Certification Memorandum

Flight Crew Human Factors Assumptions in Aircraft and System Safety Assessments

EASA CM No.: CM–SA-002 Issue 02

Regulatory requirement(s): CS 25.1309(b) and (c)

EASA Certification Memoranda clarify the European Union Aviation Safety Agency's general course of action on specific certification items. They are intended to provide guidance on a particular subject and, as non-binding material, may provide complementary information and guidance for compliance demonstration with current standards. Certification Memoranda are provided for information purposes only and must not be misconstrued as formally adopted Acceptable Means of Compliance (AMC) or as Guidance Material (GM). Certification Memoranda are not intended to introduce new certification requirements or to modify existing certification requirements and do not constitute any legal obligation.

EASA Certification Memoranda are living documents into which either additional criteria or additional issues can be incorporated as soon as a need is identified by EASA.

An agency of the European Union

TE.CERT.00141-001 © European Union Aviation Safety Agency. All rights reserved. ISO9001 Certified.
Proprietary document. Copies are not controlled. Confirm revision status through the EASA-Internet/Intranet.

Log of issues

Issue	Issue date	Change description
1	23 March 2022	First Issue
2	10 May 2023	Second issue after public consultation.

Table of Content

An agency of the European Union

TE.CERT.00141-001 © European Union Aviation Safety Agency. All rights reserved. ISO9001 Certified.
Proprietary document. Copies are not controlled. Confirm revision status through the EASA-Internet/Intranet.

1. Introduction

1.1. Purpose and scope

This Certification Memorandum (CM) aims at stressing the importance of considering human factors (HF) in aircraft and system safety assessments for large aeroplanes, especially in frame of the classification of failure conditions identified using functional hazard assessments (FHAs) of the aircraft and system functions. It provides applicants with a structured HF process that may be used to confirm the assumptions made about the expected flight crew behaviours.

This CM focusses on flight crew HF aspects and more specifically on:

- identifying and defining elements to complement AMC 25.1309, including cognitive aspects underlying the failure condition recognition, the elaboration of the diagnosis of the situation, and the flight crew response and post failure management,
- establishing the criteria driving the level of scrutiny required to demonstrate the validity of the assumptions,
- providing guidance for the selection of methods and means to be used to show compliance with the applicable certification specifications.

1.2. References

The following reference materials should be used in conjunction with this Certification Memorandum:

Reference	Title	Code	Issue	Date
AMC 25.1302	Installed Systems and Equipment for Use by the Flight Crew	CS-25	Amdt. 27	24 November 2021
AMC 25.1309	System Design and Analysis	CS-25	Amdt. 27	24 November 2021
AMC 25.1322	Flight Crew Alerting	CS-25	Amdt. 27	24 November 2021
ARP 4761 (or the latest revision)	SAE Aerospace Recommended Practice (ARP) 4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment	-		December 1996
ED-79A / ARP 4754A (or the latest revision)	EUROCAE document ED-79A, Guidelines for Development of Civil Aircraft and Systems, or the equivalent SAE Aerospace Recommended Practice (ARP) 4754A.	-		December 2010

1.3. Abbreviations

A/C	Aircraft

TE.CERT.00141-001 © European Union Aviation Safety Agency. All rights reserved. ISO9001 Certified.
Proprietary document. Copies are not controlled. Confirm revision status through the EASA-Internet/Intranet.

AMC	Acceptable Means of Compliance
CS	Certification Specification
FHA	Functional Hazard Assessment
HF	Human Factors
N/A	Not Applicable
PF	Pilot Flying
PM	Pilot Monitoring

1.4. Definitions

Classification of an alert	In this document, the classification of an alert refers to the categories of alerts specified by CS 25.1322 (i.e. warning, caution and advisory).
Confidence degree	Perceived validity of the assumption from the review team based on the plausibility of the described expected flight crew behaviour.
Failure Condition	Definition per AMC 25.1309 section 5, i.e.: A condition having an effect on the aeroplane and/or its occupants, 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.
Human Error	A deviation from what is considered correct in some context, especially in hindsight of the analysis of accidents, incidents, or other events of interest. Some types of human error may be the following: an inappropriate action, a difference from what is expected in a procedure, an incorrect decision, an incorrect keystroke, or an omission.
Validate	Determine correctness and completeness (refer to ARP4754A).
Verify	Evaluate the implementation of requirements to determine that they have been met (refer to ARP4754A).

