European Union Aviation Safety Agency

Notice of Proposed Amendment 2019-11

Human factors in rotorcraft design

RMT.0713

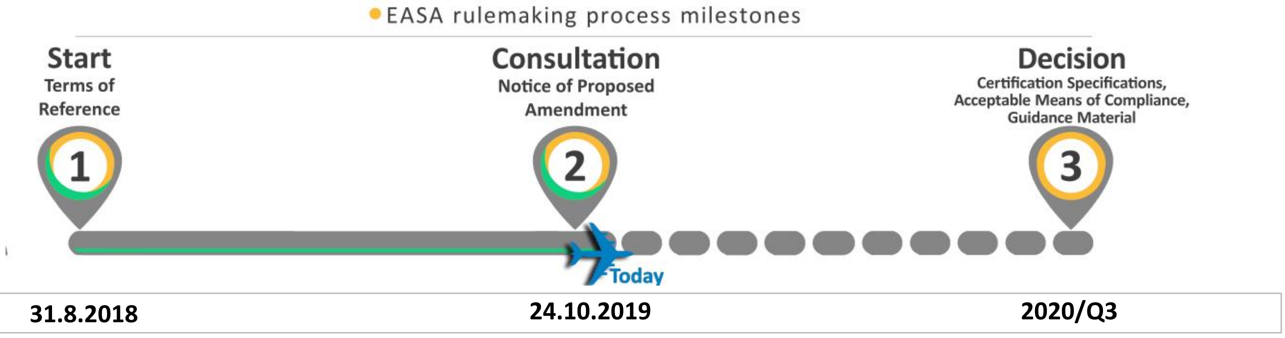
EXECUTIVE SUMMARY

The objective of this rulemaking task is to reduce the risk of design-related human factors (HFs) errors that may lead or contribute to an accident or incident.

This Notice of Proposed Amendment (NPA) proposes to introduce specific provisions into the rotorcraft certification specifications (CSs) to ensure that HFs are systematically taken into account during the design and certification processes of rotorcraft cockpits.

The proposed amendments are expected to moderately increase safety, as compliance with the new CSs is expected to reduce the probability of HFs and pilot workload issues that could lead to an accident or incident.

Action area:	Rotorcraft operations; human factors (HFs)		
Affected rules:	CS-27; CS-29		
Affected stakeholders:	Design approval holders (DAHs)		
Driver:	Safety	**Rulemaking group:**	No
Impact assessment:	Light	**Rulemaking Procedure:**	Standard



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1 About this NPA

1.1 How this NPA was developed

The European Union Aviation Safety Agency (EASA) developed this NPA in line with Regulation (EU) 2018/1139[1] (the 'Basic Regulation') and the Rulemaking Procedure[2]. This rulemaking activity is included in the European Plan for Aviation Safety (EPAS) 2019–2023 under rulemaking task (RMT).0713. The text of this NPA has been developed by EASA, and a preliminary consultation with the most affected stakeholders was performed during a dedicated workshop in March 2019. It is hereby submitted to all interested parties for consultation[3].

1.2 How to comment on this NPA

Please submit your comments using the automated **Comment-Response Tool (CRT)** available at **http://hub.easa.europa.eu/crt/**[4].

The deadline for submission of comments is **8 January 2020**.

1.3 The next steps

Following the closing of the public commenting period, EASA will review all the comments.

Based on the comments received, EASA may develop a decision that amends CS-27 and CS-29.

The comments received and the EASA responses to them will be reflected in a comment-response document (CRD), which will be published on the EASA website[5].

[1] Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91 (OJ L 212, 22.8.2018, p. 1) (https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1535612134845&uri=CELEX:32018R1139).

[2] EASA is bound to follow a structured rulemaking process as required by Article 115(1) of Regulation (EU) 2018/1139. Such a process has been adopted by the EASA Management Board (MB) and is referred to as the 'Rulemaking Procedure'. See MB Decision No 18-2015 of 15 December 2015 replacing Decision 01/2012 concerning the procedure to be applied by EASA for the issuing of opinions, certification specifications and guidance material (http://www.easa.europa.eu/the-agency/management-board/decisions/easa-mb-decision-18-2015-rulemaking-procedure).

[3] In accordance with Article 115 of Regulation (EU) 2018/1139, and Articles 6(3) and 7 of the Rulemaking Procedure.

[4] In the case of technical problems, please contact the CRT webmaster (crt@easa.europa.eu).

[5] https://www.easa.europa.eu/document-library/comment-response-documents

2 In summary — why and what

2.1 Why we need to change the rules — issue/rationale

Human factors (HFs) may contribute either directly or indirectly to aircraft accidents and incidents. Already today, the design of a cockpit and its systems can strongly influence the performance of the crew and the potential for crew errors. Currently, the certification specifications (CSs) for rotorcraft do not contain any specific provisions for a HFs assessment of the design of the cockpit and the associated systems, while such provisions were introduced into the Certification Specifications for Large Aeroplanes (CS-25) 12 years ago.

Additionally, new generations of rotorcraft are characterised by having a high level of integration of cockpit equipment, displays, controls and automation. It is also likely that future rotorcraft projects, embodying, for instance, fly-by-wire technology flight controls that include enhanced piloting control laws, will pose new and additional challenges from a HFs perspective.

2.2 What we want to achieve — objectives

The overall objectives of the EASA system are defined in Article 1 of the Basic Regulation. This proposal will contribute to the achievement of the overall objectives by addressing the issues outlined in Section 2.1.

The specific objective of this proposal is to ensure that HFs are systematically taken into account during the design and the certification processes of rotorcraft cockpits.

The availability of CSs for HFs in the designs of new rotorcraft cockpits is expected to reduce the probability of HFs and pilot workload issues that could lead to an accident or incident.

2.3 How we want to achieve it — overview of the proposals

This NPA proposes to amend CS-29 and CS-27 by introducing:

— a new point 27/29.1302 covering specifications for a HFs assessment of an entire cockpit environment, and

— acceptable means of compliance (AMC) and guidance material (GM) containing explanations and guidance to support compliance with point 27/29.1302.

These have been drafted starting from the existing CS 25.1302 and the associated AMC 25.1302. Although derived from large aeroplanes, the HFs principles applied to cockpit and system designs have been found to be relevant to all aircraft types, including the new generation of complex rotorcraft.

While the draft text of CS 27/29.1302 is substantially identical to the text of CS 25.1302, AMC 25.1302 has been significantly restructured and reworded in order to adapt it to the different kinds of missions and the related operational scenarios which could be performed by rotorcraft. Additionally, some improvements and clarifications have been introduced on the basis of the experience and lessons learned during the latest certification projects of large aeroplanes.

The main differences between AMC 25.1302 and AMC 27/29.1302 are listed hereafter:

— The existing material has been restructured. All the informative elements and some explanatory material have been moved to the new GM No 1 to 27/29.1302;

— Several clarifications have been made throughout the text;

— Simplifications for the demonstration of compliance of certain types of rotorcraft, and related changes, have been added to the applicability (refer to paragraph 1.3);

— A new figure has been introduced to show the methodological approach to certification for design related to human performance issues (refer to paragraph 3.1);

— The new level of involvement (LoI) concept (refer to points 21.A.15(b)(5) and (6) and similar points of Part 21) has been reflected wherever the involvement of EASA was described;

— The certification strategy has been clarified and expanded (refer to paragraph 3.3.1); and

— The scenario-based approach has been described (refer to paragraph 3.3.2).

As a result, the proposed AMC 27/29.1302 provides a more streamlined approach towards the demonstration of compliance with CS 27/29.1302.

A practical example of the minimum information which should be included in the compliance matrix related to CS 27/29.1302 is provided in new GM No 2 to 27/29.1302.

2.3.1 Proportionate implementation

The purpose of this rulemaking task is to deliver an effective and proportionate set of amendments to CS-27/29 that address HFs in rotorcraft designs.

The first level of proportionality is, de facto, embedded in the process itself because the level of scrutiny is determined by assessing the novelty, complexity and level of system integration. Therefore, the demonstration of compliance with CS 27/29.1302 for simple rotorcraft, or for simple changes to rotorcraft, will trigger a low level of scrutiny.

Additionally, some simplifications have been introduced into the applicability paragraph of AMC 29.1302 and 27.1302 to facilitate the demonstration of compliance for simpler rotorcraft and for non-significant changes.

2.4 What are the expected benefits and drawbacks of the proposals

Safety impacts

The design and certification phases of a new or modified rotorcraft are the most appropriate times to address the effects of crew workstation features and characteristics on the performance of the crew, and to tackle any shortfalls that have the potential to induce errors or poor performance.

Regarding those accidents or incidents for which HFs shortfalls in the design of rotorcraft were considered to be the root cause, it is expected that the proposed new certification specifications (CSs) will help to significantly reduce the probability of such accidents occurring. The new CSs will also provide a better tool and basis for design organisations and EASA to deal with the increased level of complexity and integration that is expected in rotorcraft in the years to come.

For other accidents or incidents, for which HFs shortfalls in the design of rotorcraft have been identified as a contributing factor, it is expected that there will be a significant positive impact on safety. In fact, an improved crew workstation design that is optimised for HFs will contribute to reducing the crew’s workload and increasing the crew’s situational awareness. It is qualitatively estimated that these benefits could reduce the number of incidents and accidents by between 10 and 20 %.

Considering the above, an appreciable safety benefit is expected from the introduction of new CSs in comparison with the current situation.

Economic impacts

The introduction of new CSs will contribute to improving the efficiency of the certification process. A structured approach will be available upfront, with no need to adapt the existing CS-25 material through the issuance of project-related certification review items (CRIs), as has been the case for recent CS-29 large rotorcraft projects.

The introduction of new CSs for HFs assessments is not expected to significantly increase the costs for the industry due to the fact that HFs assessments have already been performed for the most recent rotorcraft certification projects, based on the project-related CRIs. The availability of CSs for HFs from the start of the certification process may even save costs. This is due to the fact that the applicant will clearly be aware upfront of what is required to certify the aircraft. The applicant may, therefore, be able to better plan the certification project, and discussions with EASA may be eased.

Where project-related CRIs have not been systematically issued in the past, e.g. for some CS-27 small rotorcraft, there may be an impact on cost. The increased costs for these aircraft may, however, easily outweigh the risk of certifying them with unidentified HFs issues. If such HFs issues are discovered during operation, they may require a very expensive redesign of the rotorcraft. In order to limit potential additional costs, in this NPA, EASA proposes a proportionate approach for the application of CS 27.1302. For the simplest cases, an assessment carried out by DOA test pilots may be acceptable. This means that flights made during the development and certification phases for other areas of investigation can be given credit for demonstrating compliance with CS 27.1302. Refer also to Section 2.3.1 above.

Conclusion

The proposed amendments are expected to provide an appreciable safety benefit, would have no social or environmental impacts, would have a slight impact on certification costs, and would streamline the certification process.

3 Proposed amendments

The text of the amendment is arranged to show deleted text, new or amended text as shown below:

— deleted text is ~~struck through~~;

— new or amended text is highlighted in blue;

— an ellipsis '[…]' indicates that the rest of the text is unchanged.

3.1 Draft certification specifications (draft EASA Decision)

CS 29.1302 Installed systems and equipment for use by the crew

(See AMC 29.1302, GM No 1 and No 2 to 29.1302)

This point applies to installed equipment intended for use by crew members in the operation of the rotorcraft from their normal seating positions in the cockpit or operating positions in the cabin. This installed equipment must be shown, individually and in combination with other such equipment, to be designed so that trained crew members can safely perform their tasks associated with the intended function of the equipment by meeting the following requirements:

(a) All the controls and information necessary to accomplish these tasks must be provided;

(b) All the controls and information required by paragraph (a), which are intended for use by the crew, must:

(1) be presented in a clear and unambiguous form, at a resolution and with a precision appropriate to the task;

(2) be accessible and usable by the crew in a manner consistent with the urgency, frequency, and duration of their tasks; and

(3) make the crew aware of the effects that their actions may have on the rotorcraft or systems, if they need awareness for safe operation.

(c) Operationally relevant behaviour of the installed equipment must be:

(1) predictable and unambiguous; and

(2) designed to enable the crew to intervene in a manner appropriate to accomplish the task.

(d) Installed equipment must enable the crew to manage the errors resulting from the kinds of crew interactions with the equipment that can be reasonably expected in service, assuming the crew is acting in good faith. Paragraph (d) does not apply to skill-related errors associated with the manual control of the rotorcraft.

AMC 29.1302 Installed systems and equipment for use by the crew

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1)_INTRODUCTION

1.1_Scope

Demonstrating compliance with design requirements that relate to human abilities and limitations is subject to a great deal of interpretation. Findings may vary depending on the novelty, complexity or degree of integration of the system design. EASA considers that describing a structured approach to selecting and developing acceptable means of compliance is useful in aiding standardised compliance demonstration practices.

1.2_Applicability

(a) This Acceptable Means of Compliance (AMC) provides means for demonstrating compliance with the requirements of CS 29.1302 and several other paragraphs in CS-29 (refer to paragraph 2, Table 1 of this AMC) that relate to the installed equipment used by the crew in the operation of a rotorcraft. In particular, this AMC addresses the design and approval of installed equipment that is intended for use by the crew members from their normal seating positions in the cockpit, or their normal operating positions in the cabin.

(b) This AMC applies to the crew interfaces and system behaviour for all the installed systems and equipment used by the crew in the cockpit and the cabin while operating the rotorcraft in normal, abnormal and emergency conditions. The functions of the crew members operating from the cabin need to be considered if they may interfere with the ones under the responsibility of the cockpit crew, or if dedicated airworthiness requirements are included in the rules.

(c) This AMC does not apply to crew training, qualification, or licensing requirements.

(d) The material contained in this AMC is expected to be used for new types and for changes to existing types, as follows:

  (1) Applicants for a CS-29 rotorcraft approved for CAT B and IFR operations, or CAT A, or for a significant change potentially affecting the HFs, should follow all this material.

  (2) Applicants for a CS-29 rotorcraft approved only for CAT B and VFR operations should follow the same criteria as those applicable to subparagraph (1) above. However, if the specific characteristics or the types of operations for which the rotorcraft is designed justify it, the applicant may propose to EASA the use of appropriate alleviations.

  (3) Applicants for a non-significant change (refer to classification in point 21.A.101 and the related GM) are:

    (i) not required to develop a dedicated HFs test programme (refer to paragraph 3.2.8(a)); and

    (ii) allowed to use single tests for compliance demonstration (refer to paragraph 3.3.1(b)).

1.3_Definitions

For the purposes of this AMC, the following definitions apply:

- **Alert**: A cockpit indication meant to attract the attention of the crew, and identify to them an operational or aircraft system condition. Warnings, cautions, and advisories are considered to be alerts. (For further information, refer to AMC 25.1322.)
- **Assessment**: The process of finding and interpreting evidence to be used by the applicant in order to establish compliance with a requirement. For the purpose of this AMC, the term 'assessment' can refer to both evaluations and tests. Evaluations are intended to be conducted using partially representative test means, whereas tests make use of conformed test articles.
- **Automation**: The autonomous execution of a task (or tasks) by aircraft systems started by a high-level control action of the crew.
- **Catachresis**: Applied to the area of tools, 'catachresis' means the use of a tool for a function other than the one planned by the designer of the tool. For instance, using a circuit breaker as a switch.
- **Clutter**: An excessive number and/or variety of symbols, colours, or other information that may reduce crew access and increase their interpretation time and the probability of interpretation error.
- **Cockpit**: The area of the aircraft where the crew members work and where all the controls are located. For the purpose of this AMC, the cockpit may include workstations located in the cabin and used by crew members to operate systems that are critical for safety (e.g. rescue hoist control stations, secondary crew stations, as those are used for precision hovering).
- **Conformity**: Official verification that the cockpit/system/product conforms to the type design data. Conformity of the facility is one parameter that distinguishes one means of compliance from another.
- **Cockpit controls**: Interaction with a control means that the crew manipulates it in order to operate, configure, and manage the aircraft or its flight control surfaces, systems, and other equipment.

  This may include equipment in the cockpit such as:

  - control devices,
  - buttons,
  - switches,
  - knobs,
  - flight controls, and
  - levers.
- **Control device**: A control device is a piece of equipment that allows the crew to interact with virtual controls, typically used with the graphical user interface. Control devices may include the following:
  - keyboards,
  - touchscreens,
  - cursor control devices (keypads, trackballs, pointing devices),

  - knobs, and
  - voice-activated controls.

- **Crew member**: A person involved in the operation of the aircraft and its systems. In the case of rotorcraft, operators in the cabin dedicated to operating the rescue hoist or to helping the crew to control the aircraft in a hover are considered to be crew members.
- **Cursor control device**: A control device for interacting with virtual controls, typically used with a graphical user interface on an electro-optical display.
- **Design eye reference point (DERP)**: A point in the cockpit that provides a finite reference enabling the precise determination of geometric entities that define the layout of the cockpit.
- **Design philosophy**: A high-level description of the human-centred design principles that guide the designer and aid in ensuring that a consistent, coherent user interface is presented to the crew.
- **Design-related human performance issue**: A deficiency resulting from the interaction between the crew and the system. It includes human errors, but also encompasses other kinds of shortcomings such as hesitation, doubt, difficulty in finding information, suboptimal strategies, inappropriate levels of workload, or any other observable item that cannot be considered to be a human error, but still reveals a design-related concern.
- **Display**: A device (typically visual, but it may be accompanied by auditory or tactile feedback) that transmits data or information from the aircraft to the crew.
- **Human error**: A deviation, attributable to the crew, from what is considered correct in some context, especially in the 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.
- **Multifunction control**: A control device that can be used for many functions, as opposed to a control device with a single dedicated function.
- **Abnormal or emergency conditions**: For the purpose of this AMC, abnormal or emergency operating conditions refer to conditions that do require the crew to apply procedures different from the normal procedures included in the rotorcraft flight manual.
- **System function allocation**: A human factors (HFs) method for deciding whether a particular function will be accomplished by a person, technology (hardware or software) or some mix of a person and technology (also referred to as ‘task allocation’).
- **Task analysis**: A formal analytical method used to describe the nature and relationships of complex tasks involving a human operator.

1.4_Abbreviations

For the purposes of this AMC, the following abbreviations apply:

AC	advisory circular
AMC	acceptable means of compliance
CSs	certification specifications
DoT	Department of Transportation
EASA	European Union Aviation Safety Agency
FAA	Federal Aviation Administration
HFs	human factors
ICAO	International Civil Aviation Organization
ISO	International Standards Organization
LoI	level of involvement
MC	means of compliance
RFM	rotorcraft flight manual
SAE	Society of Automotive Engineers
STC	supplemental type certificate
TAWS	terrain awareness warning system
TCAS	traffic collision avoidance system
TSO	technical standard order
VOR	very high frequency omnidirectional range

2)_RELATION BETWEEN CS 29.1302 AND OTHER REQUIREMENTS, AND ASSUMPTIONS

2.1_The relation of CS 29.1302 to other requirements

(a) This AMC provides guidance for demonstrating compliance with CS 29.1302 and the guidance related to several other requirements associated with the installed equipment that the crew uses in operating the rotorcraft. Table 1 below contains a list of the requirements related to cockpit design and crew interfaces for which this AMC provides guidance. Note that this AMC does not provide a comprehensive means of compliance for any of the requirements beyond CS 29.1302.

(b) CS-29 Book 2 establishes that the guidance material for CS-29 is included in the revision of FAA AC 29-2 adopted by EASA with the changes/additions included within Book 2. AC 29-2 includes Miscellaneous Guidance MG-20 'Human Factors' that provides dedicated guidance material for all the human-factors-related paragraphs, but does not include specific guidance for 29.1302. Therefore, adherence to the guidance material included within AC 29-2 and the associated MG-20 is not considered sufficient to demonstrate compliance with CS 29.1302, for which this material provides additional guidance.

CS-29 BOOK 1 requirements	***General topic***	***Referenced material in this AMC***
CS 29.771(a)	Unreasonable concentration or fatigue	Error, 4.5. Integration, 4.6. Controls, 4.2. System behaviour, 4.4.
CS 29.771(b)	Controllable from either pilot seat	Controls, 4.2. Integration, 4.6.
CS 29.773	Pilot compartment view	Integration, 4.6.
CS 29.777(a)	Convenient operation of the controls	Controls, 4.2. Integration, 4.6.
CS 29.777(b)	Fully and unrestricted movement	Controls, 4.2. Integration, 4.6.
CS 29.779	Motion and effect of cockpit controls	Controls, 4.2
CS 29.1301(a)	Intended function of installed systems	Error, 4.5. Integration, 4.6. Controls, 4.2. Presentation of information, 4.3. System behaviour, 4.4.
CS 29.1302	Crew error	Error, 4.5. Integration, 4.6. Controls, 4.2. Presentation of information, 4.3. System behaviour, 4.4.
CS 29.1309(a)	Intended function of required equipment under all operating conditions	Controls, 4.2. Integration, 4.6.

CS-29 BOOK 1 requirements	***General topic***	***Referenced material in this AMC***
CS 29.1309(c)	Unsafe system operating conditions and minimising crew errors which could create additional hazards	Presentation of information, 4.3. Errors, 4.5.
CS 29.1321	Visibility of instruments	Integration, 4.6.
CS 29.1322	Warning caution and advisory lights	Integration, 4.6.
CS 29.1329 and Appendix B VII	Automatic pilot system	System behaviour, 4.4.
CS 29.1335	Flight director systems	System behaviour, 4.4
CS 29.1523	Minimum crew	Controls, 4.2. Integration, 4.6.
CS 29.1543(b)	Visibility of instrument markings	Presentation of information, 4.3.
CS 29.1549	Powerplant instruments	Presentation of information, 4.3
CS 29.1555 (a)	Control markings	Controls, 4.2.
CS 29.1557	Miscellaneous marking and placards	Presentation of information, 4.3

Paragraph 2 — Table 1: Requirements relevant to this AMC

(c) Where means of compliance in other AMC are provided for specific equipment and systems, those means are assumed to take precedence if a conflict exists with the means provided here.

2.2_Crew capabilities

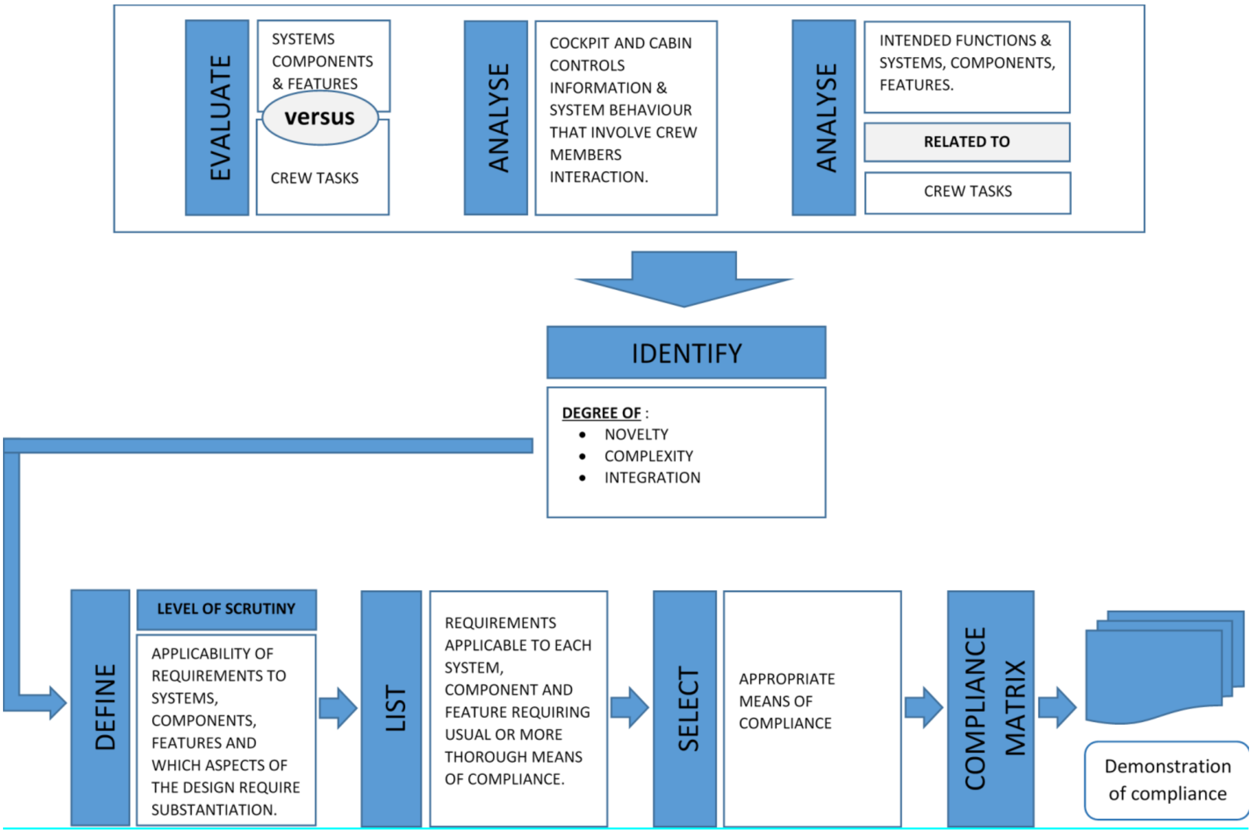
In order to demonstrate compliance with all the requirements referenced by this AMC, all the certification activities should be based on the assumption that the rotorcraft will be operated by qualified crew members who are trained in the use of the installed equipment.

3)_HUMAN FACTORS CERTIFICATION

3.1_Overview

(a) This paragraph provides an overview of the human factors certification process that is necessary to demonstrate compliance with CS 29.1302. This includes a description of the recommended applicant activities, the communication between the applicant and EASA, and the expected deliverables.

(b) Figure 1 illustrates the main steps in the human factors certification process.



Paragraph 3 — Figure 1: Methodical approach to certification for design-related human performance issues

3.2_Certification steps and deliverables

3.2.1_Identification of the cockpit controls, information and systems that involve crew interaction

(a) As an initial step, the applicant should consider the entire cockpit or the modification introduced into it with the aim of identifying the controls, information and system behaviour that involve crew interaction.

(b) The objective is to analyse and document the crew tasks to be performed in the cockpit, or how crew tasks might be changed or modified as a result of introducing a new system(s), component(s) or feature(s) into an existing cockpit.

(c) Rotorcraft can be operated in different environments and types of missions. Therefore, while mapping the entire cockpit and cabin or the modified one against the tasks of the crew and the intended functions of the rotorcraft and systems, the type of approval envisaged for the rotorcraft under assessment should be considered and documented. For instance, approvals for:

— VFR,

— IFR,

— NVIS,

— SAR,

— aerial work (cargo hook or rescue hoist), or

— flight in known icing conditions

require different equipment to be installed or a different use of the same equipment. Therefore, the applicant should clarify the assumptions made when the assessment of the cockpit and cabin functions is carried out.

3.2.2_The intended function of equipment and the associated crew tasks

(a) CS 29.1301(a) requires that 'each item of installed equipment must be of a kind and design appropriate to its intended function'. CS 29.1302 establishes requirements to ensure that the design supports the ability of the crew members to perform the tasks associated with the intended function of a system. In order to demonstrate compliance with CS 29.1302, the intended function of a system and the tasks expected of the crew must be known.

(b) An applicant's statement of the intended function should be sufficiently specific and detailed so that EASA can evaluate whether the system is appropriate for the intended function(s) and the associated crew tasks. For example, a statement that a new display system is intended to 'enhance situational awareness' should be further explained. A wide variety of different displays enhance situational awareness in different ways. Some examples are terrain awareness, vertical profiles, and even the primary flight displays. The applicant may need to provide more detailed descriptions for designs with greater levels of novelty, complexity, or integration.

(c) An applicant should describe the intended function(s) and associated task(s) for:

(1) each item of the cockpit equipment,

(2) crew indications and controls for that equipment, and

(3) the prominent characteristics of those indications and controls.

This type of information is of the level typically provided in a pilot's handbook or an operations manual. It would describe the indications, controls, and crew procedures.

(d) As discussed later in paragraph 3.2.3, novel features may require more detail, while previously approved systems and features typically require less detail. Paragraph 3.2.4 discusses functions that are sufficiently novel and additional scrutiny is required. Applicants may evaluate whether statements of the intended function(s) and the associated task(s) are sufficiently specific and detailed by using the following questions:

(1) Does each feature and function have a stated intent?

(2) Are the crew tasks associated with the function described?

(3) What assessments, decisions, and actions are crew members expected to make based on the information provided by the system?

(4) What other information is assumed to be used in combination with the system?

(5) Will the installation or use of the system interfere with the ability of the crew to operate other cockpit systems?

(6) Are any assumptions made about the operational environment in which the equipment will be used?

(7) What assumptions are made about the attributes or abilities of the crew beyond those required in the regulations governing flight operations, training, or qualification?

(e) The output of this step is a list of items, with each of the associated intended functions that has been related to the crew tasks.

3.2.3_Determining the level of scrutiny

(a) The depth and extent of the human factors investigation to be performed in order to demonstrate compliance with CS 29.1302 is driven by the level of scrutiny.

