

CS-27 AMENDMENT 8 — CHANGE INFORMATION

EASA publishes amendments to the Certification Specifications for Small Rotorcraft (CS-27) as consolidated documents. These documents are used for establishing the certification basis for applications made after the date of entry into force of the applicable amendment.

Consequently, except for a note '[Amdt No: 27/8]' under the amended paragraph, the consolidated text of CS-27 does not allow readers to see the detailed changes introduced compared to the previous amendment. To allow readers to also see these detailed changes, this document has been created. The same format as for the publication of notices of proposed amendments (NPAs) is used to show the changes:

- deleted text is ~~struck through~~;
- new or amended text is highlighted in blue;
- an ellipsis '[...]' indicates that the rest of the text is unchanged.

BOOK 1 — CERTIFICATION SPECIFICATIONS

SUBPART F — EQUIPMENT

CS 27.1302 Installed systems and equipment for use by the crew members

(See AMC 27.1302, GM1 and GM2 27.1302)

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

- (a) The controls and information necessary for the accomplishment of the tasks must be provided.
- (b) The controls and information required by paragraph (a), which are intended for use by the crew members, must:
 - (1) be presented in a clear and unambiguous form, at a resolution and with a precision appropriate to the crew member tasks;
 - (2) be accessible and usable by the crew members in a manner appropriate to the urgency, frequency, and duration of their tasks; and
 - (3) make the crew members aware of the effects their actions may have on the rotorcraft or its systems, if they require awareness for the safe operation of the rotorcraft.

- (c) Operationally relevant behaviour of the installed systems and equipment must be:
- (1) predictable and unambiguous; and
 - (2) designed to enable the crew members to intervene in a manner that is appropriate to accomplish their tasks.
- (d) The installed systems and equipment must enable the crew members to manage the errors that result from the kinds of crew member interactions with the system and equipment that can be reasonably expected in service, assuming the crew member acts in good faith. Paragraph (d) does not apply to skill-related errors associated with the manual control of the rotorcraft.

BOOK 2 — ACCEPTABLE MEANS OF COMPLIANCE AND GUIDANCE MATERIAL

AMC and GM — SUBPART F

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1)_ INTRODUCTION

1.1_Background

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

1.2_Applicability

- (a) This acceptable means of compliance (AMC) provides the means for demonstrating compliance with CS 27.1302 and complements the means of compliance (MoC) for several other paragraphs in CS-27 (refer to paragraph 2, Table 1 of this AMC) that relate to the installed systems and equipment used by the crew members for the operation of a rotorcraft. In particular, this AMC addresses the design and approval of installed systems and equipment 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 crew member interfaces and system behaviour for all the installed systems and equipment used by the crew members in the cockpit and the cabin while operating the rotorcraft in normal, abnormal/malfunction and emergency conditions. The functions of the crew members that operate from the cabin need to be considered in case they may interfere with the ones under the responsibility of the cockpit crew, or in case dedicated certification specifications are included in CS-27.
- (c) This AMC does not apply to crew member training, qualification or licensing requirements.
- (d) EASA recognises that when Part 21 requires 27.1302 to be part of the certification basis, the amount of effort the applicant has to make for demonstrating compliance with it may vary and not all the material contained within this AMC should be systematically followed. A proportionate approach is embedded within the AMC and is described in paragraph 3.2.9. The proportionate approach affects the demonstration of compliance and depends on criteria such as the rotorcraft category (A or B), the type of operation (VFR, IFR), and the classification of the change.

1.3 Definitions

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

- **alert:** a cockpit indication that is meant to attract the attention of the crew, and identify to them an operational or aircraft system condition. Warnings, cautions, and advisories are considered alerts.
- **assessment:** the process of finding and interpreting evidence to be used by the applicant in order to establish compliance with a specification. For the purposes of this AMC, the term 'assessment' may 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 technique of controlling an apparatus, a process or a system by means of electronic and/or mechanical devices, which replaces the human organism in the sensing, decision-making and deliberate output.
- **cabin:** the area of the aircraft, excluding the cockpit, where the crew members can operate the rotorcraft systems; for the purposes of this AMC, the scope of the cabin is limited to the areas used by the crew members to operate:
 - the systems that share controls and information with the cockpit;
 - the systems which have controls and information with similar direct or indirect consequences other than the one in the cockpit (e.g. precision hovering).
- **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, the use of a circuit breaker as a switch.
- **clutter:** an excessive number and/or variety of symbols, colours, or other information that may reduce the access to the relevant information, increase interpretation time and the likelihood of interpretation error.
- **cockpit:** the area of the aircraft where the flight crew members work and where the primary flight controls are located.
- **conformity:** official verification that the cockpit/system/product conforms to the type design data.
- **cockpit controls:** the interaction with a control means that the crew manipulates 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 the 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 that is involved in the operation of the aircraft and its systems; in the case of rotorcraft, the operator in the cabin that can interfere with the cockpit-crew tasks (for instance, the operator in the cabin assigned to operate the rescue hoist or to help the cockpit-crew control the aircraft in a hover is considered a crew member).
- **cursor-control device:** a control device for interacting with the 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 feature:** a design feature is an attribute or a characteristic of a design.
- **design item:** a design item is a system, an equipment, a function, a component or a design feature.
- **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 that results 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 that transmits data or information from the aircraft to the crew.
- **flight crew member:** a licensed crew member charged with duties that are essential for the operation of an aircraft during a flight duty period.
- **human error:** a deviation 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. In the context of this AMC, human error is sometimes referred to as 'crew error' or 'pilot error'.

- **multifunction control:** a control device that can be used for many functions, as opposed to a control device with a single dedicated function.
- **abnormal/malfunction or emergency conditions:** for the purposes of this AMC, abnormal/malfunction 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 (RFM).
- **operationally relevant behaviour:** 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.
- **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

The following is a list of abbreviations used in this AMC:

AC	advisory circular
AMC	acceptable means of compliance
CAM	cockpit area microphone
CRM	crew resource management
CVR	cockpit voice recorder
CS	certification specification
DLR	data link recorder
DOT	Department of Transportation
EASA	European Union Aviation Safety Agency
ED	EUROCAE Document
FAA	Federal Aviation Administration
FMS	flight management system
GM	guidance material
HF	human factors
HMI	human–machine interface
ICAO	International Civil Aviation Organization
ISO	International Standards Organization
LoI	level of involvement
MoC	means of compliance
PA	public address
RFM	rotorcraft flight manual
SAE	Society of Automotive Engineers
STC	supplemental type certificate
TAWS	terrain awareness and warning system
TCAS	traffic alert and collision avoidance system
TSO	technical standard order
VOR	very high frequency omnidirectional range

