U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: Installed Systems and Equipment for Use by the Flightcrew

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This advisory circular (AC) provides guidance for the design and methods of compliance for installed equipment on transport airplanes intended for use by the flightcrew. The guidance provided by this AC is intended to minimize the occurrence of design-related errors by the flightcrew and to enable the flightcrew to detect and manage errors that do occur. This AC provides recommendations for the design and evaluation of controls, displays, system behavior, and system integration that are all part of human factors considerations.

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Chapter 1. AC 25.1302 as an Acceptable Means of Compliance.

1-1. Purpose of this AC.

This advisory circular (AC) describes an acceptable means of showing compliance with certain requirements of Title 14, Code of Federal Regulations (14 CFR) part 25. In particular, this AC addresses the design and approval of installed equipment intended for flight crewmembers to use from their normally seated positions on the flightdeck. It also provides recommendations for the design and evaluation of controls, displays, system behavior, and system integration, as well as design guidance for error management.

1-2. Applicability.

a. The guidance provided in this document is directed towards airplane manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration (FAA) transport airplane type certification engineers, human factors specialists, flight test pilots, flight test engineers, and their designees.

b. The guidance in this AC is neither mandatory nor regulatory in nature and does not constitute a requirement. You may follow alternate FAA-approved design recommendations. Mandatory words such as “must” apply only to show compliance to a specific rule by use of a method prescribed in this AC without deviation.

c. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

d. This material does not change, create any additional, authorize changes in, or permit deviations from, regulatory requirements.

1-3. Organization of this AC.

a. This AC is intended to harmonize with European Aviation Safety Agency (EASA) Acceptable Means of Compliance (AMC) CS 25.1302.

b. Chapter 3, Scope and Assumptions, describes affected equipment, assumptions of flightcrew capability, and exceptions.

c. Chapter 4, Certification Planning, describes the activities for certification planning and the communication between the applicant and the FAA.

d. Chapter 5, Design Considerations and Guidance, identifies human-factors-related design issues applicants should address to show compliance with § 25.1302 and other relevant rules. If compliance to a specific rule is cited in a paragraph text, then applicants must address the cited rule.

e. Chapter 6, Means of Compliance, describes general means of compliance and how they may be used.

Chapter 2. Background.

2-1. Human Error.

a. Human error is generally characterized as a deviation from what is considered correct in some context, especially in the hindsight of analysis of accidents, incidents, or other events of interest. Some types of human error can be the following: an inappropriate action, a difference from what is expected in a procedure, a mistaken decision, an incorrect keystroke, or an omission of some kind. Many other situations can also illustrate what we mean by the term "human error."

b. Flightcrews make a positive contribution to the safety of the air transportation system because of their ability to assess continuously changing conditions and situations, analyze potential actions, and make reasoned decisions. However, even well trained, qualified, healthy, and alert flightcrew members make errors. Some errors may be influenced by the design of the systems the flightcrew uses to operate the airplane and by the flightcrew interfaces of those systems, even those that are carefully designed. Most of these errors have no significant safety effects, or are detected and/or mitigated in the normal course of events. Still, accident analyses have identified flightcrew performance and error as significant factors in a majority of accidents involving transport category airplanes.

c. Accidents result most often from a sequence or combination of errors and safety-related events. Analyses show that the design of the flightdeck and other systems can influence flightcrew task performance and the occurrence and effects of some flightcrew errors.

2-2. Past Practice for Mitigating Human Error Through Design.

a. Some current regulatory requirements intend to improve aviation safety by requiring the flightdeck and its equipment be designed with certain capabilities and characteristics. Approval of flightdeck systems with respect to design-related flightcrew error has typically been addressed by referring to system-specific or general applicability requirements, such as §§ 25.1301(a), 25.771(a), and 25.1523. But until now, little or no guidance has existed to show the applicant how they may address potential flightcrew limitations and design-related errors. Section 25.1302 and this guidance material have been developed for this purpose.

b. Often, showing compliance with design requirements that relate to human abilities and limitations is subject to interpretation. Findings may vary depending on the novelty, complexity, or degree of integration of the system design. The FAA considers the guidance described here as a structured approach to selecting and developing acceptable means of compliance that will be useful in aiding standardized certification practices.

Chapter 3. Scope and Assumptions.

3-1. Relation of § 25.1302 to Other Requirements.

This AC provides guidance for showing compliance with § 25.1302 as well as with several other requirements associated with all installed equipment the flightcrew uses in operating the airplane. Table 1 contains a list of requirements related to flightdeck design and flightcrew interfaces for which this AC provides guidance.