The level of scrutiny is determined by analysing the cockpit features and items using the criteria described in the following subparagraph:

(1) **Integration**. In this document, the term 'level of systems' integration' refers to the extent to which there are interdependencies between the systems that affect the crew's operation of the rotorcraft. The applicant should describe the integration between systems because it may affect the means of compliance. Paragraph 4.6 also refers to integration. In the context of that paragraph, 'integration' defines how specific systems are integrated into the cockpit and how the level of integration may affect the means of compliance.

(2) **Complexity**. The complexity of the system design from the crew's perspective is an important factor that may also affect the means of compliance in this process. Complexity has multiple dimensions, for instance:

— the number, the accessibility and level of integration of information that the crew has to use (the number of items of information on a display, the number of colours), alerts, or voice messages may be an indication of the complexity;

— the number, the location and the design of the cockpit controls associated with each system and the logic associated with each of the controls; and

— the number of steps required to perform a task, and the complexity of the workflows.

(3) **Novelty.** The applicant should identify any design novelty based on the following factors:

(i) Are any new functions introduced into the cockpit design?

(ii) Are any new technologies introduced that operate in new ways for either established or new cockpit designs?

(iii) Are any unusual or additional operational procedures needed as a result of the introduction of new technologies?

(iv) Does the design introduce a new way for the crew to interact with the systems using either conventional or innovative technology?

(v) Does the design introduce new uses for existing systems that change the tasks or responsibilities of the crew?

A function or system that the applicant chooses to refer to as a baseline from which the novelty is derived needs to have been certified by the applicant under CS 29.1302.

One positive answer to any of the above questions is sufficient to trigger the novelty criterion.

(b) If at least one of the above criteria is met, the related item should be included by the applicant in the list of candidate items to be scrutinised, and it should be proposed to EASA.

(c) The level of scrutiny performed by the applicant should be proportionate to the number of the above criteria which are met by each item. Applicants should be aware that the impact of a complex feature might also be affected by its novelty and the extent of its integration with other elements of the cockpit. For example, a complex but not novel feature is likely to require a lower level of scrutiny than one that is both complex and novel.

3.2.4_Determination of the list of items requiring extra scrutiny

EASA will review the applicant's proposal with a view to reaching an agreement on the list of items that require a higher level of scrutiny. The assessment of the classifications proposed by the applicant requires the EASA Flight and HF panels to be familiarised with the cockpit, making use of the available material and tools.

Irrespective of the above, the EASA involvement in the verification of compliance demonstration of the subsequent steps of the human factors process will depend on the LoI determined by EASA in accordance with point 21.B.100 of Part 21.

3.2.5_Applicable human factors design requirements

(a) The applicant should identify the human factors (HFs) design requirements applicable to each of the systems, components, and features for which compliance must be demonstrated. This may be accomplished by identifying any design characteristics that could adversely affect the performance of the crew, or that pertain to the avoidance and management of crew errors.

(b) Specific design considerations for the requirements that involve human performance are discussed in paragraph 4. The applicability of each design consideration in paragraph 4 will depend on the design characteristics identified in paragraph 3.2.3.

(c) The expected output of this step is a compliance matrix that links the design features and the HFs design requirements that are deemed to be relevant and applicable for each design feature, so that a detailed assessment objective can be derived from each pair of a design feature and an HFs design requirement. That objective will have then to be verified using the most adequate means of compliance, or a combination of means of compliance.

(d) GM No 2 to 29.1302 provides one possible example of this matrix.

3.2.6_Selecting the appropriate means of compliance

(a) After identifying what should be shown in order to demonstrate compliance, the applicant should review paragraph 5.2 for guidance on selecting the means of compliance, or multiple means of compliance, appropriate to the design. In general, it is expected that the level of scrutiny should increase with higher levels of novelty, complexity, criticality or integration of the design. It is also expected that the amount of effort dedicated to the demonstration of compliance should increase with higher levels of scrutiny (e.g. by using multiple means of compliance and/or multiple HFs assessments on the same topic).

(b) The output of this step will consist of the list of means of compliance that will be used to verify the HFs objectives.

3.2.7_Certification programme

(a) The applicant should document the certification process, outputs and agreements described in the previous paragraphs. This may be done in a separate plan or incorporated into a higher-level certification programme.

(b) Additionally, for each assessment or inspection listed in the certification programme and included in the EASA level of involvement (LoI), the related scheduling should be provided to EASA for acceptance.

3.2.8_Other deliverables

(a) An HFs test programme should be produced for each assessment and should describe the experimental protocol (the number of scenarios, the number and profiles of the crews, practical organisation of the assessment, etc.), the HFs objectives that are meant to be addressed, the expected crew behaviours, and the scenarios expected to be run. When required by the LoI, the HFs test programme should be provided well in advance to EASA.

(b) An HFs test report should be produced including at least the following information:

(1) A summary of the:

(i) test vehicle configuration,

(ii) test vehicle limitations/representativeness,

(iii) detailed HFs objectives, and

(iv) HFs test protocol, including the number of sessions and crews, type of crews (test or operational pilots from the applicant, authority pilots, airline pilots), a description of the scenarios, the organisation of the session (training, briefing, assessment, debriefing), and the observers;

(2) A description of the data gathered related to every HFs objective;

(3) In-depth analyses of the observed HFs issues;

(4) Conclusions regarding the related HFs test objective; and

(5) If applicable, a description of the proposed way to mitigate the HFs issue (by a design modification, improvements in procedures, and/or training actions).

If EASA has retained the review of the test report as part of its LoI, then the applicant should deliver it following every HFs assessment.

3.3_Certification strategy and methodologies

3.3.1_Certification strategy

(a) The HFs assessment should follow an iterative process. Consequently, where appropriate, there may be several iterations of a same system-specific assessment allowing the applicant to reassess the system if the previous campaigns resulted in design modifications.

(b) An HFs certification strategy based only on one test, aimed at demonstrating that the design assumptions are valid, is generally not acceptable (i.e. one final exercise proposed for compliance demonstration at the very end of the process).

(c) Since the beginning of the certification process, EASA has to be able to monitor the development process through familiarisation sessions, regular witnessing of the HFs at the system-level and rotorcraft-level assessments, and reviews of test plans and test reports for assessments that will support the determination of the EASA LoI. Both parties may find an interest in this method, as the authority is continuously gaining experience and confidence in the HFs process and the compliance of the cockpit design. The applicant may be granted partial early certification credit, leading to a proper mitigation of the certification risk. Additionally, potential issues may be identified early on by using this approach, thus reducing the risk of a late redesign of features that may not be acceptable to EASA.

This paragraph may not apply in cases of simple changes.

(d) The representativeness of the systems and of the simulation means in the early stages of the development is not a key driver, and will not prevent EASA's involvement as long as the representativeness issues do not compromise the validity of the data to be collected.

(e) If an applicant plans to use data provided by a supplier for compliance demonstration, the approach and the criteria for accepting that data will have to be shared and agreed with EASA as part of the HFs certification plan.

3.3.2_Methodological considerations applicable to HFs assessments

Various means of compliance may be selected, as described in paragraph 5.
For the highest level of scrutiny, the 'scenario-based' approach is likely to be the most appropriate methodology for some means of compliance.

The purpose of the following points is to provide guidelines on how to implement the scenario-based approach.

(a) The scenario-based approach is intended to substantiate the compliance of human–machine interfaces. It is based on a methodology that involves a sample of various crews, who are representative of the future users, being exposed to realistic operational conditions in a test bench or a simulator, or in the rotorcraft. 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. The scenario designers can make use of triggering events or conditions (e.g. a system failure, an ATC request, weather conditions, etc.) in order to build operational situations that are likely to trigger observable crew errors, difficulties or misunderstandings. The scenarios need to be well consolidated before the test campaign begins. EASA recommends in that respect that dry-run sessions should be performed by the applicant before any HFs campaign in order to validate the operational relevance of the scenarios. This approach should be used for both system- and rotorcraft-level assessments.

(b) System-level assessments focus on a specific system/function/feature and are intended for an in-depth assessment of the related functional and operational aspects, including all the operational procedures. The representativeness of the test article is to be evaluated taking into account the scope of the assessment. Rotorcraft-level assessments consider the scope of the full cockpit, and focus on integration and interdependence issues.

(c) The scenarios are expected to cover a subset of the detailed HFs test objectives. The link between each scenario and the test objectives should be made obvious to EASA. This rationale should be described in the test plan or in any other relevant document, and is subject to comments from EASA.

(d) The criteria to select the crews involved in the HFs assessments should be presented to EASA for acceptance.

(e) Due to interindividual variability, HFs scenario-based assessments performed with a single crew are not acceptable. The usually accepted number of different crews used for a given campaign varies from three to five, including the authority crew, if applicable. In the case of a crew of two with HFs objectives focused on the duties of only one of the crew members, it is fully acceptable for the applicant to use the same pilot flying or monitoring (the one who is not expected to produce any HFs data) throughout the campaign.

(f) In addition to the test report, and in order to reduce the certification risk, it is recommended that the preliminary analyses resulting from recorded observations and comments should be presented by the applicant to EASA soon after the simulator/flight sessions in order to allow expert discussions to take place.

(g) An initial briefing should be given to the crew at the beginning of each session to present the following general information:

(1) Detailed schedule describing the type and duration of the activities (the duration of the session, the organisation of briefing and debriefings, breaks, etc.);

(2) What is expected from the crew: it has to be clearly mentioned that the purpose of the assessment is to assess the design of the cockpit, not the performance of the pilot;

(3) The policy for simulator occupancy: how many people should be in the simulator versus the number of people in the control room, and who they should be; and

(4) The roles of the crews: if crews from the applicant participate in the assessment, they should be made aware that their role differs significantly from their classic expert pilot role in the development process. For the process to be valid without significant bias, they are expected to react and behave in the cockpit as standard operational pilots.

(5) However, the crew that participate in the assessment should not be:

(i) briefed in advance about the details of the failures and events to be simulated; this is to avoid an obvious risk of experimental bias; nor

(ii) asked before the assessment for their opinion about the scenarios to be flown.

(h) The crews need to be properly trained prior to every assessment so that during the analysis, the 'lack of training' factor can be excluded to the maximum extent possible from the set of potential causes of any observed human performance issue. Furthermore, for operational representativeness purposes, realistic crew task sharing, from normal to emergency workflows and checklists, should be respected during HFs assessments. The applicant should make available any draft or final rotorcraft flight manual (RFM), procedures and checklists sufficiently in advance for the crew to prepare.

(i) When using simulation, the immersion feeling of crews should be maximised in order to increase the validity of the data. This generally leads to recommendations about a sterile environment (with no outside noise or visual perturbation), no intervention by observers, no interruptions in the scenarios unless required by the nature of the objectives, realistic simulation of ATC communications, pilots wearing headsets, etc.

(j) The method used to collect HFs data needs to take into account the following principles:

(1) The observables should not be limited to human errors, but should also include pilots' verbalisations in addition to behavioural indicators such as hesitation, suboptimal or unexpected strategies, catachresis, etc.

(2) The primary means of collecting data should be direct observation (including videos). Other tools such as questionnaires and rating scales should be used as complementary means only. In any case, it is not adequate to merely rely on self-administrated questionnaires.

(3) It is very important to conduct debriefings after HFs assessments. They allow the applicant's HFs observers to gather all the necessary data that has to be used in the subsequent HFs analyses.

(4) HFs observers should respect the best practices with regard to observation and debriefing techniques.

(5) Debriefings should be based on non-directive or semidirective interviewing techniques and should avoid the experimental biases that are well described in the literature in the field of social sciences (e.g. the expected answer contained in the question, non-neutral attitude of the interviewer, etc.).

(k) If HFs concerns are raised that are not directly related to the object of the assessment, they should nevertheless be developed, adequately investigated and analysed in the test report.

(l) Every design-related human performance issue observed or reported by the crew should be analysed following the assessment. In the case of a human error, the analysis should provide information about at least the following elements:

(1) The type of error;

(2) The observed operational consequences, and any reductions in safety margins;

(3) The description of the operational context at the time of observation;

(4) Was the error detected? By whom, when and how?

(5) Was the error recovered? By whom, when and how?

(6) Existing means of mitigation;

(7) Possible effects of the representativeness of the test means on the validity of the data; and

(8) The possible causes of the error.

(m) The analysis of human performance issues has to be concluded by detailing the appropriate way forward, which is one of the following:

(1) No action required;

(2) An operational recommendation (for a procedural improvement or a training action);

(3) A recommendation for a design improvement; or

(4) A combination of items (2) and (3).

(n) If a design recommendation is rejected by the applicant, a sound justification should be provided to EASA to demonstrate that the safety of the product is not impaired by that decision.

4)_DESIGN CONSIDERATIONS AND GUIDANCE

4.1_Overview

(a) This material provides the standard which should be applied in order to design a cockpit that is in line with the objectives of 29.1302. Not all the criteria can or should be met by all systems. The applicant and EASA should use their judgment and experience in determining which design standard should apply to each part of the design in each situation.

(b) The following items provide a cross reference between this paragraph and the requirements listed in CS 29.1302:

(1) 'Controls' mainly relates to 1302(a) and (b);

(2) 'Presentation of information' mainly relates to 1302(a) and (b);

(3) 'System behaviour' mainly relates to 1302(c); and

(4) 'Error management' mainly relates to 1302(d).

Additionally, specific considerations on integration are given in paragraph 4.6.

4.2_Controls

(a) Applicants should propose means of compliance to show that the controls in the proposed design, as defined in CS 29.777, 29.779, 29.1543 and 29.1555, comply with CS 29.1302(b).

(b) The proposed means of compliance should be sufficiently detailed to demonstrate that each function, method of operating a control, and result of actuating a control complies with the requirements. Each control must be shown to be:

(1) clear,

(2) unambiguous,

(3) appropriate in resolution and precision,

(4) accessible, and

(5) usable.

(6) It must also enable crew awareness, including by providing adequate feedback.

(c) For each of these requirements, the proposed means of compliance should include consideration of the following control characteristics for each control individually and in relation to other controls:

(1) The physical location of the control;

(2) The physical characteristics of the control (e.g. its shape, dimensions, surface texture, range of motion, and colour);

(3) The equipment or system(s) that the control directly affects;

(4) How the control is labelled;

(5) The available settings of the control;

(6) The effect of each possible actuation or setting, as a function of the initial control setting or other conditions;

(7) Whether there are other controls that can produce the same effect (or can affect the same target parameter), and the conditions under which this will happen; and

(8) The location and nature of the feedback that shows the control was actuated.

The following discussion provides additional guidance for the design of controls that comply with CS 29.1302.

(d) The clear and unambiguous presentation of control-related information

(1) Distinguishable and predictable controls (CS 29.1301(a), CS 29.1302)

(i) Each crew member should be able to identify and select the current function of the control with the speed and accuracy appropriate to the task. The function of a control should be readily apparent so that little or no familiarisation is required.

(ii) The applicant should evaluate the consequences of activating each control and show they are predictable and obvious to each crew member. This includes the control of multiple displays with a single device, and shared display areas that crew members may access with individual controls. The use of a single control should also be assessed.

(iii) Controls can be made distinguishable or predictable by differences in form, colour, location, motion, effect and/or labelling.

(iv) Colour coding is usually not sufficient as a sole distinguishing feature. This applies to physical controls, as well as to controls that are part of an interactive graphical user interface.

(2) Labelling (CS 29.1301(b), CS 29.1543(b), CS 29.1555(a))

(i) For the general marking of controls, see CS 29.1555(a).

CS 29.1302(a) and (b) require the information necessary to accomplish defined tasks to be provided precisely and clearly. They also require the controls to be accessible and usable by the crew in a way that is consistent with the urgency, frequency and duration of the tasks. Therefore, labels should be readable from the crew members' normal seating positions, including the marking used by the crew member, from their operating positions in the cabin (if applicable) in all lighting and environmental conditions. If a control performs more than one function, the labelling should include all the intended functions unless the function of the control is obvious. Labels of graphical controls accessed by a cursor control device such as a trackball should be included on the graphical display. If menus lead to additional choices (submenus), the menu label should provide a reasonable description of the next submenu.

(ii) The applicant can label controls with text or icons. The text and the icons should be shown to be distinct and meaningful for the function that they label. The applicant should use standard or unambiguous abbreviations, nomenclature, or icons, consistent within a function and across the cockpit. ICAO Doc 8400 'ICAO

Abbreviations and Codes' provides standard abbreviations, and is an acceptable basis for selecting labels.

(iii) The design should avoid hidden functions (such as clicking on empty space on a display to make something happen). However, such hidden functions may be acceptable if adequate alternate means are available to access the function. The design should still be assessed for its ease of use and crew understanding.

(iv) If an icon is used instead of a text label, the applicant should show that the crew requires only a brief exposure to the icon to determine the function of the control and how it operates. Based on design experience, the following guidelines for icons have been shown to lead to usable designs:

(A) The icon should be analogous to the object it represents;

(B) The icon should be in general use in aviation and well known to crews, or has been validated during an HFs assessment; and

(C) The icon should be based on established standards, if they exist, and on conventional meanings.

(v) In all cases, the applicant should show that the use of icons is at least equivalent to the use of text labels in terms of the speed of recognition by the crew and the crew's error rate. Alternatively, the applicant should show that any increase in the error rate or the task completion time has no unacceptable effects on safety or on the crew workload (e.g. incurred task times), and does not cause crew confusion.

(3) Interactions of multiple controls (CS 29.1302(a))

If multiple controls for one function are provided to the crew, the applicant should show that there is sufficient information to make the crew aware of which control is currently functioning. As an example, crew members need to know which crew member's input has priority when two cursor control devices can access the same display. Designers should use caution if dual controls can affect the same parameter simultaneously.

(e) The accessibility of controls (CS 29.777(a), CS 29.777(b), CS 29.1302)

(1) The applicant must show that each crew member in the minimum crew, as defined by CS 29.1523, has access to and can operate all the necessary controls. Accessibility is one factor in determining whether controls support the intended function of the equipment used by the crew. Any control required for crew member operation (in normal, abnormal and emergency conditions) must be shown to be viewable, reachable, and operable by crew members with the stature specified in CS 29.777(b), from the seated position with shoulder restraints on. If the shoulder restraints are lockable, this may be shown with the shoulder restraints locked.

(2) Layering of information, as with menus or multiple displays, should not hinder the crew from identifying the location of the desired control. CS 29.1302(b) requires information intended for the use by the crew to be provided in a clear and unambiguous form, to be accessible, and to enable crew awareness. Evaluating the location and accessibility of a control requires the consideration of more than just the physical aspects of the control. Other location and accessibility considerations include where the control functions may be located within

various menu layers, and how the crew member navigates those layers to access the functions. Accessibility should be shown in conditions of system failures (including crew incapacitation) and of a minimum equipment list (MEL) dispatch.

(3) The position and direction of motion of a control should be oriented according to the standards in CS 29.777.

(f) Use of controls

(1) Environmental issues affecting controls (CS 29.1301(a) and CS 29.1302)

(i) Turbulence or vibration, and extreme lighting levels should not prevent the crew from performing all their tasks at an acceptable level of performance and workload.

(ii) If the use of gloves is anticipated, the cockpit design should allow their use with an adequate precision as per CS 29.1302(b)(2) and (c)(2).

(iii) The sensitivity of controls should provide sufficient precision (without being overly sensitive) to perform tasks even in adverse environments as defined for the rotorcraft's operational envelope per CS 29.1302(c)(2) and (d). Analysis of the environmental issues as a means of compliance is necessary, but not sufficient, for new control types or technologies, or for novel uses of controls that are themselves not new or novel.

(iv) The applicant should show that the controls required to regain control of the rotorcraft or system and the controls required to continue operating the rotorcraft in a safe manner are usable in conditions such as dense smoke in the cockpit or severe vibrations.

(2) Control display compatibility (CS 29.777(b) and CS 29.779)

CS 29.777(b) states that the direction of movement of a cockpit control must meet the requirements of CS 29.779. Wherever practicable, the sense of motion involved in the operation of other controls should correspond to the sense of the effect of the operation upon the rotorcraft or upon the part operated. Controls of a variable nature that use a rotary motion must move clockwise from the OFF position, through an increasing range, to the full ON position.

(i) To ensure that a control is unambiguous per CS 29.1302(b)(1), the relationship and interaction between a control and its associated display or indications should be readily apparent, understandable, and logical. A control input is often required in response to information on a display or to change a parameter setting on a display. The applicant should specifically assess any rotary knob that has no obvious 'increase' or 'decrease' function with regard to crew expectations and its consistency with the other controls in the cockpit. The Society of Automotive Engineers' (SAE) publication ARP4102, Chapter 5, is an acceptable means of compliance for controls used in cockpit equipment.

(ii) CS 29.777(a) requires each cockpit control to be located to provide convenient operation and to prevent confusion and inadvertent operation. The controls associated with a display should be located so that they do not interfere with the performance of the crew task. Controls whose function is specific to a particular display surface should be mounted near to the display or the function being controlled. Locating controls immediately below a display is generally preferable, as mounting controls immediately above a display has, in many cases, caused the crew member's hand to obscure their view of the display when operating the controls. However, controls on the bezel of multifunction displays have been found to be acceptable.

(iii) Spatial separation between a control and its display may be necessary. This is the case with a control of a system that is located with other controls for that same system, or when it is one of several controls on a panel dedicated to controls for that multifunction display. When there is a large spatial separation between a control and its associated display, the applicant should show that the use of the control for the associated task(s) is acceptable in accordance with 29.777(a) and 29.1302.

(iv) In general, the design and placement of controls should avoid the possibility that the visibility of information could be blocked. If the range of movement of a control temporarily blocks the crew's view of information, the applicant should show that this information is either not necessary at that time or is available in another accessible location (CS 29.1302(b)(2) requires information intended for use by the crew to be accessible and useable by the crew in a manner consistent with the urgency, frequency, and duration of the crew tasks).

(v) Annunciations/labels on electronic displays should be identical to the labels on the related switches and buttons located elsewhere on the cockpit. If display labels are not identical to those on the related controls, the applicant should show that crew members can quickly, easily, and accurately identify the associated controls so they can safely perform all the tasks associated with the intended function of the systems and equipment (29.1302).

(g) Adequacy of feedback (CS 29.771(a), CS 29.1301(a), CS 29.1302)

(1) Feedback for the operation of controls is necessary to give the crew awareness of the effects of their actions. Each control should provide feedback to the crew member for menu selections, data entries, control actions, or other inputs. There should be a clear and unambiguous indication when a crew input is not accepted or not followed by the system (29.1302(b)(1)). This feedback can be visual, auditory, or tactile.

(2) Feedback, in an appropriate form, should be provided to inform the crew that:

(i) a control has been activated (commanded state/value);

(ii) the function is in process (given an extended processing time);

(iii) the action associated with the control has been initiated (actual state/value if different from the commanded state); or

(iv) when a control is used to move an actuator through its range of travel, the equipment should provide, within the time required for the relevant task, operationally significant feedback of the actuator's position within its range. Examples of information that could appear relative to an actuator's range of travel include the target speed, and the state of the valves of various systems.

(3) The type, duration and appropriateness of the feedback will depend upon the crew's task and the specific information required for successful operation. As an example, the switch position alone is insufficient feedback if awareness of the actual system response or the state of the system as a result of an action is required as per CS 29.1302(b)(3).

(4) Controls that may be used while the user is looking outside or at unrelated displays should provide tactile feedback. Keypads should provide tactile feedback for any key depression. In cases when this is omitted, it should be replaced with appropriate visual or other feedback indicating that the system has received the inputs and is responding as expected.

(5) Equipment should provide appropriate visual feedback, not only for knob, switch, and push-button positions, but also for graphical control methods such as pull-down menus and pop-up windows. The user interacting with a graphical control should receive a positive indication that a hierarchical menu item has been selected, a graphical button has been activated, or another input has been accepted.

(6) To meet the requirements of CS 29.1302, the applicant should show that feedback in all forms is obvious and unambiguous to the crew in their performance of the tasks associated with the intended function of the equipment.

4.3_The presentation of information

(a) Introduction

(1) Applicants should use this AMC to show that the information displayed in the proposed design complies with CS 29.1302(b). The proposed means should be of sufficient detail to show that the function, method of control operation, and results comply with the requirements in CS 29.1301 and that the results of the presented information are:

— clear,

— unambiguous,

— appropriate in resolution and precision,

— accessible,

— usable, and

— able to provide adequate feedback for crew awareness.

(2) The presentation of information to the crew can be visual (for instance, on a display), auditory (a 'talking' checklist) or tactile (for example, control feel). The presentation of information in the integrated cockpit, regardless of the medium used, should meet all of the requirements bulleted above. For visual displays, this AMC addresses mainly display format issues and not display hardware characteristics. The following provides design considerations for the requirements found in CS 29.1301(a), CS 29.1301(b), CS 29.1302, and CS 29.1543(b).

(b) The clear and unambiguous presentation of information

Qualitative and quantitative display formats (CS 29.1301(a) and CS 29.1302)

(1) Applicants should show, per CS 29.1302(b), that display formats include the type of information the crew needs for the task, specifically with regard to the required speed and

precision of reading. For example, the information could be in the form of a text message, numerical value, or a graphical representation of state or rate information. State information identifies the specific value of a parameter at a particular time. Rate information indicates the rate of change of that parameter.

(2) If the crew's sole means of detecting abnormal values is by monitoring the values presented on the display, the equipment should offer qualitative display formats. Analogue displays of data are best for conveying rate and trend information. If this is not practical, the applicant should show that the crew can perform the tasks for which the information is used. Digital presentations of information are better for tasks requiring precise values. Refer to CS 29.1322 when an abnormal value is associated with a crew alert.

(c) Characters, fonts, lines and scale markings (CS 29.1301(b) and CS 29.1543(b))

Crew members, seated at their stations and using normal head movement, should be able to see and read display format features such as fonts, symbols, icons and markings. In some cases, cross-cockpit readability may be required to meet the intended function that both pilots must be able to access and read the display. Examples of situations where this might be needed are cases of display failures or when cross-checking flight instruments. Readability must be maintained in sunlight viewing conditions (per CS 29.773(a)) and under other adverse conditions such as vibration. Figures and letters should subtend not less than the visual angles defined in SAE ARP4102-7 at the design eye position of the crew member who normally uses the information.

(d) Colour (CS 29.1302)

(1) The use of many different colours to convey meaning on displays should be avoided. However, if thoughtfully used, colour can be very effective in minimising the workload and response time associated with display interpretation. Colour can be used to group functions or data types in a logical way. A common colour philosophy across the cockpit is desirable.

(2) Different systems in the cockpit should use the same colour coordinates.

(3) Applicants should show that the chosen colour set is not susceptible to confusion or misinterpretation due to differences in colour usage between displays. Improper colour coding increases the response times for display item recognition and selection, and increases the likelihood of errors, which is particularly true in situations where the speed of performing a task is more important than the accuracy, so the compatibility of colours with the background should be verified in all the foreseeable lighting conditions. The use of the red and amber colours for other than alerting functions or potentially unsafe conditions is discouraged. Such use diminishes the attention-getting characteristics of true warnings and cautions.

(4) The use of colour as the sole means of characterising an item of information is also discouraged. It may be acceptable, however, to indicate the criticality of the information in relation to the task. Colour, as a graphical attribute of an essential item of information,

should be used in addition to other coding characteristics such as texture or differences in luminance. AMC 25-11 contains recommended colour sets for specific display features.

(5) Applicants should show that the layering of information on a display does not add to confusion or clutter as a result of the colour standards and symbols used. Designs that require crew members to manually declutter such displays should also be avoided.

(e) Symbology, text, and auditory messages (CS 29.1302)

(1) Designs can base many elements of electronic display formats on established standards and conventional meanings. For example, ICAO Doc 8400 provides abbreviations, and is one standard that could be applied to cockpit text.

SAE ARP4102-7, Appendices A to C, and SAE ARP5289A are acceptable standards for avionics display symbols.

(2) The position of a message or symbol within a display also conveys meaning to the crew member. Without the consistent or repeatable location of a symbol in a specific area of the electronic display, interpretation errors and response times may increase.

(3) Applicants should give careful attention to symbol priority (the priority of displaying one symbol overlaying another symbol by editing out the secondary symbol) to ensure that higher-priority symbols remain viewable.

(4) New symbols (a new design or a new symbol for a function which historically had an associated symbol) should be assessed for their distinguishability and for crew understanding and retention.

(5) The applicant should show that displayed text and auditory messages are distinct and meaningful for the information presented. CS 29.1302 requires information intended for use by the crew to be provided in a clear and unambiguous format in a resolution and precision appropriate to the task, and the information to convey the intended meaning. Equipment should display standard and/or unambiguous abbreviations and nomenclature, consistent within a function and across the cockpit.

(f) The accessibility and usability of information

(1) The accessibility of information (CS 29.1302)

(i) Information intended for the crew must be accessible and useable by the crew in a manner consistent with the urgency, frequency, and duration of their tasks, per CS 29.1302(b)(2). The crew may, at certain times, need some information immediately, while other information may not be necessary during all phases of flight. The applicant should show that the crew can access and manage (configure) all the necessary information on the dedicated and multifunction displays for the phase of flight. The applicant should show that any information required for continued safe flight and landing is accessible in the relevant degraded display modes following failures as defined by CS 29.1309. The applicant should specifically assess what information is necessary in those conditions, and how such information will be simultaneously displayed. The applicant should also show that supplemental information does not displace or otherwise interfere with the required information.