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

2.1_The relation of CS 27.1302 to other specifications

- (a) CS-27 Book 2 establishes that the AMC for CS-27 is the respective FAA AC 27-1 revision adopted by EASA with the changes/additions included within Book 2. AC 27-1 includes the Miscellaneous Guidance MG-20 'Human Factors'. MG-20 aims to assist the applicant in understanding the HFs implications of the CS-27 paragraphs. In order to achieve this objective, MG-20 provides a list of all CS-27 HFs-related specifications, including those relevant to the performance and handling qualities, and helps to address within the certification plan some of the specifications that deal with the system design with additional guidance. However, MG-20 does not include specific guidance on how to perform a comprehensive HFs assessment as required by 27.1302. Therefore, adherence to the guidance material included within AC 27-1 and the associated MG-20 is not sufficient to demonstrate compliance with CS 27.1302.
- (b) This AMC provides dedicated guidance for demonstrating compliance with CS 27.1302. To help the applicant reach the objectives of CS 27.1302, some additional guidance related to other specifications associated with the installed equipment that the crew members use to operate the rotorcraft is also provided in Section 4. Table 1 below contains a list of these specifications related to cockpit design and crew member interfaces for which this AMC provides additional design guidance. Note that this AMC does not provide a comprehensive means of compliance for any of the specifications beyond CS 27.1302.

Paragraph 2 — Table 1: Certification specifications relevant to this AMC

CS-27 BOOK 1 references	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 BOOK 1 references	General topic	Referenced material in this AMC
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 27.1329 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.

(c) Where means of compliance in other AMCs 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 member capabilities

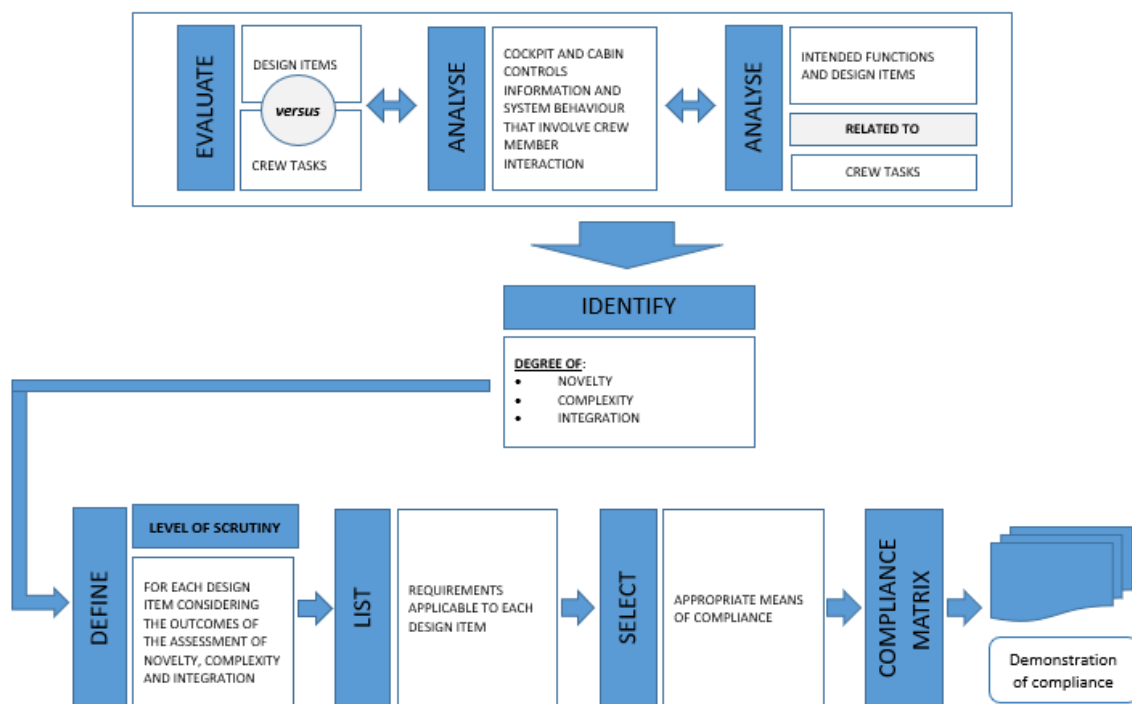
In order to demonstrate compliance with all the specifications referenced by this AMC, all the certification activities should be based on the assumption that the rotorcraft will be operated by qualified crew members who are trained in the use of the installed systems and equipment.

3)_ HUMAN FACTORS CERTIFICATION

3.1_ Overview

- (a) This paragraph provides an overview of the human factors (HFs) certification process that is acceptable 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 HFs certification process.

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



3.2_ Certification steps and deliverables

3.2.1_ Identification of the cockpit and cabin controls, information and systems that involve crew member interaction

- (a) As an initial step, the applicant should consider all the design items used by the crew members with the aim of identifying the controls, information and system behaviour that involve crew member interaction.
- (b) In case of a modification, the scope of the functions to be analysed is limited to the design items affected by the modification and its integration.
- (c) The objective is to analyse and document the crew member tasks to be performed, or how tasks might be changed or modified as a result of introducing a new design item(s).

- (d) Rotorcraft can be operated in different environments and types of missions. Therefore, while mapping the cockpit and the applicable crew member interfaces in the cabin or, in case of modification, the modified design items versus the crew member tasks and the design item intended functions, the type of approvals under the type design applicable to 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 the cabin functions is carried out.

3.2.2_The intended function of the equipment and the associated crew member 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 the 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 to be performed by the crew members must be known.

- (b) An applicant’s statement of the intended function should be sufficiently specific and detailed so that it is possible to evaluate whether the system is appropriate for the intended function(s) and the associated crew member 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 the 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) The applicant should describe the intended function(s) and associated task(s) for:

- (1) each design item affected by the modification and its integration;
- (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 handbook or an operations manual. It would describe the indications, controls, and crew member procedures.

- (d) The applicant may evaluate whether the statement of the intended function(s) and the associated task(s) is sufficiently specific and detailed by using the following questions:

- (1) Does each design item have a stated intent?
 - (2) Are the crew member tasks associated with the function(s) 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 members 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 members beyond those required in the regulations governing operations, training, or qualification?
- (e) The output of this step is a list of design items, with each of the associated intended functions that has been related to the crew member tasks.

