EASA European Union Aviation Safety Agency	Equivalent Safety Finding Normal Load Factor Limiting System	Doc. No.: ESF-B25.143-01 Issue : 1 Date : 12 March 2021 Proposed ☒ Final ☐ Deadline for comments: 07 Apr 2021

SUBJECT	:	**Electronic Flight Control Systems – Normal Load Factor Limiting System**
REQUIREMENTS incl. Amdt.	:	**CS 25.143(l) at amdt. 22**
ASSOCIATED IM/MoC[1]	:	Yes☒ / No ☐
ADVISORY MATERIAL	:	**N/A**

INTRODUCTORY NOTE:

The following Equivalent Safety Finding (ESF) has been classified as important and as such shall be subject to public consultation in accordance with EASA Management Board decision 12/2007 dated 11 September 2007, Article 3 (2.) which states:

"*2. Deviations from the applicable airworthiness codes, environmental protection certification specifications and/or acceptable means of compliance with Part 21, as well as important special conditions and equivalent safety findings, shall be submitted to the panel of experts and be subject to a public consultation of at least 3 weeks, except if they have been previously agreed and published in the Official Publication of the Agency. The final decision shall be published in the Official Publication of the Agency.*"

IDENTIFICATION OF ISSUE:

A request for an Equivalent Safety Finding (ESF) to CS 25 paragraph 25.143(l) at Amdt. 22 was submitted to EASA for a large aeroplane equipped with an Electronic Flight Control System (EFCS) with a normal load factor limiting function and flight envelope protections. For this design, the maximum reachable negative load factor may be limited by flight control system characteristics or flight envelope protections other than load factor limitation.

This specification was introduced at CS-25 amendment 13 to deal with Electronic Flight Control Systems (EFCS) which embody a normal load factor limiting system. This requirement has later been discussed, for aircraft equipped with flight envelope protections, within the Flight Test Harmonisation Working Group FTHWG (an advisory group created by the ARAC to conduct a task assigned by the FAA in the USA) Phase 2 and the result is reflected in the Phase 2 Report Rev. A Topic 1 dated April 2017.

<u>CS 25.143(l) content:</u>

CS 25.143(l) includes the paragraph 25.143(l)(4) that requires:

"(4) Maximum reachable negative load factor may be limited by flight control system characteristics or flight envelope protections (other than load factor limitation), provided that:

(i) pitch down responsiveness is satisfactory, and

(ii) *from level flight, 0 g is readily achievable, or, at least, a trajectory change of 5 degrees per second is readily achievable at operational speeds (from V_{LS} to Max speed – 10 kt). V_{LS} is the*

[1] In case of SC, the associated Interpretative Material and/or Means of Compliance may be published for awareness only and they are not subject to public consultation.

lowest speed that the crew may fly with auto thrust or auto pilot engaged. Max speed – 10 kt is intended to cover typical margin from V_{MO}/M_{MO} to cruise speeds and typical margin from V_{FE} to standard speed in high-lift configurations."

It is reminded that CS 25.143(l) applies only to EFCS functioning in its normal mode and for both, high lift devices retracted and high lift devices extended.

Background on the creation of CS 25.143(l):

CS 25.143(l) was introduced in CS-25 Amdt. 13 based on the proposal made by NPA 2011-09. CS 25.143(l) specifies a minimum normal load factor envelope for aeroplanes equipped with EFCS which embody a normal load factor limiting system. As explained in NPA 2011-09, the objective of this specification is to ensure that sufficient maneuverability remains available like on non fly-by-wire aeroplanes, in order to be able to effect sudden changes to the flight path which may be required to avoid obstacles, terrain or to capture level-off altitudes following climb or descent.

It has also to be noted that the aim of NPA 2011-09 was to reflect the certification practices at that time and to facilitate certification projects by incorporating existing generic Special Conditions and Means of Compliance CRIs in CS-25.

More recently the FTHWG decided that CS 25.143(l) should be reviewed. This working group issued recommendations for load factor capability in the Phase 2 Report Rev. A Topic 1 dated April 2017, particularly to create a new specification 25.144 Envelope Protection Functions—General, to replace CS 25.143(l) in the future for aeroplanes equipped with EFCS.

It is proposed to apply the FTHWG recommendations of Topic 1 through this ESF instead of the current CS 25.143(l). Furthermore, the complete FTHWG proposal shall be used instead of adapting only the 25.143(l)(4)(ii) to apply a consistent and complete set of specification and AMC.