(ii) Analysis as the sole means of compliance is not sufficient for new or novel display management schemes. The applicant should use simulation of typical operational scenarios to validate the crew's ability to manage the available information.

(2) Clutter (CS 29.1302)

(i) Visual or auditory clutter is undesirable. To reduce the crew member's interpretation time, equipment should present information simply and in a well-ordered way. Applicants should show that an information delivery method (whether visual or auditory) presents the information that the crew member actually requires to perform the task at hand. The crew can use their own discretion to limit the amount of information that needs to be presented at any point in time. For instance, a design might allow the crew to program a system so that it displays the most important information all the time, and less important information on request. When a design allows the crew to select additional information, the basic display modes should remain uncluttered.

(ii) Display options that automatically hide information for the purpose of reducing visual clutter may hide needed information from the crew member. If equipment uses automatic deselection of data to enhance the crew member's performance in certain emergency conditions, the applicant must show, per CS 29.1302(a), that it provides the information the crew member needs. The use of part-time displays depends not only on the removal of clutter from the information, but also on the availability and criticality of the display. Therefore, when designing such features, the applicant should follow the guidance in AMC 25-11, Chapter 6.

(iii) Because of the transient nature of auditory information presentation, designers should be careful to avoid the potential for competing auditory presentations that may conflict with each other and hinder their interpretation. Prioritisation and timing may be useful to avoid this potential problem.

(iv) Information should be prioritised according to the criticality of the task. Lower-priority information should not mask higher-priority information, and higher-priority information should be available, readily detectable, easily distinguishable and usable.

(3) Long or variable response times between a control input and the system response can adversely affect the usability of the system. The applicant should show that the response to a control input, such as setting values, displaying parameters, or moving a cursor symbol on a graphical display, is fast enough to allow the crew to complete the task at an acceptable

level of performance. For actions that require a noticeable system processing time, equipment should indicate that the system response is pending.

4.4_System behaviour

(a) Introduction

This paragraph provides means for demonstrating compliance with the design considerations for the requirements found in CS 29.1302(c), CS 29.1301(a), CS 29.1309(c), or any other relevant paragraphs of CS-29.

The demands of crew tasks vary depending on the characteristics of the system design. Systems differ in their responses to relevant crew inputs. The response can be direct and unique, as in mechanical systems, or it can vary as a function of an intervening subsystem (such as hydraulics or electrics). Some systems even automatically vary their responses to capture or maintain a desired rotorcraft or system state.

(1) CS 29.1302(c) states that installed equipment must be designed so that the behaviour of the equipment that is operationally relevant to the crew's tasks is: (1) predictable and unambiguous, and (2) designed to enable the crew to intervene in a manner appropriate to the task (and intended function).

(2) The requirement for operationally relevant system behaviour to be predictable and unambiguous will enable the crew to know what the system is doing and why. This means that a crew should have enough information about what the system will do under foreseeable circumstances as a result of their action or a changing situation so that they can operate the system safely. This distinguishes system behaviour from the functional logic within the system design, much of which the crew does not know or does not need to know.

(3) If crew intervention is part of the intended function, or part of abnormal or emergency procedures for the system, the crew member may need to take some action, or change an input to the system. The system must be designed accordingly. The requirement for crew intervention capabilities recognises this reality.

(4) Improved technologies, which have increased safety and performance, have also introduced the need to ensure proper cooperation between the crew and the integrated, complex information and control systems. If the system behaviour is not understood or expected by the crew, confusion may result.

(5) Some automated systems involve tasks that require crew attention for effective and safe performance. Examples include flight management systems (FMSs) or flight guidance systems. Alternatively, systems designed to operate autonomously, in the sense that they require very limited or no human interaction, are referred to as 'automatic systems'. Such systems are switched 'ON' or 'OFF' or run automatically, and, when operating in normal conditions, the guidance material of this paragraph is not applicable to them. Examples

include fly-by-wire systems and full authority digital engine controls (FADECs). Detailed specific guidance for automatic systems can be found in the relevant parts of CS-29.

(b) The allocation of system functions

The applicant should show that the allocation of functions is conducted in such a way that:

(1) the crew is able to perform all the tasks assigned to them, considering normal, abnormal and emergency operating conditions, within the bounds of an acceptable workload and without requiring undue concentration or causing undue fatigue (see CS 29.1523 for workload assessment);

(2) the system enables the crew to understand the situation, and enables timely failure detection and crew intervention when appropriate; and

(3) the allocation of tasks between the crew and the rotorcraft during operations is considered.

(c) The functional behaviour of a system

(1) The functional behaviour of a system results from the interaction between the crew and the automated system, and is determined by:

(i) the functions of the system and the logic that governs its operation; and

(ii) the user interface, which consists of the controls that communicate the crew's inputs to the system, and the information that provides feedback to the crew on the behaviour of the system.

(2) The design should consider both the functions of the system and the user interface together. This will avoid a design in which the functional logic governing the behaviour of the system can have an unacceptable effect on the performance of the crew. Examples of system functional logic and behavioural issues that may be associated with errors and other difficulties for the crew are the following:

(i) The complexity of the crew interface for both control actuation and data entry, and the complexity of the corresponding system indications provided to the crew;

(ii) The crew having inadequate understanding and inaccurate expectations of the behaviour of the system following mode selections and transitions; and

(iii) The crew having inadequate understanding and incorrect expectations of what the system is preparing to do next, and how it is behaving.

(3) Predictable and unambiguous system behaviour (CS 29.1302(c)(1))

Applicants should propose the means they will use to show that the behaviour of the system or the system mode in the proposed design is predictable and unambiguous to the crew.

(i) System or system mode behaviour that is ambiguous or unpredictable to the crew has been found to cause or contribute to crew errors. It can also potentially degrade the crew's ability to perform their tasks in normal, abnormal and emergency conditions. Certain design characteristics have been found to minimise crew errors and other crew performance problems.

(ii) The following design considerations are applicable to operationally relevant systems and to the modes of operation of the systems:

(A) The design should be simple (for example, the number of modes, or mode transitions).

(B) Mode annunciation should be clear and unambiguous. For example, a mode engagement or arming selection by the crew should result in annunciation, indication or display feedback that is adequate to provide awareness of the effect of their action. Additionally, any change in the mode as a result of the rotorcraft changing from one operational mode (for instance, on an approach) to another should be clearly and unambiguously annunciated and fed back to the crew.

(C) Methods of mode arming, engagement and deselection should be accessible and usable. For example, the control action necessary to arm, engage, disarm or disengage a mode should not depend on the mode that is currently armed or engaged, on the setting of one or more other controls, or on the state or status of that or another system.

(D) Uncommanded mode changes and reversions should have sufficient annunciation, indication, or display information to provide awareness of any uncommanded changes of the engaged or armed mode of a system.

(E) The current mode should remain identified and displayed at all times.

(iii) Note that formal descriptions of modes typically define them as mutually exclusive, so that a system cannot be in more than one mode at a particular time. For instance, a display can be in 'north-up' mode or 'track-up' mode, but not both at the same time.

(4) Crew intervention (CS 29.1302(c)(2))

(i) Applicants should propose the means that they will use to show that the behaviour of the systems in the proposed design allows the crew to intervene in the operation of the systems without compromising safety. This should include descriptions of how they will determine that the functions and conditions in which intervention should be possible have been addressed.

(ii) If the means of demonstrating compliance is by analysis, the applicant should describe it thoroughly. In addition, the methods proposed by applicants should describe how they would determine that each means of intervention is appropriate to the task.

(5) Controls for automated systems

Automated systems can perform various tasks selected by and under the supervision of the crew. Controls should be provided for managing the functionality of such a system or set of systems. The design of such 'automation-specific' controls should enable the crew to:

(i) safely prepare the system for the immediate task to be executed or the subsequent task to be executed; preparation of a new task (for example, a new flight trajectory) should not interfere, or be confused, with the task being executed by the automated system;

(ii) activate the appropriate system function and clearly understand what is being controlled; for example, the crew must clearly understand that they can set either the vertical speed or the flight path angle when they operate a vertical speed indicator;

(iii) manually intervene in any system function, as required by the operational conditions, or revert to manual control; for example, manual intervention might be necessary if a system loses functions, operates abnormally, or fails.

(6) Displays for automated systems

Automated systems can perform various tasks with minimal crew intervention, but under the supervision of the crew. To ensure effective supervision and maintain crew awareness of the system state and system 'intention' (future states), displays should provide recognisable feedback on:

(i) the entries made by the crew into the system so that the crew can detect and correct errors;

(ii) the present state of the automated system or its mode of operation (What is it doing?);

(iii) actions taken by the system to achieve or maintain a desired state (What is it trying to do?);

(iv) future states scheduled by the automation (What is it going to do next?); and

(v) transitions between system states.

(7) The applicant should consider the following aspects of automated system designs:

(i) Indications of the commanded and actual values should enable the crew to determine whether the automated systems will perform according to their expectations;

(ii) If the automated system nears its operational authority or is operating abnormally for the conditions, or is unable to perform at the selected level, it should inform the crew, as appropriate for the task;

(iii) The automated system should support crew coordination and cooperation by ensuring that there is shared awareness of the system status and the crew inputs to the system; and

(iv) The automated system should enable the crew to review and confirm the accuracy of commands before they are activated. This is particularly important for automated systems because they can require complex input tasks.

4.5_Crew error management

(a) Demonstrating compliance with CS 29.1302(d)

(1) CS 29.1302(d) states that 'The installed equipment must enable the crew to manage errors resulting from crew interaction with the equipment that can be reasonably expected in service, assuming crews acting in good faith. This subparagraph does not apply to skill-related errors associated with manual control of the rotorcraft.' This addresses the fact that

crews will make errors, even when they are well trained, experienced, rested, and are using well-designed systems.

(2) To comply with CS 29.1302(d), the design should meet one of the following criteria. It should:

(i) enable the crew to detect (see 4.5(b)) and recover from errors (see 4.5(c)); or

(ii) ensure that the effects of crew errors on the rotorcraft functions or capabilities are evident to the crew, and continued safe flight and landing is possible (see 4.5(d)); or

(iii) discourage crew errors by using switch guards, interlocks, confirmation actions, or similar means; or

(iv) preclude the effects of errors through system logic and/or redundant, robust, or fault-tolerant system design (see 4.5(e)).

(3) These above objectives:

(i) are, in a general sense, in a preferred order;

(ii) recognise and assume that crew errors cannot be entirely prevented, and that no validated methods exist to reliably predict either their probability or all the sequences of events with which they may be associated;

(iii) call for means of compliance that are methodical and complementary to, and separate and distinct from, rotorcraft system analysis methods such as system safety assessments.

(iv) CS 29.1302(d) addresses errors that are design related. It is not intended to require consideration of errors resulting from acts of violence, sabotage or threats of violence.

(4) Errors that do have a design-related component are considered to be within the scope of this AMC. Examples are a procedure that is inconsistent with the design of the equipment, or indications and controls that are complex and inconsistent with each other or other systems on the cockpit.

(5) When demonstrating compliance, the applicant should consider the crew tasks in all operating conditions, considering that many of the same design characteristics are relevant in each case. For example, under abnormal or emergency conditions, the flying tasks (navigation, communication and monitoring) are generally still present, although they may be more difficult. So the tasks associated with the abnormal or emergency conditions should be considered as additive. The applicant should not expect the errors considered to be different from those in normal conditions, but any assessment should account for the change in the expected tasks.

(6) To demonstrate compliance with CS 29.1302(d), an applicant may employ any of the general types of methods of compliance discussed in paragraph 5, individually or in combination. These methods must be consistent with an approved certification plan as discussed in paragraph 3, and account for the objectives above and the considerations described below. When using some of these methods, it may be helpful for some applicants to refer to other

references related to understanding the occurrence of errors. Here is a brief summary of those methods and how they can be applied to address crew error considerations:

(i) Statement of similarity (paragraph 5.3): A statement of similarity may be used to substantiate that the design has sufficient certification precedent to conclude that the ability of the crew to manage errors has not significantly changed. Applicants may also use service experience data to identify errors known to commonly occur for similar crew interfaces or system behaviour. As part of compliance demonstration, the applicant should identify the steps taken in the new design to avoid or mitigate similar errors. However, the absence of in-service events related to a particular function, system or feature cannot be considered to be an acceptable means of demonstrating compliance with CS 29.1302.

(ii) Design descriptions (paragraph 5.3): Applicants may structure design descriptions and rationales to show how various types of errors are considered in the design and addressed, mitigated or managed. Applicants can also use a description of how the design adheres to an established and valid design philosophy to substantiate that the design enables crews to manage errors.

(iii) Calculation and engineering analysis (paragraph 5.3): As one possible means of demonstrating compliance with CS 29.1302(d), an applicant may document means of error management through analysis of controls, indications, system behaviour, and related crew tasks. This would need to be done in conjunction with an understanding of the potential error opportunities and the means available for the crew to manage those errors. In most cases, it is not considered feasible to predict the probability of crew errors with sufficient validity or precision to support a means of compliance. If an applicant chooses to use a quantitative approach, the validity of the approach should be established.

(iv) Assessments (paragraph 5.3): For compliance purposes, assessments are intended to identify error possibilities that may be considered for mitigation in design or training. In any case, scenario objectives and assumptions should be clearly stated before running the evaluations or tests. In that way, any discrepancy in those expectations can be discussed and explained in the analysis of the results.

(7) As discussed further in paragraph 5, these evaluations or tests should use appropriate scenarios that reflect the intended functions and tasks, including the use of the equipment in normal, abnormal and emergency conditions. Scenarios should be designed to consider crew errors. If inappropriate scenarios are used or important conditions are not considered, incorrect conclusions can result. For example, if no errors occur during an assessment, it may only mean that the scenarios are too simple, incomplete, or not fully representative. On the other hand, if some errors do occur, it may mean any of the following:

(i) The design, procedures, or training should be modified;

(ii) The scenarios are unrealistically challenging; or

(iii) Insufficient training was delivered prior to the assessment.

(8) In such assessments, it is not considered feasible to establish criteria for the frequency of errors.

(b) Error detection

(1) Applicants should design equipment to provide information so the crew can become aware of an error or a system/rotorcraft state resulting from a system action. Applicants should show that this information is available to the crew, is adequately detectable, and that it shows a clear relationship between the crew action and the error so a recovery can be made in a timely manner.

(2) Information for error detection may take three basic forms:

(i) Indications provided to the crew during normal monitoring tasks.

(A) As an example, if an incorrect knob was used, resulting in an unintended heading change, the change would be detected through the display of target values. The presentation of a temporary flight plan for crew review before accepting it would be another way of providing crew awareness of errors.

(B) Indications on instruments in the primary field of view that are used during normal operations may be adequate if the indications themselves contain information used on a regular basis and are provided in a readily accessible form. These may include mode annunciations and normal rotorcraft state information such as the altitude or heading. Other locations for the information may be appropriate depending on the crew's tasks, such as on the control display unit when the task involves dealing with a flight plan. Paragraph 5.4 'Presentation of information' contains additional guidance to determine whether the information is adequately detectable.

(ii) Crew indications that provide information of an error or a resulting rotorcraft system condition.

(A) An alert that could activate after a crew error may be a sufficient means for the applicant to show that information about an error exists and that the error is adequately detectable, if the alert directly and appropriately relates to the error. If the content of the alert does not directly relate to the error, the indication may lead the crew to believe there may be non-error causes for the annunciated condition.

(B) If a crew error is only one of several possible causes for an alert about a system, then the information that the alert provides is insufficient. If, on the other hand, additional information is available that would allow the crew to identify and correct the error, then the alert, in combination with the additional information, would be sufficient to comply with CS 29.1302(d) for that error.

(C) An error that is detectable by the system should provide an alert and provide sufficient information that a crew error has occurred, such as in the case of a take-off configuration warning. On the other hand, an alert about the system state resulting from accidentally shutting down a hydraulic pump, for example, may not provide sufficient information to the crew to enable them to distinguish an error from a system fault. In this case, flight manual procedures may provide the error detection means as the crew performs the 'Loss of Hydraulic System' procedures.

(D) If the system can detect pilot error, the system could be designed to prevent pilot error. For example, if the system can detect an incorrect frequency entry by the pilot, then the system should be able to disallow that entry and provide appropriate feedback to the pilot. Examples are automated error checking and filters that prevent the entry of unallowable or illogical entries.

(iii) 'Global' alerts cover a multitude of possible errors by annunciating external hazards, or the envelope of the rotorcraft, or operational conditions. Examples include monitoring systems such as a terrain awareness warning system (TAWS) and a traffic alert and collision avoidance system (TCAS). An example would be a TAWS alert resulting from turning in the wrong direction in a holding pattern in mountainous terrain.

(3) The applicant should consider the following when establishing whether the degree or type of information is available to the crew, adequately detectable, and clearly related to the error:

(i) The effects of some errors are easily and reliably determined by the system because of its design, and some are not. For those that cannot be sensed by the system, the design and arrangement of the information monitored and scanned by the crew can facilitate error detection. An example would be the alignment of engine speed indicator needles in the same direction during normal operations. Failure of the needles to align in the same direction during normal operations would indicate a problem with one of the engines, since one engine would be rotating at a different speed from the other engine.

(ii) Rotorcraft alerting and indication systems may not detect whether an action is erroneous because the systems cannot know the intent of the crew in many operational circumstances. In these cases, reliance is often placed on the crew's ability to scan and observe indications that will change as a result of an action such as selecting a new altitude or heading, or making a change to a flight plan in a flight management system (FMS). For errors of this nature, error detection depends on the crew's interpretation of the available information. Training, crew resource management (CRM), and monitoring systems such as TAWS and TCAS are examples of ways to provide a redundant level of safety if any or all the crew members fail to detect certain errors.

(4) The applicant may establish that information is available and clearly related to the error by using a design description when a precedent exists or when a reasonable case may be made that the content of the information is clearly related to the error that caused it. In some

cases, a crew assessment (see 5.3) may be needed to assess whether the information provided is adequately available and detectable.

(c) Error recovery

(1) Assuming that the crew detects an error or its effects, the next logical step is to ensure that the error can be reversed, or that the effect of the error can be mitigated in some way so that the rotorcraft is returned to a safe state.

(2) An acceptable means to establish that an error is recoverable is to show that:

(i) controls and indications exist that can be used either to reverse an erroneous action directly so that the rotorcraft or system is returned to the original state, or to mitigate the effect so that the rotorcraft or system is returned to a safe state; and

(ii) the crew can be expected to use those controls and indications to accomplish the corrective actions in a timely manner.

(3) For simple or familiar types of system interfaces, or systems that are not novel, even if they are complex, a statement of similarity or a description of the design of the crew interfaces and the procedures associated with the indications may be an acceptable means of compliance.

(4) To establish that the crew can be expected to use those controls and indications to accomplish corrective actions in a timely manner, an assessment of the crew procedures in a simulated cockpit environment can be highly effective. This assessment should include an examination of the nomenclature used in alert messages, controls, and other indications. It should also include the logical flow of procedural steps and the effects that executing the procedures have on other systems.

(d) Error effects

(1) Another means of satisfying the objective of error mitigation is to ensure that the effects of the error or the relevant effects on the state of the rotorcraft:

(i) are evident to the crew; and

(ii) do not adversely impact on safety (do not prevent continued safe flight and landing).

(2) Piloted assessments in the rotorcraft or in simulation may be relevant if crew performance issues are in question for determining whether a state following an error permits continued safe flight and landing. Assessments and/or analyses may be used to show that, following an error, the crew has the information in an effective form and has the rotorcraft capability required for continued safe flight and landing.

(e) Precluding errors or their effects

(1) For irreversible errors that have potential safety implications, means to discourage the errors are recommended. Acceptable ways to discourage errors include switch guards, interlocks, or multiple confirmation actions. For example, generator drive controls on many rotorcraft have guards over the switches to discourage their inadvertent actuation, because once disengaged, the drives cannot be re-engaged while in flight or with the engine running. An

example of multiple confirmations would be the presentation of a temporary flight plan that the crew can review before accepting it.

(2) Another way of avoiding crew error is to design systems to remove misleading or inaccurate information (e.g. sensor failures) from displays. An example would be a system that removes the flight director bars from a primary flight display or removes the 'own-ship' position from an airport surface map display when the data driving the symbols is incorrect.

(3) The applicant should avoid applying an excessive number of protections for a given error. The excessive use of protections could have unintended safety consequences. They might hamper the crew member's ability to use judgment and take action in the best interest of safety in situations that were not predicted by the applicant. If protections become a nuisance in daily operation, crews may use well-intentioned and inventive means to circumvent them. This could have further effects that were not anticipated by the operator or the designer.

4.6_Integration

(a) Introduction

(1) Many systems, such as flight management systems (FMSs), are integrated physically and functionally into the cockpit and may interact with other cockpit systems. It is important to consider a design not just in isolation, but in the context of the overall cockpit. Integration issues include where a display or control is installed, how it interacts with other systems, and whether there is internal consistency across functions within a multi-function display, as well as consistency with the rest of the cockpit equipment.

(2) Analyses, evaluations, tests and other data developed to establish compliance with each of the specific requirements in CS 29.1302(a) to (d) should address the integration of new or novel design features or equipment with previously approved features or equipment, as well as with other new items. It should include consideration of the following integration factors:

(i) consistency (see 4.6(b)),

(ii) consistency trade-offs (see 4.6(c)),

(iii) the cockpit environment (see 4.6(d)), and

(iv) integration-related workload and error (see 4.6(e)).

(b) Consistency

(1) If similar information is presented in multiple locations or modes (both visual and auditory, for example), consistent presentation of the information is desirable. If information cannot be presented consistently within the cockpit, the applicant should show that the differences do not increase the error rates or task times, which would lead to a significant reduction in the safety margins or an increase in the crew workload, and do not cause crew confusion.

(2) Consistency needs to be considered within a given system and across the cockpit. Inconsistencies may result in vulnerabilities, such as increased workload and errors, especially during stressful situations. For example, in some flight management systems (FMSs), the format for entering the latitude and longitude differs between the display pages.

This may induce crew errors, or at least increase the crew's workload. Additionally, errors may result if the latitude and longitude are displayed in a format that differs from the formats used on the most commonly used paper charts. Because of this, it is desirable to use formats that are consistent with other media whenever possible. Although trade-offs exist, as discussed in the next paragraph, the following are design attributes to consider for their consistency within and across systems:

(i) Symbology, data entry conventions, formatting, the colour philosophy, terminology, and labelling.

(ii) Function and logic. For example, when two or more systems are active and performing the same function, they should operate consistently and use an interface in the same style.

(iii) Information presented with other information of the same type that is used in the cockpit. For example, the navigation symbology used on other cockpit systems or on commonly used paper charts should be considered when developing the symbology to be used on electronic map displays.

(iv) The operational environment. It is important that an FMS is consistent with the operational environment so that the order of the steps required to enter a clearance into the system is consistent with the order in which they are given by air traffic management (ATM).

(v) One way in which the applicant can achieve consistency within a given system, as well as within the overall cockpit, is to adhere to a comprehensive cockpit design philosophy.

(3) Another way is to standardise certain aspects of the design by using accepted, published standards such as the labels and abbreviations recommended in ICAO Doc 8400 or in SAE ARP4105C. The applicant might standardise the symbols used to depict navigation aids (very high frequency omnidirectional range, VOR, for example), by following the conventions recommended in SAE ARP5289A. However, inappropriate standardisation, rigidly applied, can be a barrier to innovation and product improvement. Thus, guidance in this paragraph promotes consistency rather than rigid standardisation.

(c) Consistency trade-offs

It is recognised that it is not always possible or desirable to provide a consistent crew interface. Despite conformance with the cockpit design philosophy, principles of consistency, etc., it is possible to negatively impact on the crew's workload. For example, all the auditory alerts may adhere to a cockpit alerting philosophy, but the number of alerts may be unacceptable. The use of a consistent format across the cockpit may not work when individual task requirements necessitate the presentation of data in two significantly different formats. An example is a weather radar display formatted to show a sector of the environment, while a moving map display shows a 360-degree view. In such cases, it should be demonstrated that the design of the interface is compatible with the requirements of the piloting task, and that it can be used individually and in combination with other interfaces without interference with either the system or the function.

Additionally:

(1) The applicant should provide an analysis identifying each piece of information or data presented in multiple locations, and show that the data is presented in a consistent manner or, where that is not true, justify why that is not appropriate.

(2) Where information is inconsistent, that inconsistency should be obvious or annunciated, and should not contribute to errors in the interpretation of information.

(3) There should be a rationale for instances where the design of a system diverges from the cockpit design philosophy. Applicants should consider any impact on the workload and on errors as a result of such divergences.

(4) The applicant should describe what conclusion the crew is expected to draw and what action should be taken when information on the display conflicts with other information in the cockpit (either with or without a failure).

(d) Cockpit environment

(1) The cockpit system is influenced by the physical characteristics of the rotorcraft into which a system is integrated, as well as by the characteristics of the operational environment. The system is subject to such influences on the cockpit as turbulence, noise, ambient light, smoke, and vibrations (such as those that may result from ice or the loss of a fan blade). The design of the system should recognise the effect of such influences on usability, workload, and crew task performance. Turbulence and ambient light, for example, may affect the readability of a display. Cockpit noise may affect the audibility of aural alerts. The applicant should also consider the impact of the cockpit environment for abnormal situations, such as recovery from an unusual attitude or regaining control of the rotorcraft or system.

(2) The cockpit environment includes the layout, or the physical arrangement of the controls and information displays. Layouts should take into account the crew requirements in terms of:

(i) access and reach (to the controls);

(ii) visibility and readability of the displays and labels; and

(iii) the task-oriented location and grouping of human–machine interaction elements.

An example of poor physical integration would be a required piece of information that is obscured by a control in its normal operating position.

(e) Integration-related workload and error

(1) When integrating functions and/or equipment, designers should be aware of the potential effects, both positive and negative, that integration can have on the workload of the crew and its subsequent impact on error management. Systems must be designed and assessed, both in isolation and in combination with other cockpit systems, to ensure that the crew is able to detect, reverse, or recover from errors. This may be more challenging when

integrating systems that employ higher levels of automation or have a high degree of interaction and dependency on other cockpit systems.

(2) Applicants should show that the integrated design does not adversely impact on the workload or errors in the context of the entire flight regime. Examples of such impacts would be taking more time to:

(i) interpret a function;

(ii) make a decision; or

(iii) take appropriate action.

(3) Controls, particularly multi-function controls and/or novel types of control, may present the potential for misidentification and increased response times. Designs should generally avoid multi-function controls with hidden functions, because they increase both the workload of the crew and the potential for error.

(4) Two examples of integrated design features that may or may not impact on errors and the workload are as follows:

(i) Presenting the same information in two different formats. This may increase the workload, such as when altitude information is presented concurrently in both tape and round-dial formats. However, different formats may be suitable, depending on the design and the crew task. For example, an analogue display of engine revolutions per minute (rpm) can facilitate a quick scan, whereas a digital numeric display can facilitate precise inputs. The applicant is responsible for demonstrating compliance with CS 29.1523 and showing that the differences in the formats do not result in unacceptable levels of workload.

(ii) Presenting conflicting information. Increases in workload and error may result from two displays depicting conflicting altitude information on the cockpit concurrently, regardless of the formats. Systems may exhibit minor differences between each crew member station, but all such differences should be assessed specifically to ensure that the potential for interpretation error is minimised, or that a method exists for the crew to detect any incorrect information, or that the effects of these errors can be precluded.

(iii) The applicant should show that the proposed function will not inappropriately draw attention away from other cockpit information and tasks in a way that degrades the performance of the crew and decreases the overall level of safety. There are some cases in which it may be acceptable for the system design to increase the workload. For example, adding a display into the cockpit may increase the workload by virtue of the additional time crew members spend looking at it, but the safety benefit that the additional information provides may make it an acceptable trade-off.

(iv) Because each new system integrated into the cockpit may have a positive or negative effect on the workload, each must be assessed in isolation and in combination with the other systems for compliance with CS 29.1523. This is to ensure that the overall workload is acceptable, i.e. that the performance of flight tasks is not adversely impacted and that the crew's detection and interpretation of information does not lead to unacceptable response times. Special attention should be paid to items that are workload factors. They include the 'accessibility, ease, and simplicity of operation of all necessary flight, power, and equipment controls'.

5)_MEANS OF COMPLIANCE

5.1_Overview

This paragraph discusses considerations in selecting the means used for the demonstration of compliance. It discusses seven types of means of compliance that can be used when demonstrating compliance with human performance issues. These means of compliance are generic and are to be indicated in certification programmes. The means of compliance to be used on any given project should be determined on a case-by-case basis, driven by the specific compliance issues. They should be developed and proposed by the applicant, and then agreed to by EASA. The uses and limitations of each type of means of compliance are provided in paragraph 5.3.