3.2.3_Determining the level of scrutiny

- (a) The depth and extent of the HFs 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 design items using the criteria described in the following subparagraph:

- (1) **Integration.** The level of the systems' integration refers to the extent to which there are interdependencies between the systems that affect the operation of the rotorcraft by the crew members. 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 level of complexity of the system design from the crew members' perspective is an important factor that may also affect the means of compliance. Complexity has multiple dimensions, for instance:
 - the number, the accessibility and the level of integration of information that the crew members have 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 novelty of a design item is an important factor that may also affect the means of compliance. The applicant should characterise the degree of novelty on the basis of the answers to the following questions:

- (i) Are any new functions introduced into the cockpit design?
- (ii) Does the design introduce a new intended function for an existing or a new design item?
- (iii) Are any new technologies introduced that affect the way the crew members interact with the systems?
- (iv) Are any new design items introduced at aircraft level that affect crew member tasks?
- (v) Are any unusual procedures needed as a result of the introduction of a new design item?
- (vi) Does the design introduce a new way for the crew members to interact with the system?

While answering the above questions, each negative response should be justified by the applicant identifying the reference product as well that has been considered. The reference product can be an avionics suite or an entire flight deck previously certified by the same applicant.

The degree of novelty should be proportionate to the number of positive answers to the above questions.

- (b) All the affected design items (refer to point 3.2.1) are expected to be scrutinised. If none of the criteria in point (a) above is met, the related design item is candidate for a low level of scrutiny.

The level of scrutiny performed by the applicant should be proportionate to the number of the above criteria which are met by each design item. Applicants should be aware that the impact of a complex design item 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 design item is likely to require a lower level of scrutiny than one that is both complex and novel. The applicant is expected to include in the certification plan all the items that have been analysed with the associated level of scrutiny.

- (c) The applicant may use a simpler approach for design items that have been assigned a low level of scrutiny.

3.2.4_Determining the level of scrutiny — EASA's familiarity with the project

The assessment of the classifications of the level of scrutiny proposed by the applicant requires the EASA flight and HFs panels to be familiar with the project, making use of the available material and tools.

3.2.5_Applicable HFs design requirements

- (a) The applicant should identify the HFs design requirements applicable to each design item for which compliance must be demonstrated. This may be accomplished by identifying the design characteristics of the design items that could adversely affect the performance of the crew members, or that pertain to the avoidance and management of crew member errors. Specific design considerations for the requirements that involve human performance are discussed in paragraph 4.

- (b) The expected output of this step is a compliance matrix that links the design items and the HF design requirements that are deemed to be relevant and applicable so that a detailed assessment objective can be derived from each pair of a design item and a HF design requirement. That objective will have then to be verified using the most appropriate means of compliance, or a combination of means of compliance. GM2 27.1302 provides one possible example of this matrix.

3.2.6 Selecting the appropriate means of compliance

- (a) The applicant should review paragraph 5.2 for guidance on the selection of 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 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 HF 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 HF objectives.

3.2.7 Certification programme

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.

3.2.8 Other deliverables

- (a) A HF test programme should be produced for each assessment and should describe the experimental protocol (the number of scenarios, the number and profiles of the crew members, practical organisation of the assessment, etc.), the HF objectives that are meant to be addressed, the expected crew member behaviour, and the scenarios expected to be run. When required by the Lol, the HF test programme should be provided well in advance to EASA.
- (b) A HF test report should be produced including at least the following information:
- (1) A summary of:
 - (i) the test vehicle configuration,
 - (ii) of test vehicle limitations/representativeness,
 - (iii) the detailed HF objectives, and
 - (iv) the HF test protocol, including the number of sessions and crew members, type of crews (test or operational pilots from the applicant, authority pilots, customer 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 with the link to the HF objectives;
 - (3) In-depth analyses of the observed HF findings;
 - (4) Conclusions regarding the related HF test objectives; and

(5) A description of the proposed way to mitigate the HF findings (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 HF assessment.

3.2.9 Proportional approach in the compliance demonstration

In order to determine the certification programme, some alleviations (in terms of certification strategy and certification deliverables) may be granted by EASA for compliance demonstration process, according to the criteria below:

(a) New types

(1) An applicant that seeks an approval for a CS-27 rotorcraft for IFR or CAT A operations, should follow this AMC in its entirety.

(2) An applicant that seeks an approval for a CS-27 rotorcraft only for CAT B and VFR operations, may take advantage of the alleviations listed in (b)(2) below.

In particular, the alleviations listed in (b)(2) are expected to be fully recognised if at least one of the following conditions is met:

(i) the rotorcraft is single engine;

(ii) the rotorcraft design to be approved is not compatible with a future approval for IFR operations.

(b) Significant and non-significant changes

(1) An applicant for a significant change should follow the criteria established in (a)(1) or (a)(2) above, depending on the case.

(2) An applicant for a non-significant change (refer to the change classification in point 21.A.101 of Part 21 and the related GM):

(i) is not required to develop a dedicated HF test programme;

(ii) is allowed to use a single occurrence of a test for compliance demonstration;

(iii) is allowed to use a single crew to demonstrate the HF-scenario-based assessments.

3.3 Certification strategy and methodologies

3.3.1 Certification strategy

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

(b) A HF certification strategy based only on one assessment, aiming to demonstrate that the design assumptions are valid, is generally not sufficient (i.e. one final exercise proposed for compliance demonstration at the very end of the process).

(c) In order to allow a sufficient amount of design and assessment iterations, it is suggested that the applicant initiate the certification process as early as possible starting from the early

development phase. The certification process could include familiarisation sessions that would allow EASA to become familiar with the proposed design, but also participate in assessments that would possibly allow early credits to be granted. Potential issues may be identified early on by using this approach, thus reducing the risk of a late redesign of design items that may not be acceptable to EASA. Both parties may have an interest in authority early involvement, as the authority is continuously gaining experience and confidence in the HFs process and the compliance of the cockpit design. 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.