2. Background

2.1. Flight crew actions in aircraft and system functional hazard assessments

FHA is a key element within the safety assessment process of large aeroplanes designs for showing compliance with CS 25.1309. It supports the compliance demonstration by ensuring that the identification of failure conditions is **complete**, and the severity classification of the failure conditions is **correct**, and **adequately substantiated**.

TE.CERT.00141-001 © European Union Aviation Safety Agency. All rights reserved. ISO9001 Certified.
Proprietary document. Copies are not controlled. Confirm revision status through the EASA-Internet/Intranet.

The severity of some failure conditions[1] may be mitigated by flight crew recognition and response. In such cases, flight crew recognition and response would therefore directly affect the failure condition classification, and subsequently the safety objectives. The adequacy of such mitigation depends on the capability of flight crews to perform the actions that are expected from them, and the absence of any additional hazard that could result from human errors while the failure condition is being managed. From a certification standpoint, those aspects are covered by a combination of CS 25.1309(b) and CS 25.1309(c).

From a cognitive standpoint, prerequisites for a proper application of corrective actions are:

- adequate recognition of the failure condition,
- establishment of a valid interpretation of the situation,
- elaborate an appropriate plan of action, and
- sufficient time is available to establish an appropriate interpretation of the situation and perform the corrective action(s) necessary to address the failure condition.

These prerequisites are usually considered by applicants in aircraft and system FHA as implicitly given and fulfilled by default. These assumptions may be indirectly confirmed, and their associated requirements verified in other processes that are not directly connected to the FHA. Recent experience has shown that a disparity may exist between:

- the actually observed flight crew behaviours, and
- the underlying assumptions about flight crew recognition, interpretation, and response that applicants have made during the design and certification process.

These disparities may invalidate the assumptions made in aircraft and system FHA and ultimately the validity of other assessments. Most applicants do not conduct any systematic and structured activity to demonstrate the validity of FHA assumptions.

2.2. Existing Guidance Materials

Whenever credit is sought from flight crew recognition of flight deck effects and/or from flight crew actions when assessing system failure conditions for compliance with CS 25.1309(b), the related AMC 25.1309 (section 9(b).5) requests to verify that:

- any identified indications will, in fact, be recognised,
- any action(s) required has(have) a reasonable expectation of being accomplished successfully and in a timely manner, appropriate for the condition.

Apart from indicating that reviews with pilots and HF specialists are to be organised, and that the most complex situations are to be confirmed by simulator, ground tests, or flight tests, no further guidance is provided to the applicants. The results of the assessments performed to comply with CS 25.1302 or equivalent should be used where relevant and appropriate to complement the human error considerations in the safety assessment process.

The efficient recognition of a system failure condition and the human performance aspects related to the management of this failure condition are indirectly covered per CS 25.1302. The related AMC 25.1302 states that both **normal** and **non-normal conditions** are to be considered, without defining which non-normal conditions are to be considered for that compliance demonstration, and whether environmental conditions or system failure conditions are to be addressed. The non-normal conditions due to system failures and malfunctions should be addressed in addition to relevant adverse environmental conditions.

[1] Depending on the safety process used by each applicant, the relevant level and/or terminology for the failure conditions could be different (e.g. functional failure scenario). For the sake of simplicity, the term 'failure condition' is used in this CM.

Therefore, neither AMC 25.1309 nor AMC 25.1302 provides adequate guidance for the development of a dedicated and structured human factors process for confirming the assumptions made by applicants about flight crew behaviours in aircraft and system FHA. Some general guidance on the management and validation of assumptions can be found in ED79A/ARP4754A, paragraph 5.4.2.d.

3. EASA Certification Policy

This CM highlights the importance of Human Factors consideration in the failure condition classification for large aeroplanes. It applies to all failure conditions which consider flight crew recognition and/or action with a particular emphasis on scenarios taking credit of flight crew behaviour when defining the severity classification. This CM identifies the minimum expectations in terms of applying a systematic and structured approach, using a documented process, and generating traceable evidence.

3.1. Task Analysis Framework

Human Factors in management of failure conditions should be assessed on a task basis, using a structured analysis model as presented in Table 1. This analysis model, developed by EASA, provides an acceptable structured framework supporting a systematic assessment of the failure management. Alternative analysis methods or frameworks should be agreed with EASA. This model describes the cognitive processes, the flight deck effects, the task demands and HF vulnerabilities that may exist during the occurrence of a system failure condition and its management by the flight crew. The model is distributed among the five following steps:

- occurrence of the failure condition (stimulus),
- perception by the flight crew of the failure condition indication(s),
- processing of information by the flight crew,
- flight crew response, and
- post failure management.

