like the Aircraft Maintenance Manual (AMM) or Standard Practices Manual (SPM)) into a separate manual, e.g. “Cable Fabrication Manual”, “Duct Repair Manual” or “Instrument Display Manual”, these manuals are considered as ICA. On the other hand, certain information dedicated to a specific subject may be integrated in a principal manual (as e.g. trouble-shooting information as part of the Aircraft Maintenance Manual (AMM) instead of a separate Trouble Shooting Manual (TSM)).

When reviewing the different requirements of CS-27 Appendix A, it should be noted that in the majority of the cases there is more than just one manual produced to provide the required information. To facilitate the compliance finding an applicant should provide an overview of the publications and manuals produced.

In this context, it should be clearly defined which manual is intended to be the "principal manual".

7. Service Documentation, Information

The TCH can use their customer service documents as a method of making changes to ICA available and to deliver them in a timely manner. Typical publications could include, Alert Service Bulletin, Inspection Service Bulletin, Service Bulletin, Service Information Letter, etc.

An applicant should demonstrate which of its service documents may be used as ICA or may be used as a means of communication to provide information to the operator other than ICA.

These documents do not replace publications required for EASA type certification needing approval, such as the Airworthiness Limitations Section (ALS).

8. Electronic Media

Some applicants provide their documentation in an electronic format, e.g. CDs, internet, etc.. Manuals may be provided in such an electronic format instead of paper copies. Eventually, in integrating and cross-linking documentation into a common database, a classical manual structure (e.g. in accordance with previous ATA 100 standard), a set of manuals like AMM, WDM, TSM…, may be not visible. Therefore, an integrated documentation provided in a database may increase the difficulty to identify ICA related information. Nevertheless, the applicant should demonstrate which of its elements are required as ICA.

Within the EASA Part-21 (Regulation 748/2012) and CS-27 (and other documents), the term "manual" is used. For an integrated documentation provided in a database, the applicant should define and clarify the composition of documentation data for equivalent visibility as to a classical manual structure.

In the context of data base management, aspects like the production of data, its validation and verification, data submission, traceability of updates, data security and relevant operational requirements should be defined and explained by the applicant.