- (d) 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 (HMIs). It is based on a methodology that involves a sample of various crews that are representative of the future users, being exposed to real operational conditions in a test bench or a simulator, or in the rotorcraft. The scenarios are designed to show compliance with selected rules and to identify any potential deviations between the expected behaviour of the crew members and the activities of the crew members 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 member errors, difficulties or misunderstandings. The scenarios need to be well consolidated before the test campaign begins. A dry-run session 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 design item 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 substantiated. This rationale should be described in the certification test plan or in any other relevant document.
- (d) The criteria used to select the crew members involved in the HFs assessments with certification credit should be adequate to the scope of the tests to be conducted and the selection process

- of the crew members should be recorded. The applicant should ensure that the test participants are representative of the end users.
- (e) Due to interindividual variability, HF scenario-based assessments performed with a single crew member are not acceptable. The usually accepted number of different crew members 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 HF 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 HF 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 members at the beginning of each session to present the following general information:
- (1) A 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 members: 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 crew members: if crew members from the applicant participate in the assessment, they should be made aware that their role differs significantly from their typical 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 members 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 crew members 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 design-related human performance issue. Furthermore, for operational representativeness purposes, realistic crew member task sharing, from normal to emergency workflows and checklists, should be respected during HF assessments. The applicant should make available any draft or final RFM, procedures and checklists sufficiently in advance for the crew members to prepare.
- (i) When using simulation, the immersion feeling of the crew 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) Principles applicable to the collection of HFs-related data
 - (i) In order to substantiate compliance with CS 27.1302, it is necessary to collect both objective and related subjective data.
 - (A) **Objective data** on crew member performance and behaviour should be collected through direct observation. The observables should not be limited to human errors, but should also include pilot verbalisations in addition to behavioural indicators such as hesitation, suboptimal or unexpected strategies, catachresis, etc.
 - (B) **Subjective data** should be collected during the debriefing by the observer through an interactive dialogue with the observed crew members. The debriefing should be led using a neutral and critical positioning from the observer.
This subjective data is typically data that cannot be directly observed (e.g. pilot intention, pilot reasoning, etc.) and facilitate better understanding of the observed objective data from (i).
 - (ii) Other tools such as questionnaires and rating scales could be used as complementary means. However, it is never sufficient to rely solely on self-administered questionnaires due to the fact that crew members are not necessarily aware of all their errors, or of deviations with respect to the intended use.
 - (2) The HFs assessment should be systematically video recorded (both ambient camera and displays). Records may be used by the applicant as a complementary observation means, and by the authority for verification purposes, when required.
 - (3) It is very important to conduct debriefings after the 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-related concerns are raised that are not directly related to the objective of the assessment, they should nevertheless be recorded, adequately investigated and analysed in the test report.
- (l) Every design-related human performance issue observed or reported by the crew members should be analysed following the assessment. In the case of a human error, the analysis should provide information about at least the following:

- (1) The type of error;
 - (2) The observed operational consequences, and any reductions in the 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 design-related 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) Workload assessment is considered and addressed in different ways through several requirements within CS-27.
- (1) The intent of CS 27.1523 is to evaluate the workload with the objective of demonstrating compliance with the minimum flight crew requirements.
 - (2) The intent of CS 27.1302 is to identify design-related human performance issues.
 - (3) As per CS 27.1302, the acceptability of workload levels is one parameter among many to be investigated in order to highlight potential usability problems. The CS 27.1302 evaluations should not be limited to the workload alone. Workload ratings should be complementary to other data from observations of crew member behaviour or other types.
 - (4) The techniques used to collect data in the context of the CS 27.1302 evaluations could make use of workload rating scales, but in that case no direct conclusion should be made from the results about the compliance with CS 27.1302.

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 CS 27.1302. Not all the criteria can or should be met by all systems. Applicants 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 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 show that in the proposed design, as defined in CS 27.777, 27.779, 27.1543 and 27.1555, the controls comply with CS 27.1302(a) and (b).
- (b) Each function, method of operating a control, and result of actuating a control should comply 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 member awareness, including the provision of adequate feedback.
- (c) For each of these design requirements, consideration should be given to 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 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 actuating 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 should be made distinguishable and/or predictable by differences in form, colour, location, motion, effect and/or labelling. For example, the use of colour alone as an identifying feature is usually not sufficient.

(2) Labelling (CS 27.1301(b), CS 27.1302(a) and (b), CS 27.1543(b), CS 27.1555(a))

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

Labels should be readable from the crew member's 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.

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 the 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 'Procedures for Air Navigation Services (PANS) — ICAO Abbreviations and Codes' provides standard abbreviations, and is an acceptable basis for selecting labels.
- (iii) If an icon is used instead of a text label, the applicant should show that the crew members require 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 generally used in aviation and well known to crews, or has been validated during a HF's assessment; and

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

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

If multiple controls for one function are provided to the crew members, the applicant should show that there is sufficient information to make the crew members 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 for dual controls that can affect the same parameter simultaneously.

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

(1) Any control required for crew member operation (in normal, abnormal/malfunction and emergency conditions) should be shown to be visible, reachable, and operable by the 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, the applicant should show that the pilots can reach and actuate high-priority controls needed for the safe operation of the aircraft with the shoulder harnesses locked.

(2) Layering of information, as with menus or multiple displays, should not hinder the crew members from identifying the location of the desired control. 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 and of a master minimum equipment list (MMEL) dispatch.

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

(f) The use of controls

(1) Environmental factors affecting the controls (CS 27.1301(a) and CS 27.1302)

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

(ii) The sensitivity of the 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). The analysis of the environmental factors as a means of compliance is necessary, but not sufficient, for new control types or technologies, or for novel use of the controls that are themselves not new or novel.

(iii) 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 with extreme lighting conditions and

severe vibration levels and should not prevent the crew members from performing all their tasks with an acceptable level of performance and workload.

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

CS 27.779 describes the direction of movement of the cockpit controls.

- (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. For example, the applicant should specifically assess any rotary knob that has no obvious 'increase' or 'decrease' function with regard to the crew members' 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 so that it provides convenient operation and prevents 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 members' tasks. 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 members' 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 the information intended for use by the crew members to be accessible and useable by the crew members in a manner appropriate to the urgency, frequency, and duration of the crew members' 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).

(3) Control display design

(i) Controls of a variable nature that use a rotary motion should move clockwise from the OFF position, through an increasing range, to the full ON position.

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

(1) Feedback for the operation of the controls is necessary to give the crew members awareness of the effects of their actions. The meaning of the feedback should be clear and unambiguous. For example, if the intent of the feedback is to indicate a commanded event versus system state. Additionally, provide feedback when a crew member's input is not accepted or not followed by the system (27.1302(b)(1)). This feedback can be visual, auditory, or tactile.

(2) To meet the objectives of CS 27.1302, the applicant should show that feedback in all forms is obvious and unambiguous to the crew members when performing their tasks associated with the intended function of the equipment. Feedback, in an appropriate form, should be provided to inform the crew members 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, if needed (for example, fly-by-wire system), 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 member'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 in accordance with 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) The 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.

4.3_The presentation of information

(a) Introduction

(1) The presentation of information to the crew members 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).

(2) Applicants should show that, in the proposed design, as defined in CS 27.1301, 27.771(a) and 27.771(b), the presented information is:

- clear,
- unambiguous,
- appropriate in resolution and precision,
- accessible,
- usable, and
- able to provide adequate feedback for crew member awareness.

