# Notification of a Proposal to issue a Certification Memorandum

# Human Factors Considerations in Aircraft and System Functional Hazard Assessments

**EASA CM No.: Proposed CM–SA-002 Issue 01**

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

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## Log of issues

| Issue | Issue date | Change description |
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| 1 | 23 March 2022 | First Issue |

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# 1. Introduction

## 1.1. Purpose and scope

This Certification Memorandum (CM) aims at stressing the importance of considering the Human Factors in Aircraft and System Functional Hazard Assessments for Large Aeroplanes. It provides applicants with a structured Human Factors methodology to validate the assumptions made about the expected flight crew behaviours, in the aircraft and system Functional Hazard Assessments (FHA).

This Certification Memorandum focusses on flight crew aspects and more specifically on:

- identifying and defining the elements missing in the existing guidance material, incl. cognitive aspects underlying the failure condition recognition and the elaboration of the diagnosis of the situation,
- establishing the criteria driving the level of scrutiny required to demonstrate the validity of these assumptions,
- providing guidance in terms of acceptable methods and means to be developed for compliance with the regulations.

## 1.2. References

It is intended that the following reference materials 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 |

## 1.3. Abbreviations

| | |
|---|---|
| A/C | Aircraft |
| 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

| | |
|---|---|
| Confidence degree | Perceived validity of the assumption from the review team based on the plausibility of the described expected crew behaviour. |
| Failure Condition | 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. |
| Validate | Determine correctness and completeness. |
| Verify | Evaluate the implementation of requirements to determine that they have been met. |

# 2. Background

## 2.1. Flight Crew Actions in aircraft and system Functional Hazard Assessments

Functional Hazard Assessments (FHA) are key elements within the Safety Assessment Process of Large Aeroplanes designs for showing compliance with CS 25.1309. They support 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**.

**The consequences of failure conditions or functional failure scenario[1] and their severity may be mitigated by relying on flight crew actions. Whether these mitigations trigger the expected effect directly affects the classification, and subsequently the safety objectives.**

The expected effects of such mitigations depend 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, and
- sufficient time to address the failure condition.

These prerequisites are usually considered by applicants in aircraft and system FHAs as implicitly given and fulfilled by default. These assumptions may be indirectly validated or verified in other processes that are not directly connected to the FHAs. Recent experience has shown that a disparity may exist between:
- the 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 the safety assessment and ultimately the validity of these assessments. Most applicants do not conduct any systematic and structured activity to demonstrate the validity of assumptions.

[1] Depending on the safety process of each applicant, the relevant level could be the functional failure scenario as it is recognised that a failure condition may include several scenarios. For the sake of simplicity, the term failure condition is used in the document.

## 2.2. Existing Guidance Materials

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

- any identified indications will, in fact, be recognised,
- any actions required have a reasonable expectation of being accomplished successfully and in a timely manner.

Apart from indicating that reviews with pilots and human factors (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 given to the applicants.
As both CS 25.1302 and CS 25.1309 are dealing with human performance including human errors, the results of the assessments performed to address CS 25.1302 or equivalent, should be used where relevant and appropriate to complement the human error portion of 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 states that both **normal** and **non-normal conditions** are to be considered, without defining however what non-normal conditions are to be considered for that compliance demonstration, and whether environmental conditions or system failure conditions are to be addressed. The Agency position is that the non-normal conditions due to system failures and malfunctions should be addressed in addition to environmental conditions.

Therefore, no existing guidance material either in CS 25.1309 or in CS 25.1302 provides a dedicated and structured human factors methodology for validating the assumptions made by applicants about flight crew behaviours in aircraft and system FHAs. 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 certification memorandum (CM) aims at stressing the importance of the consideration of HF in Aircraft and System Functional Hazard Assessments 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 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 Factor management of failure conditions should be assessed on a per task basis, using a structured analysis model as presented in Table 1. This model, developed by EASA, provides an acceptable structured framework supporting a systematic assessment of the failure management. Alternative methods or frameworks should be agreed with the Agency. 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 and its management by the flight crew. The model is distributed among the five following phases:

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

Flight deck effects, tasks and relevant design and Human Factors vulnerabilities are different depending 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 causal information is provided, Failure Management Case #2 for all other cases.

For each applicable system failure condition, and based on the agreed task analysis framework, the applicant should provide the full set of information described in Table 1.