Table 1. Requirements Related to this AC.

Part 25 Requirements	General topic	Relevant material in this AC
§ 25.771(a)	Pilot compartment - Unreasonable concentration or fatigue	• Flightcrew Error Management, subchapter 5-7. • Integration, subchapter 5-8. • Controls, subchapter 5-4. • System Behavior, subchapter 5-6.
§ 25.771(c)	Pilot compartment - Equipment controllable from either pilot seat	• Controls, subchapter 5-4. • Integration, subchapter 5-8.
§ 25.773	Pilot compartment view	• Integration, subchapter 5-8.
§ 25.777(a)	Cockpit controls - Location of cockpit controls	• Controls, subchapter 5-4. • Integration, subchapter 5-8.
§ 25.777(b)	Cockpit controls - Direction of movement of cockpit controls	• Controls, subchapter 5-4. • Integration, subchapter 5-8.
§ 25.777(c)	Cockpit controls - Full and unrestricted movement of controls	• Controls, subchapter 5-4. • Integration, subchapter 5-8.
§ 25.1301(a)	Equipment function and installation - Intended function of installed systems	• Flightcrew Error Management, subchapter 5-7. • Integration, subchapter 5-8. • Controls, subchapter 5-4. • Presentation of Information, subchapter 5-5. • System Behavior, subchapter 5-6.
§ 25.1302	Installed systems and equipment for use by the flightcrew - Flightcrew error	• Flightcrew Error Management, subchapter 5-7. • Integration, subchapter 5-8. • Controls, subchapter 5-4 • Presentation of Information,

Part 25 Requirements	General topic	Relevant material in this AC
		subchapter 5-5. • System Behavior, subchapter 5-6.
§ 25.1303	Flight and navigation instruments	• Integration, subchapter 5-8.
§ 25.1309(a)	Equipment, systems, and installations - Intended function of required equipment under foreseeable operating conditions	• Controls, subchapter 5-4. • Integration, subchapter 5-8.
§ 25.1309(c)	• Provide warning for unsafe operation and enable crew to take corrective action. • System design for minimizing flightcrew errors which could create additional hazards	• Presentation of Information, subchapter 5-5. • Flightcrew Error Management, subchapter 5-7.
§ 25.1321	Instrument arrangement and visibility	• Integration, subchapter 5-8.
§ 25.1322	Flightcrew Alerting	• Integration, subchapter 5-8.
§ 25.1329	Flight guidance system - Autopilot, flight director, and autothrust	• System Behavior, subchapter 5-6.
§ 25.1523	Minimum flightcrew	• Controls, subchapter 5-4. • Integration, subchapter 5-8.
§ 25.1543(b)	Instrument markings - Visibility	• Presentation of Information, subchapter 5-5.
§ 25.1549	Powerplant and auxiliary power unit instruments	• Flightcrew Error Management, subchapter 5-7.
§ 25.1555 (a)	Control markings	• Controls, subchapter 5-4.
Part 25 Appendix D	Criteria for determining minimum flightcrew	• Integration, subchapter 5-8.

3-2. Covered Equipment.

a. This material applies to flightcrew interfaces and system behavior for all installed systems and equipment used by the flightcrew on the flightdeck while operating the airplane in both normal and non-normal conditions. It applies to those airplane and equipment design considerations within the scope of part 25 for type certificate (TC) and supplemental type certificate (STC) projects. It does not apply to training, qualification, or licensing requirements for flightcrews. Similarly, it does not apply to procedures for flightcrews, except as required within part 25.

b. This material does not address systems or equipment used at times other than while flightcrews perform their duties in operating the airplane in normal and non-normal conditions. For instance, actions performed on the ground that do not involve operation of the aircraft are not applicable, such as use of certain circuit breakers or maintenance controls intended for use by maintenance personnel or by the flightcrew when they are not operating the airplane.

3-3. Flightcrew Capabilities.

In showing compliance with the requirements referenced by this AC, the applicant may assume a qualified flightcrew is trained and checked in the use of the installed equipment. This compliance refers to a flightcrew allowed to fly the airplane because the flightcrew meets the requirements of the operating rules for transport category airplanes.

3-4. Exceptions.

To the extent practicable, installed equipment must incorporate means to enable the flightcrew to manage errors resulting from flightcrew interactions with the equipment that can be reasonably expected in service, per § 25.1302. This AC does not apply to the following, as referenced in § 25.1302(d):

(1) Skill-related errors associated with manual control of the airplane;

(2) Errors that result from decisions, actions, or omissions committed with malicious intent;

(3) Errors arising from a flight crewmember's reckless decision, actions, or omissions reflecting a substantial disregard for safety; and

(4) Errors resulting from acts or threats of violence, including actions taken under duress.