5.2_Selecting the means of compliance

(a) The types of means of compliance discussed in this paragraph include:

(1) MC0: Compliance statements, reference to the type design document, definitions,

(2) MC1: Design review,

(3) MC2: Calculation and analysis,

(4) MC4: Laboratory tests,

(5) MC5: Ground tests,

(6) MC6: Flight tests, and

(7) MC8: Simulation.

(b) There is no generic method to determine the appropriate means of compliance for a specific project. The choice of an appropriate means of compliance or combination of several different means depends on a number of factors specific to a project.

(c) Some certification projects may necessitate more than one means of demonstrating compliance with a particular CS requirement. For example, when flight testing in a conforming rotorcraft is not possible, a combination of a design review and a part-task simulation evaluation may be proposed.

5.3_Description of the means of compliance

The seven general means of compliance found to be acceptable for use in demonstrating compliance related to cockpit design are described in the following subparagraphs.

(a) MC0 Compliance statement based on similarity

Description
A statement of similarity is a description of the system to be approved and a description of a previously approved system detailing the physical, logical, and operational similarities with respect to compliance with the requirements.
Deliverable

A statement of similarity could be part of a certification report, containing references to existing certification data/documents. The document is delivered to EASA depending on the defined LoI.
Participants
Not applicable.
Conformity
Not applicable.
Uses
It may be possible to substantiate the adequacy of a design by comparing it with previously certified systems that were shown to be robust with respect to a lack of contribution to crew error and/or the capability of the crew to manage the situation if an error occurs. This avoids the repetition of unnecessary effort to justify the safety of such systems.
Limitations
A statement of similarity to demonstrate compliance must be used with care. The cockpit should be assessed as a whole, not as merely a set of individual functions or systems. Two functions or features previously approved on separate programmes may be incompatible when combined in a single cockpit. Also, changing one feature in a cockpit may necessitate corresponding changes in other features, to maintain consistency and prevent confusion.
Example
If the window design in a new rotorcraft is identical to that in an existing rotorcraft, a statement of similarity may be an acceptable means of compliance to meet CS 29.773.

(b) MC1 Design review

The applicant may elect to substantiate that the design meets the requirements of a specific paragraph by describing the design. Applicants have traditionally used drawings, configuration descriptions, and/or design philosophies to demonstrate compliance. The selection of participants and conformity are not relevant to this means of compliance.

(1) Drawings

Description
Layout drawings or engineering drawings, or both, depicting the geometric arrangement of hardware or display graphics.
Deliverable
The drawings, which can be part of a certification report. The documents are delivered to EASA, depending on the defined LoI.
Uses

Applicants can use drawings for very simple certification programmes when the change to the cockpit is very simple and straightforward. Drawings can also be used to support compliance findings for more complex interfaces.
Limitations
The use of drawings is limited to physical arrangements and graphical concerns.

(2) Configuration description

Description
A configuration description is a description of the layout, general arrangement, direction of movement, etc., of a regulated item. It can also be a reference to documentation that provides such a description (for example, from a different project with a similar layout). It could be used to show the relative locations of flight instruments, groupings of control functions, the allocation of colour codes to displays and alerts, etc.
Deliverable
An explanation of the functional aspects of the crew interface: a textual description of a certification item and/or the functional aspects of the crew interface with the system (with visuals as appropriate). The document is delivered to EASA, depending on the defined LoI.
Uses
Configuration descriptions are generally less formalised than engineering drawings. They are developed to point out features of the design that support a finding of compliance. In some cases, such configuration descriptions may provide sufficient information for a finding of compliance. More often, however, they provide important background information, while the final confirmation of compliance is found through other means, such as demonstrations or tests. The background information provided by configuration descriptions may significantly reduce the complexity and/or risk associated with demonstrations or tests. The applicant will have already communicated how a system works with the configuration description, and any discussions or assumptions may have already been coordinated.
Limitations
Configuration descriptions may provide sufficient information for a finding of compliance with a specific requirement. More often, though, they provide important background information, while the final confirmation of compliance is found by other means, such as demonstrations or tests. Background information provided by configuration descriptions may significantly reduce the complexity and/or risk associated with the demonstrations or tests.

(3) Design philosophy

Description

A design philosophy approach can be used to demonstrate that an overall safety-centred philosophy, as detailed in the design specifications for the product/system or cockpit, has been applied.
Deliverable
A textual description of the certification item and/or the functional aspects of the crew interface with the system (with figures and drawings as appropriate) and its relationship to the overall design philosophy. The document is delivered to EASA, depending on the defined LoI.
Uses
Documents the ability of a design to meet the requirements of a specific paragraph.
Limitations
In most cases, this means of compliance will be insufficient as the sole means to demonstrate compliance.
Example
The design philosophy may be used as a means of compliance when a new alert is added to the cockpit if the new alert is consistent with the acceptable existing alerting philosophy.

(c) MC2 Calculation/analysis

Description
Calculations or engineering analyses ('paper and pencil' assessments) that do not require direct participant interaction with a physical representation of the equipment.
Deliverable
Substantiation report. A report detailing the analysis, its components, assumptions, and the basis for decision making. The report details results and conclusions and is delivered to EASA, depending on the defined LoI.
Participants
Conducted by the applicant.
Conformity
Not applicable.
Uses
Provides a systematic analysis of specific or overall aspects of the human interface part of the product/system/cockpit.
Limitations
The applicant should carefully consider the validity of the assessment technique if the analyses are not based on advisory material or accepted industry standard methods. Applicants may be asked to

validate any computational tools used in such analyses. If the analysis involves comparing measured characteristics with recommendations derived from pre-existing research (internal or public domain), the applicant may be asked to justify the applicability of the data to the project. While analyses are useful to start investigating the potential for design-related human errors, as well as the theoretical efficiency of the available means of protection, this demonstration needs to be complemented by observations through assessments.
Example
An applicant may conduct a vision analysis to demonstrate that the crew has a clear and undistorted view out of the windows. Similarly, an analysis may also demonstrate that flight, navigation and power plant instruments are plainly visible from the crew member station. The applicant may need to validate the results of the analysis in a ground or flight test, or by using a means of simulation that is geometrically representative. An applicant may also conduct an analysis based on evidence collected during similar previous human factors assessments.

(d) MC4 Laboratory test

Description
An assessment made using an early prototype of the human–machine interface. This can be conducted on an avionics bench when the purpose is to assess the information, or on a mock-up when the purpose is to assess the cockpit geometry.
Deliverable
A report, delivered to EASA, depending on the defined LoI.
Participants
The applicant and possibly EASA, depending on the defined LoI.
Conformity
Conformity is not required.
Bench or laboratory assessment
The applicant can conduct an assessment using devices emulating crew interfaces for a single system or a group of related systems. The applicant can use flight hardware, simulated systems, or combinations of these.
Example of a bench or laboratory assessment
A bench assessment for an integrated system could be conducted using an avionics suite installed in a mock-up of a cockpit, with the main displays and autopilot controls included. Such a tool may be valuable during development and for providing system familiarisation to EASA. However, in a highly integrated architecture, it may be difficult or impossible to assess how well the avionics system will fit into the overall cockpit without more complete simulation or use of the actual rotorcraft.

Mock-up evaluation
A mock-up is a full-scale, static representation of the physical configuration (form and fit). It does not include functional aspects of the cockpit and its installed equipment. Mock-ups can be used as representations of the design, allowing participants to physically interact with the design. Three-dimensional representations of the design in a CAD system, in conjunction with three-dimensional models of the cockpit occupants, have also been used as 'virtual' mock-ups for certain limited types of evaluations. Reachability, for example, can be addressed using either type of mock-up.
Example of a mock-up evaluation
An analysis to demonstrate that controls are arranged so that crew members from 1.58 m (5 ft 2 inches) to 1.91 m (6 ft 3 inches) in height can reach all controls. This analysis may use computer-generated data based on engineering drawings. The applicant may demonstrate the results of the analysis in the actual rotorcraft.
Limitations
Both bench and mock-up assessments are limited due to the fact that they are static exercises. Most of the human performance issues are usually revealed when observing the behaviour of pilots in dynamic situations. However, laboratory assessments can still be useful during the early stages of developing the design to identify simple and obvious design shortcomings.

(e) MC5 Ground test

Description
An assessment conducted on a flight test article on ground.
Deliverable
A report, delivered to EASA, depending on the defined LoI.
Participants
The applicant and possibly EASA, depending on the defined LoI.
Conformity
By definition, the cockpit geometry is representative, or almost. The conformity of the avionics is not required.
Limitations
Ground tests cannot be used to assess complex cognitive issues.
Example
An example of a ground test is an assessment of the potential of reflections on displays. Such an assessment usually involves covering the cockpit windows to simulate darkness and setting the

cockpit lighting to the desired levels. This particular assessment may not be possible in a simulator, because of differences in the light sources, display hardware, and/or construction of the windows.

(f) MC6 Flight test and MC8 Simulation

The applicant may use a wide variety of part-task to full-installation representations of the product/system or cockpit for assessments. The representation of the human–machine interface does not necessarily conform to the final design. The paragraphs below address part-task simulations, rotorcraft-level simulations, and in-flight assessments that typically make up this group of means of compliance.

Description
As soon as the maturity of the design allows pilots to take part in the compliance demonstration, HFs assessments are conducted in a dynamic operational context. Depending on the HFs objectives to be addressed, and according to the HFs test programme, those assessments can be either conducted at the system level or the rotorcraft level. Both simulators and real rotorcraft can be used, but the selection of the MoC depends on the nature of the test objectives.
Deliverable
A report, delivered to EASA, depending on the defined LoI.
Participants
Applicant and possibly EASA, depending on the defined LoI.
Conformity
The required level of conformity is dependent on the purpose of the exercise. When the assessment is conducted during the early phases of the design and certification process, with the aim of obtaining early and partial certification credit, the cockpit should be representative of the final design only for the part that is scrutinised. When the assessment is conducted at the end of the design and certification programme for the purpose of a final verification and validation, conformity is required.
Uses
Traditionally, these types of activities are part of the design process. They allow applicants to continuously improve their designs thanks to the application of an iterative approach. When EASA is involved in such activities, and depending on the level of representativeness of the assessed part of the design, early and partial certification credit may be granted.

(g)(i) MC8 Simulation

Simulator assessment

A simulator assessment uses devices that present an integrated emulation (using flight hardware, simulated systems, or combinations of these) of the cockpit and the operational environment. These devices can also be 'flown' with response characteristics that replicate, to some extent, the responses of the rotorcraft. The required functional and physical representativeness of the simulation (or degree of realism) will typically depend on the configurations, functions, tasks, and equipment to be assessed.
Simulator assessment conformity and representativeness issues
Applicants may use a crew training simulator to validate most of the normal, abnormal and emergency procedures for the design, and any workload effects of the equipment on the crew. If the cockpit is fully representative and the avionics are driven by conforming hardware and software, then the applicant may conduct and use integrated avionics testing for demonstrating compliance. Note that not all aspects of the simulation must have a high level of representativeness for any given compliance issue. The requirements for the representativeness of the simulator depend on the issue being checked.

(g)(ii) MC6 Flight test

Rotorcraft assessment
Flight testing during certification is the final demonstration of the design. These are tests conducted in a conforming rotorcraft during flight. The rotorcraft and its components (cockpit) are the most representative of the type design to be certified and will be the closest to real operations of the equipment. In-flight testing is the most realistic testing environment, although it is limited to those tests that can be conducted safely. Flight testing can be used to validate and verify other assessments previously conducted during the development and certification programme. It is often best to use flight testing as the final confirmation of data collected using other means of compliance, including analyses and assessments. Flights tests made during the development and certification phases for other areas of investigation can be given partial credit for demonstrating compliance with 29.1302 to a certain extent. The acceptability of this approach has, however, to be assessed by EASA on a case-by-case basis. A prerequisite for acceptance by EASA is the respect of the basic HFs methodological principles for data collection and processing. Additionally, this approach should not be used as a substitute for dedicated HFs assessments conducted on simulators or flight test vehicles, and it should only be used as a complementary approach.

(g)(iii) MC6 versus MC8

MC6 versus MC8:
The selection of the actual rotorcraft as the means of assessment should not be exclusively motivated by the absence of any other available means, but should be duly justified, taking into account its inherent limitations: — The actual rotorcraft may be inappropriate for the assessment of abnormal situations for safety reasons.

— A flight environment does not normally allow the manipulation of the operational environment which may be needed to apply the scenario-based approach.

— HFs scenarios performed using flight tests may be difficult to duplicate due to the lack of controllability of the operational context. For example, events like ATC communications, weather, etc., that are expected to trigger a crew reaction to be tested may not be repeatable. This may hamper the collection of homogeneous data and may adversely affect the validity of the experiment.

However, flight test vehicles are deemed adequate when the operational and/or system representativeness is a key driver for the validity of HFs data. For example, an assessment in real flight conditions may be more adequate when dealing with workload assessments due to its proper system and ATC representation.

In any case, the nature of the HFs objective to be assessed should drive the selection of the appropriate means, and not the contrary. EASA and the applicant should thoroughly discuss how and when flight tests and their results will be used to demonstrate compliance.

AMC 29.1302 APPENDIX 1: Related regulatory material and documents

FAA Orders and Policy

— Policy Memo ANM-99-2, Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Transport Airplane Flight Decks.

— Policy Memo ANM-0103, Factors to Consider When Reviewing an Applicant's Proposed Human Factors Methods of Compliance for Flight Deck Certification.

— FAA Notice 8110.98, Addressing Human Factors/Pilot Interface Issues of Complex, Integrated Avionics as Part of the Technical Standard Order (TSO) Process.

Other documents

The following is a list of other documents relevant to cockpit design and crew interfaces that may be useful when applying this AMC. Some are not aviation specific, such as International Standard ISO 9241-4, which, however, provides useful guidance. When using that document, applicants should consider environmental factors such as the intended operational environment, turbulence, and lighting, as well as cross-side reach.

— AMC 25-11, Electronic Flight Deck Displays, November 2018

— SAE ARP4033, Pilot-System Integration, August 1995

— SAE ARP5289A, Electronic Aeronautical Symbols

— SAE ARP4102/7, Electronic Displays

— SAE ARP4105C, Abbreviations, Acronyms, and Terms for Use on the Flight Deck

— ICAO Doc 8400, Procedures for Air Navigation Services — ICAO Abbreviations and Codes, Ninth Edition, 2016

— ICAO Doc 9683 – AN/950 Human Factors Training Manual, First Edition, 1998

— International Standards ISO 9241-4, Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)

— FAA Human Factors Team report on: The Interfaces Between Flight crews and Modern Flight Deck Systems, 1996

— DOT/FAA/RD–93/5: Human Factors for Flight Deck Certification Personnel

GM No 1 to 29.1302 Explanatory material

1_Introduction

(a) Accidents most often result from a sequence or combination of different errors and safety-related events (e.g. equipment failures and weather conditions). Analyses show that the design of the cockpit and other systems can influence the crew's task performance and the occurrence and effects of some crew errors.

(b) Crews make a positive contribution to the safety of the aviation system because of their ability to continuously assess changing conditions and situations, analyse potential actions, and make reasoned decisions. However, even well-trained, qualified, healthy, alert crew members make errors. Some of these errors may be induced or influenced by the designs of the systems and their crew interfaces, even with those that are carefully designed. Most of these errors have no significant safety effects, or are detected and mitigated in the normal course of events. However, some of them may lead or contribute to the occurrence of unsafe conditions. Accident analyses have identified crew performance and errors as recurrent factors in the majority of accidents involving rotorcraft.

(c) Some current requirements are intended to improve safety by requiring the cockpit and its equipment to be designed with certain capabilities and characteristics. The approval of cockpit systems with respect to design-related crew error has typically been addressed by referring to system-specific or general applicability requirements, such as CS 29.1301(a), CS 29.771(a), and CS 29.1523. However, little or no guidance exists to show how the applicant may address potential crew limitations and errors. That is why CS 29.1302 and this guidance material have been developed.

(d) CS 29.1302 was developed to provide a basis for addressing the design-related aspects of the avoidance and management of crew error by taking the following approach.

(i) Firstly, by providing means to address the design characteristics that are known to reduce or avoid crew error and that address crew capabilities and limitations. The requirements of CS 29.1302(a) to (c) are intended to reduce the design contribution to such errors by ensuring that the information and controls needed by the crew to perform the tasks associated with the intended function of installed equipment are provided, and that they are provided in a usable form.

In addition, operationally relevant system behaviour must be understandable, predictable, and supportive of the crew's tasks. Guidance is provided in this paragraph on the avoidance of design-induced crew errors.

(ii) Secondly, CS 29.1302(d) addresses the fact that since crew errors will occur, even with a well-trained and proficient crew operating well-designed systems, the design must support the management of those errors to avoid any safety consequences. Paragraph 5.7 below on crew error management provides the relevant guidance.

(e) EASA would like to bring the applicants' attention to the fact that the implementation of the CS 29.1302 process may require up to several years, depending on the characteristics of the project. However, STCs may require much less time.

2_Applicability and Explanatory Material to CS 29.1302

(a) CS-29 contains requirements for the design of cockpit equipment that is system specific (refer to AMC 29.1302, Table 1, in paragraph 2), generally applicable (e.g. CS 29.1301(a), CS 29.1309(c), CS 29.771(a)), and establishes minimum crew requirements (e.g. CS 29.1523). CS 29.1302 augments the generally applicable requirements by adding more explicit requirements for the design attributes related to the avoidance and management of crew errors. Other ways to avoid and manage crew errors are regulated through the requirements governing the licensing and qualification of crew members and rotorcraft operations. Taken together, these complementary approaches provide an adequate level of safety.

(b) The complementary approach is important. It is based upon recognition that equipment design, training/licensing/qualification, and operations/procedures each provide safety contributions to risk mitigation. An appropriate balance is needed between them. There have been cases in the past where design characteristics known to contribute to crew errors were accepted based upon the rationale that training or procedures would mitigate that risk. We now know that this can often be an inappropriate approach. Similarly, due to unintended consequences, it would not be appropriate to require equipment design to provide total risk mitigation.

(c) A proper balance is needed between the design approval requirements in the minimum airworthiness standards of CS-29 and the requirements for training/licensing/qualification and operations/procedures. CS 29.1302 and this GM were developed with the intent of achieving that appropriate balance.

(1) Introduction. The introductory sentence of CS 29.1302 states that the provisions of this paragraph apply to each item of installed equipment intended for the crew's use in operating the rotorcraft from their normal seating positions in the cockpit or operating positions in the cabin.

(i) 'Intended for the crew member's use in the operation of the rotorcraft from their normal seating position in the cockpit or operating positions in the cabin,' means that the intended function of the installed equipment includes its use by the crew in operating the rotorcraft. An example of such installed equipment would be a display that provides information enabling the crew to navigate. The term 'crew members' is intended to include any or all individuals comprising the minimum crew as determined for compliance with CS 29.1523. The phrase 'from their normal seating positions in the cockpit' means that the crew members are seated at their normal duty stations for operating the rotorcraft.

(ii) The phrase 'from their normally operating positions in the cabin' means that crew members are located at their normal duty stations in the cabin. These phrases are intended to limit the scope of this requirement so that it does not address the systems or equipment that are not used by the crew while performing their duties in operating the rotorcraft in normal, abnormal and emergency conditions. For example, this paragraph is not intended to apply to items such as certain circuit breakers or maintenance controls intended for use by the maintenance crew (or by the crew when not operating the rotorcraft).

(iii) The phrase 'This installed equipment must be shown…' in the first paragraph means that the applicant must provide sufficient evidence to support compliance determinations for each of the CS 29.1302 requirements. This is not intended to require a demonstration of compliance beyond that required by 21.A.21(b) of Part 21. Accordingly, for simple items or items similar to previously approved equipment and installations, the demonstrations, assessments or data needed to demonstrate compliance with CS 29.1302 are not expected to entail more extensive or onerous efforts than are necessary to demonstrate compliance with the previous requirements.

(iv) The phrase 'individually and in combination with other such equipment' means that the requirements of this paragraph must be met when equipment is installed in the cockpit with other equipment. The installed equipment must not prevent other equipment from complying with these requirements. For example, applicants must not design a display so that the information it provides is inconsistent with or is in conflict with information from other installed equipment.

(v) In addition, the provisions of this paragraph presume a qualified crew that is trained to use the installed equipment. This means that the design must meet these requirements for crew members who are allowed to fly the rotorcraft by meeting the operating rules qualification requirements. If the applicant seeks a type design or supplemental type design approval before a training programme is accepted, the applicant should document any novel, complex, or highly integrated design features and assumptions made during the design phase that have the potential to affect the training time or the crew procedures. The requirements and associated material are written assuming that either these design features and assumptions or the knowledge of a training programme (proposed or in the process of being developed) will be coordinated with the appropriate operational approval organisation when assessing the adequacy of the design.

(vi) The requirement for equipment to be designed so the crew can safely perform the tasks associated with the intended function of the equipment applies in normal, abnormal and emergency conditions. The tasks intended to be performed under all the above conditions are generally those prescribed by the crew procedures. The phrase 'safely perform their tasks' is intended to describe one of the safety objectives of this requirement. The requirement is for the equipment design to enable the crew to perform their tasks with sufficient accuracy and in a timely manner, without unduly interfering with their other required tasks. The phrase 'tasks associated with its intended function' is intended to characterise either the tasks required to operate the equipment or the tasks for which the intended function of the equipment provides support.

(2) **CS 29.1302(a)** requires the applicant to install appropriate controls and provide the necessary information for any cockpit equipment identified in the first paragraph of CS 29.1302. The controls and the information displays must be sufficient to allow the crew to accomplish their tasks. Although this may seem obvious, this requirement is included because a review of CS-29 on the subject of human factors revealed that a specific

requirement for cockpit controls and information to meet the needs of the crew is necessary. This requirement is not reflected in other parts of the rules, so it is important to be explicit.

(3) **CS 29.1302(b)** addresses the requirements for cockpit controls and information that are necessary and appropriate for the crew to accomplish their tasks, as determined through (a) above. The intent is to ensure that the design of the control and information devices makes them usable by the crew. This subparagraph seeks to reduce design-induced crew errors by imposing design requirements on cockpit information presentation and controls. Subparagraphs (1) through (3) specify these design requirements. Design requirements for information and controls are necessary to:

(i) properly support the crew in planning their tasks;

(ii) make available to the crew appropriate, effective means to carry out planned actions; and

(iii) enable the crew to have appropriate feedback information about the effects of their actions on the rotorcraft.

(4) **CS 29.1302(b)(1)** specifically requires controls and information to be provided in a clear and unambiguous form, at a resolution and precision appropriate to the task.

(i) As applied to information, 'clear and unambiguous' means that it can be perceived correctly (is legible) and can be comprehended in the context of the crew tasks associated with the intended functions of the equipment, such that the crew can perform all the associated tasks.

(ii) For controls, the requirement for 'clear and unambiguous' presentation means that the crew must be able to use them appropriately to achieve the intended functions of the equipment. The general intent is to foster the design of equipment controls whose operation is intuitive, consistent with the effects on the parameters or states that they affect, and compatible with the operation of the other controls in the cockpit.

(iii) 29.1302(b)(1) also requires the information or control to be provided, or to operate, at a level of detail and accuracy appropriate for accomplishing the task. Insufficient resolution or precision would mean the crew could not perform the task adequately. Conversely, excessive resolution has the potential to make a task too difficult because of poor readability or the implication that the task should be accomplished more precisely than is actually necessary.

(5) **CS 29.1302(b)(2)** requires controls and information to be accessible and usable by the crew in a manner consistent with the urgency, frequency, and duration of their tasks. For example, controls that are used more frequently or urgently must be readily accessed, or require fewer steps or actions to perform the task. Less accessible controls may be acceptable if they are needed less frequently or urgently. Controls that are used less frequently or urgently should not interfere with those used more urgently or frequently. Similarly, tasks requiring a longer time for interaction should not interfere with the accessibility to information required for urgent or frequent tasks.

(6) **CS 29.1302(b)(3)** requires equipment to present information advising the crew of the effects of their actions on the rotorcraft or systems, if that awareness is required for safe operation.

The intent is for the crew to be aware of the system or rotorcraft states resulting from crew actions, permitting them to detect and correct their own errors. This subparagraph is included because new technology enables new kinds of crew interfaces that previous requirements did not address. Specific deficiencies of existing requirements in addressing human factors are described below:

(i) CS 29.771(a) addresses this topic for controls, but does not include criteria for the presentation of information;

(ii) CS 29.777(a) addresses controls, but only their location;

(iii) CS 29.777(b) and CS 25.779 address the direction of motion and actuation but do not encompass new types of controls such as cursor devices. These requirements also do not encompass types of control interfaces that can be incorporated into displays via menus, for example, thus affecting their accessibility;

(iv) CS 29.1523 has a different context and purpose (determining the minimum crew), so it does not address these requirements in a sufficiently general way.

(7) **CS 29.1302(c)** requires installed equipment to be designed so its behaviour that is operationally relevant to crew tasks is:

(i) predictable and unambiguous, and

(ii) designed to enable the crew to intervene in a manner appropriate to the task (and intended function).

Other related considerations are the following:

(iii) Improved cockpit technologies involving integrated and complex information and control systems have increased safety and performance. However, they have also introduced the need to ensure proper interactions between the crew and those systems. Service experience has found that some equipment behaviour (especially from automated systems) is excessively complex or dependent upon logical states or mode transitions that are not well understood or expected by the crew. Such design characteristics can confuse the crew and have been determined to contribute to incidents and accidents.

(iv) The phrase 'operationally relevant behaviour' is meant to convey the net effect of the system logic, controls, and displayed information of the equipment upon the awareness of the crew or their perception of the operation of the system to the extent necessary for planning actions or operating the system. The intent is to distinguish such system behaviour from the functional logic within the system design, much of which the crew does not know or does not need to know, and which should be transparent to them.

(8) **CS 29.1302(c)(1)** requires the behaviour of a system to be such that a qualified crew can know what the system is doing and why. It requires operationally relevant system behaviour to be 'predictable and unambiguous'. This means that a crew can retain enough information about what their action or a changing situation will cause the system to do under foreseeable circumstances, so they can operate the system safely.

The behaviour of a system must be unambiguous because the actions of the crew may have different effects on the rotorcraft, depending on its current state or operational circumstances.

(9) **CS 29.1302(c)(2)** requires the design to be such that the crew will be able to take some action, or change or alter an input to the system, in a manner appropriate to the task.

(10) **CS 29.1302(d)** addresses the reality that even well-trained, proficient crews using well-designed systems will make errors. It requires equipment to be designed to enable the crew to manage such errors. For the purpose of this rule, errors 'resulting from crew interaction with the equipment' are those errors that are in some way attributable, or related, to the design of the controls, the behaviour of the equipment, or the information presented. Examples of designs or information that could cause errors are indications and controls that are complex and inconsistent with each other or with other systems on the cockpit. Another example is a procedure that is inconsistent with the design of the equipment. Such errors are considered to be within the scope of this requirement and AMC.

(i) What is meant by a design which enables the crew to 'manage errors' is that:

(A) the crew must be able to detect and/or recover from errors resulting from their interaction with the equipment; or

(B) the effects of such crew errors on the rotorcraft functions or capabilities must be evident to the crew, and continued safe flight and landing must be possible; or

(C) crew errors must be discouraged by switch guards, interlocks, confirmation actions, or other effective means; or

(D) the effects of errors must be precluded by system logic or redundant, robust, or fault-tolerant system design.

(ii) The requirement to manage errors applies to those errors that can be reasonably expected in service from qualified and trained crews. The term 'reasonably expected in service' means errors that have occurred in service with similar or comparable equipment. It also means errors that can be predicted to occur based on general experience and knowledge of human performance capabilities and limitations related to the use of the type of controls, information, or system logic being assessed.

(iii) CS 29.1302(d) includes the following statement: 'This sub-paragraph does not apply to skill-related errors associated with manual control of the rotorcraft.' That statement is intended to exclude errors resulting from the crew's proficiency in the control of the flight path and attitude with the primary roll, pitch, yaw and thrust controls, and which are related to the design of the flight control systems. These issues are considered to be adequately addressed by the existing requirements, such as CS-29 Subpart B and CS 29.671(a). It is not intended that the design should be required to compensate for deficiencies in crew training or experience. This assumes at least the minimum crew requirements for the intended operation, as discussed at the beginning of paragraph 5.1 above.

(iv) This requirement is intended to exclude the management of errors resulting from decisions, acts, or omissions by the crew that are not in good faith. It is intended to avoid imposing requirements on the design to accommodate errors committed with malicious or purely contrary intent. CS 29.1302 is not intended to require applicants to consider errors resulting from acts of violence or threats of violence.

This 'good faith' exclusion is also intended to avoid imposing requirements on designs to accommodate errors due to a crew member's obvious disregard for safety. However, it is recognised that errors committed intentionally may still be in good faith, but could be influenced by the characteristics of the design under certain circumstances. An example would be a poorly designed procedure that is not compatible with the controls or information provided to the crew.