(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, as per CS 27.1302(b), that display formats include the type of information the crew member 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 member'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 members 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) Display readability (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 (as 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 that 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) Applicants should show that the chosen colour set is not susceptible to confusion or misinterpretation due to differences in colour coordinates between the displays.

(3) 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. FAA AC 27-1B Change 7, MG-19, 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 'Procedures for Air Navigation Services (PANS) — ICAO Abbreviations and Codes' provides abbreviations, and is one standard that could be applied to the textual material used in the cockpit.

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 members. 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) Applicants should show that displayed text and auditory messages are distinct and meaningful for the information presented. CS 27.1302 requires the information intended for use by the crew members 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. The 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 members must be accessible and useable by the crew members in a manner appropriate to the urgency, frequency, and duration of their tasks, as per CS 27.1302(b)(2). The crew members 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 members can access and manage (configure) all the necessary information on the dedicated and multifunction displays for the given 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 member'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, the 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. Crew members 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 members 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 members 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 the equipment uses automatic deselection of data to enhance the crew member's performance in certain emergency conditions, the applicant must show, as 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 design items, the applicant should follow the guidance in CS-27 Book 2 (e.g. FAA AC 27, MG-19).
- (iii) Because of the transient nature of the 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) System response time.

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 members to complete the task at an acceptable level of performance. For actions that require a noticeable system processing time, the equipment should indicate that the system response is pending.

4.4 System behaviour

(a) Introduction

The demands of the crew members' tasks vary depending on the characteristics of the system design. Systems differ in their responses to relevant crew member 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 the installed equipment must be designed so that the behaviour of the equipment that is operationally relevant to the crew members' tasks is:

-
- (1) predictable and unambiguous, and (2) designed to enable the crew members 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 members to know what the system is doing and what they did to enable/disable the behaviour. This distinguishes the system behaviour from the functional logic within the system design, much of which the crew members do not know or do not need to know.
 - (3) If crew member intervention is part of the intended function, or part of the abnormal/malfunction 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 member 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 members and the integrated, complex information and control systems. If the system behaviour is not understood or expected by the crew members, confusion may result.
 - (5) Some automated systems involve tasks that require crew members' 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 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 functions between crew members and automation.
- The applicant should show that the allocation of functions is conducted in such a way that:
- (1) the crew members are able to perform all the tasks allocated to them, considering normal, abnormal/malfunction and emergency operating conditions, within the bounds of an acceptable workload and without requiring undue concentration or causing undue fatigue (see CS 27.1523 and 27.771(a) for workload assessment); and
 - (2) the system enables the crew members to understand the situation, and enables timely failure detection and crew member intervention when appropriate.
- (c) The functional behaviour of a system
- (1) The functional behaviour of an automated system results from the interaction between the crew members 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 members' inputs to the system, and the information that provides feedback to the crew members 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 members. Examples of system functional logic and behavioural issues that may be associated with errors and other difficulties for the crew members are the following:

- (i) The complexity of the crew members' interface for both control actuation and data entry, and the complexity of the corresponding system indications provided to the crew members;
- (ii) The crew members having inadequate understanding and incorrect expectations of the behaviour of the system following mode selections and transitions; and
- (iii) The crew members 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 detail how they will show that the behaviour of the system or the system mode in the proposed design is predictable and unambiguous to the crew members.

- (i) System or system mode behaviour that is ambiguous or unpredictable to the crew members 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/malfunction 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 system behaviour 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 members 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 members.
 - (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. 'Uncommanded' could refer both to a mode change not commanded by the

pilot but by the automation as part of its normal operation, or to a mode change resulting from a malfunction.

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

(4) Crew member 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 members 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) The methods proposed by the 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 members. 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 members 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 members 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 member intervention, but under the supervision of the crew members. To ensure effective supervision and maintain crew member awareness of the system state and system 'intention' (future states), displays should provide recognisable feedback on:

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

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

(iii) the 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 members to determine whether the automated systems will perform according to the crew members' expectations;

(ii) If the automated system nears its operational authority or is operating abnormally for the given conditions, or is unable to perform at the selected level, it should inform the crew members, 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 members' inputs to the system; and

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

4.5_Crew member error management

(a) Meeting the objective of CS 27.1302(d)

(1) CS 27.1302(d) addresses the fact that crews will make errors, even when they are well trained, experienced, rested, and use well-designed systems.

CS 27.1302(d) addresses errors that are design related only. It is not intended to require consideration of errors resulting from acts of violence, sabotage or threats of violence.

(2) To meet the objective of CS 27.1302(d), the applicant should consider the following:

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

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

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

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

(3) The strategies described in (2) above:

(i) recognise and assume that crew member 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;

(ii) 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.

- (4) When demonstrating compliance, the applicant should consider the crew members' tasks in all operating conditions, considering that many of the same design characteristics are relevant in each case. For example, under abnormal/malfunction 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/malfunction 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.
- (5) To demonstrate compliance with CS 27.1302(d), the 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 member 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 members to manage errors has not significantly changed. Applicants may also use in-service data to identify errors known to commonly occur for similar crew member 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 design item 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 the means of error management through the analysis of controls, indications, system behaviour, and related crew member tasks. This would need to be done in conjunction with an understanding of the potential error opportunities and the means available for the crew members to manage those errors. In most cases, it is not considered feasible to predict the probability of crew member 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.

(6) 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/malfunction and emergency conditions. Scenarios should be designed to consider crew member 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.

(7) 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 to the crew members so that they can become aware of an error. Applicants should show that this information is available to the crew members, is adequately detectable, and it shows a clear relationship between the crew member action and the error so a recovery can be made in a timely manner.

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

- (i) Indications provided to the crew members 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 and the importance of the information, 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) Indications to the crew members that provide information of an error or a resulting rotorcraft system condition.

- (A) An alert that activates following a crew member error may be sufficient to show an error is detectable and provides sufficient information. The alert should directly relate to the error or be easily assessed by the crew members as related to the error. Alerts should not be confusing leading the crew members to believe there may be non-error causes for the annunciated condition.
- (B) If a crew member 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 member 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 members 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 errors. 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, the envelope of the rotorcraft, or operational conditions. Examples include monitoring systems such as a terrain awareness and 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 level or type of information available to the crew members is 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 members can facilitate error detection.
- An example would be the alignment of engine speed indicator needles in the same direction during normal operations. In the event of an engine asymmetrical thrust linked to crew member error, which manifested itself in a change in the rpm on

one engine, the spatial misalignment of the needles could assist the pilots in diagnosing the issue and identifying asymmetrical thrust-lever position.

(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. For crew member 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.

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

(c) Error recovery

(1) When an error or its effects are detected, 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) those controls and indications can be expected to be used by the crew members 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 member interfaces and the procedures associated with the indications may be an acceptable means of compliance.