3-5. Additional Guidance for Other Requirements.

Section 25.1302 is a generally applicable requirement for flightdeck systems and equipment. Other part 25 requirements exist for specific equipment and systems. Where guidance is provided in other ACs for specific equipment and systems, that specific guidance is assumed to have precedence if a conflict exists with guidance provided here. Appendix A of this AC lists references to other related regulatory material and documents.

Chapter 4. Certification Planning.

4-1. Overview.

a. This chapter describes applicant activities, communications between the applicant and the FAA Aircraft Certification Office (ACO), and documentation needed for finding compliance when using the compliance means provided in this AC. Procedural requirements for issuance of type certificates under 14 CFR part 25 may be found in 14 CFR part 21.

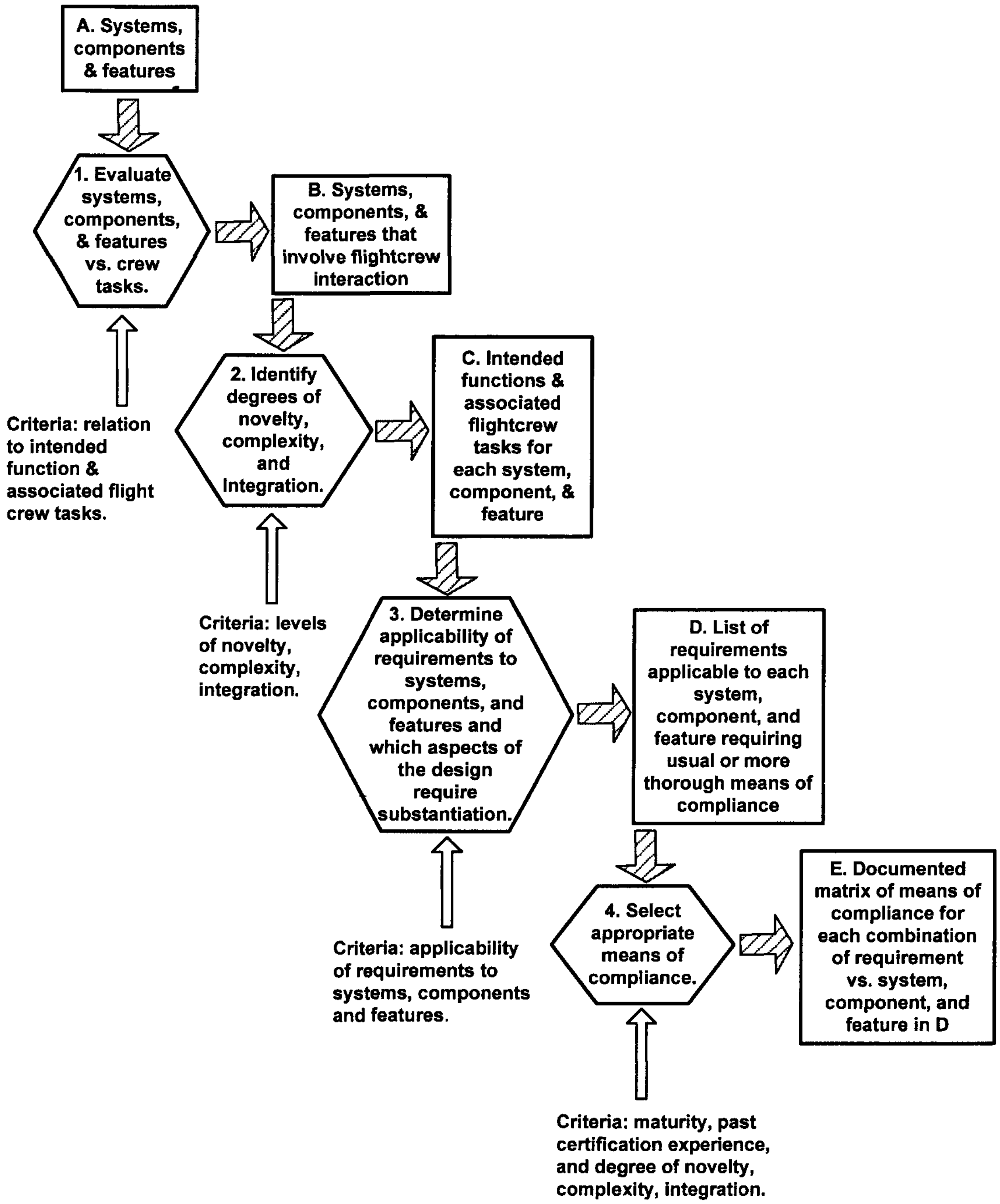
b. Applicants can gain significant benefits by involving the FAA ACO in the earliest possible phases of application and design. This will enable timely agreements to be reached on potential design-related human factors issues and thereby reduce the applicant's risk of investing in design features that may be found non-compliant.