Imposing requirements without considering their economic feasibility or the commensurate safety benefits should be avoided. Operational practicability should also be addressed, such as the need to avoid introducing error management features into the design that would inappropriately impede crew actions or decisions in normal, abnormal and emergency conditions. For example, it is not intended to require so many guards or interlocks on the means to shut down an engine that the crew would be unable to do this reliably within the available time. Similarly, it is not intended to reduce the authority or means for the crew to intervene or carry out an action when it is their responsibility to do so using their best judgment in good faith.

This subparagraph was included because managing errors that result from crew interactions with equipment (that can be reasonably expected in service) is an important safety objective. Even though the scope of applicability of this material is limited to errors for which there is a contribution from or a relationship to the design, CS 29.1302(d) is expected to result in design changes that will contribute to safety. One example, among others, would be the use of 'undo' functions in certain designs.

GM No 2 to 29.1302 Example of compliance matrix

EASA expects to receive from the applicant the essential information in order to understand the relationship between the following elements:

— the features of the design,

— the regulations,

— the test objectives,

— the MoCs, and

— the deliverables.

The two matrices below are provided as examples only. However, the applicants are free to present the necessary information to EASA through any format discussed and agreed with EASA.

An example with a design feature entry:

Function	Sub-function	Focus	Reference to requirement	Description of requirement	Assessed dimension	MoC	Reference to the related deliverable
Electronic checklist (ECL) function	Display electronic checklist	Electronic checklist quick access keys (ECL QAKs)	CS 29.777(a)	Each cockpit control must be located to provide convenient operation and to prevent confusion or inadvertent operation.	Assess ECL QAKs location for convenient operation and prevention of inadvertent operation.	MoC8 HFs campaign #2 Scenario #4	Human Factors Test Report XXX123
			CS29.777(b)	The controls must be located and arranged with respect to the pilots' seats so that there is full and unrestricted movement of each control without interference from the cockpit structure or the pilot's clothing when pilots from 1.57 m (5 ft 2 inches) to 1.8 m (6 ft) in height are seated.	Assess accessibility to control ECL QAKs.	MoC4 HFs Reachability Analysis MoC5 HFs Reachability and Accessibility Campaign	HFs Reachability and Accessibility Assessment Report XXX123
			[…]	[…]	[…]	[…]	[…]
			CS 29.1302(a)	Flight deck controls must be installed to allow the accomplishment of these tasks, and the information necessary to accomplish these tasks must be provided.	Assess appropriate control is provided in order to display ECL.	MoC1 ECL implementation description for XXXX.	ECL implementation description document for XXXX.

Function	**Sub-function**	**Focus**	**Reference to requirement**	**Description of requirement**	**Assessed dimension**	**MoC**	**Reference to the related deliverable**
			CS 29.1302(b)(1)	Flight deck controls and information intended for flight crew use must be presented in a clear and unambiguous form, at a resolution and precision appropriate to the task.	Assess appropriateness of ECL QAKs labels.	MoC8 HFs campaign #4 Scenario #1	Human Factors test Report XXX345

Another example with a requirement entry:

Reference to requirement	Description of requirement	Focus	Assessed dimension	MoC	Reference to the related deliverable
CS 29.777(a)	Each cockpit control must be located to provide convenient operation and to prevent confusion and inadvertent operation.	All cockpit controls	Assess the locations of all cockpit controls for convenient operation and prevention of inadvertent operation.	MoC8 All HFs simulator evaluations	Human Factors Test Reports XXX123 XXX456 XXX789
		ECL QAKs	Assess the location of ECL QAKs for convenient operation and prevention of inadvertent operation.	MoC8 HFs campaign #2 Scenario #4	Human Factors Test Report XXX123
CS 29.777(b)	The controls must be located and arranged with respect to the pilots' seats so that there is full and unrestricted movement of each control without interference from the cockpit structure or the pilot's clothing when pilots from 1.57 m (5 ft 2 inches) to 1.8 m (6 ft) in height are seated.	All cockpit controls	Assess the accessibility of all cockpit controls.	MoC4 HFs Reachability Analysis. MoC5 HFs Reachability and Accessibility Campaign.	HFs Reachability and Accessibility Assessment Report XXX123
		ECL QAKs	Assess accessibility to control ECL QAKs.	MoC4 HFs Reachability Analysis. MoC5 HFs Reachability and Accessibility Campaign.	HFs Reachability and Accessibility Assessment Report XXX123
[…]	[…]				
CS 29.1302(a)	Flight deck controls must be installed to allow the accomplishment of these tasks, and the information necessary to accomplish these tasks must be provided.				
CS 29.1302(b)(1)	Flight deck controls and information intended for flight crew use must be presented in a clear and unambiguous form, at a				

Reference to requirement	Description of requirement	Focus	Assessed dimension	MoC	Reference to the related deliverable
	resolution and precision appropriate to the task.				

CS 27.1302 Installed systems and equipment for use by the crew

(See AMC 27.1302, GM No 1 and No 2 to 27.1302)

This point applies to installed equipment intended for use by crew members in the operation of the rotorcraft from their normal seating positions in the cockpit or operating positions in the cabin. This installed equipment must be shown, individually and in combination with other such equipment, to be designed so that trained crew members can safely perform their tasks associated with the intended function of the equipment by meeting the following requirements:

(a) All the controls and information necessary to accomplish these tasks must be provided;

(b) All the controls and information required by paragraph (a), which are intended for use by the crew, must:

(1) be presented in a clear and unambiguous form, at a resolution and with a precision appropriate to the task;

(2) be accessible and usable by the crew in a manner consistent with the urgency, frequency, and duration of their tasks; and

(3) make the crew aware of the effects that their actions may have on the rotorcraft or systems, if they need awareness for safe operation.

(c) Operationally relevant behaviour of the installed equipment must be:

(1) predictable and unambiguous; and

(2) designed to enable the crew to intervene in a manner appropriate to accomplish the task.

(d) Installed equipment must enable the crew to manage the errors resulting from the kinds of crew interactions with the equipment that can be reasonably expected in service, assuming the crew is acting in good faith. Paragraph (d) does not apply to skill-related errors associated with the manual control of the rotorcraft.

AMC 27.1302 Installed systems and equipment for use by the crew

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1)_INTRODUCTION

1.1_Scope

Demonstrating compliance with design requirements that relate to human abilities and limitations is subject to a great deal of interpretation. Findings may vary depending on the novelty, complexity or degree of integration of the system design. EASA considers that describing a structured approach to selecting and developing acceptable means of compliance is useful in aiding standardised compliance demonstration practices.

1.2_Applicability

(a) This Acceptable Means of Compliance (AMC) provides means for demonstrating compliance with the requirements of CS 27.1302 and several other paragraphs in CS-27 (refer to paragraph 2, Table 1 of this AMC) that relate to the installed equipment used by the crew in the operation of a rotorcraft. In particular, this AMC addresses the design and approval of installed equipment that is intended for use by the crew members from their normal seating positions in the cockpit, or their normal operating positions in the cabin.

(b) This AMC applies to the crew interfaces and system behaviour for all the installed systems and equipment used by the crew in the cockpit and the cabin while operating the rotorcraft in normal, abnormal and emergency conditions. The functions of the crew members operating from the cabin need to be considered if they may interfere with the ones under the responsibility of the cockpit crew, or if dedicated airworthiness requirements are included in the rules.

(c) This AMC does not apply to crew training, qualification, or licensing requirements.

(d) The material contained in this AMC is expected to be used for new types and for changes to existing types as follows:

(1) Applicants for a CS-27 rotorcraft approved for CAT A and IFR operation, or CAT A, or for a significant change potentially affecting the HFs, should follow all this material;

(2) Applicants for CS-27 rotorcraft approved for CAT A and VFR operations only, or CAT B and IFR operations, are:

(i) not required to develop a dedicated HFs test programme (refer to point 3.2.8 (a)); and are

(ii) allowed to apply individual tests to confirm that the design assumptions are valid (refer to point 3.3.1(b)).

(3) Applicants for CS-27 rotorcraft approved for CAT B and VFR operations only are:

(i) not required to develop a dedicated HFs test programme (refer to point 3.2.8(a));

(ii) allowed to apply individual tests to confirm that the design assumptions are valid (refer to point 3.3.1(b)); and are

(iii) allowed to use a single crew member to demonstrate the HFs scenario-based assessments (refer to 3.3.2(e)).

(4) Applicants for a non-significant change (refer to the classification in point 21.A.101 and related GM) are:

(i) not required to develop a dedicated HFs test programme (refer to paragraph 3.2.8(a)); and are

(ii) allowed to use single tests for the compliance demonstration (refer to paragraph 3.3.1(b)).

Additionally, applicants for a non-significant change to CS-27 rotorcraft approved only for CAT B and VFR are allowed to apply individual tests to confirm that the design assumptions are valid (refer to point 3.3.1(b)).

(5) For applicants for a change approval modifying the category of the rotorcraft or introducing the capability for IFR operation, the applicability of paragraphs (2) to (4) above will have to be reassessed taking into account the final category and type of operations.

1.3_Definitions

For the purposes of this AMC, the following definitions apply:

— **Alert**: A cockpit indication meant to attract the attention of the crew, and identify to them an operational or aircraft system condition. Warnings, cautions, and advisories are considered to be alerts. (For further information, refer to AMC 25.1322.)

— **Assessment**: The process of finding and interpreting evidence to be used by the applicant in order to establish compliance with a requirement. For the purpose of this AMC, the term 'assessment' can refer to both evaluations and tests. Evaluations are intended to be conducted using partially representative test means, whereas tests make use of conformed test articles.

— **Automation**: The autonomous execution of a task (or tasks) by aircraft systems started by a high-level control action of the crew.

— **Catachresis**: Applied to the area of tools, 'catachresis' means the use of a tool for a function other than the one planned by the designer of the tool. For instance, using a circuit breaker as a switch.

— **Clutter**: An excessive number and/or variety of symbols, colours, or other information that may reduce crew access and increase their interpretation time and the probability of interpretation error.

— **Cockpit**: The area of the aircraft where the crew members work and where all the controls are located. For the purpose of this AMC, the cockpit may include workstations located in the cabin and used by crew members to operate systems that are critical for safety (e.g. rescue hoist control stations, secondary crew stations, as those are used for precision hovering).

— **Conformity**: Official verification that the cockpit/system/product conforms to the type design data. Conformity of the facility is one parameter that distinguishes one means of compliance from another.

— **Cockpit controls**: Interaction with a control means that the crew manipulates it in order to operate, configure, and manage the aircraft or its flight control surfaces, systems, and other equipment.

This may include equipment in the cockpit such as:

— control devices,

— buttons,

— switches,

— knobs,

— flight controls, and

— levers.

— **Control device**: A control device is a piece of equipment that allows the crew to interact with virtual controls, typically used with the graphical user interface. Control devices may include the following:

— keyboards,

— touchscreens,

— cursor control devices (keypads, trackballs, pointing devices),

— knobs, and

— voice-activated controls.

— **Crew member**: A person involved in the operation of the aircraft and its systems. In the case of rotorcraft, operators in the cabin dedicated to operating the rescue hoist or to helping the crew to control the aircraft in a hover are considered to be crew members.

— **Cursor control device**: A control device for interacting with virtual controls, typically used with a graphical user interface on an electro-optical display.

— **Design eye reference point (DERP)**: A point in the cockpit that provides a finite reference enabling the precise determination of geometric entities that define the layout of the cockpit.

— **Design philosophy**: A high-level description of the human-centred design principles that guide the designer and aid in ensuring that a consistent, coherent user interface is presented to the crew.

— **Design-related human performance issue**: A deficiency resulting from the interaction between the crew and the system. It includes human errors, but also encompasses other kinds of shortcomings such as hesitation, doubt, difficulty in finding information, suboptimal strategies, inappropriate levels of workload, or any other observable item that cannot be considered to be a human error, but still reveals a design-related concern.

— **Display**: A device (typically visual, but it may be accompanied by auditory or tactile feedback) that transmits data or information from the aircraft to the crew.

— **Human error**: A deviation, attributable to the crew, from what is considered correct in some context, especially in the 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.

— **Multifunction control**: A control device that can be used for many functions, as opposed to a control device with a single dedicated function.

— **Abnormal or emergency conditions**: For the purpose of this AMC, abnormal or emergency operating conditions refer to conditions that do require the crew to apply procedures different from the normal procedures included in the rotorcraft flight manual.

— **System function allocation**: A human factors (HFs) method for deciding whether a particular function will be accomplished by a person, technology (hardware or software) or some mix of a person and technology (also referred to as 'task allocation').

— **Task analysis**: A formal analytical method used to describe the nature and relationships of complex tasks involving a human operator.

1.4_Abbreviations

For the purposes of this AMC, the following abbreviations apply:

AC	advisory circular
AMC	acceptable means of compliance
CSs	certification specifications
DoT	Department of Transportation
EASA	European Union Aviation Safety Agency
FAA	Federal Aviation Administration
HFs	human factors
ICAO	International Civil Aviation Organization
ISO	International Standards Organization
LoI	level of involvement
MC	means of compliance
RFM	rotorcraft flight manual
SAE	Society of Automotive Engineers
STC	supplemental type certificate
TAWS	terrain awareness warning system
TCAS	traffic collision avoidance system
TSO	technical standard order
VOR	very high frequency omnidirectional range

2)_RELATION BETWEEN CS 27.1302 AND OTHER REQUIREMENTS, AND ASSUMPTIONS

2.1_The relation of CS 27.1302 to other requirements

(a) This AMC provides guidance for demonstrating compliance with CS 27.1302 and the guidance related to several other requirements associated with the installed equipment that the crew uses in operating the rotorcraft. Table 1 below contains a list of the requirements related to cockpit design and crew interfaces for which this AMC provides guidance. Note that this AMC does not provide a comprehensive means of compliance for any of the requirements beyond CS 27.1302.

(b) CS-27 Book 2 establishes that the guidance material for CS-27 is included in the revision of FAA AC 27-1 adopted by EASA with the changes/additions included within Book 2. AC 27-1 includes Miscellaneous Guidance MG-20 'Human Factors' that provides dedicated guidance material for all the human-factors-related paragraphs, but does not include specific guidance for 27.1302. Therefore, adherence to the guidance material included within AC 27-1 and the associated MG-20 is not considered sufficient to demonstrate compliance with CS 27.1302, for which this material provides additional guidance.

CS-27 BOOK 1 requirements	***General topic***	***Referenced material in this AMC***
CS 27.771(a)	Unreasonable concentration or fatigue	Error, 4.5. Integration, 4.6. Controls, 4.2. System behaviour, 4.4.
CS 27.771(b)	Controllable from either pilot seat	Controls, 4.2. Integration, 4.6.
CS 27.773	Pilot compartment view	Integration, 4.6.
CS 27.777(a)	Convenient operation of the controls	Controls, 4.2. Integration, 4.6.
CS 27.777(b)	Fully and unrestricted movement	Controls, 4.2. Integration, 4.6.
CS 27.779	Motion and effect of cockpit controls	Controls, 4.2
CS 27.1301(a)	Intended function of installed systems	Error, 4.5. Integration, 4.6. Controls, 4.2. Presentation of information, 4.3. System behaviour, 4.4.
CS 27.1302	Crew error	Error, 4.5. Integration, 4.6. Controls, 4.2. Presentation of information, 4.3. System behaviour, 4.4.
CS 27.1309(a)	Intended function of required equipment under all operating conditions	Controls, 4.2. Integration, 4.6.
CS 27.1321	Visibility of instruments	Integration, 4.6.
CS 27.1322	Warning caution and advisory lights	Integration, 4.6.

CS-27 BOOK 1 requirements	***General topic***	***Referenced material in this AMC***
CS 27.1329 and Appendix B VII	Automatic pilot system	System behaviour, 4.4.
CS 27.1335	Flight director systems	System behaviour, 4.4
CS 27.1523	Minimum crew	Controls, 4.2. Integration, 4.6.
CS 27.1543(b)	Visibility of instrument markings	Presentation of information, 4.3.
CS 27.1549	Powerplant instruments	Presentation of information, 4.3
CS 27.1555 (a)	Control markings	Controls, 4.2.
CS 27.1557	Miscellaneous marking and placards	Presentation of information, 4.3

Paragraph 2 — Table 1: Requirements relevant to this AMC

(c) Where means of compliance in other AMC are provided for specific equipment and systems, those means are assumed to take precedence if a conflict exists with the means provided here.

2.2_Crew capabilities

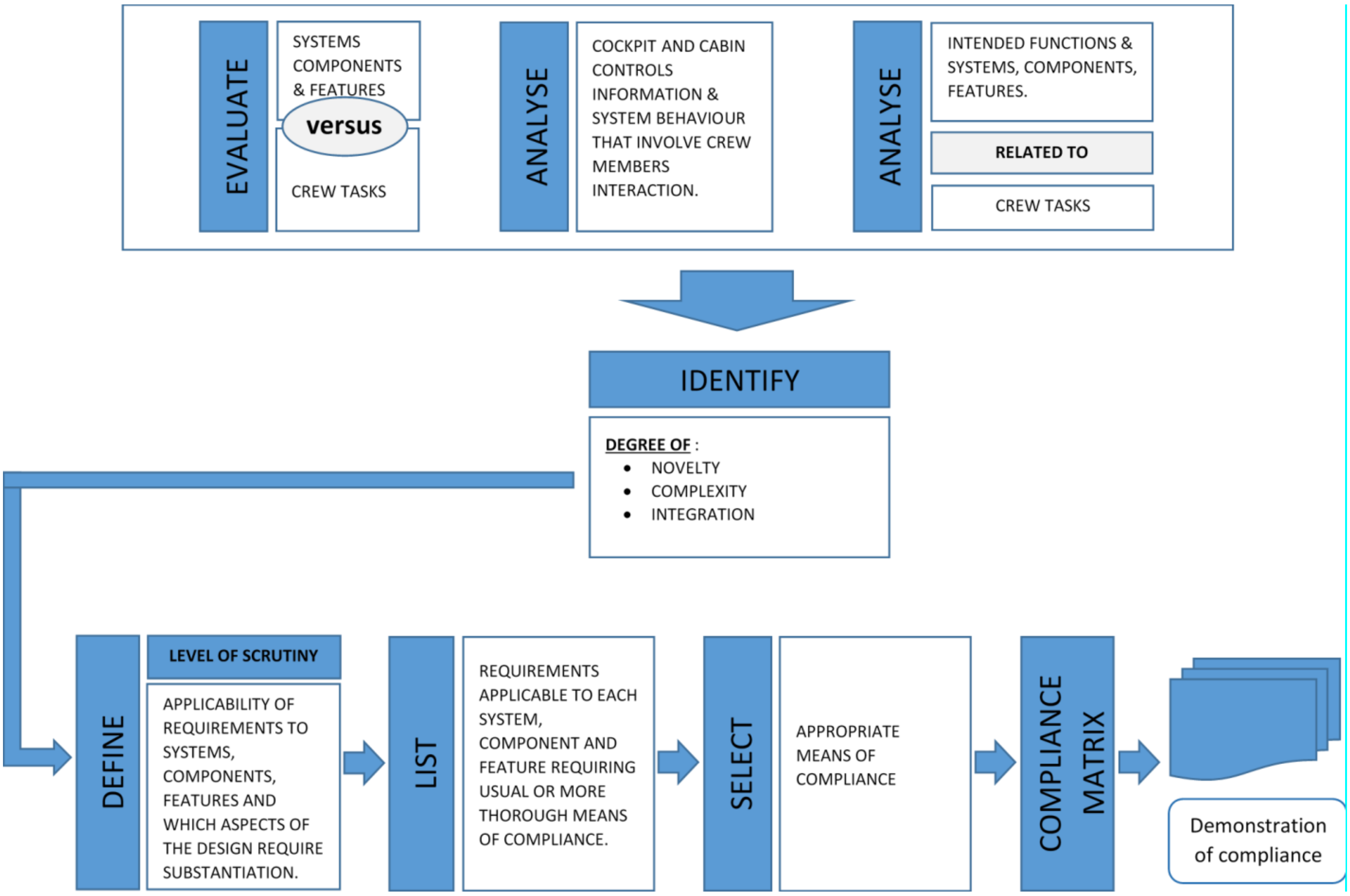
In order to demonstrate compliance with all the requirements referenced by this AMC, all the certification activities should be based on the assumption that the rotorcraft will be operated by qualified crew members who are trained in the use of the installed equipment.

3)_HUMAN FACTORS CERTIFICATION

3.1_Overview

(a) This paragraph provides an overview of the human factors certification process that is necessary to demonstrate compliance with CS 27.1302. This includes a description of the recommended applicant activities, the communication between the applicant and EASA, and the expected deliverables.

(b) Figure 1 illustrates the main steps in the human factors certification process.



Paragraph 3 — Figure 1: Methodical approach to certification for design-related human performance issues

3.2_Certification steps and deliverables

3.2.1_Identification of the cockpit controls, information and systems that involve crew interaction

(a) As an initial step, the applicant should consider the entire cockpit or the modification introduced into it with the aim of identifying the controls, information and system behaviour that involve crew interaction.

(b) The objective is to analyse and document the crew tasks to be performed in the cockpit, or how crew tasks might be changed or modified as a result of introducing a new system(s), component(s) or feature(s) into an existing cockpit.

(c) Rotorcraft can be operated in different environments and types of missions. Therefore, while mapping the entire cockpit and cabin or the modified one against the tasks of the crew and the intended functions of the rotorcraft and systems, the type of approval envisaged for the rotorcraft under assessment should be considered and documented. For instance, approvals for:

— VFR,

— IFR,

— NVIS,

— SAR,

— aerial work (cargo hook or rescue hoist), or

— flight in known icing conditions

require different equipment to be installed or a different use of the same equipment. Therefore, the applicant should clarify the assumptions made when the assessment of the cockpit and cabin functions is carried out.

3.2.2_The intended function of equipment and the associated crew tasks

(a) CS 27.1301(a) requires that 'each item of installed equipment must be of a kind and design appropriate to its intended function'. CS 27.1302 establishes requirements to ensure that the design supports the ability of the crew members to perform the tasks associated with the intended function of a system. In order to demonstrate compliance with CS 27.1302, the intended function of a system and the tasks expected of the crew must be known.

(b) An applicant's statement of the intended function should be sufficiently specific and detailed so that EASA can evaluate whether the system is appropriate for the intended function(s) and the associated crew tasks. For example, a statement that a new display system is intended to 'enhance situational awareness' should be further explained. A wide variety of different displays enhance situational awareness in different ways. Some examples are terrain awareness, vertical profiles, and even the primary flight displays. The applicant may need to provide more detailed descriptions for designs with greater levels of novelty, complexity, or integration.

(c) An applicant should describe the intended function(s) and associated task(s) for:

(1) each item of the cockpit equipment,

(2) crew indications and controls for that equipment, and

(3) the prominent characteristics of those indications and controls.

This type of information is of the level typically provided in a pilot's handbook or an operations manual. It would describe the indications, controls, and crew procedures.

(d) As discussed later in paragraph 3.2.3, novel features may require more detail, while previously approved systems and features typically require less detail. Paragraph 3.2.4 discusses functions that are sufficiently novel and additional scrutiny is required. Applicants may evaluate whether statements of the intended function(s) and the associated task(s) are sufficiently specific and detailed by using the following questions:

(1) Does each feature and function have a stated intent?

(2) Are the crew tasks associated with the function described?

(3) What assessments, decisions, and actions are crew members expected to make based on the information provided by the system?

(4) What other information is assumed to be used in combination with the system?

(5) Will the installation or use of the system interfere with the ability of the crew to operate other cockpit systems?

(6) Are any assumptions made about the operational environment in which the equipment will be used?

(7) What assumptions are made about the attributes or abilities of the crew beyond those required in the regulations governing flight operations, training, or qualification?

(e) The output of this step is a list of items, with each of the associated intended functions that has been related to the crew tasks.

3.2.3_Determining the level of scrutiny

(a) The depth and extent of the human factors investigation to be performed in order to demonstrate compliance with CS 27.1302 is driven by the level of scrutiny.

The level of scrutiny is determined by analysing the cockpit features and items using the criteria described in the following subparagraph:

(1) **Integration**. In this document, the term 'level of systems' integration' refers to the extent to which there are interdependencies between the systems that affect the crew's operation of the rotorcraft. The applicant should describe the integration between systems because it may affect the means of compliance. Paragraph 4.6 also refers to integration. In the context of that paragraph, 'integration' defines how specific systems are integrated into the cockpit and how the level of integration may affect the means of compliance.

(2) **Complexity**. The complexity of the system design from the crew's perspective is an important factor that may also affect the means of compliance in this process. Complexity has multiple dimensions, for instance:

— the number, the accessibility and level of integration of information that the crew has to use (the number of items of information on a display, the number of colours), alerts, or voice messages may be an indication of the complexity;

— the number, the location and the design of the cockpit controls associated with each system and the logic associated with each of the controls; and

— the number of steps required to perform a task, and the complexity of the workflows.

(3) **Novelty.** The applicant should identify any design novelty based on the following factors:

(i) Are any new functions introduced into the cockpit design?

(ii) Are any new technologies introduced that operate in new ways for either established or new cockpit designs?

(iii) Are any unusual or additional operational procedures needed as a result of the introduction of new technologies?

(iv) Does the design introduce a new way for the crew to interact with the systems using either conventional or innovative technology?

(v) Does the design introduce new uses for existing systems that change the tasks or responsibilities of the crew?

A function or system that the applicant chooses to refer to as a baseline from which the novelty is derived needs to have been certified by the applicant under CS 27.1302.

One positive answer to any of the above questions is sufficient to trigger the novelty criterion.

(b) If at least one of the above criteria is met, the related item should be included by the applicant in the list of candidate items to be scrutinised, and it should be proposed to EASA.

(c) The level of scrutiny performed by the applicant should be proportionate to the number of the above criteria which are met by each item. Applicants should be aware that the impact of a complex feature might also be affected by its novelty and the extent of its integration with other elements of the cockpit. For example, a complex but not novel feature is likely to require a lower level of scrutiny than one that is both complex and novel.

3.2.4_Determination of the list of items requiring extra scrutiny

EASA will review the applicant's proposal with a view to reaching an agreement on the list of items that require a higher level of scrutiny. The assessment of the classifications proposed by the applicant requires the EASA Flight and HF panels to be familiarised with the cockpit, making use of the available material and tools.

Irrespective of the above, the EASA involvement in the verification of compliance demonstration of the subsequent steps of the human factors process will depend on the LoI determined by EASA in accordance with point 21.B.100 of Part 21.

3.2.5_Applicable human factors design requirements

(a) The applicant should identify the human factors (HFs) design requirements applicable to each of the systems, components, and features for which compliance must be demonstrated. This may be accomplished by identifying any design characteristics that could adversely affect the performance of the crew, or that pertain to the avoidance and management of crew errors.

(b) Specific design considerations for the requirements that involve human performance are discussed in paragraph 4. The applicability of each design consideration in paragraph 4 will depend on the design characteristics identified in paragraph 3.2.3.

(c) The expected output of this step is a compliance matrix that links the design features and the HFs design requirements that are deemed to be relevant and applicable for each design feature, so that a detailed assessment objective can be derived from each pair of a design feature and an HFs design requirement. That objective will have then to be verified using the most adequate means of compliance, or a combination of means of compliance.

(d) GM No 2 to 27.1302 provides one possible example of this matrix.

3.2.6_Selecting the appropriate means of compliance

(a) After identifying what should be shown in order to demonstrate compliance, the applicant should review paragraph 5.2 for guidance on selecting the means of compliance, or multiple means of compliance, appropriate to the design. In general, it is expected that the level of scrutiny should increase with higher levels of novelty, complexity, criticality or integration of the design. It is also expected that the amount of effort dedicated to the demonstration of compliance should increase with higher levels of scrutiny (e.g. by using multiple means of compliance and/or multiple HFs assessments on the same topic).

(b) The output of this step will consist of the list of means of compliance that will be used to verify the HFs objectives.

3.2.7_Certification programme

(a) The applicant should document the certification process, outputs and agreements described in the previous paragraphs. This may be done in a separate plan or incorporated into a higher-level certification programme.

(b) Additionally, for each assessment or inspection listed in the certification programme and included in the EASA level of involvement (LoI), the related scheduling should be provided to EASA for acceptance.

3.2.8_Other deliverables

(a) An HFs test programme should be produced for each assessment and should describe the experimental protocol (the number of scenarios, the number and profiles of the crews, practical organisation of the assessment, etc.), the HFs objectives that are meant to be addressed, the expected crew behaviours, and the scenarios expected to be run. When required by the LoI, the HFs test programme should be provided well in advance to EASA.

(b) An HFs test report should be produced including at least the following information:

(1) A summary of the:

(i) test vehicle configuration,

(ii) test vehicle limitations/representativeness,

(iii) detailed HFs objectives, and

(iv) HFs test protocol, including the number of sessions and crews, type of crews (test or operational pilots from the applicant, authority pilots, airline pilots), a description of the scenarios, the organisation of the session (training, briefing, assessment, debriefing), and the observers;

(2) A description of the data gathered related to every HFs objective;

(3) In-depth analyses of the observed HFs issues;

(4) Conclusions regarding the related HFs test objective; and

(5) If applicable, a description of the proposed way to mitigate the HFs issue (by a design modification, improvements in procedures, and/or training actions).