(4) To establish that the crew members can be expected to use those controls and indications to accomplish corrective actions in a timely manner, an assessment of the crew member 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.

(2) Piloted assessments in the rotorcraft or in simulation may be relevant if crew member 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 member 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 prevent errors are recommended. Acceptable ways to prevent errors include switch guards, interlocks, or confirmation actions. For example, generator drive controls on many rotorcraft have guards over the switches to prevent their inadvertent actuation, because once disengaged, the drives cannot be re-engaged while in flight or with the engine running. An example of confirmation action would be the presentation of a flight plan modification in a temporary flight plan, where the crew members will activate the flight plan through a confirmation action.

(2) Another way of avoiding crew member 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 design 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), the 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 members' workload, and do not cause confusion to crew members.
- (2) Consistency needs to be considered within a given system and across the cockpit. Inconsistencies may result in vulnerabilities that may lead to human performance issues, 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 member 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. 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. 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 perform 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. It is important that functions that convey the same information be consistent. One example is symbol sets. Traffic or terrain awareness systems should display consistent symbol sets if generated by separate installed systems.
- (3) Another way to demonstrate consistency is to show that certain aspects of the design are consistent with accepted, published standards such as the labels and abbreviations recommended in ICAO Doc 8400 'Procedures for Air Navigation Services (PANS) - ICAO Abbreviations and Codes' or in SAE ARP4105C 'Abbreviations, Acronyms, and Terms for Use on the Flight Deck'. 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 'Electronic Aeronautical Symbols'. However, inappropriate standardisation, rigidly applied, can be a barrier to

innovation and product improvement. Thus, the 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 member 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 members are 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 member 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 member 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 HMI 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 members 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 members are 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 members and the potential for error.
- (4) Two examples of integrated design items 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 members 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 members 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) Since 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 provides considerations the applicant should use when selecting the means of compliance. It discusses seven types of means of compliance and provides specific HFs considerations for their use.

The applicant should determine the means of compliance to be used on a given project on a case-by-case basis, taking into account the specific compliance issues. In any case, the nature of the HFs objective to be assessed should drive the selection of the appropriate means of compliance.

Some certification projects may necessitate more than one means of demonstrating compliance with a particular CS. For example, when flight testing in a conforming rotorcraft is not possible, a combination of a design review and a part-task evaluation may be proposed. In this context, part-task evaluation focuses only on specific sub-functions of the design item.

The uses and limitations of each type of means of compliance are provided in paragraph 5.3.

5.2_ List of the means of compliance

The most common means of compliance that are used to demonstrate compliance with HFs certification specifications are discussed in this paragraph and include:

- (a) MC0: Compliance statements,
- (b) MC1: Design review,
- (c) MC2: Calculations and analyses,
- (d) MC4: Laboratory tests,
- (e) MC5: Ground tests,
- (f) MC6: Flight tests,
- (g) MC8: Simulation.

When the 'scenario-based' methodology is used as part of the above-listed means of compliance, additional guidance can be found in paragraph 3.3.2.

5.3_ Selecting the means of compliance

5.3.1_ Credit from previous compliance certification processes

When determining the level of scrutiny applicable to each design item, the applicant should identify a reference product.

The reference product can also play a role in the compliance demonstration process if data from previous certification exercises is used. However, the following two dimensions should be taken into account when assessing the extent to which certification credits can be granted:

- The reference product from which the applicant intends to claim compliance;
- The certification basis that was used to certify that reference product.

The applicant is then expected to gain more certification credits from the equipment installed on one of its rotorcraft already certified under CS 27/29.1302.

Fewer certification credits can be requested when the equipment installed on a rotorcraft was certified by the applicant under a HF's regulatory material different from CS 27.1302. The acceptability of this approach will be evaluated on a case-by-case basis by assessing the compatibility of the reference regulatory material and the methods used at the time of the initial certification.

As a general principle, no certification credit can be claimed when the design item installed on a rotorcraft was certified by another design organisation or when it was not certified by EASA. However, in accordance with 3.3.1(d), the applicant might take credit for the activities carried out by an equipment supplier that performed certain HF's assessments on a voluntary basis.

5.3.2_Representativeness of the test article

Means of compliance MC4, MC5, MC6 and MC8 require the use of a test article (benches, mock-ups, the actual rotorcraft, or a simulator).

As explained in paragraph 3.3.1, in order to achieve its objectives, the HF's assessment should be started in the early stage of the project and follow an iterative process. This iterative nature of the process may require the applicant to perform assessments in the early stage of the project when the design is still likely to change. On the other hand, test articles that are not fully representative of the final design can be available later on during the certification process and may be the only available ones to actually perform some assessments (for example, a bench or a simulator may be the only means to assess the behaviour for failures that cannot be simulated in flight).

Therefore, the verification of the test article's representativeness, with its deviations from the intended final standard, is a step of paramount importance for the HF's assessment. These deviations should be evaluated taking into account the objectives of the assessment.

For example:

- If a ground test is carried out to assess the controls reachability, specific attention should be paid at the cockpit geometry being representative of the design under certification while the conformity of the avionics is not required.
- If a simulator is used, the required functional and physical representativeness of the simulation (or degree of realism) will typically depend on the configurations, design items, and crew tasks to be assessed.

As a general principle, as long as the deviations from the intended final standard are known and monitored and do not compromise the validity of the data to be collected, the lack of full representativeness should not prevent the use of a test article. In such cases, partial certification credits may still be granted, provided that the applicant can show that the deviations do not affect the test results.

5.3.3 Presentation of the means of compliance

(a) MCO Compliance statement based on similarity

Description
A statement of similarity is a declaration of (full or partial) compliance based on a description of the system to be approved compared to a description of a previously approved system, detailing the physical, logical, and operational similarities relevant for the regulation the applicant wishes to demonstrate compliance with.
Use
A statement of similarity can be sufficient or used in combination with other means of compliance.
Limitations
A statement of similarity, for the purpose of compliance demonstration, should be used with care. The cockpit should be assessed as a whole, not merely as a set of individual functions or systems. Two design items previously approved on separate programmes may be incompatible when combined in a single cockpit. Also, changing one feature in the 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 objectives of a specific paragraph by describing the design. The applicant has traditionally used drawings, configuration descriptions, and/or design philosophies to demonstrate compliance.