c. Certain activities that typically take place during development of a new product, or a new flightdeck system or function, may occur before official certification data are submitted to show compliance with the requirements. The applicant may choose to discuss or share these activities with the FAA on an information-only basis.

d. When the FAA agrees, as part of the certification planning process, that a specific evaluation, analysis, or assessment of a human factors issue can become part of the demonstration to show the design complies with the requirements, that part of the evaluation, analysis, or assessment is given "certification credit."

e. Figure 1 illustrates the methodical approach to planning certification for design-related human performance issues.

Figure 1. Methodical Approach to Planning Certification for Design-Related Human Performance Issues.



4-2. Scope of the Flightdeck Certification Program.

a. The applicant must show that these (installed systems and equipment for use by the flightcrew) systems, and that proposed equipment, individually and in combination with other such systems and equipment, are designed so that qualified flightcrew members can safely perform all of the tasks associated with the installed systems' and equipment's intended function. A qualified flightcrew is one trained and checked in the use of the applicable systems and equipment (see subchapter 3-3). The applicant should analyze and consider flightdeck controls, information, and system behavior that involve flightcrew interaction. The applicant should analyze and relate the intended functions of the system(s), components, and features to flightcrew tasks. The objective of this analysis is to improve understanding about how flightcrew tasks are affected by the proposed system(s), components, and features. Subchapter 5-2 of this AC provides guidance regarding flightcrew interaction, functions, and tasking.

b. The certification program may be affected by the level of integration, complexity, and novelty of the design features, as discussed in the sub-paragraphs that follow. Taking the level of integration, complexity, and novelty into account, the applicant should reach an agreement with the FAA on which flightdeck controls, information, and system behaviors require extra scrutiny during the certification process. The impact of a novel feature might be affected by its complexity and by the extent of its integration with other elements of the flightdeck. A novel but simple feature will likely require less rigorous scrutiny than one that is both novel and complex.

(1) Integration. In this document, the term "level of systems integration" refers to the extent to which interactions or dependencies exist between systems affecting the flightcrew's operation of the airplane. The applicant should describe such integration of systems, because it may affect means of compliance. When the word "integration" is used in subchapter 5-8, it defines how specific systems are combined with other systems and equipment in the flightdeck, and how the number and complexity of the couplings may affect the means of compliance.

(2) Complexity. Complexity of the system design from the flightcrew's perspective is an important factor that may also affect the means of compliance. Complexity has multiple dimensions. The number of information elements the flightcrew must use (the number of pieces of information on a display, for instance) may be one kind of complexity. The level of system integration may be another measure of complexity of that system from the flightcrew's perspective. Design of controls can also be complex – for example, a knob with multiple control modes. Subchapters 5-1 through 5-6 address several aspects of complexity.

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

(a) Are new technologies introduced that operate in novel ways for either established or new flightdeck designs? These technologies include both software and hardware.

(b) Are different or additional operational procedures needed as a result of the introduction of new technologies?

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

(d) Does the design introduce new uses for existing systems that change the flightcrew's tasks or responsibilities?

c. The applicant should characterize features by their integration, complexity, and novelty based on the above criteria. Features characterized as more novel generally require additional scrutiny during certification. Features considered less novel should still be shown to comply with § 25.1302 requirements.

4-3. Applicable Requirements.

a. The applicant should identify design requirements applicable to each of the systems, components, and features. This can be accomplished in part by identifying design characteristics that can adversely affect flightcrew performance and those that pertain to avoiding and managing flightcrew errors.

b. Specific design considerations for requirements involving human performance are discussed in Chapter 5. The applicability of these considerations depends on the levels of integration, novelty and complexity identified subchapter 4-2.

c. The expected result of this analysis is a list of regulatory requirements that the applicant will comply with in their design. The design attributes will also be scrutinized based on this list. It will be the basis for a compliance matrix identifying the means of compliance proposed for each requirement.