If EASA has retained the review of the test report as part of its LoI, then the applicant should deliver it following every HFs assessment.

3.3_Certification strategy and methodologies

3.3.1_Certification strategy

(a) The HFs assessment should follow an iterative process. Consequently, where appropriate, there may be several iterations of a same system-specific assessment allowing the applicant to reassess the system if the previous campaigns resulted in design modifications.

(b) An HFs certification strategy based only on one test, aimed at demonstrating that the design assumptions are valid, is generally not acceptable (i.e. one final exercise proposed for compliance demonstration at the very end of the process).

(c) Since the beginning of the certification process, EASA has to be able to monitor the development process through familiarisation sessions, regular witnessing of the HFs at the system-level and rotorcraft-level assessments, and reviews of test plans and test reports for assessments that will support the determination of the EASA LoI. Both parties may find an interest in this method, as the authority is continuously gaining experience and confidence in the HFs process and the compliance of the cockpit design. The applicant may be granted partial early certification credit, leading to a proper mitigation of the certification risk. Additionally, potential issues may be identified early on by using this approach, thus reducing the risk of a late redesign of features that may not be acceptable to EASA.

This paragraph may not apply in cases of simple changes.

(d) The representativeness of the systems and of the simulation means in the early stages of the development is not a key driver, and will not prevent EASA's involvement as long as the representativeness issues do not compromise the validity of the data to be collected.

(e) If an applicant plans to use data provided by a supplier for compliance demonstration, the approach and the criteria for accepting that data will have to be shared and agreed with EASA as part of the HFs certification plan.

3.3.2_Methodological considerations applicable to HFs assessments

Various means of compliance may be selected, as described in paragraph 5.
For the highest level of scrutiny, the 'scenario-based' approach is likely to be the most appropriate methodology for some means of compliance.

The purpose of the following points is to provide guidelines on how to implement the scenario-based approach.

(a) The scenario-based approach is intended to substantiate the compliance of human–machine interfaces. It is based on a methodology that involves a sample of various crews, who are representative of the future users, being exposed to realistic operational conditions in a test bench or a simulator, or in the rotorcraft. 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. The scenario designers can make use of triggering events or conditions (e.g. a system failure, an ATC request, weather conditions, etc.) in order to build operational situations that are likely to trigger observable crew errors, difficulties or misunderstandings. The scenarios need to be well consolidated before the test campaign begins. EASA recommends in that respect that dry-run sessions should be performed by the applicant before any HFs campaign in order to validate the operational relevance of the scenarios. This approach should be used for both system- and rotorcraft-level assessments.

(b) System-level assessments focus on a specific system/function/feature and are intended for an in-depth assessment of the related functional and operational aspects, including all the operational procedures. The representativeness of the test article is to be evaluated taking into account the scope of the assessment. Rotorcraft-level assessments consider the scope of the full cockpit, and focus on integration and interdependence issues.

(c) The scenarios are expected to cover a subset of the detailed HFs test objectives. The link between each scenario and the test objectives should be made obvious to EASA. This rationale should be described in the test plan or in any other relevant document, and is subject to comments from EASA.

(d) The criteria to select the crews involved in the HFs assessments should be presented to EASA for acceptance.

(e) Due to interindividual variability, HFs scenario-based assessments performed with a single crew are not acceptable. The usually accepted number of different crews used for a given campaign varies from three to five, including the authority crew, if applicable. In the case of a crew of two with HFs objectives focused on the duties of only one of the crew members, it is fully acceptable for the applicant to use the same pilot flying or monitoring (the one who is not expected to produce any HFs data) throughout the campaign.

(f) In addition to the test report, and in order to reduce the certification risk, it is recommended that the preliminary analyses resulting from recorded observations and comments should be presented by the applicant to EASA soon after the simulator/flight sessions in order to allow expert discussions to take place.

(g) An initial briefing should be given to the crew at the beginning of each session to present the following general information:

(1) Detailed schedule describing the type and duration of the activities (the duration of the session, the organisation of briefing and debriefings, breaks, etc.);

(2) What is expected from the crew: it has to be clearly mentioned that the purpose of the assessment is to assess the design of the cockpit, not the performance of the pilot;

(3) The policy for simulator occupancy: how many people should be in the simulator versus the number of people in the control room, and who they should be; and

(4) The roles of the crews: if crews from the applicant participate in the assessment, they should be made aware that their role differs significantly from their classic expert pilot role in the development process. For the process to be valid without significant bias, they are expected to react and behave in the cockpit as standard operational pilots.

(5) However, the crew that participate in the assessment should not be:

(i) briefed in advance about the details of the failures and events to be simulated; this is to avoid an obvious risk of experimental bias; nor

(ii) asked before the assessment for their opinion about the scenarios to be flown.

(h) The crews need to be properly trained prior to every assessment so that during the analysis, the 'lack of training' factor can be excluded to the maximum extent possible from the set of potential causes of any observed human performance issue. Furthermore, for operational representativeness purposes, realistic crew task sharing, from normal to emergency workflows and checklists, should be respected during HFs assessments. The applicant should make available any draft or final rotorcraft flight manual (RFM), procedures and checklists sufficiently in advance for the crew to prepare.

(i) When using simulation, the immersion feeling of crews should be maximised in order to increase the validity of the data. This generally leads to recommendations about a sterile environment (with no outside noise or visual perturbation), no intervention by observers, no interruptions in the scenarios unless required by the nature of the objectives, realistic simulation of ATC communications, pilots wearing headsets, etc.

(j) The method used to collect HFs data needs to take into account the following principles:

(1) The observables should not be limited to human errors, but should also include pilots' verbalisations in addition to behavioural indicators such as hesitation, suboptimal or unexpected strategies, catachresis, etc.

(2) The primary means of collecting data should be direct observation (including videos). Other tools such as questionnaires and rating scales should be used as complementary means only. In any case, it is not adequate to merely rely on self-administrated questionnaires.

(3) It is very important to conduct debriefings after HFs assessments. They allow the applicant's HFs observers to gather all the necessary data that has to be used in the subsequent HFs analyses.

(4) HFs observers should respect the best practices with regard to observation and debriefing techniques.

(5) Debriefings should be based on non-directive or semidirective interviewing techniques and should avoid the experimental biases that are well described in the literature in the field of social sciences (e.g. the expected answer contained in the question, non-neutral attitude of the interviewer, etc.).

(k) If HFs concerns are raised that are not directly related to the object of the assessment, they should nevertheless be developed, adequately investigated and analysed in the test report.

(l) Every design-related human performance issue observed or reported by the crew should be analysed following the assessment. In the case of a human error, the analysis should provide information about at least the following elements:

(1) The type of error;

(2) The observed operational consequences, and any reductions in safety margins;

(3) The description of the operational context at the time of observation;

(4) Was the error detected? By whom, when and how?

(5) Was the error recovered? By whom, when and how?

(6) Existing means of mitigation;

(7) Possible effects of the representativeness of the test means on the validity of the data; and

(8) The possible causes of the error.

(m) The analysis of human performance issues has to be concluded by detailing the appropriate way forward, which is one of the following:

(5) No action required;

(6) An operational recommendation (for a procedural improvement or a training action);

(7) A recommendation for a design improvement; or

(8) A combination of items (2) and (3).

(n) If a design recommendation is rejected by the applicant, a sound justification should be provided to EASA to demonstrate that the safety of the product is not impaired by that decision.

4)_DESIGN CONSIDERATIONS AND GUIDANCE

4.1_Overview

(a) This material provides the standard which should be applied in order to design a cockpit that is in line with the objectives of 27.1302. Not all the criteria can or should be met by all systems. The applicant and EASA should use their judgment and experience in determining which design standard should apply to each part of the design in each situation.

(b) The following items provide a cross reference between this paragraph and the requirements listed in CS 27.1302:

(1) 'Controls' mainly relates to 1302(a) and (b);

(2) 'Presentation of information' mainly relates to 1302(a) and (b);

(3) 'System behaviour' mainly relates to 1302(c); and

(4) 'Error management' mainly relates to 1302(d).

Additionally, specific considerations on integration are given in paragraph 4.6.

4.2_Controls

(a) Applicants should propose means of compliance to show that the controls in the proposed design, as defined in CS 27.777, 27.779, 27.1543 and 27.1555, comply with CS 27.1302(b).

(b) The proposed means of compliance should be sufficiently detailed to demonstrate that each function, method of operating a control, and result of actuating a control complies with the requirements. Each control must be shown to be:

(1) clear,

(2) unambiguous,

(3) appropriate in resolution and precision,

(4) accessible, and

(5) usable.

(6) It must also enable crew awareness, including by providing adequate feedback.

(c) For each of these requirements, the proposed means of compliance should include consideration of the following control characteristics for each control individually and in relation to other controls:

(1) The physical location of the control;

(2) The physical characteristics of the control (e.g. its shape, dimensions, surface texture, range of motion, and colour);

(3) The equipment or system(s) that the control directly affects;

(4) How the control is labelled;

(5) The available settings of the control;

(6) The effect of each possible actuation or setting, as a function of the initial control setting or other conditions;

(7) Whether there are other controls that can produce the same effect (or can affect the same target parameter), and the conditions under which this will happen; and

(8) The location and nature of the feedback that shows the control was actuated.

The following discussion provides additional guidance for the design of controls that comply with CS 27.1302.

(d) The clear and unambiguous presentation of control-related information

(1) Distinguishable and predictable controls (CS 27.1301(a), CS 27.1302)

(i) Each crew member should be able to identify and select the current function of the control with the speed and accuracy appropriate to the task. The function of a control should be readily apparent so that little or no familiarisation is required.

(ii) The applicant should evaluate the consequences of activating each control and show they are predictable and obvious to each crew member. This includes the control of multiple displays with a single device, and shared display areas that crew members may access with individual controls. The use of a single control should also be assessed.

(iii) Controls can be made distinguishable or predictable by differences in form, colour, location, motion, effect and/or labelling.

(iv) Colour coding is usually not sufficient as a sole distinguishing feature. This applies to physical controls, as well as to controls that are part of an interactive graphical user interface.

(2) Labelling (CS 27.1301(b), CS 27.1543(b), CS 27.1555(a))

(i) For the general marking of controls, see CS 27.1555(a).

CS 27.1302(a) and (b) require the information necessary to accomplish defined tasks to be provided precisely and clearly. They also require the controls to be accessible and usable by the crew in a way that is consistent with the urgency, frequency and duration of the tasks. Therefore, labels should be readable from the crew members' normal seating positions, including the marking used by the crew member, from their operating positions in the cabin (if applicable) in all lighting and environmental conditions. If a control performs more than one function, the labelling should include all the intended functions unless the function of the control is obvious. Labels of graphical controls accessed by a cursor control device such as a trackball should be included on the graphical display. If menus lead to additional choices (submenus), the menu label should provide a reasonable description of the next submenu.

(ii) The applicant can label controls with text or icons. The text and the icons should be shown to be distinct and meaningful for the function that they label. The applicant should use standard or unambiguous abbreviations, nomenclature, or icons, consistent within a function and across the cockpit. ICAO Doc 8400 'ICAO

Abbreviations and Codes' provides standard abbreviations, and is an acceptable basis for selecting labels.

(iii) The design should avoid hidden functions (such as clicking on empty space on a display to make something happen). However, such hidden functions may be acceptable if adequate alternate means are available to access the function. The design should still be assessed for its ease of use and crew understanding.

(iv) If an icon is used instead of a text label, the applicant should show that the crew requires only a brief exposure to the icon to determine the function of the control and how it operates. Based on design experience, the following guidelines for icons have been shown to lead to usable designs:

(A) The icon should be analogous to the object it represents;

(B) The icon should be in general use in aviation and well known to crews, or has been validated during an HFs assessment; and

(C) The icon should be based on established standards, if they exist, and on conventional meanings.

(v) In all cases, the applicant should show that the use of icons is at least equivalent to the use of text labels in terms of the speed of recognition by the crew and the crew's error rate. Alternatively, the applicant should show that any increase in the error rate or the task completion time has no unacceptable effects on safety or on the crew workload (e.g. incurred task times), and does not cause crew confusion.

(3) Interactions of multiple controls (CS 27.1302(a))

If multiple controls for one function are provided to the crew, the applicant should show that there is sufficient information to make the crew aware of which control is currently functioning. As an example, crew members need to know which crew member's input has priority when two cursor control devices can access the same display. Designers should use caution if dual controls can affect the same parameter simultaneously.

(e) The accessibility of controls (CS 27.777(a), CS 27.777(b), CS 27.1302)

(1) The applicant must show that each crew member in the minimum crew, as defined by CS 27.1523, has access to and can operate all the necessary controls. Accessibility is one factor in determining whether controls support the intended function of the equipment used by the crew. Any control required for crew member operation (in normal, abnormal and emergency conditions) must be shown to be viewable, reachable, and operable by crew members with the stature specified in CS 27.777(b), from the seated position with shoulder restraints on. If the shoulder restraints are lockable, this may be shown with the shoulder restraints locked.

(2) Layering of information, as with menus or multiple displays, should not hinder the crew from identifying the location of the desired control. CS 27.1302(b) requires information intended for the use by the crew to be provided in a clear and unambiguous form, to be accessible, and to enable crew awareness. Evaluating the location and accessibility of a control requires the consideration of more than just the physical aspects of the control. Other location and accessibility considerations include where the control functions may be located within

various menu layers, and how the crew member navigates those layers to access the functions. Accessibility should be shown in conditions of system failures (including crew incapacitation) and of a minimum equipment list (MEL) dispatch.

(3) The position and direction of motion of a control should be oriented according to the standards in CS 27.777.

(f) Use of controls

(1) Environmental issues affecting controls (CS 27.1301(a) and CS 27.1302)

(i) Turbulence or vibration, and extreme lighting levels should not prevent the crew from performing all their tasks at an acceptable level of performance and workload.

(ii) If the use of gloves is anticipated, the cockpit design should allow their use with an adequate precision as per CS 27.1302(b)(2) and (c)(2).

(iii) The sensitivity of controls should provide sufficient precision (without being overly sensitive) to perform tasks even in adverse environments as defined for the rotorcraft's operational envelope per CS 27.1302(c)(2) and (d). Analysis of the environmental issues as a means of compliance is necessary, but not sufficient, for new control types or technologies, or for novel uses of controls that are themselves not new or novel.

(iv) The applicant should show that the controls required to regain control of the rotorcraft or system and the controls required to continue operating the rotorcraft in a safe manner are usable in conditions such as dense smoke in the cockpit or severe vibrations.

(2) Control display compatibility (CS 27.777(b) and CS 27.779)

CS 27.777(b) states that the direction of movement of a cockpit control must meet the requirements of CS 27.779. Wherever practicable, the sense of motion involved in the operation of other controls should correspond to the sense of the effect of the operation upon the rotorcraft or upon the part operated. Controls of a variable nature that use a rotary motion must move clockwise from the OFF position, through an increasing range, to the full ON position.

(i) To ensure that a control is unambiguous per CS 27.1302(b)(1), the relationship and interaction between a control and its associated display or indications should be readily apparent, understandable, and logical. A control input is often required in response to information on a display or to change a parameter setting on a display. The applicant should specifically assess any rotary knob that has no obvious 'increase' or 'decrease' function with regard to crew expectations and its consistency with the other controls in the cockpit. The Society of Automotive Engineers' (SAE) publication ARP4102, Chapter 5, is an acceptable means of compliance for controls used in cockpit equipment.

(ii) CS 27.777(a) requires each cockpit control to be located to provide convenient operation and to prevent confusion and inadvertent operation. The controls associated with a display should be located so that they do not interfere with the performance of the crew task. Controls whose function is specific to a particular display surface should be mounted near to the display or the function being controlled. Locating controls immediately below a display is generally preferable, as mounting controls immediately above a display has, in many cases, caused the crew member's hand to obscure their view of the display when operating the controls. However, controls on the bezel of multifunction displays have been found to be acceptable.

(iii) Spatial separation between a control and its display may be necessary. This is the case with a control of a system that is located with other controls for that same system, or when it is one of several controls on a panel dedicated to controls for that multifunction display. When there is a large spatial separation between a control and its associated display, the applicant should show that the use of the control for the associated task(s) is acceptable in accordance with 27.777(a) and 27.1302.

(iv) In general, the design and placement of controls should avoid the possibility that the visibility of information could be blocked. If the range of movement of a control temporarily blocks the crew's view of information, the applicant should show that this information is either not necessary at that time or is available in another accessible location (CS 27.1302(b)(2) requires information intended for use by the crew to be accessible and useable by the crew in a manner consistent with the urgency, frequency, and duration of the crew tasks).

(v) Annunciations/labels on electronic displays should be identical to the labels on the related switches and buttons located elsewhere on the cockpit. If display labels are not identical to those on the related controls, the applicant should show that crew members can quickly, easily, and accurately identify the associated controls so they can safely perform all the tasks associated with the intended function of the systems and equipment (27.1302).

(g) Adequacy of feedback (CS 27.771(a), CS 27.1301(a), CS 27.1302)

(1) Feedback for the operation of controls is necessary to give the crew awareness of the effects of their actions. Each control should provide feedback to the crew member for menu selections, data entries, control actions, or other inputs. There should be a clear and unambiguous indication when a crew input is not accepted or not followed by the system (27.1302(b)(1)). This feedback can be visual, auditory, or tactile.

(2) Feedback, in an appropriate form, should be provided to inform the crew that:

(i) a control has been activated (commanded state/value);

(ii) the function is in process (given an extended processing time);

(iii) the action associated with the control has been initiated (actual state/value if different from the commanded state); or

(iv) when a control is used to move an actuator through its range of travel, the equipment should provide, within the time required for the relevant task, operationally significant feedback of the actuator's position within its range. Examples of information that could appear relative to an actuator's range of travel include the target speed, and the state of the valves of various systems.

(3) The type, duration and appropriateness of the feedback will depend upon the crew's task and the specific information required for successful operation. As an example, the switch position alone is insufficient feedback if awareness of the actual system response or the state of the system as a result of an action is required as per CS 27.1302(b)(3).

(4) Controls that may be used while the user is looking outside or at unrelated displays should provide tactile feedback. Keypads should provide tactile feedback for any key depression. In cases when this is omitted, it should be replaced with appropriate visual or other feedback indicating that the system has received the inputs and is responding as expected.

(5) Equipment should provide appropriate visual feedback, not only for knob, switch, and push-button positions, but also for graphical control methods such as pull-down menus and pop-up windows. The user interacting with a graphical control should receive a positive indication that a hierarchical menu item has been selected, a graphical button has been activated, or another input has been accepted.

(6) To meet the requirements of CS 27.1302, the applicant should show that feedback in all forms is obvious and unambiguous to the crew in their performance of the tasks associated with the intended function of the equipment.

4.3_The presentation of information

(a) Introduction

(1) Applicants should use this AMC to show that the information displayed in the proposed design complies with CS 27.1302(b). The proposed means should be of sufficient detail to show that the function, method of control operation, and results comply with the requirements in CS 27.1301 and that the results of the presented information are:

— clear,

— unambiguous,

— appropriate in resolution and precision,

— accessible,

— usable, and

— able to provide adequate feedback for crew awareness.

(2) The presentation of information to the crew can be visual (for instance, on a display), auditory (a 'talking' checklist) or tactile (for example, control feel). The presentation of information in the integrated cockpit, regardless of the medium used, should meet all of the requirements bulleted above. For visual displays, this AMC addresses mainly display format issues and not display hardware characteristics. The following provides design considerations for the requirements found in CS 27.1301(a), CS 27.1301(b), CS 27.1302, and CS 27.1543(b).

(b) The clear and unambiguous presentation of information

Qualitative and quantitative display formats (CS 27.1301(a) and CS 27.1302)

(1) Applicants should show, per CS 27.1302(b), that display formats include the type of information the crew needs for the task, specifically with regard to the required speed and

precision of reading. For example, the information could be in the form of a text message, numerical value, or a graphical representation of state or rate information. State information identifies the specific value of a parameter at a particular time. Rate information indicates the rate of change of that parameter.

(2) If the crew's sole means of detecting abnormal values is by monitoring the values presented on the display, the equipment should offer qualitative display formats. Analogue displays of data are best for conveying rate and trend information. If this is not practical, the applicant should show that the crew can perform the tasks for which the information is used. Digital presentations of information are better for tasks requiring precise values. Refer to CS 27.1322 when an abnormal value is associated with a crew alert.

(c) Characters, fonts, lines and scale markings (CS 27.1301(b) and CS 27.1543(b))

Crew members, seated at their stations and using normal head movement, should be able to see and read display format features such as fonts, symbols, icons and markings. In some cases, cross-cockpit readability may be required to meet the intended function that both pilots must be able to access and read the display. Examples of situations where this might be needed are cases of display failures or when cross-checking flight instruments. Readability must be maintained in sunlight viewing conditions (per CS 27.773(a)) and under other adverse conditions such as vibration. Figures and letters should subtend not less than the visual angles defined in SAE ARP4102-7 at the design eye position of the crew member who normally uses the information.

(d) Colour (CS 27.1302)

(1) The use of many different colours to convey meaning on displays should be avoided. However, if thoughtfully used, colour can be very effective in minimising the workload and response time associated with display interpretation. Colour can be used to group functions or data types in a logical way. A common colour philosophy across the cockpit is desirable.

(2) Different systems in the cockpit should use the same colour coordinates.

(3) Applicants should show that the chosen colour set is not susceptible to confusion or misinterpretation due to differences in colour usage between displays. Improper colour coding increases the response times for display item recognition and selection, and increases the likelihood of errors, which is particularly true in situations where the speed of performing a task is more important than the accuracy, so the compatibility of colours with the background should be verified in all the foreseeable lighting conditions. The use of the red and amber colours for other than alerting functions or potentially unsafe conditions is discouraged. Such use diminishes the attention-getting characteristics of true warnings and cautions.

(4) The use of colour as the sole means of characterising an item of information is also discouraged. It may be acceptable, however, to indicate the criticality of the information in relation to the task. Colour, as a graphical attribute of an essential item of information,

should be used in addition to other coding characteristics such as texture or differences in luminance. AMC 25-11 contains recommended colour sets for specific display features.

(5) Applicants should show that the layering of information on a display does not add to confusion or clutter as a result of the colour standards and symbols used. Designs that require crew members to manually declutter such displays should also be avoided.

(e) Symbology, text, and auditory messages (CS 27.1302)

(1) Designs can base many elements of electronic display formats on established standards and conventional meanings. For example, ICAO Doc 8400 provides abbreviations, and is one standard that could be applied to cockpit text.

SAE ARP4102-7, Appendices A to C, and SAE ARP5289A are acceptable standards for avionics display symbols.

(2) The position of a message or symbol within a display also conveys meaning to the crew member. Without the consistent or repeatable location of a symbol in a specific area of the electronic display, interpretation errors and response times may increase.

(3) Applicants should give careful attention to symbol priority (the priority of displaying one symbol overlaying another symbol by editing out the secondary symbol) to ensure that higher-priority symbols remain viewable.

(4) New symbols (a new design or a new symbol for a function which historically had an associated symbol) should be assessed for their distinguishability and for crew understanding and retention.

(5) The applicant should show that displayed text and auditory messages are distinct and meaningful for the information presented. CS 27.1302 requires information intended for use by the crew to be provided in a clear and unambiguous format in a resolution and precision appropriate to the task, and the information to convey the intended meaning. Equipment should display standard and/or unambiguous abbreviations and nomenclature, consistent within a function and across the cockpit.

(f) The accessibility and usability of information

(1) The accessibility of information (CS 27.1302)

(i) Information intended for the crew must be accessible and useable by the crew in a manner consistent with the urgency, frequency, and duration of their tasks, per CS 27.1302(b)(2). The crew may, at certain times, need some information immediately, while other information may not be necessary during all phases of flight. The applicant should show that the crew can access and manage (configure) all the necessary information on the dedicated and multifunction displays for the phase of flight. The applicant should show that any information required for continued safe flight and landing is accessible in the relevant degraded display modes following failures as defined by CS 27.1309. The applicant should specifically assess what information is necessary in those conditions, and how such information will be simultaneously displayed. The applicant should also show that supplemental information does not displace or otherwise interfere with the required information.

(ii) Analysis as the sole means of compliance is not sufficient for new or novel display management schemes. The applicant should use simulation of typical operational scenarios to validate the crew's ability to manage the available information.

(2) Clutter (CS 27.1302)

(i) Visual or auditory clutter is undesirable. To reduce the crew member's interpretation time, equipment should present information simply and in a well-ordered way. Applicants should show that an information delivery method (whether visual or auditory) presents the information that the crew member actually requires to perform the task at hand. The crew can use their own discretion to limit the amount of information that needs to be presented at any point in time. For instance, a design might allow the crew to program a system so that it displays the most important information all the time, and less important information on request. When a design allows the crew to select additional information, the basic display modes should remain uncluttered.

(ii) Display options that automatically hide information for the purpose of reducing visual clutter may hide needed information from the crew member. If equipment uses automatic deselection of data to enhance the crew member's performance in certain emergency conditions, the applicant must show, per CS 27.1302(a), that it provides the information the crew member needs. The use of part-time displays depends not only on the removal of clutter from the information, but also on the availability and criticality of the display. Therefore, when designing such features, the applicant should follow the guidance in AMC 25-11, Chapter 6.

(iii) Because of the transient nature of auditory information presentation, designers should be careful to avoid the potential for competing auditory presentations that may conflict with each other and hinder their interpretation. Prioritisation and timing may be useful to avoid this potential problem.

(iv) Information should be prioritised according to the criticality of the task. Lower-priority information should not mask higher-priority information, and higher-priority information should be available, readily detectable, easily distinguishable and usable.

(3) Long or variable response times between a control input and the system response can adversely affect the usability of the system. The applicant should show that the response to a control input, such as setting values, displaying parameters, or moving a cursor symbol on a graphical display, is fast enough to allow the crew to complete the task at an acceptable

level of performance. For actions that require a noticeable system processing time, equipment should indicate that the system response is pending.

4.4_System behaviour

(a) Introduction

This paragraph provides means for demonstrating compliance with the design considerations for the requirements found in CS 27.1302(c), CS 27.1301(a), or any other relevant paragraphs of CS-27.

The demands of crew tasks vary depending on the characteristics of the system design. Systems differ in their responses to relevant crew inputs. The response can be direct and unique, as in mechanical systems, or it can vary as a function of an intervening subsystem (such as hydraulics or electrics). Some systems even automatically vary their responses to capture or maintain a desired rotorcraft or system state.

(1) CS 27.1302(c) states that installed equipment must be designed so that the behaviour of the equipment that is operationally relevant to the crew's tasks is: (1) predictable and unambiguous, and (2) designed to enable the crew to intervene in a manner appropriate to the task (and intended function).

(2) The requirement for operationally relevant system behaviour to be predictable and unambiguous will enable the crew to know what the system is doing and why. This means that a crew should have enough information about what the system will do under foreseeable circumstances as a result of their action or a changing situation so that they can operate the system safely. This distinguishes system behaviour from the functional logic within the system design, much of which the crew does not know or does not need to know.

(3) If crew intervention is part of the intended function, or part of abnormal or emergency procedures for the system, the crew member may need to take some action, or change an input to the system. The system must be designed accordingly. The requirement for crew intervention capabilities recognises this reality.

(4) Improved technologies, which have increased safety and performance, have also introduced the need to ensure proper cooperation between the crew and the integrated, complex information and control systems. If the system behaviour is not understood or expected by the crew, confusion may result.

(5) Some automated systems involve tasks that require crew attention for effective and safe performance. Examples include flight management systems (FMSs) or flight guidance systems. Alternatively, systems designed to operate autonomously, in the sense that they require very limited or no human interaction, are referred to as 'automatic systems'. Such systems are switched 'ON' or 'OFF' or run automatically, and, when operating in normal conditions, the guidance material of this paragraph is not applicable to them. Examples

include fly-by-wire systems and full authority digital engine controls (FADECs). Detailed specific guidance for automatic systems can be found in the relevant parts of CS-27.

(b) The allocation of system functions

The applicant should show that the allocation of functions is conducted in such a way that:

(1) the crew is able to perform all the tasks assigned to them, considering normal, abnormal and emergency operating conditions, within the bounds of an acceptable workload and without requiring undue concentration or causing undue fatigue (see CS 27.1523 for workload assessment);

(2) the system enables the crew to understand the situation, and enables timely failure detection and crew intervention when appropriate; and

(3) the allocation of tasks between the crew and the rotorcraft during operations is considered.

(c) The functional behaviour of a system

(1) The functional behaviour of a system results from the interaction between the crew and the automated system, and is determined by:

(i) the functions of the system and the logic that governs its operation; and

(ii) the user interface, which consists of the controls that communicate the crew's inputs to the system, and the information that provides feedback to the crew on the behaviour of the system.

(2) The design should consider both the functions of the system and the user interface together. This will avoid a design in which the functional logic governing the behaviour of the system can have an unacceptable effect on the performance of the crew. Examples of system functional logic and behavioural issues that may be associated with errors and other difficulties for the crew are the following:

(i) The complexity of the crew interface for both control actuation and data entry, and the complexity of the corresponding system indications provided to the crew;

(ii) The crew having inadequate understanding and inaccurate expectations of the behaviour of the system following mode selections and transitions; and

(iii) The crew having inadequate understanding and incorrect expectations of what the system is preparing to do next, and how it is behaving.