(1) Drawings

Description
Drawings depicting the physical arrangement of hardware or display graphics.
Use
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

<p>A configuration description is a description of the layout, general arrangement, direction of movement, etc., of a design item. It can also be a reference to documentation that provides such a description. 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.</p>
<p>Use</p>
<p>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 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.</p>
<p>Limitations</p>
<p>Configuration descriptions may provide sufficient information for a finding of compliance only with a specific requirement.</p>

(3) Design philosophy

<p>Description</p>
<p>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.</p>
<p>Use</p>
<p>It documents that the design qualifies to meet the objectives of a specific paragraph.</p>
<p>Limitations</p>
<p>In most cases, this means of compliance will be insufficient as the sole means to demonstrate compliance.</p>
<p>Example</p>
<p>The design philosophy may be used as a means of compliance when a new alert is added to the cockpit provided the new alert is consistent with the acceptable, existing alerting philosophy.</p>

(c) MC2 Calculations/analyses

<p>Description</p>

Calculations or engineering analyses ('paper and pencil' assessments) that do not require direct participant interaction with a physical representation of the equipment.
Use
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 recognised industry standard methods. The applicant 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 should be complemented by observations through other means of compliance when required.
Analysis cannot be used to assess complex cognitive issues.
Example
An applicant may conduct a vision analysis to demonstrate that the crew member has a clear and undistorted view out of the windshield. Similarly, an analysis may also demonstrate that flight, navigation and power plant instruments are plainly visible from the crew member stations. 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 HFs assessments.

(d) MC4 Laboratory tests

Description
An assessment made using a bench test representing the HMI. 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.
Bench or laboratory assessment
The applicant can conduct an assessment using devices emulating crew member 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 making EASA familiar with the system. 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 the controls are arranged so that crew members from 1.57 m (5 ft 2 in) to 1.83 m (6 ft) 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
Bench tests or mock-ups cannot be used to assess complex cognitive issues.

(e) MC5 Ground tests

Description
An assessment conducted on a flight test article on ground.
Limitations
Ground tests cannot be used to assess complex cognitive issues.
Example
An example of a ground test is the assessment of the displays' potential for reflections on the windshield and on the windows. Such an assessment 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 tests and MC8 Simulation

The applicant may use a wide variety of part-task to full-installation representations of the product/system or cockpit for assessment purposes. The representation of the HMI does not

necessarily conform to the final design. The paragraphs below address both system- and rotorcraft-level evaluations 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, HF assessments are conducted in a dynamic operational context. Depending on the HF objectives to be addressed, and according to the HF 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.
Use
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.

(f)(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.

(f)(ii) MC6 Flight tests

In-flight assessment
Flight testing during certification is the final compliance demonstration of the design, and is 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 carried out for areas of investigation outside the HF scope can be given partial credit for demonstrating compliance with 27.1302. 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 HF methodical principles for data collection and processing. These flight tests should only be used as a complementary approach to dedicated HF assessments.

(f)(iii) MC6 versus MC8

MC6 versus MC8:

The selection of the flight test as a 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:

- Due to safety reasons, the actual testing on a rotorcraft may be inappropriate for the malfunction assessment.
- Flight test does not normally allow the manipulation of the operational environment which may be needed to apply the scenario-based approach.
- HFs in-flight scenarios may be challenging to replicate due to the difficulty in reproducing the operational context. For example, events like ATC communications, weather, etc., which 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 its validity.

However, flight test is deemed adequate when the operational and/or system representativeness is a key driver for the validity of HFs data. For example, an in-flight assessment is typically more adequate when dealing with workload determination.

AMC 27.1302 APPENDIX 1: Related regulatory material and documents

EASA AMC:

- AC 27-1B Change 7 MG-19 *Electronic Display Systems* and MG-20 *Human Factors*
- PS-ANM100-01-03A, *Factors to Consider When Reviewing an Applicant's Proposed Human Factors Methods for Compliance for Flight Deck Certification*

Other documents:

The following is a list of other documents relevant to cockpit design and crew member 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.

- Policy Memo ANM-99-2, *Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Transport Airplane Flight Decks*
- 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*, 1993
- FAA AC 20-175 *Controls for Flight Deck Systems*, 2011
- FAA AC 00-74 *Avionics Human Factors Considerations for Design and Evaluation*, 2019
- DOT/FAA/TC-13/44 *Human Factors Considerations in the Design and Evaluation of Flight Deck Displays and Controls*, 2016

GM1 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 member errors.
- (b) Crew members 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 member 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 member 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 member 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 member errors by taking the following approach.
- (i) Firstly, by providing means to address the design characteristics that are known to reduce or avoid crew member error and that address crew member capabilities and limitations. 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 members 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 member errors.
- (ii) Secondly, CS 27.1302(d) addresses the fact that since crew member 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 member 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_CS 27.1302: applicability and explanatory material

- (a) CS-27 contains certification specifications 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 complements the generally applicable requirements by adding more explicit objectives for the design attributes related to the avoidance and management of crew member errors. Other ways to avoid and manage crew member errors are regulated through the requirements governing the licensing and qualifications 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 the recognition that equipment design, training/licensing/qualifications 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 member 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 certification specifications in CS-27 and the requirements for training/licensing/qualifications 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 'this paragraph applies to installed systems and equipment intended to be used by the crew members when operating the rotorcraft from their normal seating positions in the cockpit or their operating positions in the cabin'.
- (i) 'Intended to be used by the crew members when operating the rotorcraft from their normal seating positions in the cockpit or their operating positions in the cabin' means that the intended function of the installed equipment includes its use by the crew members when 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 normal seating positions in the cockpit or their operating positions in the cabin' means that the crew members are positioned 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/is not used by the crew members while performing their duties in operating the rotorcraft in normal, abnormal/malfunction and emergency conditions. For

example, this paragraph is not intended to apply to design 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 'The installed systems and 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 objectives. This is not intended to require a demonstration of compliance beyond that required by point 21.A.21(a) of Part 21. Accordingly, for simple design 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 objectives 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 objectives. For example, applicants must not design a display so that the information it provides is inconsistent or in conflict with information provided from other installed equipment.
- (v) In addition, this paragraph presumes a qualified crew member that is trained to use the installed equipment. This means that the design must meet these objectives for crew members who are allowed to fly the rotorcraft by meeting the qualification requirements of the operating rules. 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 items and assumptions made during the design phase that have the potential to affect the training time or the crew member procedures. The certification specification and associated material are written assuming that either these design items 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 objective for the equipment to be designed so that the crew members can safely perform their tasks associated with the intended function of the equipment applies in normal, abnormal/malfunction and emergency conditions. The tasks intended to be performed under all the above conditions are generally those prescribed by the crew member procedures. The phrase 'safely perform their tasks' is intended to describe one of the safety objectives of this certification specification. The objective is for the equipment design to enable the crew members 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 the 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 members to accomplish their tasks. Although this may seem obvious, this objective is included because a review of CS-27 on the subject of HFs revealed that a specific objective for cockpit controls and information to meet the crew member needs is necessary. This objective is not reflected in other parts of the rules, so it is important to be explicit.
- (3) **CS 27.1302(b)** addresses the objective for cockpit controls and information that are/is necessary and appropriate for the crew members to accomplish their tasks, as determined in (a) above. The intent is to ensure that the design of the controls and information devices makes them usable by the crew members. This subparagraph seeks to reduce design-induced crew member errors by imposing design objectives for cockpit information presentation and controls. Subparagraphs (1) through (3) specify these design objectives. The design objectives for information and controls are necessary to:
- (i) properly support the crew members in planning their tasks;
 - (ii) make available to the crew members appropriate, effective means to carry out planned actions; and
 - (iii) enable the crew members 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 designed 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 member tasks associated with the intended functions of the equipment, such that the crew members can perform all the associated tasks.
 - (ii) For controls, the objective for 'clear and unambiguous' presentation means that the crew members 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 members 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 members in a manner appropriate to the urgency, frequency, and duration of their tasks. For example, controls that are used more frequently or urgently must be readily