4-4. Selecting an Appropriate Means of Compliance.

a. After identifying what should be shown in order to demonstrate compliance, the applicant should review subchapter 6-2 for guidance on selecting the means, or multiple means, of compliance appropriate to the design. In general, we expect the level of scrutiny or rigor represented by the means of compliance to increase with higher levels of integration, complexity, and novelty of the design.

b. Chapter 6 identifies general means of compliance that have been used on many certification programs and discusses their selection, appropriate uses, and limitations. The applicant may propose other general means of compliance, subject to approval by the FAA.

c. Once the human performance issues have been identified and means of compliance have been selected and proposed to the FAA, the FAA may agree, as part of the certification planning process, that a specific evaluation, analysis, or assessment of a human factors issue may become part of the compliance demonstration. When the human factors issue is successfully demonstrated and the success criteria are satisfied, the design will be found to comply with FAA requirements. Certification credit can be granted when data are transmitted to and accepted by the FAA using standard certification procedures. These data will become part of the final record of how the applicant has complied with the requirements.

4-5. Certification Plan.

a. The applicant should document the certification process, resulting data produced and collected, and agreements described in the previous sections. This may be done in a separate plan or incorporated into a higher level certification plan.

b. The following is a summary of what may be contained in such a document:

(1) Identification of the new airplane, system, control, information, or feature(s).

(2) Identification of the design feature(s) being evaluated and whether or not the feature(s) is (are) novel or unusual.

(3) Explanation of the integration or complexity of the new feature(s).

(4) The list of flightcrew tasks affected or any new tasks introduced by the new features.

(5) Any flightcrew procedure changes.

(6) Specific requirements that must be complied with per § 25.1.

(7) The means (one or several) to be used to show compliance.

(8) How this data will be provided to the FAA certification office.

(9) Description of intended function.

c. See associated policy contained in Appendix A.

Chapter 5. Design Considerations and Guidance.

5-1. Overview.

a. The applicant should first complete the following steps:

(1) Identify the applicability of the regulatory requirements to the systems, components, and features of a new design.

(2) Assess levels of integration and degrees of complexity and novelty using the initial process steps in Chapter 4-2b.

b. Once these two steps have been completed, use the contents of this chapter to identify which aspects of the design require substantiation to part 25. Each aspect identified must be referenced to a specific rule.

c. To comply with requirements of part 25, the design of flightdeck systems must appropriately address foreseeable capabilities and limitations of the flightcrew. Systems and equipment must be designed so qualified flightcrew members trained and checked in their use (see subchapter 3-3) can safely perform all tasks associated with the systems' and equipment's intended functions.

d. Each subchapter in this chapter discusses what the applicant must or should show to establish compliance with applicable certification requirements and guidelines. Compliance is not the same as industry "best practices." The guidance presented here is the compliance guideline to part 25. The part 25 design requirements and the requirements for training, licensing, qualification, and operations procedures are necessary and complementary. Section 25.1302 and this AC were developed with the intent of linking these complementary requirements.

e. As described in Chapters 2 and 3, flightcrew error is a contributing factor in accidents. Section 25.1302 provides a regulatory basis for designing ways to avoid and manage flightcrew error. This AC provides guidance for addressing those methods and designs.

f. Section 25.1302 mandates design characteristics known to reduce or avoid flightcrew error in light of flightcrew capabilities and limitations. Requirements in § 25.1302(a)-(d) are intended to reduce the design contribution to such errors by ensuring information and controls needed by the flightcrew to perform tasks associated with the intended function of installed equipment are provided, in a usable form, without unduly interfering with other required tasks.

(1) Section 25.1302(a) requires flight deck controls be installed to allow accomplishment of all tasks required to safely perform the equipment's intended function and information must be provided to the flightcrew necessary to accomplish the defined tasks.

(2) Section 25.1302 (b) requires flight deck controls and information intended for the flightcrew use be provided in a clear and unambiguous form, at a resolution and precision

appropriate to the task. The flight deck controls and information must be accessible and usable by the flightcrew (e.g. including all lighting conditions and all phases of flight) in a manner consistent with the urgency, frequency, and duration of their tasks, and must enable flightcrew awareness, if awareness is required for safe operation, of the effects on the airplane or systems resulting from flightcrew actions.

(3) In addition, operationally relevant system behavior must be understandable, predictable, unambiguous, and supportive of flightcrew tasks. That is, § 25.1302(c) requires operationally-relevant behavior of the installed equipment be predictable and unambiguous, and designed to enable the flightcrew to intervene in a manner appropriate to the task. This chapter provides guidance on avoiding design-related flightcrew error.

(4) Finally, § 25.1302(d) requires that, to the extent practicable, installed equipment must incorporate means to enable the flightcrew to manage errors resulting from flightcrew interactions with the equipment that can be reasonably expected to occur in service. Since flightcrew errors will occur, even with a well-trained and proficient flightcrew operating well-designed systems, system and equipment design must support management of those errors to avoid safety consequences. Subchapter 5-7 provides relevant guidance.