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

| **Task Analysis Model** | **Failure case#1:**<br>Explicit alert from the Crew Alerting System (CAS) unambiguously pointing to the primary failure | **Failure case#2:**<br>Set of heterogeneous symptoms:<br>– Primary failure observable indication<br>– Multiple secondary indications<br>– Other observable Flight deck effects<br>– Aircraft physical feedback |
|---|---|---|
| **1. Stimulus**<br>(occurrence of the failure condition) | Which of the two cases characterize the FHA?<br>Note: It can be a combination of both cases. | |
| **2. Perception**<br>(by the flight crew of flight deck effects) | - Does the failure require immediate crew awareness?<br>- Does the failure require immediate crew response?<br>- What is the classification of the alert used to inform the crew of the failure?<br>- How does the alert appear (location of the visual cues, number of modalities used, graphical and/or aural attributes and characteristics)?<br>- What is the maximum period of time within which the crew is assumed to detect the alert? | - What is the **primary failure** and how is it observable by the flight crew?<br>- What is the comprehensive list of secondary failures that are triggered?<br>- How are all the secondary failures presented?<br>- What is the comprehensive list of additional observable flight deck effects?<br>- What are the associated aircraft physical feedback?<br>- In which order do all those effects appear? |
| **3. Information processing**<br>(by the flight crew) | Not applicable since the crew is expected to directly go from the alert to the procedure. | - What is the description of the reasoning assumed to allow the crew to establish the failure condition diagnosis?<br>- How is the crew assumed to prioritize the secondary effects to be dealt with?<br>- 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?<br>- Which memory items are assumed to be used, if any?<br>- Which procedure(s) is (are) assumed to be used?<br>- Is the flight crew expected to use basic airmanship? | - What is the sequence of actions the flight crew is assumed to accomplish? The kind of action, the relevant means (i.e. controls and information) as well as the order needs to be described in the sequence of actions.<br>- What are the temporal constraints if any?<br>- Which memory items are assumed to be used, if any? |
| **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.)?<br>– What are the operational limitations to be respected due to the failure?<br>– Are there any procedural deferred items?<br>– What are the means to make the crew aware of the system status, operational limitation, and procedural deferred items?<br>– What are the actions the flight crew is obliged to accomplish manually due to the failure?<br>– Does the post failure situation imply unusual workload?<br>– Does the post failure situation imply unusual concentration?<br>– Does the post failure situation imply application of unusual force on the flight controls? | |

## 3.2. Process Considerations

The applicant should describe the process used to manage the assumptions in general and consider in particular the validation and verification (as required) 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 demonstrate (verify) the validity of assumptions about flight crew behaviour in FHAs. Therefore, the applicant should implement a process to ensure that the assumptions about crew behaviour are properly validated and verified. At least the following elements should be identified and documented:

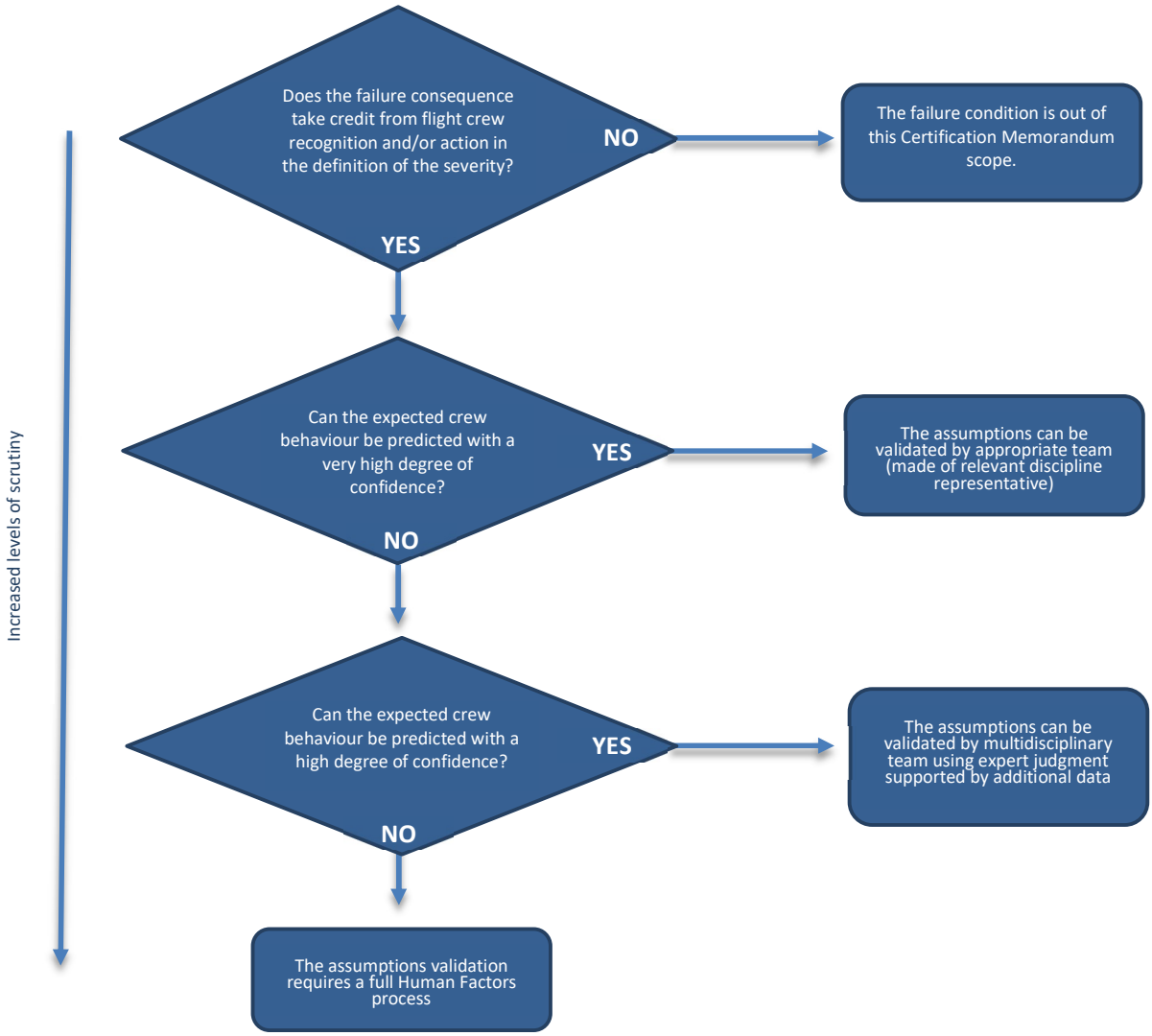
- the available means (engineering benches, engineering simulators, full flight simulators, aircraft),
- the methods used (engineering judgement, flight test pilot evaluation, human factors assessments, scenario-based evaluations, etc.)
- the criteria used to decide what are the most suitable means and methods to address the HF considerations of FHAs.