accessible, or require fewer steps or actions to perform the task. Less accessible controls may be acceptable if they are needed less frequently or less urgently. Controls that are used less frequently or less urgently should not interfere with those used more urgently or more 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 that makes the crew members aware of the effects of their actions on the rotorcraft or systems, if that awareness is required for the safe operation of the rotorcraft. The intent is for the crew members 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 member interfaces that previous objectives did not address. Specific deficiencies of existing objectives in addressing HFs 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 25.779 address the direction of motion and actuation but do not encompass new types of controls, such as cursor-control 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 that its behaviour that is operationally relevant to crew member tasks is:

(i) predictable and unambiguous, and

(ii) designed to enable the crew members 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. In-service experience has shown 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 members. Such design characteristics can confuse the crew members and have been determined to contribute to incidents and accidents.

(8) **CS 27.1302(c)(1)** requires the behaviour of a system to be such that a qualified crew member knows what the system is doing and why it is doing it. 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 members 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 the equipment to be designed such in order to enable the crew members to manage such errors. For the purpose of this CS, 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 CS and the related AMC.
- (i) What is meant by a design which enables the crew members to ‘manage errors’ is that:
- (A) the crew members must be able to detect and/or recover from errors resulting from their interaction with the equipment; or
 - (B) the effects of such crew member errors on the rotorcraft functions or capabilities must be evident to the crew members, and continued safe flight and landing must be possible; or
 - (C) crew member errors must be prevented 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 objective 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 subparagraph does not apply to skill-related errors associated with the 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 certification specifications, 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 objective is intended to exclude the management of errors resulting from crew member decisions, acts or omissions 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 members.

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/malfunction 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 members 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 is included because managing errors (which can be reasonably expected in service) that result from crew member interactions with the equipment 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.

GM2 27.1302 Examples of compliance matrices

The compliance matrix developed by the applicant should provide the essential information in order to understand the relationship between the following elements:

- the design items,
- the applicable certification specifications,
- the test objectives,
- the means of compliance, and
- the deliverables.

The two matrices below are provided as examples only. The applicant might present the necessary information through any format that meets the above objectives.

An example with a *design item* entry:

Function	Sub-function	Focus	CS reference	CS description	Assessed dimension	MoC	Reference to the related deliverable
Electronic checklist (ECL) function	Display electronic checklist (ECL)	Electronic checklist quick access keys (ECL QAKs)	CS 79.777(a)	The cockpit controls must be: (a) located so in order to provide convenient operation and to prevent confusion and inadvertent operation;	Assess the ECL QAKs location for convenient operation and prevention of inadvertent operation.	MoC8 HFs campaign #2 Scenario #4	HFs Test Report XXX123
			CS27.777(b)	The cockpit controls must be: (b) located and arranged with respect to the pilot seats so that there is full and unrestricted movement of each control without interference from the cockpit structure or the pilot clothing when pilots from 1.57 m (5ft 2in) to 1.83 m (6 ft) in height are seated.	Assess accessibility to control the ECL QAKs.	MoC4 HFs Reachability Analysis MoC5 HFs Reachability and Accessibility Campaign	HFs Reachability and Accessibility Assessment Report XXX123
			[...]	[...]	[...]	[...]	[...]

Function	Sub-function	Focus	CS reference	CS description	Assessed dimension	MoC	Reference to the related deliverable
			CS 27.1302(a)	All the controls and information necessary to accomplish these tasks must be provided;	Assess that appropriate controls are provided in order to display ECL.	MoC1 ECL implementation description for XXXX	ECL implementation description document for XXXX
			CS 27.1302(b)(1)	(b) All the controls and information required by paragraph (a), which are intended for use by the crew members, must: (1) be presented in a clear and unambiguous form, at a resolution and with a precision appropriate to the task;	Assess the appropriateness of the ECL QAKs labels.	MoC8 HFs campaign #4 Scenario #1	HFs Test Report XXX345

Another example with a *certification specification* entry:

CS reference	CS description	Focus	Assessed dimension	MoC	Reference to the related deliverable
CS 27.777(a)	The cockpit controls must be: (a) Located so in order 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 HF's simulator evaluations	HF's Test Reports XXX123 XXX456 XXX789
		ECL QAKs	Assess the location of the ECL QAKs for convenient operation and prevention of inadvertent operation.	MoC8 HF's campaign #2 Scenario #4	HF's Test Report XXX123
CS 27.777(b)	The cockpit controls must be: (b) located and arranged with respect to the pilot seats so that there is full and unrestricted movement of each control without interference from the cockpit structure or the pilot clothing when pilots from 1.57 m (5ft 2in) to 1.83 m (6ft) in height are seated.	All cockpit controls	Assess the accessibility of all cockpit controls.	MoC4 HF's Reachability Analysis MoC5 HF's Reachability and Accessibility Campaign	HF's Reachability and Accessibility Assessment Report XXX123
		ECL QAKs	Assess the accessibility to control the ECL QAKs.	MoC4 HF's Reachability Analysis MoC5 HF's Reachability and Accessibility Campaign	HF's Reachability and Accessibility Assessment Report XXX123
[...]	[...]				
CS 27.1302(a)	All the controls and information necessary to accomplish these tasks must be provided;				
CS 27.1302(b) (1)	(b) All the controls and information required by paragraph (a), which are intended for use by the crew members, must: (1) be presented in a clear and unambiguous form, at				

CS reference	CS description	Focus	Assessed dimension	MoC	Reference to the related deliverable
	a resolution and with a precision appropriate to the task;				