5-2. Applicability of Material to § 25.1302.

a. Part 25 contains some requirements for the design of flightdeck equipment that are system specific (§§ 25.777, 25.1321, 25.1329, 25.1543, etc.), some that are generally applicable (for example §§ 25.1301(a), 25.1309(c), 25.771(a)), and some that establish minimum flightcrew requirements (for example, § 25.1523 and part 25 Appendix D). Section 25.1302 augments generally applicable part 25 requirements by adding more explicit requirements for design attributes related to the avoidance and management of flightcrew error. Other ways to avoid and manage flightcrew error are regulated through operational requirements in 14 CFR governing licensing and qualification of flightcrew members and aircraft operations. Taken together, these complementary requirements provide an appropriate degree of safety and certification.

b. This complementary approach to avoiding and managing flightcrew error is important. It recognizes that equipment design, training, qualifying through licensing, and establishing correct operations and procedures all contribute to safety by avoiding or minimizing risk. An appropriate integration is needed among them. In the past design characteristics known to contribute to flightcrew error were accepted, with the rationale that training or procedures would mitigate that risk. We now know such an approach is often inappropriate. Conversely, it would also be inappropriate to require equipment design always provide complete risk avoidance or mitigation, because such an approach may not be practicable in some cases, and may even create new risks.

c. The part 25 design requirements and the requirements for training, qualifying through licensing, and establishing correct operations and procedures are necessary and complementary. Section 25.1302 and this AC were developed with the intent of linking these complementary requirements together.

(1) Section 25.1302 Introduction. The introductory sentence of § 25.1302 states the provisions of this paragraph apply to each item of installed equipment, individually and in combination with other such equipment, intended for the flightcrew's use in operating the airplane from their normally seated positions on the flightdeck. The equipment must be designed so that qualified flightcrew members trained in its use can safely perform all of the tasks associated with the equipment's intended function. Tasks associated with the intended function or functions include all of the tasks required to operate the equipment, such as entering flight plan data into a flight management system (FMS), and tasks for which the equipment's intended function provides support, such as "indicator bugs" for minimum and critical speeds to support airspeed management by the flightcrew.

(a) "Intended for the flight crewmember's use in the operation of the airplane from their normally seated position" means that the intended function of the installed equipment includes its use by the flightcrew in operating the airplane. An example of such installed equipment would be a display providing information that enables the flightcrew to navigate. The phrase "flightcrew members" is intended to include any or all individuals comprising the minimum flightcrew as determined for compliance with § 25.1523. The phrase "from their normally seated position" means flightcrew members are seated at their normal duty stations for operating the airplane. Note that § 25.777(c) is referenced in Table 3 of this document to emphasize the controls are operated by the flightcrew with seat belt and shoulder harness (if provided) fastened.

(b) The words "individually and in combination with other such equipment" from the introduction to § 25.1302 mean that showing compliance with the requirements of this rule for any particular equipment must consider its use in context with other installed equipment, including flight controls, and not simply in isolation. The requirement of this rule must be met when equipment is installed on the flightdeck with other equipment. The installed equipment must not prevent other equipment from complying with these requirements. As an example, applicants must not design a display so that the certain symbology it provides is either inconsistent with or conflicts with the same or similar symbology displayed on other installed equipment.

(c) Provisions of this paragraph presume a qualified flightcrew is trained to use the installed equipment as required by the operational requirements in 14 CFR. It also presumes the installed systems and equipment intended for flightcrew members are designed so that the flightcrew can safely perform all the tasks associated with the installed equipment's intended functions. If the applicant seeks type design or supplemental type design approval before a training program is accepted, the applicant should document any novel, complex, or highly integrated design features and assumptions made during design that have the potential to affect training time or flight crew procedures. The requirement and associated material are written assuming that either these design features and assumptions, or knowledge of a training program (proposed or in the process of being developed) will be coordinated with the appropriate operational approval organization when judging the adequacy of the design.

(d) The applicant should initiate proposals for flightcrew qualification criteria (minimum training, checking, and currency) through the FAA Flight Standardization Board (FSB) process, specified in AC 120-53A, Guidance for Conducting and Use of Flight Standardization Board Evaluations, in coordination with their application for a type certificate or supplemental type certificate.