The process should describe the level of scrutiny to be applied when validating and verifying an assumption, as well as the criteria used for its establishment. This approach should be considered during all systems certification plans and the System Safety Assessment (SSA) reviews utilizing multi-disciplinary teams (e.g. Engineering, Flight Test and HF).

**Relevant information about the means and methods selected to assess, to justify, and to verify the assumptions about flight crew behaviours, for each applicable system failure condition should be included and 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. It is expected that any categorisation process is adequately documented and presented, and that the outputs of this process are provided to the authority. EASA considers that the process presented in figure 01 provides an acceptable approach.
The following activities are meant to be run by a multidisciplinary team consisting of test pilots, HF specialists, safety specialists and panel experts.

***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.

***Table 2:*** *Recommended methods, means and deliverables*

| CONFIDENCE DEGREE | METHODS | MEANS | DELIVERABLES |
|---|---|---|---|
| **Very high degree of confidence** | Expert judgement only | Appropriate team made of relevant discipline representative. | Summary of cases supported by applicable evidence. |
| **High degree of confidence** | Expert judgement supported by additional data | HF analysis, mock-up, bench or simulator review | Analyses or Review Reports |
| **All other cases** | Full Human Factors process | Complex tools and methods (simulator, aircraft, scenario-based approach) in addition to analysis and engineering judgement. | Test plans and Reports |

The scenario-based approach is based on a methodology that involves a sample of various crews, who are representative of the future users, being exposed to realistic operational scenarios in a test bench or a simulator, or in the 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 the 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.

Allowing for the Agency to assess the approach, a failure condition sample selected by the applicant is to be agreed with the EASA. The Agency reserves the right to increase its involvement in the oversight of human factor aspects.

## 3.3. Traceability

The expected flight crew behaviour must be documented as an assumption as part of the safety assessment process. A process must be defined to validate these assumptions. The applicants should describe in an aircraft-level document, the process that will be used to ensure the traceability of assumptions (to an AFM procedure for instance) and provide a statement that all assumptions have been validated and/or verified prior to submit the final safety assessments.

# 4. Who this Certification Memorandum affects

The guidance in this Certification Memorandum affects applicants showing compliance with CS 25.1309 and CS 25.1302 for certification of a new type design, significant major changes (or STCs) to a type design or any major change that introduces new failure conditions or significantly affects existing failure conditions (change in cockpit effects or in assumed pilot reaction) on Large Aeroplanes. The application will be discussed on project level on a case-by-case basis.

## 5. Remarks

1. This EASA Proposed Certification Memorandum will be closed for public consultation on the **14th April 2022**. Comments received after the indicated closing date for consultation might not be taken into account.
2. Suggestions for amendment(s) to this EASA Certification Memorandum should be referred to the Policy, Innovation, and Knowledge Department, Certification Directorate, EASA. E-mail CM@easa.europa.eu.
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