Flight crew actions and HF vulnerabilities depend on whether the system provides explicit and unambiguous information allowing the flight crew to immediately identify the nature of the failure condition.
Thus, the model addresses both situations, Failure Management Case #1 where explicit and unambiguous alert pointing to the initial failure causal information is provided, and Failure Management Case #2 for all other cases.

For each system failure condition where expected flight crew action is part of the severity determination, and based on the agreed task analysis framework, the applicant should provide the full set of information described in Table 1.

TE.CERT.00141-001 © European Union Aviation Safety Agency. All rights reserved. ISO9001 Certified.
Proprietary document. Copies are not controlled. Confirm revision status through the EASA-Internet/Intranet.

Table 1: *Task Analysis Model and Information required for Failure Management*

Task Analysis Model	Failure case#1: Explicit alert from the Crew Alerting System (CAS) unambiguously pointing to the initial failure	Failure case#2: Set of heterogeneous symptoms: – Initial failure observable indication – Multiple /subsequent indications – Other observable flight deck effects – Aircraft physical feedback
1. Stimulus (occurrence of the failure condition)	Which of the two cases characterize the failure condition? Note: It can be a combination of both cases.	
2. Perception (by the flight crew of flight deck effects)	- Does the failure require immediate crew awareness? - Does the failure require immediate crew response? - What is the classification of the alert, as per CS 25.1322 and associated AMC, used to inform the crew of the failure? - What kind of alert(s) is used (e.g. visual, aural, tactile) and how does it appear (e.g. location, number of modalities used, characteristics of the alert)? - What is the maximum period of time within which the crew is assumed to detect the alert?	- What is the initial failure and how is it observable by the flight crew? - What are the affected systems and the associated flight deck effects? - What is the comprehensive list of additional observable flight deck effects? - What are the associated aircraft physical feedback? - In which order do all those effects appear? - What is the maximum period of time within which the crew is assumed to detect the alerts/flight deck effects?
3. Information processing (by the flight crew)	Not applicable since the crew is expected to directly go from the alert to the procedure/Memory Item.	- What is the description of the reasoning assumed to allow the crew to establish the failure condition diagnosis? - How is the crew assumed to prioritize the effects related to the affected systems? - What are the assumptions about the time spent from the failure detection to the flight crew response?
4. Flight crew response	- What part of the training syllabus is assumed to be used in the context of the failure management? - Which memory items are assumed to be used, if any? - Which procedure(s)/checklist(s) is (are) assumed to be used? - Is the flight crew expected to use basic airmanship? - Is unusual workload concentration and force required as part of the flight crew response ?	- What is the sequence of actions the flight crew is assumed to accomplish? The kind of action, the relevant means (e.g. controls and information) as well as the order needs to be described in the sequence of actions. - What part of the training syllabus is assumed to be used in the context of the failure management? - What are the temporal constraints if any? - Which memory items are assumed to be used, if any? - Which procedure(s) /checklist is (are) assumed to be used? - Is unusual workload concentration and force required as part of the flight crew response ?
5. Post failure management	– What are the consequences of the failure condition on the aircraft systems (inoperative systems, unavailable systems, reversibility of the status, etc.)? – What are the operational limitations to be respected due to the failure(e.g.: altitude, speed, temperatures...)? – Are there any procedural deferred items? – What are the means to make the crew aware of the systems' status, operational limitations, and procedural deferred items? – What are the actions the flight crew is obliged to accomplish manually due to the resulting failure effects for the rest of the flight? – Does the post failure situation imply unusual workload? – Does the post failure situation imply unusual concentration?	

TE.CERT.00141-001 © European Union Aviation Safety Agency. All rights reserved. ISO9001 Certified.
Proprietary document. Copies are not controlled. Confirm revision status through the EASA-Internet/Intranet.

	– Does the post failure situation imply application of unusual force on the flight controls? – Are there some physiological impacts that are susceptible to emerge and modify the crew performance in responding to the scenario ? (e.g. temperature runaway, excessive noise or vibration, visibility degradation in the flight deck, etc.).

3.2. Process Considerations

The applicant should define and document the process used to manage the assumptions in general and consider in particular the confirmation of the assumptions made about flight crew behaviour in safety assessments.