(e) The requirement that equipment be designed so the flightcrew can safely perform all tasks associated with the equipment's intended function applies in both normal and non-normal conditions. Tasks intended for performance under non-normal conditions are generally those prescribed by non-normal procedures and emergency flightcrew procedures. The words "safely perform all tasks" are meant to describe one of the safety objectives of this rule. The requirement is that equipment design enable the flightcrew to perform all tasks with sufficient accuracy and in a timely manner, without unduly interfering with other required tasks. The phrase "all tasks associated with its intended function" is meant to characterize either tasks required for operating the equipment or tasks for which the equipment's intended function provides support.

(2) Section 25.1302(a) requires the applicant to install appropriate controls and provide necessary information for any flightdeck equipment identified in the first paragraph of § 25.1302. Controls and information displays must be sufficient to allow the flightcrew to safely accomplish all of their tasks. To show compliance, the applicant should identify the tasks associated with each piece of installed equipment, and show the controls for the equipment, and the information provided for operation of the equipment, are adequate to enable the flightcrew members to perform the identified tasks, per Paragraph 5-3.c.

(3) Section 25.1302(b) contains requirements for flightdeck controls and information necessary and appropriate so the flightcrew can accomplish all of their tasks, as determined by compliance with § 25.1302(a). The intent of § 25.1302(b) is to ensure the design of control and information devices are usable by the flightcrew. This sub-paragraph seeks to reduce design-related flightcrew errors by imposing design requirements on flightdeck information presentation and controls. Sub-paragraphs (1) through (3) of the regulation specify these design requirements. Design requirements for information and controls are necessary to:

(a) properly support the flightcrew in planning and decision making for their tasks;

(b) make available to the flightcrew appropriate, effective means to carry out planned actions and decision making; and

(c) provide the flightcrew with appropriate feedback information about the effects of their actions on the airplane.

(4) Section 25.1302(b)(1) requires controls and information be provided in a clear and unambiguous form, at a resolution and precision appropriate to the task. As applied to information, "clear and unambiguous" is defined as follows:

(a) The information can be perceived correctly (is legible).

(b) The information can be comprehended in the context of all the flightcrew tasks associated with the intended functions of the equipment, such that the flightcrew can perform all the associated tasks.

(c) For controls, the requirement for “clear and unambiguous form” presentation means the flightcrew must be able to correctly and reliably identify the control by using control distinctiveness such as control shape, color and/or location as stated in §§ 25.777, 25.779, 25.781, 25.1543, and 25.1555.

(d) Section 25.1302(b)(1) also requires that the information or control be provided, or that it operate at a level of detail and accuracy which is appropriate to accomplishing the task. If the resolution or precision of the control is insufficient, the flightcrew cannot perform their task adequately. Conversely, if information has excessive resolution, the task could be too difficult because of poor readability. Excessive resolution of control may imply that the task requires more precision than it needs.

(5) Section 25.1302(b)(2) requires controls and information be accessible and usable by the flightcrew in a manner consistent with the urgency, frequency, and duration of their tasks. For example, controls used more frequently or urgently must be readily accessed, or require fewer steps or actions to perform the task. Less accessible controls may be acceptable if they are needed less frequently or urgently. Controls must also meet the requirements of § 25.777(a) and (b) for convenient location and inadvertent operation.

(6) Section 25.1302(b)(3) requires that equipment present information advising the flightcrew of the effects of their actions on the airplane or systems, if safe operation depends on their awareness of those effects. This enables them to detect and correct their own errors. This sub-paragraph is included because new technology may enable new kinds of flightcrew interfaces that previous requirements did not address. Specific deficiencies of other existing requirements in addressing human factors are described below.

(a) Section 25.771(a) addresses this topic for controls, but does not include criteria for information presentation.

(b) Section 25.777(a) addresses control location to provide convenient operation, and to prevent confusion and inadvertent operation.

(c) Sections 25.777(b) and 25.779 address the direction of motion and actuation of controls, but do not encompass new types of controls such as cursor devices. These requirements also do not cover types of control interfaces that can be incorporated into displays by using menus, for example, thus affecting their accessibility.

(d) Section 25.1523 and part 25 Appendix D have a different context and purpose (determining minimum flightcrew), so they do not address these requirements in a sufficiently general way.

(7) Section 25.1302(c) requires installed equipment be designed so that its behavior that is operationally relevant to flightcrew tasks must be:

(a) predictable and unambiguous, and

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

(c) Improved flightdeck technologies involving integrated and complex information and control systems have increased safety and performance. However, they have also sometimes illustrated the need to ensure proper interaction between the flightcrew and those systems. Service experience has found the behavior of some equipment, especially from automated systems, can be complex or dependent upon logical states or mode transitions that are not well understood or expected by the flightcrew. Such design characteristics can confuse the flightcrew and have been determined to contribute to incidents and accidents.