(3) Predictable and unambiguous system behaviour (CS 27.1302(c)(1))

Applicants should propose the means they will use to show that the behaviour of the system or the system mode in the proposed design is predictable and unambiguous to the crew.

(i) System or system mode behaviour that is ambiguous or unpredictable to the crew has been found to cause or contribute to crew errors. It can also potentially degrade the crew's ability to perform their tasks in normal, abnormal and emergency conditions. Certain design characteristics have been found to minimise crew errors and other crew performance problems.

(ii) The following design considerations are applicable to operationally relevant systems and to the modes of operation of the systems:

(A) The design should be simple (for example, the number of modes, or mode transitions).

(B) Mode annunciation should be clear and unambiguous. For example, a mode engagement or arming selection by the crew should result in annunciation, indication or display feedback that is adequate to provide awareness of the effect of their action. Additionally, any change in the mode as a result of the rotorcraft changing from one operational mode (for instance, on an approach) to another should be clearly and unambiguously annunciated and fed back to the crew.

(C) Methods of mode arming, engagement and deselection should be accessible and usable. For example, the control action necessary to arm, engage, disarm or disengage a mode should not depend on the mode that is currently armed or engaged, on the setting of one or more other controls, or on the state or status of that or another system.

(D) Uncommanded mode changes and reversions should have sufficient annunciation, indication, or display information to provide awareness of any uncommanded changes of the engaged or armed mode of a system.

(E) The current mode should remain identified and displayed at all times.

(iii) Note that formal descriptions of modes typically define them as mutually exclusive, so that a system cannot be in more than one mode at a particular time. For instance, a display can be in 'north-up' mode or 'track-up' mode, but not both at the same time.

(4) Crew intervention (CS 27.1302(c)(2))

(i) Applicants should propose the means that they will use to show that the behaviour of the systems in the proposed design allows the crew to intervene in the operation of the systems without compromising safety. This should include descriptions of how they will determine that the functions and conditions in which intervention should be possible have been addressed.

(ii) If the means of demonstrating compliance is by analysis, the applicant should describe it thoroughly. In addition, the methods proposed by applicants should describe how they would determine that each means of intervention is appropriate to the task.

(5) Controls for automated systems

Automated systems can perform various tasks selected by and under the supervision of the crew. Controls should be provided for managing the functionality of such a system or set of systems. The design of such 'automation-specific' controls should enable the crew to:

(i) safely prepare the system for the immediate task to be executed or the subsequent task to be executed; preparation of a new task (for example, a new flight trajectory) should not interfere, or be confused, with the task being executed by the automated system;

(ii) activate the appropriate system function and clearly understand what is being controlled; for example, the crew must clearly understand that they can set either the vertical speed or the flight path angle when they operate a vertical speed indicator;

(iii) manually intervene in any system function, as required by the operational conditions, or revert to manual control; for example, manual intervention might be necessary if a system loses functions, operates abnormally, or fails.

(6) Displays for automated systems

Automated systems can perform various tasks with minimal crew intervention, but under the supervision of the crew. To ensure effective supervision and maintain crew awareness of the system state and system 'intention' (future states), displays should provide recognisable feedback on:

(i) the entries made by the crew into the system so that the crew can detect and correct errors;

(ii) the present state of the automated system or its mode of operation (What is it doing?);

(iii) actions taken by the system to achieve or maintain a desired state (What is it trying to do?);

(iv) future states scheduled by the automation (What is it going to do next?); and

(v) transitions between system states.

(7) The applicant should consider the following aspects of automated system designs:

(i) Indications of the commanded and actual values should enable the crew to determine whether the automated systems will perform according to their expectations;

(ii) If the automated system nears its operational authority or is operating abnormally for the conditions, or is unable to perform at the selected level, it should inform the crew, as appropriate for the task;

(iii) The automated system should support crew coordination and cooperation by ensuring that there is shared awareness of the system status and the crew inputs to the system; and

(iv) The automated system should enable the crew to review and confirm the accuracy of commands before they are activated. This is particularly important for automated systems because they can require complex input tasks.

4.5_Crew error management

(a) Demonstrating compliance with CS 27.1302(d)

(1) CS 27.1302(d) states that 'The installed equipment must enable the crew to manage errors resulting from crew interaction with the equipment that can be reasonably expected in service, assuming crews acting in good faith. This subparagraph does not apply to skill-related errors associated with manual control of the rotorcraft.' This addresses the fact that

crews will make errors, even when they are well trained, experienced, rested, and are using well-designed systems.

(2) To comply with CS 27.1302(d), the design should meet one of the following criteria. It should:

(i) enable the crew to detect (see 4.5(b)) and recover from errors (see 4.5(c)); or

(ii) ensure that the effects of crew errors on the rotorcraft functions or capabilities are evident to the crew, and continued safe flight and landing is possible (see 4.5(d)); or

(iii) discourage crew errors by using switch guards, interlocks, confirmation actions, or similar means; or

(iv) preclude the effects of errors through system logic and/or redundant, robust, or fault-tolerant system design (see 4.5(e)).

(3) These above objectives:

(i) are, in a general sense, in a preferred order;

(ii) recognise and assume that crew errors cannot be entirely prevented, and that no validated methods exist to reliably predict either their probability or all the sequences of events with which they may be associated;

(iii) call for means of compliance that are methodical and complementary to, and separate and distinct from, rotorcraft system analysis methods such as system safety assessments.

(iv) CS 27.1302(d) addresses errors that are design related. It is not intended to require consideration of errors resulting from acts of violence, sabotage or threats of violence.

(4) Errors that do have a design-related component are considered to be within the scope of this AMC. Examples are a procedure that is inconsistent with the design of the equipment, or indications and controls that are complex and inconsistent with each other or other systems on the cockpit.

(5) When demonstrating compliance, the applicant should consider the crew tasks in all operating conditions, considering that many of the same design characteristics are relevant in each case. For example, under abnormal or emergency conditions, the flying tasks (navigation, communication and monitoring) are generally still present, although they may be more difficult. So the tasks associated with the abnormal or emergency conditions should be considered as additive. The applicant should not expect the errors considered to be different from those in normal conditions, but any assessment should account for the change in the expected tasks.

(6) To demonstrate compliance with CS 27.1302(d), an applicant may employ any of the general types of methods of compliance discussed in paragraph 5, individually or in combination. These methods must be consistent with an approved certification plan as discussed in paragraph 3, and account for the objectives above and the considerations described below. When using some of these methods, it may be helpful for some applicants to refer to other

references related to understanding the occurrence of errors. Here is a brief summary of those methods and how they can be applied to address crew error considerations:

(i) Statement of similarity (paragraph 5.3): A statement of similarity may be used to substantiate that the design has sufficient certification precedent to conclude that the ability of the crew to manage errors has not significantly changed. Applicants may also use service experience data to identify errors known to commonly occur for similar crew interfaces or system behaviour. As part of compliance demonstration, the applicant should identify the steps taken in the new design to avoid or mitigate similar errors. However, the absence of in-service events related to a particular function, system or feature cannot be considered to be an acceptable means of demonstrating compliance with CS 27.1302.

(ii) Design descriptions (paragraph 5.3): Applicants may structure design descriptions and rationales to show how various types of errors are considered in the design and addressed, mitigated or managed. Applicants can also use a description of how the design adheres to an established and valid design philosophy to substantiate that the design enables crews to manage errors.

(iii) Calculation and engineering analysis (paragraph 5.3): As one possible means of demonstrating compliance with CS 27.1302(d), an applicant may document means of error management through analysis of controls, indications, system behaviour, and related crew tasks. This would need to be done in conjunction with an understanding of the potential error opportunities and the means available for the crew to manage those errors. In most cases, it is not considered feasible to predict the probability of crew errors with sufficient validity or precision to support a means of compliance. If an applicant chooses to use a quantitative approach, the validity of the approach should be established.

(iv) Assessments (paragraph 5.3): For compliance purposes, assessments are intended to identify error possibilities that may be considered for mitigation in design or training. In any case, scenario objectives and assumptions should be clearly stated before running the evaluations or tests. In that way, any discrepancy in those expectations can be discussed and explained in the analysis of the results.

(7) As discussed further in paragraph 5, these evaluations or tests should use appropriate scenarios that reflect the intended functions and tasks, including the use of the equipment in normal, abnormal and emergency conditions. Scenarios should be designed to consider crew errors. If inappropriate scenarios are used or important conditions are not considered, incorrect conclusions can result. For example, if no errors occur during an assessment, it may only mean that the scenarios are too simple, incomplete, or not fully representative. On the other hand, if some errors do occur, it may mean any of the following:

(i) The design, procedures, or training should be modified;

(ii) The scenarios are unrealistically challenging; or

(iii) Insufficient training was delivered prior to the assessment.

(8) In such assessments, it is not considered feasible to establish criteria for the frequency of errors.

(b) Error detection

(1) Applicants should design equipment to provide information so the crew can become aware of an error or a system/rotorcraft state resulting from a system action. Applicants should show that this information is available to the crew, is adequately detectable, and that it shows a clear relationship between the crew action and the error so a recovery can be made in a timely manner.

(2) Information for error detection may take three basic forms:

(i) Indications provided to the crew during normal monitoring tasks.

(A) As an example, if an incorrect knob was used, resulting in an unintended heading change, the change would be detected through the display of target values. The presentation of a temporary flight plan for crew review before accepting it would be another way of providing crew awareness of errors.

(B) Indications on instruments in the primary field of view that are used during normal operations may be adequate if the indications themselves contain information used on a regular basis and are provided in a readily accessible form. These may include mode annunciations and normal rotorcraft state information such as the altitude or heading. Other locations for the information may be appropriate depending on the crew's tasks, such as on the control display unit when the task involves dealing with a flight plan. Paragraph 5.4 'Presentation of information' contains additional guidance to determine whether the information is adequately detectable.

(ii) Crew indications that provide information of an error or a resulting rotorcraft system condition.

(A) An alert that could activate after a crew error may be a sufficient means for the applicant to show that information about an error exists and that the error is adequately detectable, if the alert directly and appropriately relates to the error. If the content of the alert does not directly relate to the error, the indication may lead the crew to believe there may be non-error causes for the annunciated condition.

(B) If a crew error is only one of several possible causes for an alert about a system, then the information that the alert provides is insufficient. If, on the other hand, additional information is available that would allow the crew to identify and correct the error, then the alert, in combination with the additional information, would be sufficient to comply with CS 27.1302(d) for that error.

(C) An error that is detectable by the system should provide an alert and provide sufficient information that a crew error has occurred, such as in the case of a take-off configuration warning. On the other hand, an alert about the system state resulting from accidentally shutting down a hydraulic pump, for example, may not provide sufficient information to the crew to enable them to distinguish an error from a system fault. In this case, flight manual procedures may provide the error detection means as the crew performs the 'Loss of Hydraulic System' procedures.

(D) If the system can detect pilot error, the system could be designed to prevent pilot error. For example, if the system can detect an incorrect frequency entry by the pilot, then the system should be able to disallow that entry and provide appropriate feedback to the pilot. Examples are automated error checking and filters that prevent the entry of unallowable or illogical entries.

(iii) 'Global' alerts cover a multitude of possible errors by annunciating external hazards, or the envelope of the rotorcraft, or operational conditions. Examples include monitoring systems such as a terrain awareness warning system (TAWS) and a traffic alert and collision avoidance system (TCAS). An example would be a TAWS alert resulting from turning in the wrong direction in a holding pattern in mountainous terrain.

(3) The applicant should consider the following when establishing whether the degree or type of information is available to the crew, adequately detectable, and clearly related to the error:

(i) The effects of some errors are easily and reliably determined by the system because of its design, and some are not. For those that cannot be sensed by the system, the design and arrangement of the information monitored and scanned by the crew can facilitate error detection. An example would be the alignment of engine speed indicator needles in the same direction during normal operations. Failure of the needles to align in the same direction during normal operations would indicate a problem with one of the engines, since one engine would be rotating at a different speed from the other engine.

(ii) Rotorcraft alerting and indication systems may not detect whether an action is erroneous because the systems cannot know the intent of the crew in many operational circumstances. In these cases, reliance is often placed on the crew's ability to scan and observe indications that will change as a result of an action such as selecting a new altitude or heading, or making a change to a flight plan in a flight management system (FMS). For errors of this nature, error detection depends on the crew's interpretation of the available information. Training, crew resource management (CRM), and monitoring systems such as TAWS and TCAS are examples of ways to provide a redundant level of safety if any or all the crew members fail to detect certain errors.

(4) The applicant may establish that information is available and clearly related to the error by using a design description when a precedent exists or when a reasonable case may be made that the content of the information is clearly related to the error that caused it. In some

cases, a crew assessment (see 5.3) may be needed to assess whether the information provided is adequately available and detectable.

(c) Error recovery

(1) Assuming that the crew detects an error or its effects, the next logical step is to ensure that the error can be reversed, or that the effect of the error can be mitigated in some way so that the rotorcraft is returned to a safe state.

(2) An acceptable means to establish that an error is recoverable is to show that:

(i) controls and indications exist that can be used either to reverse an erroneous action directly so that the rotorcraft or system is returned to the original state, or to mitigate the effect so that the rotorcraft or system is returned to a safe state; and

(ii) the crew can be expected to use those controls and indications to accomplish the corrective actions in a timely manner.

(3) For simple or familiar types of system interfaces, or systems that are not novel, even if they are complex, a statement of similarity or a description of the design of the crew interfaces and the procedures associated with the indications may be an acceptable means of compliance.

(4) To establish that the crew can be expected to use those controls and indications to accomplish corrective actions in a timely manner, an assessment of the crew procedures in a simulated cockpit environment can be highly effective. This assessment should include an examination of the nomenclature used in alert messages, controls, and other indications. It should also include the logical flow of procedural steps and the effects that executing the procedures have on other systems.

(d) Error effects

(1) Another means of satisfying the objective of error mitigation is to ensure that the effects of the error or the relevant effects on the state of the rotorcraft:

(i) are evident to the crew; and

(ii) do not adversely impact on safety (do not prevent continued safe flight and landing).

(2) Piloted assessments in the rotorcraft or in simulation may be relevant if crew performance issues are in question for determining whether a state following an error permits continued safe flight and landing. Assessments and/or analyses may be used to show that, following an error, the crew has the information in an effective form and has the rotorcraft capability required for continued safe flight and landing.

(e) Precluding errors or their effects

(1) For irreversible errors that have potential safety implications, means to discourage the errors are recommended. Acceptable ways to discourage errors include switch guards, interlocks, or multiple confirmation actions. For example, generator drive controls on many rotorcraft have guards over the switches to discourage their inadvertent actuation, because once disengaged, the drives cannot be re-engaged while in flight or with the engine running. An

example of multiple confirmations would be the presentation of a temporary flight plan that the crew can review before accepting it.

(2) Another way of avoiding crew error is to design systems to remove misleading or inaccurate information (e.g. sensor failures) from displays. An example would be a system that removes the flight director bars from a primary flight display or removes the ‘own-ship’ position from an airport surface map display when the data driving the symbols is incorrect.

(3) The applicant should avoid applying an excessive number of protections for a given error. The excessive use of protections could have unintended safety consequences. They might hamper the crew member’s ability to use judgment and take action in the best interest of safety in situations that were not predicted by the applicant. If protections become a nuisance in daily operation, crews may use well-intentioned and inventive means to circumvent them. This could have further effects that were not anticipated by the operator or the designer.

4.6_Integration

(a) Introduction

(1) Many systems, such as flight management systems (FMSs), are integrated physically and functionally into the cockpit and may interact with other cockpit systems. It is important to consider a design not just in isolation, but in the context of the overall cockpit. Integration issues include where a display or control is installed, how it interacts with other systems, and whether there is internal consistency across functions within a multi-function display, as well as consistency with the rest of the cockpit equipment.

(2) Analyses, evaluations, tests and other data developed to establish compliance with each of the specific requirements in CS 27.1302(a) to (d) should address the integration of new or novel design features or equipment with previously approved features or equipment, as well as with other new items. It should include consideration of the following integration factors:

(i) consistency (see 4.6(b)),

(ii) consistency trade-offs (see 4.6(c)),

(iii) the cockpit environment (see 4.6(d)), and

(iv) integration-related workload and error (see 4.6(e)).

(b) Consistency

(1) If similar information is presented in multiple locations or modes (both visual and auditory, for example), consistent presentation of the information is desirable. If information cannot be presented consistently within the cockpit, the applicant should show that the differences do not increase the error rates or task times, which would lead to a significant reduction in the safety margins or an increase in the crew workload, and do not cause crew confusion.

(2) Consistency needs to be considered within a given system and across the cockpit. Inconsistencies may result in vulnerabilities, such as increased workload and errors, especially during stressful situations. For example, in some flight management systems (FMSs), the format for entering the latitude and longitude differs between the display pages. This may induce crew errors, or at least increase the crew’s workload. Additionally, errors

may result if the latitude and longitude are displayed in a format that differs from the formats used on the most commonly used paper charts. Because of this, it is desirable to use formats that are consistent with other media whenever possible. Although trade-offs exist, as discussed in the next paragraph, the following are design attributes to consider for their consistency within and across systems:

(i) Symbology, data entry conventions, formatting, the colour philosophy, terminology, and labelling.

(ii) Function and logic. For example, when two or more systems are active and performing the same function, they should operate consistently and use an interface in the same style.

(iii) Information presented with other information of the same type that is used in the cockpit. For example, the navigation symbology used on other cockpit systems or on commonly used paper charts should be considered when developing the symbology to be used on electronic map displays.

(iv) The operational environment. It is important that an FMS is consistent with the operational environment so that the order of the steps required to enter a clearance into the system is consistent with the order in which they are given by air traffic management (ATM).

(v) One way in which the applicant can achieve consistency within a given system, as well as within the overall cockpit, is to adhere to a comprehensive cockpit design philosophy.

(3) Another way is to standardise certain aspects of the design by using accepted, published standards such as the labels and abbreviations recommended in ICAO Doc 8400 or in SAE ARP4105C. The applicant might standardise the symbols used to depict navigation aids (very high frequency omnidirectional range, VOR, for example), by following the conventions recommended in SAE ARP5289A. However, inappropriate standardisation, rigidly applied, can be a barrier to innovation and product improvement. Thus, guidance in this paragraph promotes consistency rather than rigid standardisation.

(c) Consistency trade-offs

It is recognised that it is not always possible or desirable to provide a consistent crew interface. Despite conformance with the cockpit design philosophy, principles of consistency, etc., it is possible to negatively impact on the crew’s workload. For example, all the auditory alerts may adhere to a cockpit alerting philosophy, but the number of alerts may be unacceptable. The use of a consistent format across the cockpit may not work when individual task requirements necessitate the presentation of data in two significantly different formats. An example is a weather radar display formatted to show a sector of the environment, while a moving map display shows a 360-degree view. In such cases, it should be demonstrated that the design of the interface is compatible with the requirements of the piloting task, and that it can be used individually and in combination with other interfaces without interference with either the system or the function.

Additionally:

(1) The applicant should provide an analysis identifying each piece of information or data presented in multiple locations, and show that the data is presented in a consistent manner or, where that is not true, justify why that is not appropriate.

(2) Where information is inconsistent, that inconsistency should be obvious or annunciated, and should not contribute to errors in the interpretation of information.

(3) There should be a rationale for instances where the design of a system diverges from the cockpit design philosophy. Applicants should consider any impact on the workload and on errors as a result of such divergences.

(4) The applicant should describe what conclusion the crew is expected to draw and what action should be taken when information on the display conflicts with other information in the cockpit (either with or without a failure).

(d) Cockpit environment

(1) The cockpit system is influenced by the physical characteristics of the rotorcraft into which a system is integrated, as well as by the characteristics of the operational environment. The system is subject to such influences on the cockpit as turbulence, noise, ambient light, smoke, and vibrations (such as those that may result from ice or the loss of a fan blade). The design of the system should recognise the effect of such influences on usability, workload, and crew task performance. Turbulence and ambient light, for example, may affect the readability of a display. Cockpit noise may affect the audibility of aural alerts. The applicant should also consider the impact of the cockpit environment for abnormal situations, such as recovery from an unusual attitude or regaining control of the rotorcraft or system.

(2) The cockpit environment includes the layout, or the physical arrangement of the controls and information displays. Layouts should take into account the crew requirements in terms of:

(i) access and reach (to the controls);

(ii) visibility and readability of the displays and labels; and

(iii) the task-oriented location and grouping of human–machine interaction elements.

An example of poor physical integration would be a required piece of information that is obscured by a control in its normal operating position.

(e) Integration-related workload and error

(1) When integrating functions and/or equipment, designers should be aware of the potential effects, both positive and negative, that integration can have on the workload of the crew and its subsequent impact on error management. Systems must be designed and assessed, both in isolation and in combination with other cockpit systems, to ensure that the crew is able to detect, reverse, or recover from errors. This may be more challenging when

integrating systems that employ higher levels of automation or have a high degree of interaction and dependency on other cockpit systems.

(2) Applicants should show that the integrated design does not adversely impact on the workload or errors in the context of the entire flight regime. Examples of such impacts would be taking more time to:

(i) interpret a function;

(ii) make a decision; or

(iii) take appropriate action.

(3) Controls, particularly multi-function controls and/or novel types of control, may present the potential for misidentification and increased response times. Designs should generally avoid multi-function controls with hidden functions, because they increase both the workload of the crew and the potential for error.

(4) Two examples of integrated design features that may or may not impact on errors and the workload are as follows:

(i) Presenting the same information in two different formats. This may increase the workload, such as when altitude information is presented concurrently in both tape and round-dial formats. However, different formats may be suitable, depending on the design and the crew task. For example, an analogue display of engine revolutions per minute (rpm) can facilitate a quick scan, whereas a digital numeric display can facilitate precise inputs. The applicant is responsible for demonstrating compliance with CS 27.1523 and showing that the differences in the formats do not result in unacceptable levels of workload.

(ii) Presenting conflicting information. Increases in workload and error may result from two displays depicting conflicting altitude information on the cockpit concurrently, regardless of the formats. Systems may exhibit minor differences between each crew member station, but all such differences should be assessed specifically to ensure that the potential for interpretation error is minimised, or that a method exists for the crew to detect any incorrect information, or that the effects of these errors can be precluded.

(iii) The applicant should show that the proposed function will not inappropriately draw attention away from other cockpit information and tasks in a way that degrades the performance of the crew and decreases the overall level of safety. There are some cases in which it may be acceptable for the system design to increase the workload. For example, adding a display into the cockpit may increase the workload by virtue of the additional time crew members spend looking at it, but the safety benefit that the additional information provides may make it an acceptable trade-off.

(iv) Because each new system integrated into the cockpit may have a positive or negative effect on the workload, each must be assessed in isolation and in combination with the other systems for compliance with CS 27.1523. This is to ensure that the overall workload is acceptable, i.e. that the performance of flight tasks is not adversely impacted and that the crew's detection and interpretation of information does not lead to unacceptable response times. Special attention should be paid to items that are workload factors. They include the 'accessibility, ease, and simplicity of operation of all necessary flight, power, and equipment controls'.

5)_MEANS OF COMPLIANCE

5.1_Overview

This paragraph discusses considerations in selecting the means used for the demonstration of compliance. It discusses seven types of means of compliance that can be used when demonstrating compliance with human performance issues. These means of compliance are generic and are to be indicated in certification programmes. The means of compliance to be used on any given project should be determined on a case-by-case basis, driven by the specific compliance issues. They should be developed and proposed by the applicant, and then agreed to by EASA. The uses and limitations of each type of means of compliance are provided in paragraph 5.3.

5.2_Selecting the means of compliance

(a) The types of means of compliance discussed in this paragraph include:

(1) MC0: Compliance statements, reference to the type design document, definitions,

(2) MC1: Design review,

(3) MC2: Calculation and analysis,

(4) MC4: Laboratory tests,

(5) MC5: Ground tests,

(6) MC6: Flight tests, and

(7) MC8: Simulation.

(b) There is no generic method to determine the appropriate means of compliance for a specific project. The choice of an appropriate means of compliance or combination of several different means depends on a number of factors specific to a project.

(c) Some certification projects may necessitate more than one means of demonstrating compliance with a particular CS requirement. For example, when flight testing in a conforming rotorcraft is not possible, a combination of a design review and a part-task simulation evaluation may be proposed.

5.3_Description of the means of compliance

The seven general means of compliance found to be acceptable for use in demonstrating compliance related to cockpit design are described in the following subparagraphs.

(a) MC0 Compliance statement based on similarity

Description
A statement of similarity is a description of the system to be approved and a description of a previously approved system detailing the physical, logical, and operational similarities with respect to compliance with the requirements.
Deliverable

A statement of similarity could be part of a certification report, containing references to existing certification data/documents. The document is delivered to EASA depending on the defined LoI.
Participants
Not applicable.
Conformity
Not applicable.
Uses
It may be possible to substantiate the adequacy of a design by comparing it with previously certified systems that were shown to be robust with respect to a lack of contribution to crew error and/or the capability of the crew to manage the situation if an error occurs. This avoids the repetition of unnecessary effort to justify the safety of such systems.
Limitations
A statement of similarity to demonstrate compliance must be used with care. The cockpit should be assessed as a whole, not as merely a set of individual functions or systems. Two functions or features previously approved on separate programmes may be incompatible when combined in a single cockpit. Also, changing one feature in a cockpit may necessitate corresponding changes in other features, to maintain consistency and prevent confusion.
Example
If the window design in a new rotorcraft is identical to that in an existing rotorcraft, a statement of similarity may be an acceptable means of compliance to meet CS 27.773.

(b) MC1 Design review

The applicant may elect to substantiate that the design meets the requirements of a specific paragraph by describing the design. Applicants have traditionally used drawings, configuration descriptions, and/or design philosophies to demonstrate compliance. The selection of participants and conformity are not relevant to this means of compliance.

(1) Drawings

Description
Layout drawings or engineering drawings, or both, depicting the geometric arrangement of hardware or display graphics.
Deliverable
The drawings, which can be part of a certification report. The documents are delivered to EASA, depending on the defined LoI.
Uses

Applicants can use drawings for very simple certification programmes when the change to the cockpit is very simple and straightforward. Drawings can also be used to support compliance findings for more complex interfaces.
Limitations
The use of drawings is limited to physical arrangements and graphical concerns.

(2) Configuration description

Description
A configuration description is a description of the layout, general arrangement, direction of movement, etc., of a regulated item. It can also be a reference to documentation that provides such a description (for example, from a different project with a similar layout). It could be used to show the relative locations of flight instruments, groupings of control functions, the allocation of colour codes to displays and alerts, etc.
Deliverable
An explanation of the functional aspects of the crew interface: a textual description of a certification item and/or the functional aspects of the crew interface with the system (with visuals as appropriate). The document is delivered to EASA, depending on the defined LoI.
Uses
Configuration descriptions are generally less formalised than engineering drawings. They are developed to point out features of the design that support a finding of compliance. In some cases, such configuration descriptions may provide sufficient information for a finding of compliance. More often, however, they provide important background information, while the final confirmation of compliance is found through other means, such as demonstrations or tests. The background information provided by configuration descriptions may significantly reduce the complexity and/or risk associated with demonstrations or tests. The applicant will have already communicated how a system works with the configuration description, and any discussions or assumptions may have already been coordinated.
Limitations
Configuration descriptions may provide sufficient information for a finding of compliance with a specific requirement. More often, though, they provide important background information, while the final confirmation of compliance is found by other means, such as demonstrations or tests. Background information provided by configuration descriptions may significantly reduce the complexity and/or risk associated with the demonstrations or tests.

(3) Design philosophy

Description

A design philosophy approach can be used to demonstrate that an overall safety-centred philosophy, as detailed in the design specifications for the product/system or cockpit, has been applied.
Deliverable
A textual description of the certification item and/or the functional aspects of the crew interface with the system (with figures and drawings as appropriate) and its relationship to the overall design philosophy. The document is delivered to EASA, depending on the defined LoI.
Uses
Documents the ability of a design to meet the requirements of a specific paragraph.
Limitations
In most cases, this means of compliance will be insufficient as the sole means to demonstrate compliance.
Example
The design philosophy may be used as a means of compliance when a new alert is added to the cockpit if the new alert is consistent with the acceptable existing alerting philosophy.

(c) MC2 Calculation/analysis

Description
Calculations or engineering analyses ('paper and pencil' assessments) that do not require direct participant interaction with a physical representation of the equipment.
Deliverable
Substantiation report. A report detailing the analysis, its components, assumptions, and the basis for decision making. The report details results and conclusions and is delivered to EASA, depending on the defined LoI.
Participants
Conducted by the applicant.
Conformity
Not applicable.
Uses
Provides a systematic analysis of specific or overall aspects of the human interface part of the product/system/cockpit.
Limitations
The applicant should carefully consider the validity of the assessment technique if the analyses are not based on advisory material or accepted industry standard methods. Applicants may be asked to

validate any computational tools used in such analyses. If the analysis involves comparing measured characteristics with recommendations derived from pre-existing research (internal or public domain), the applicant may be asked to justify the applicability of the data to the project. While analyses are useful to start investigating the potential for design-related human errors, as well as the theoretical efficiency of the available means of protection, this demonstration needs to be complemented by observations through assessments.
Example
An applicant may conduct a vision analysis to demonstrate that the crew has a clear and undistorted view out of the windows. Similarly, an analysis may also demonstrate that flight, navigation and power plant instruments are plainly visible from the crew member station. The applicant may need to validate the results of the analysis in a ground or flight test, or by using a means of simulation that is geometrically representative. An applicant may also conduct an analysis based on evidence collected during similar previous human factors assessments.