It is recognised that the safety assessment is an iterative process. In case the system definition is evolving, the assumptions need to be reconsidered, as well it is expected that the table 1 content evolves based on the evolving maturity of the systems.
Several means are available to confirm assumptions about flight crew behaviour in FHAs. Therefore, the applicant should implement a process to ensure that the assumptions about crew behaviour are properly confirmed. At least the following elements should be identified and documented:

- the available testing means (engineering benches, engineering simulators, full flight simulators, aircraft),
- the validation methods used (engineering judgement, flight test pilot evaluation, human factors assessments, scenario-based evaluations, etc.)
- the criteria used to decide what are the most suitable means and methods to confirm the crew behaviour assumptions supporting the FHA.

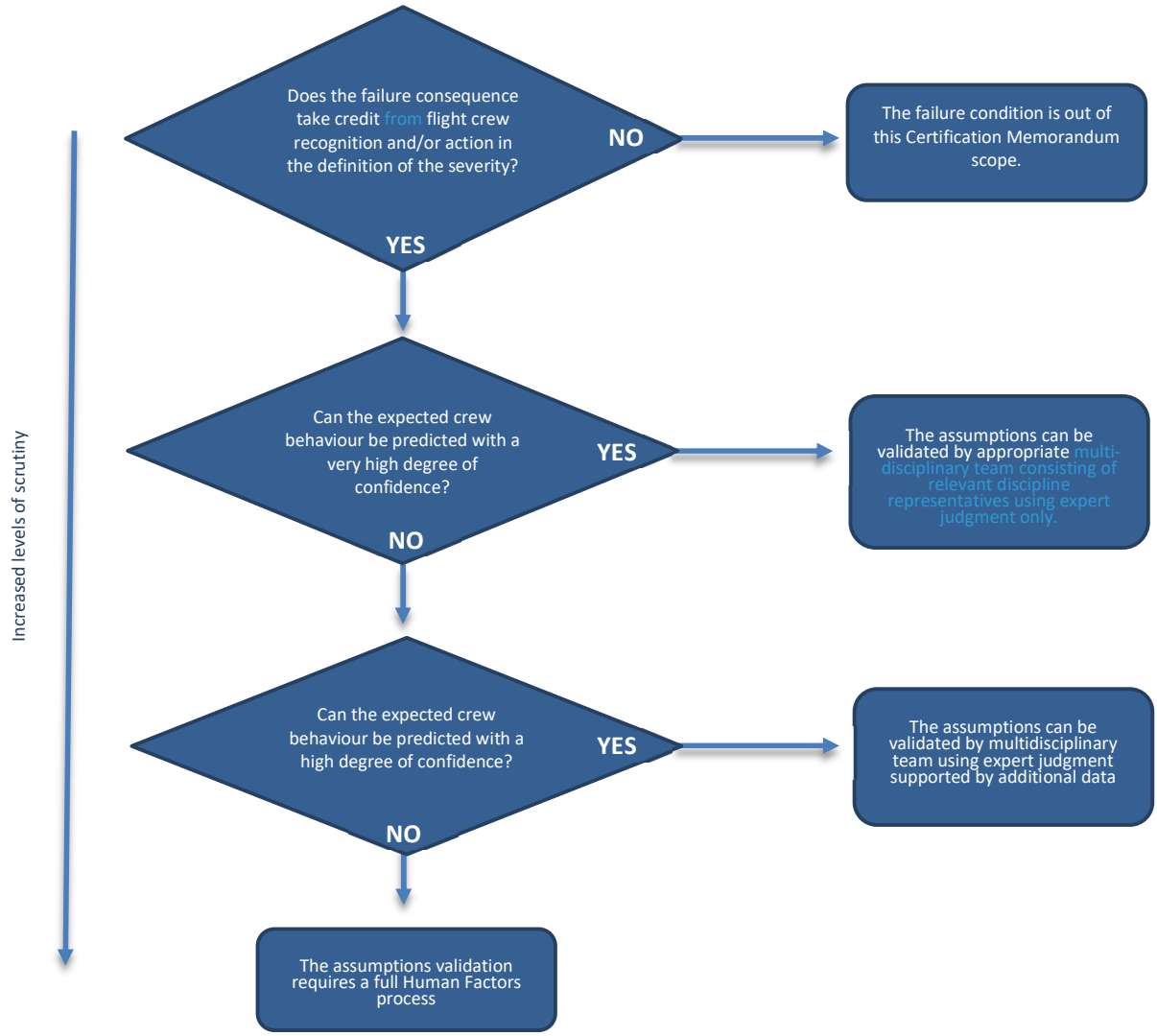
The process should describe the level of scrutiny to be applied when confirming an assumption, as well as the criteria used for its establishment. This approach should be considered during all the aircraft and system safety Assessment reviews utilizing a multi-disciplinary team consisting of relevant discipline representatives (e.g. Engineering, Safety, Flight Test and HF).