The acceptability of the proposed Equivalent Safety Finding to CS 25.143(l) at amdt 22 is based on the following justifications:

- The proposed alternative standard has been agreed by the FTHWG to be the future standard for aeroplane equipped with electronic flight control systems. This standard constitutes the conclusion of the harmonization working group, no dissenting opinions were raised regarding the here below specification and MoC. It can therefore be recognized by Airworthiness Authorities as well as aeroplane manufacturers as a balanced recommendation.
- It is considered as meeting the intent of 25.143(l) as its contents is very similar. The main difference between the CS 25.143(l) at Amdt. 22 and the alternative standard addresses the case where maximum negative load factor command may be further limited by flight control system characteristics or flight envelope protections. The quantitative requirement of 5°/s of trajectory change is replaced by a qualitative requirement of satisfactory trajectory change. In addition, the alternative standard describes more precisely the manoeuver to be performed for the assessment. CS-25 Book 2 does currently not provide an AMC for 25.143(l).
- A compliance demonstration based on a qualitative assessment of aeroplane capability to perform a satisfactory trajectory change through pilot evaluation (in a simulator or in flight) will ensure at least the same level of safety than the one achieved by a quantitative criterion that can be verified through desktop simulation like a pass-failed criterion.

- The qualitative assessment by a pilot will ensure, in particular, that the aeroplane has the required capability to effect sudden changes to the flight path which may be required to avoid obstacles, terrain or to capture level-off altitudes following climb or descent.

Therefore, the above mentioned FTHWG recommendations include a suitable alternative to compliance with CS 25.143(l). It provides compensating factors allowing to reach an equivalent level of safety per point 21.B.80(a)2 of Part-21 (Annex I to Regulation (EU) No 748/2012).

Considering the above, the following Equivalent Safety Finding to CS 25.143(l) at Amdt. 22 is proposed in Appendix A with associated Means of Compliance in Appendix B:

Appendix A

Equivalent Safety Finding to CS 25.143(l) Amdt 22

Electronic Flight Control Systems – Normal Load Factor Limiting System

The following compensating factors must be demonstrated to provide an equivalent level of safety:

1) Positive Load Factors. Unless positive maneuver capability is limited by airframe characteristics (e.g. wing lift, deterrent buffet, or pitch control power), or by other protection functions that serve specific flight characteristics design purposes (e.g., high-angle-of-attack protection or pitch attitude protection), the positive load factor command limit with EFCS functioning in its normal mode and the airplane in its normal trim state for the flight condition must not be less than:
   - 2.5 g with the high-lift devices retracted, and
   - 2.0 g with the high-lift devices extended.

   A reduced positive limiting load factor that decreases gradually from 2.5 g at Vmo/Mmo to 2.25 g at Vd/Md has been considered acceptable on aircraft with negative pitch attitude protection and highspeed protection, provided it does not hinder overspeed recovery (CS 25.335(b)(1)).

2) Negative Load Factors. Unless negative maneuver capability is limited by airframe characteristics (e.g. wing lift, deterrent buffet, or pitch control power), or by other protection functions that serve specific flight characteristics design purposes (e.g., high speed protection, low-angle-of-attack protection or pitch attitude protection), the negative limiting load factor command with the EFCS functioning in its normal mode must be equal to or more negative than:

   - -1.0 g with the high-lift devices retracted; or
   - 0 g with the high-lift devices extended.

   Maximum negative load factor command may be further limited by flight control system characteristics or flight envelope protections, provided that:

   - pitch down responsiveness is satisfactory, and
   - from trimmed level flight, 0 g can be commanded or a satisfactory trajectory change is readily achievable at operational speeds.

   It has also been considered acceptable for the control law to initially restrict the negative load factor to approximately 0 g with high-lift devices retracted to reduce the risk of inadvertent brief negative-g maneuvers, with the load factor limit increasing gradually to approximately - 1.0 g within a reasonable time.

Appendix B

Associated Means of Compliance

Electronic Flight Control Systems – Normal Factor Limiting System

The associated Means of Compliance is published for awareness only and is not subject to public consultation.

a) Positive Load Factors. Compliance for positive load factor command capability may be shown in a pullup or in turning flight, at a speed/weight/cg combination at which the specified load factor is achievable, supported by design review of the control law to show that it does not limit inappropriately at other conditions. A pull-up may be initiated from a pushover or descent condition to avoid excessive positive pitch attitudes during the pull-up. If a turning maneuver is used to demonstrate maneuver command capability, pitch response in a pull-up should be shown to be acceptably prompt.

b) Negative Load Factors. Compliance for negative load factor limits may be shown in a pushover to 0 g at a weight/speed/cg combination at which the aircraft is capable of achieving that load factor, supported by design review of the control law to show that it does not limit inappropriately at other conditions. The pushover may be initiated from a pull-up or climb condition to avoid excessive negative pitch attitude and potential overspeed.

c) Compliance demonstration with the requirements above may be performed without ice accretion on the airframe.