(d) MC4 Laboratory test

Description
An assessment made using an early prototype of the human–machine interface. This can be conducted on an avionics bench when the purpose is to assess the information, or on a mock-up when the purpose is to assess the cockpit geometry.
Deliverable
A report, delivered to EASA, depending on the defined LoI.
Participants
The applicant and possibly EASA, depending on the defined LoI.
Conformity
Conformity is not required.
Bench or laboratory assessment
The applicant can conduct an assessment using devices emulating crew interfaces for a single system or a group of related systems. The applicant can use flight hardware, simulated systems, or combinations of these.
Example of a bench or laboratory assessment
A bench assessment for an integrated system could be conducted using an avionics suite installed in a mock-up of a cockpit, with the main displays and autopilot controls included. Such a tool may be valuable during development and for providing system familiarisation to EASA. However, in a highly integrated architecture, it may be difficult or impossible to assess how well the avionics system will fit into the overall cockpit without more complete simulation or use of the actual rotorcraft.

Mock-up evaluation
A mock-up is a full-scale, static representation of the physical configuration (form and fit). It does not include functional aspects of the cockpit and its installed equipment. Mock-ups can be used as representations of the design, allowing participants to physically interact with the design. Three-dimensional representations of the design in a CAD system, in conjunction with three-dimensional models of the cockpit occupants, have also been used as 'virtual' mock-ups for certain limited types of evaluations. Reachability, for example, can be addressed using either type of mock-up.
Example of a mock-up evaluation
An analysis to demonstrate that controls are arranged so that crew members from 1.58 m (5 ft 2 inches) to 1.91 m (6 ft 3 inches) in height can reach all controls. This analysis may use computer-generated data based on engineering drawings. The applicant may demonstrate the results of the analysis in the actual rotorcraft.
Limitations
Both bench and mock-up assessments are limited due to the fact that they are static exercises. Most of the human performance issues are usually revealed when observing the behaviour of pilots in dynamic situations. However, laboratory assessments can still be useful during the early stages of developing the design to identify simple and obvious design shortcomings.

(e) MC5 Ground test

Description
An assessment conducted on a flight test article on ground.
Deliverable
A report, delivered to EASA, depending on the defined LoI.
Participants
The applicant and possibly EASA, depending on the defined LoI.
Conformity
By definition, the cockpit geometry is representative, or almost. The conformity of the avionics is not required.
Limitations
Ground tests cannot be used to assess complex cognitive issues.
Example
An example of a ground test is an assessment of the potential of reflections on displays. Such an assessment usually involves covering the cockpit windows to simulate darkness and setting the

cockpit lighting to the desired levels. This particular assessment may not be possible in a simulator, because of differences in the light sources, display hardware, and/or construction of the windows.

(f) MC6 Flight test and MC8 Simulation

The applicant may use a wide variety of part-task to full-installation representations of the product/system or cockpit for assessments. The representation of the human–machine interface does not necessarily conform to the final design. The paragraphs below address part-task simulations, rotorcraft-level simulations, and in-flight assessments that typically make up this group of means of compliance.

Description
As soon as the maturity of the design allows pilots to take part in the compliance demonstration, HFs assessments are conducted in a dynamic operational context. Depending on the HFs objectives to be addressed, and according to the HFs test programme, those assessments can be either conducted at the system level or the rotorcraft level. Both simulators and real rotorcraft can be used, but the selection of the MoC depends on the nature of the test objectives.
Deliverable
A report, delivered to EASA, depending on the defined LoI.
Participants
Applicant and possibly EASA, depending on the defined LoI.
Conformity
The required level of conformity is dependent on the purpose of the exercise. When the assessment is conducted during the early phases of the design and certification process, with the aim of obtaining early and partial certification credit, the cockpit should be representative of the final design only for the part that is scrutinised. When the assessment is conducted at the end of the design and certification programme for the purpose of a final verification and validation, conformity is required.
Uses
Traditionally, these types of activities are part of the design process. They allow applicants to continuously improve their designs thanks to the application of an iterative approach. When EASA is involved in such activities, and depending on the level of representativeness of the assessed part of the design, early and partial certification credit may be granted.

(g)(i) MC8 Simulation

Simulator assessment

A simulator assessment uses devices that present an integrated emulation (using flight hardware, simulated systems, or combinations of these) of the cockpit and the operational environment. These devices can also be 'flown' with response characteristics that replicate, to some extent, the responses of the rotorcraft. The required functional and physical representativeness of the simulation (or degree of realism) will typically depend on the configurations, functions, tasks, and equipment to be assessed.
Simulator assessment conformity and representativeness issues
Applicants may use a crew training simulator to validate most of the normal, abnormal and emergency procedures for the design, and any workload effects of the equipment on the crew. If the cockpit is fully representative and the avionics are driven by conforming hardware and software, then the applicant may conduct and use integrated avionics testing for demonstrating compliance. Note that not all aspects of the simulation must have a high level of representativeness for any given compliance issue. The requirements for the representativeness of the simulator depend on the issue being checked.

(g)(ii) MC6 Flight test

Rotorcraft assessment
Flight testing during certification is the final demonstration of the design. These are tests conducted in a conforming rotorcraft during flight. The rotorcraft and its components (cockpit) are the most representative of the type design to be certified and will be the closest to real operations of the equipment. In-flight testing is the most realistic testing environment, although it is limited to those tests that can be conducted safely. Flight testing can be used to validate and verify other assessments previously conducted during the development and certification programme. It is often best to use flight testing as the final confirmation of data collected using other means of compliance, including analyses and assessments. Flights tests made during the development and certification phases for other areas of investigation can be given partial credit for demonstrating compliance with 27.1302 to a certain extent. The acceptability of this approach has, however, to be assessed by EASA on a case-by-case basis. A prerequisite for acceptance by EASA is the respect of the basic HFs methodological principles for data collection and processing. Additionally, this approach should not be used as a substitute for dedicated HFs assessments conducted on simulators or flight test vehicles, and it should only be used as a complementary approach.

(g)(iii) MC6 versus MC8

MC6 versus MC8:
The selection of the actual rotorcraft as the means of assessment should not be exclusively motivated by the absence of any other available means, but should be duly justified, taking into account its inherent limitations: — The actual rotorcraft may be inappropriate for the assessment of abnormal situations for safety reasons.

— A flight environment does not normally allow the manipulation of the operational environment which may be needed to apply the scenario-based approach.

— HFs scenarios performed using flight tests may be difficult to duplicate due to the lack of controllability of the operational context. For example, events like ATC communications, weather, etc., that are expected to trigger a crew reaction to be tested may not be repeatable. This may hamper the collection of homogeneous data and may adversely affect the validity of the experiment.

However, flight test vehicles are deemed adequate when the operational and/or system representativeness is a key driver for the validity of HFs data. For example, an assessment in real flight conditions may be more adequate when dealing with workload assessments due to its proper system and ATC representation.

In any case, the nature of the HFs objective to be assessed should drive the selection of the appropriate means, and not the contrary. EASA and the applicant should thoroughly discuss how and when flight tests and their results will be used to demonstrate compliance.

AMC 27.1302 APPENDIX 1: Related regulatory material and documents

FAA Orders and Policy

— Policy Memo ANM-99-2, Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Transport Airplane Flight Decks.

— Policy Memo ANM-0103, Factors to Consider When Reviewing an Applicant's Proposed Human Factors Methods of Compliance for Flight Deck Certification.

— FAA Notice 8110.98, Addressing Human Factors/Pilot Interface Issues of Complex, Integrated Avionics as Part of the Technical Standard Order (TSO) Process.

Other documents

The following is a list of other documents relevant to cockpit design and crew interfaces that may be useful when applying this AMC. Some are not aviation specific, such as International Standard ISO 9241-4, which, however, provides useful guidance. When using that document, applicants should consider environmental factors such as the intended operational environment, turbulence, and lighting, as well as cross-side reach.

— AMC 25-11, Electronic Flight Deck Displays, November 2018

— SAE ARP4033, Pilot-System Integration, August 1995

— SAE ARP5289A, Electronic Aeronautical Symbols

— SAE ARP4102/7, Electronic Displays

— SAE ARP4105C, Abbreviations, Acronyms, and Terms for Use on the Flight Deck

— ICAO Doc 8400, Procedures for Air Navigation Services — ICAO Abbreviations and Codes, Ninth Edition, 2016

— ICAO Doc 9683 – AN/950 Human Factors Training Manual, First Edition, 1998

— International Standards ISO 9241-4, Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)

— FAA Human Factors Team report on: The Interfaces Between Flight crews and Modern Flight Deck Systems, 1996

— DOT/FAA/RD–93/5: Human Factors for Flight Deck Certification Personnel

GM No 1 to 27.1302 Explanatory material

1_Introduction

(a) Accidents most often result from a sequence or combination of different errors and safety-related events (e.g. equipment failures and weather conditions). Analyses show that the design of the cockpit and other systems can influence the crew's task performance and the occurrence and effects of some crew errors.

(b) Crews make a positive contribution to the safety of the aviation system because of their ability to continuously assess changing conditions and situations, analyse potential actions, and make reasoned decisions. However, even well-trained, qualified, healthy, alert crew members make errors. Some of these errors may be induced or influenced by the designs of the systems and their crew interfaces, even with those that are carefully designed. Most of these errors have no significant safety effects, or are detected and mitigated in the normal course of events. However, some of them may lead or contribute to the occurrence of unsafe conditions. Accident analyses have identified crew performance and errors as recurrent factors in the majority of accidents involving rotorcraft.

(c) Some current requirements are intended to improve safety by requiring the cockpit and its equipment to be designed with certain capabilities and characteristics. The approval of cockpit systems with respect to design-related crew error has typically been addressed by referring to system-specific or general applicability requirements, such as CS 27.1301(a), CS 27.771(a), and CS 27.1523. However, little or no guidance exists to show how the applicant may address potential crew limitations and errors. That is why CS 27.1302 and this guidance material have been developed.

(d) CS 27.1302 was developed to provide a basis for addressing the design-related aspects of the avoidance and management of crew error by taking the following approach.

(i) Firstly, by providing means to address the design characteristics that are known to reduce or avoid crew error and that address crew capabilities and limitations. The requirements of CS 27.1302(a) to (c) are intended to reduce the design contribution to such errors by ensuring that the information and controls needed by the crew to perform the tasks associated with the intended function of installed equipment are provided, and that they are provided in a usable form.

In addition, operationally relevant system behaviour must be understandable, predictable, and supportive of the crew's tasks. Guidance is provided in this paragraph on the avoidance of design-induced crew errors.

(ii) Secondly, CS 27.1302(d) addresses the fact that since crew errors will occur, even with a well-trained and proficient crew operating well-designed systems, the design must support the management of those errors to avoid any safety consequences. Paragraph 5.7 below on crew error management provides the relevant guidance.

(e) EASA would like to bring the applicants' attention to the fact that the implementation of the CS 27.1302 process may require up to several years, depending on the characteristics of the project. However, STCs may require much less time.

2_Applicability and Explanatory Material to CS 27.1302

(a) CS-27 contains requirements for the design of cockpit equipment that is system specific (refer to AMC 27.1302, Table 1, in paragraph 2), generally applicable (e.g. CS 27.1301(a), CS 27.771(a)), and establishes minimum crew requirements (e.g. CS 27.1523). CS 27.1302 augments the generally applicable requirements by adding more explicit requirements for the design attributes related to the avoidance and management of crew errors. Other ways to avoid and manage crew errors are regulated through the requirements governing the licensing and qualification of crew members and rotorcraft operations. Taken together, these complementary approaches provide an adequate level of safety.

(b) The complementary approach is important. It is based upon recognition that equipment design, training/licensing/qualification, and operations/procedures each provide safety contributions to risk mitigation. An appropriate balance is needed between them. There have been cases in the past where design characteristics known to contribute to crew errors were accepted based upon the rationale that training or procedures would mitigate that risk. We now know that this can often be an inappropriate approach. Similarly, due to unintended consequences, it would not be appropriate to require equipment design to provide total risk mitigation.

(c) A proper balance is needed between the design approval requirements in the minimum airworthiness standards of CS-27 and the requirements for training/licensing/qualification and operations/procedures. CS 27.1302 and this GM were developed with the intent of achieving that appropriate balance.

(1) Introduction. The introductory sentence of CS 27.1302 states that the provisions of this paragraph apply to each item of installed equipment intended for the crew's use in operating the rotorcraft from their normal seating positions in the cockpit or operating positions in the cabin.

(i) 'Intended for the crew member's use in the operation of the rotorcraft from their normal seating position in the cockpit or operating positions in the cabin,' means that the intended function of the installed equipment includes its use by the crew in operating the rotorcraft. An example of such installed equipment would be a display that provides information enabling the crew to navigate. The term 'crew members' is intended to include any or all individuals comprising the minimum crew as determined for compliance with CS 27.1523. The phrase 'from their normal seating positions in the cockpit' means that the crew members are seated at their normal duty stations for operating the rotorcraft.

(ii) The phrase 'from their normally operating positions in the cabin' means that crew members are located at their normal duty stations in the cabin. These phrases are intended to limit the scope of this requirement so that it does not address the systems or equipment that are not used by the crew while performing their duties in operating the rotorcraft in normal, abnormal and emergency conditions. For example, this paragraph is not intended to apply to items such as certain circuit breakers or maintenance controls intended for use by the maintenance crew (or by the crew when not operating the rotorcraft).

(iii) The phrase 'This installed equipment must be shown…' in the first paragraph means that the applicant must provide sufficient evidence to support compliance determinations for each of the CS 27.1302 requirements. This is not intended to require a demonstration of compliance beyond that required by 21.A.21(b) of Part 21. Accordingly, for simple items or items similar to previously approved equipment and installations, the demonstrations, assessments or data needed to demonstrate compliance with CS 27.1302 are not expected to entail more extensive or onerous efforts than are necessary to demonstrate compliance with the previous requirements.

(iv) The phrase 'individually and in combination with other such equipment' means that the requirements of this paragraph must be met when equipment is installed in the cockpit with other equipment. The installed equipment must not prevent other equipment from complying with these requirements. For example, applicants must not design a display so that the information it provides is inconsistent with or is in conflict with information from other installed equipment.

(v) In addition, the provisions of this paragraph presume a qualified crew that is trained to use the installed equipment. This means that the design must meet these requirements for crew members who are allowed to fly the rotorcraft by meeting the operating rules qualification requirements. If the applicant seeks a type design or supplemental type design approval before a training programme is accepted, the applicant should document any novel, complex, or highly integrated design features and assumptions made during the design phase that have the potential to affect the training time or the crew procedures. The requirements and associated material are written assuming that either these design features and assumptions or the knowledge of a training programme (proposed or in the process of being developed) will be coordinated with the appropriate operational approval organisation when assessing the adequacy of the design.

(vi) The requirement for equipment to be designed so the crew can safely perform the tasks associated with the intended function of the equipment applies in normal, abnormal and emergency conditions. The tasks intended to be performed under all the above conditions are generally those prescribed by the crew procedures. The phrase 'safely perform their tasks' is intended to describe one of the safety objectives of this requirement. The requirement is for the equipment design to enable the crew to perform their tasks with sufficient accuracy and in a timely manner, without unduly interfering with their other required tasks. The phrase 'tasks associated with its intended function' is intended to characterise either the tasks required to operate the equipment or the tasks for which the intended function of the equipment provides support.

(2) **CS 27.1302(a)** requires the applicant to install appropriate controls and provide the necessary information for any cockpit equipment identified in the first paragraph of CS 27.1302. The controls and the information displays must be sufficient to allow the crew to accomplish their tasks. Although this may seem obvious, this requirement is included because a review of CS-27 on the subject of human factors revealed that a specific requirement for cockpit controls and information to meet the needs of the crew is necessary. This requirement is not reflected in other parts of the rules, so it is important to be explicit.

(3) **CS 27.1302(b)** addresses the requirements for cockpit controls and information that are necessary and appropriate for the crew to accomplish their tasks, as determined through (a) above. The intent is to ensure that the design of the control and information devices makes them usable by the crew. This subparagraph seeks to reduce design-induced crew errors by imposing design requirements on cockpit information presentation and controls. Subparagraphs (1) through (3) specify these design requirements. Design requirements for information and controls are necessary to:

(i) properly support the crew in planning their tasks;

(ii) make available to the crew appropriate, effective means to carry out planned actions; and

(iii) enable the crew to have appropriate feedback information about the effects of their actions on the rotorcraft.

(4) **CS 27.1302(b)(1)** specifically requires controls and information to be provided in a clear and unambiguous form, at a resolution and precision appropriate to the task.

(i) As applied to information, 'clear and unambiguous' means that it can be perceived correctly (is legible) and can be comprehended in the context of the crew tasks associated with the intended functions of the equipment, such that the crew can perform all the associated tasks.

(ii) For controls, the requirement for 'clear and unambiguous' presentation means that the crew must be able to use them appropriately to achieve the intended functions of the equipment. The general intent is to foster the design of equipment controls whose operation is intuitive, consistent with the effects on the parameters or states that they affect, and compatible with the operation of the other controls in the cockpit.

(iii) 27.1302(b)(1) also requires the information or control to be provided, or to operate, at a level of detail and accuracy appropriate for accomplishing the task. Insufficient resolution or precision would mean the crew could not perform the task adequately. Conversely, excessive resolution has the potential to make a task too difficult because of poor readability or the implication that the task should be accomplished more precisely than is actually necessary.

(5) **CS 27.1302(b)(2)** requires controls and information to be accessible and usable by the crew in a manner consistent with the urgency, frequency, and duration of their tasks. For example, controls that are used more frequently or urgently must be readily accessed, or require fewer steps or actions to perform the task. Less accessible controls may be acceptable if they are needed less frequently or urgently. Controls that are used less frequently or urgently should not interfere with those used more urgently or frequently. Similarly, tasks requiring a longer time for interaction should not interfere with the accessibility to information required for urgent or frequent tasks.

(6) **CS 27.1302(b)(3)** requires equipment to present information advising the crew of the effects of their actions on the rotorcraft or systems, if that awareness is required for safe operation. The intent is for the crew to be aware of the system or rotorcraft states resulting from crew actions, permitting them to detect and correct their own errors. This subparagraph is included because new technology enables new kinds of crew interfaces that previous requirements did not address. Specific deficiencies of existing requirements in addressing human factors are described below:

(i) CS 27.771(a) addresses this topic for controls, but does not include criteria for the presentation of information;

(ii) CS 27.777(a) addresses controls, but only their location;

(iii) CS 27.777(b) and CS 27.779 address the direction of motion and actuation but do not encompass new types of controls such as cursor devices. These requirements also do not encompass types of control interfaces that can be incorporated into displays via menus, for example, thus affecting their accessibility;

(iv) CS 27.1523 has a different context and purpose (determining the minimum crew), so it does not address these requirements in a sufficiently general way.

(7) **CS 27.1302(c)** requires installed equipment to be designed so its behaviour that is operationally relevant to crew tasks is:

(i) predictable and unambiguous, and

(ii) designed to enable the crew to intervene in a manner appropriate to the task (and intended function).

Other related considerations are the following:

(iii) Improved cockpit technologies involving integrated and complex information and control systems have increased safety and performance. However, they have also introduced the need to ensure proper interactions between the crew and those systems. Service experience has found that some equipment behaviour (especially from automated systems) is excessively complex or dependent upon logical states or mode transitions that are not well understood or expected by the crew. Such design characteristics can confuse the crew and have been determined to contribute to incidents and accidents.

(iv) The phrase 'operationally relevant behaviour' is meant to convey the net effect of the system logic, controls, and displayed information of the equipment upon the awareness of the crew or their perception of the operation of the system to the extent necessary for planning actions or operating the system. The intent is to distinguish such system behaviour from the functional logic within the system design, much of which the crew does not know or does not need to know, and which should be transparent to them.

(8) **CS 27.1302(c)(1)** requires the behaviour of a system to be such that a qualified crew can know what the system is doing and why. It requires operationally relevant system behaviour to be 'predictable and unambiguous'. This means that a crew can retain enough information about what their action or a changing situation will cause the system to do under foreseeable circumstances, so they can operate the system safely.

The behaviour of a system must be unambiguous because the actions of the crew may have different effects on the rotorcraft, depending on its current state or operational circumstances.

(9) **CS 27.1302(c)(2)** requires the design to be such that the crew will be able to take some action, or change or alter an input to the system, in a manner appropriate to the task.

(10) **CS 27.1302(d)** addresses the reality that even well-trained, proficient crews using well-designed systems will make errors. It requires equipment to be designed to enable the crew to manage such errors. For the purpose of this rule, errors 'resulting from crew

interaction with the equipment' are those errors that are in some way attributable, or related, to the design of the controls, the behaviour of the equipment, or the information presented. Examples of designs or information that could cause errors are indications and controls that are complex and inconsistent with each other or with other systems on the cockpit. Another example is a procedure that is inconsistent with the design of the equipment. Such errors are considered to be within the scope of this requirement and AMC.

(i) What is meant by a design which enables the crew to 'manage errors' is that:

(A) the crew must be able to detect and/or recover from errors resulting from their interaction with the equipment; or

(B) the effects of such crew errors on the rotorcraft functions or capabilities must be evident to the crew, and continued safe flight and landing must be possible; or

(C) crew errors must be discouraged by switch guards, interlocks, confirmation actions, or other effective means; or

(D) the effects of errors must be precluded by system logic or redundant, robust, or fault-tolerant system design.

(ii) The requirement to manage errors applies to those errors that can be reasonably expected in service from qualified and trained crews. The term 'reasonably expected in service' means errors that have occurred in service with similar or comparable equipment. It also means errors that can be predicted to occur based on general experience and knowledge of human performance capabilities and limitations related to the use of the type of controls, information, or system logic being assessed.

(iii) CS 27.1302(d) includes the following statement: 'This sub-paragraph does not apply to skill-related errors associated with manual control of the rotorcraft.' That statement is intended to exclude errors resulting from the crew's proficiency in the control of the flight path and attitude with the primary roll, pitch, yaw and thrust controls, and which are related to the design of the flight control systems. These issues are considered to be adequately addressed by the existing requirements, such as CS-27 Subpart B and CS 27.671(a). It is not intended that the design should be required to compensate for deficiencies in crew training or experience. This assumes at least the minimum crew requirements for the intended operation, as discussed at the beginning of paragraph 5.1 above.

(iv) This requirement is intended to exclude the management of errors resulting from decisions, acts, or omissions by the crew that are not in good faith. It is intended to avoid imposing requirements on the design to accommodate errors committed with malicious or purely contrary intent. CS 27.1302 is not intended to require applicants to consider errors resulting from acts of violence or threats of violence.

This 'good faith' exclusion is also intended to avoid imposing requirements on designs to accommodate errors due to a crew member's obvious disregard for safety. However, it is recognised that errors committed intentionally may still be in good faith, but could be influenced by the characteristics of the design under certain circumstances. An example would be a poorly designed procedure that is not compatible with the controls or information provided to the crew.

Imposing requirements without considering their economic feasibility or the commensurate safety benefits should be avoided. Operational practicability should also be addressed, such as the need to avoid introducing error management features into the design that would inappropriately impede crew actions or decisions in normal, abnormal and emergency conditions. For example, it is not intended to require so many guards or interlocks on the means to shut down an engine that the crew would be unable to do this reliably within the available time. Similarly, it is not intended to reduce the authority or means for the crew to intervene or carry out an action when it is their responsibility to do so using their best judgment in good faith.

This subparagraph was included because managing errors that result from crew interactions with equipment (that can be reasonably expected in service) is an important safety objective. Even though the scope of applicability of this material is limited to errors for which there is a contribution from or a relationship to the design, CS 27.1302(d) is expected to result in design changes that will contribute to safety. One example, among others, would be the use of 'undo' functions in certain designs.

GM No 2 to 27.1302 Example of compliance matrix

EASA expects to receive from the applicant the essential information in order to understand the relationship between the following elements:

— the features of the design,

— the regulations,

— the test objectives,

— the MoCs, and

— the deliverables.

The two matrices below are provided as examples only. However, the applicants are free to present the necessary information to EASA through any format discussed and agreed with EASA.

An example with a design feature entry:

Function	**Sub-function**	**Focus**	**Reference to requirement**	**Description of requirement**	**Assessed dimension**	**MoC**	**Reference to the related deliverable**
Electronic checklist (ECL) function	Display electronic checklist	Electronic checklist quick access keys (ECL QAKs)	CS 27.777(a)	Each cockpit control must be located to provide convenient operation and to prevent confusion or inadvertent operation.	Assess ECL QAKs location for convenient operation and prevention of inadvertent operation.	MoC8 HFs campaign #2 Scenario #4	Human Factors Test Report XXX123
			CS27.777(b)	The controls must be located and arranged with respect to the pilots' seats so that there is full and unrestricted movement of each control without interference from the cockpit structure or the pilot's clothing when pilots from 1.57 m (5 ft 2 inches) to 1.8 m (6 ft) in height are seated.	Assess accessibility to control ECL QAKs.	MoC4 HFs Reachability Analysis MoC5 HFs Reachability and Accessibility Campaign	HFs Reachability and Accessibility Assessment Report XXX123
			[…]	[…]	[…]	[…]	[…]
			CS 27.1302(a)	Flight deck controls must be installed to allow the accomplishment of these tasks, and the information necessary to accomplish these tasks must be provided.	Assess appropriate control is provided in order to display ECL.	MoC1 ECL implementation description for XXXX.	ECL implementation description document for XXXX.

Function	Sub-function	Focus	Reference to requirement	Description of requirement	Assessed dimension	MoC	Reference to the related deliverable
			CS 27.1302(b)(1)	Flight deck controls and information intended for flight crew use must be presented in a clear and unambiguous form, at a resolution and precision appropriate to the task.	Assess appropriateness of ECL QAKs labels.	MoC8 HFs campaign #4 Scenario #1	Human Factors test Report XXX345

Another example with a requirement entry:

Reference to requirement	Description of requirement	Focus	Assessed dimension	MoC	Reference to the related deliverable
CS 27.777(a)	Each cockpit control must be located to provide convenient operation and to prevent confusion and inadvertent operation.	All cockpit controls	Assess the locations of all cockpit controls for convenient operation and prevention of inadvertent operation.	MoC8 All HFs simulator evaluations	Human Factors Test Reports XXX123 XXX456 XXX789
		ECL QAKs	Assess the location of ECL QAKs for convenient operation and prevention of inadvertent operation.	MoC8 HFs campaign #2 Scenario #4	Human Factors Test Report XXX123
CS 27.777(b)	The controls must be located and arranged with respect to the pilots' seats so that there is full and unrestricted movement of each control without interference from the cockpit structure or the pilot's clothing when pilots from 1.57 m (5 ft 2 inches) to 1.8 m (6 ft) in height are seated.	All cockpit controls	Assess the accessibility of all cockpit controls.	MoC4 HFs Reachability Analysis. MoC5 HFs Reachability and Accessibility Campaign.	HFs Reachability and Accessibility Assessment Report XXX123
		ECL QAKs	Assess accessibility to	MoC4	HFs Reachability and Accessibility

Reference to requirement	**Description of requirement**	**Focus**	**Assessed dimension**	**MoC**	**Reference to the related deliverable**
			control ECL QAKs.	HFs Reachability Analysis. MoC5 HFs Reachability and Accessibility Campaign.	Assessment Report XXX123
[…]	[…]				
CS 27.1302(a)	Flight deck controls must be installed to allow the accomplishment of these tasks, and the information necessary to accomplish these tasks must be provided.				
CS 27.1302(b)(1)	Flight deck controls and information intended for flight crew use must be presented in a clear and unambiguous form, at a resolution and precision appropriate to the task.				

4 Impact assessment (IA)

Refer to Section 2.4.

5 Proposed actions to support implementation

— A dedicated workshop was held before the public consultation of the NPA in order to communicate the intended amendments to the Certification Specifications for Large Rotorcraft (CS-29), and to allow preliminary discussions.

— Another workshop may be planned after the public consultation of this NPA, depending on the comments received.

— EASA is also considering organising an information session after the publication of the Decision related to this rulemaking task. The ultimate objective of this event would be to present the new CS provisions, and provide clear indications and best practices on how to implement them during future certification projects.

6 References

6.1 Affected decisions

— Decision No. 2003/15/RM of the Executive Director of the Agency of 14 November 2003 on certification specifications for small rotorcraft ('CS-27')

— Decision No. 2003/16/RM of the Executive Director of the Agency of 14 November 2003 on certification specifications for large rotorcraft ('CS-29')