Relevant information about the means and methods selected to assess, to justify, and to confirm the assumptions about flight crew behaviours, for each applicable system failure condition should be documented.

The degree of confidence in the flight crew behaviour assumption may vary according to several parameters, including the detectability and ease of understanding of the associated means assumed to drive the crew attention, and the complexity of the associated procedures and expected crew actions. Some assumptions may be considered as relatively obvious, whereas others may require deeper specialist discussion, or a more complex demonstration. This categorisation process should be adequately documented and presented; the outputs of this process should be provided to the authority. The process presented in figure 01 provides an acceptable approach. The following activities are meant to be run by a multi-disciplinary team consisting of relevant discipline representatives (e.g. Engineering, Safety, Flight Test and HF).

TE.CERT.00141-001 © European Union Aviation Safety Agency. All rights reserved. ISO9001 Certified.
Proprietary document. Copies are not controlled. Confirm revision status through the EASA-Internet/Intranet.

***Figure 01**. Diagram – level of scrutiny*



The following table provides recommended methods, means and deliverables depending on the confidence degree. The level of confidence drives the level of scrutiny.

TE.CERT.00141-001 © European Union Aviation Safety Agency. All rights reserved. ISO9001 Certified.
Proprietary document. Copies are not controlled. Confirm revision status through the EASA-Internet/Intranet.

Table 2: *Recommended methods, means and deliverables*

CONFIDENCE DEGREE	METHODS	MEANS	DELIVERABLES
Very high degree of confidence	Engineering judgement only	Appropriate multi-disciplinary team consisting of relevant discipline representatives.	Summary of cases characterized and stated by the review team as "very high degree of confidence"
High degree of confidence	Engineering judgement supported by additional data	HF analysis, mock-up, bench or simulator review	Analyses or Review Reports
All other cases	Full Human Factors process	Advanced tools and methods (test bench, simulator, aircraft, scenario-based approach) in addition to analysis and engineering judgement.	Test plans and Reports, in addition to analyses or review reports.

The scenario-based approach is based on a method that involves a sample of various crews, who are representative of the intended users, being exposed to realistic operational scenarios in a test bench or a simulator or in an aircraft. The scenarios are designed to identify any potential deviations between the expected behaviour of the crew and the activities of the crew that are actually observed. Due to inter-individual variability, scenario-based assessments performed with a single crew are not acceptable. The usually accepted number of different crews used for a given assessment campaign varies from three to five, including the authority crew, if applicable. To avoid an obvious risk of experimental bias, the crew participating in the assessment should not be briefed in advance about the details of the failures and events to be simulated. More detailed guidance regarding the scenario-based approach is provided in AMC 25.1302.

The applicant may be requested to provide the relevant substantiation material including – for example- means, methods, analysis, and test results used to demonstrate the validity of assumptions about flight crew behaviours when dealing with failure conditions.

The approach should be assessed by EASA, e.g. via a failure condition sample selected by the applicant and agreed with EASA. EASA reserves the right to increase its involvement in the oversight of HF considerations.

3.3. Traceability

The expected flight crew behaviour should be documented as an assumption within the safety assessment process. A process should be defined and documented taking into account the guidance provided in section 3.2 to confirm these assumptions and ensure the traceability to the supporting evidence. The applicants should also provide a statement that all relevant assumptions are confirmed prior or jointly with the submission of the final safety assessments.

4. Who this Certification Memorandum affects

The guidance in this Certification Memorandum affects applicants showing compliance with CS 25.1309 for certification of a new type design, significant major changes to a type design or any major change that introduces new failure conditions or significantly affects existing failure conditions (change in flight deck effects or in assumed flight crew reaction) on large aeroplanes. The application will be discussed on project level on a case-by-case basis.

An agency of the European Union

TE.CERT.00141-001 © European Union Aviation Safety Agency. All rights reserved. ISO9001 Certified.
Proprietary document. Copies are not controlled. Confirm revision status through the EASA-Internet/Intranet.

5. Remarks

For any question concerning please contact:
Clément Audard
Senior Expert – Safety Assessment
Phone: +49 (0)221 899902038
E-mail: clement.audard@easa.europa.eu

TE.CERT.00141-001 © European Union Aviation Safety Agency. All rights reserved. ISO9001 Certified.
Proprietary document. Copies are not controlled. Confirm revision status through the EASA-Internet/Intranet.