(d) The phrase "behavior that is operationally relevant" is the combined effect of system's operational logic, placement and function of controls, and displayed information on the flightcrew's perception and awareness of the system's operation. It is this combination of factors that affects the flightcrew's operation of the system. The phrase "behavior that is operationally relevant" distinguishes between the system behavior as perceived by the flightcrew and the functional logic of the systems flightcrews operate. The specific functional logic is normally transparent to the flightcrew. For example, in a software operated control system, the flightcrew needs to know how to use the system and its limitations, but does not need to know the actual computer code used to make the system work.

(8) Section 25.1302(c)(1) requires system behavior be such that a qualified flightcrew can know what the system is doing and why. It requires operationally relevant system behavior be "predictable and unambiguous." This means a flightcrew can retain enough information about what their action or a changing situation is so they will know what the system will do under foreseeable circumstances. This "predictable and unambiguous" behavior enables the flightcrew to operate the system safely.

(a) System behavior must be predictable and unambiguous as stated in § 25.1302(c)(1) because the actions of the flightcrew on the airplane depend on the current state of the controls or operational circumstances. Section 25.1302 (b)(3) also requires flightcrew awareness. Under some circumstances, the same actions may affect airplane performance and/or flying qualities differently. For example, autopilot response to selection or arming of a different mode can depend on which mode is currently active. In such a case, the autopilot must be designed to avoid ambiguity about the result of possible flightcrew selections, § 25.1302 (b)(1).

(9) Section 25.1302(c)(2) requires the design enable the flightcrew to determine a need for, choose, and take appropriate action, or to change or alter an input to the system, in a manner appropriate to the task, and to monitor the system and airplane response to the action. For example, to respond appropriately to a new Air Traffic Control (ATC) altitude clearance, the

flightcrew needs information about the active flight guidance and flight management mode, what means are available to comply with the new ATC requirement given the current airplane and system states, how to select those means, and how to determine the expected response is being achieved.

(10) Section 25.1302(d) addresses the reality that even well trained, proficient flightcrews using well designed systems will make errors. It requires equipment be designed to enable the flightcrew to manage such errors to the extent practicable. For the purpose of this rule, errors "resulting from flightcrew interaction with the equipment" are those errors in some way attributable to, or related to, design of the controls, behavior of the equipment, or information presented. Examples of designs or information that could cause errors are indications and controls that are complex and inconsistent with each other or other systems on the flightdeck. Another example is the presentation of a procedure inconsistent with equipment design. Errors caused by such designs or by confusing information are within the scope of this requirement and AC.

(a) The intent is for the type design to enable the flightcrew members to manage errors by one or more of the following means, as implemented in the type design. For each of these means used by the designer, the design should incorporate error prevention and management to the extent practicable so that:

1 the design enables the flightcrew to detect and/or recover from errors resulting from their interaction with the equipment; or

2 the design makes the effects of such flightcrew errors on the airplane functions or capabilities evident to them and enables them to continue a safe flight and landing; or

3 the design discourages flightcrew errors by switch guards, interlocks, confirmation actions, or other effective means; or

4 the effects of errors with potential safety consequences should be precluded by system logic or other aspects of system design that will detect and correct such errors. See paragraph 5-7, Flightcrew Error Management.

(b) The list above identifies different means for managing errors. The intent is for the installed equipment design to be such that it enables the flightcrew members to manage errors by one or more of those means. "To the extent practicable" refers to the implementation of error management capability within the one or more of those means, as provided within the equipment design.

(c) The requirement to manage errors applies to those errors that can be reasonably expected to occur in service from qualified and trained flightcrews. 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 use of the types of controls, information, or system logic being assessed.

(d) Section 25.1302(d) includes the following statement: “This sub-paragraph does not apply to skill-related errors associated with manual control of the airplane.” That statement means to exclude errors resulting from flightcrew proficiency in the control of flight path and attitude with the primary roll, pitch, yaw, and thrust controls. These issues are considered to be adequately addressed by existing requirements. We do not intend the design be required to compensate for deficiencies in flightcrew training or experience. This rule assumes at least the minimum flightcrew requirements for the intended operation, as discussed at the beginning of subchapter 5-2.

(e) This rule is not meant to require the management of errors resulting from flightcrew decisions, acts, or omissions not made in good faith. While we recognize that the dictionary definition of “error” is “an act, assertion or belief that unintentionally deviates from what is correct, right, or true," some people, including human factors researchers, have constrained the meaning of the term to include “only unintentional acts that have incorrect results.” Following the recommendations of the Aviation Rulemaking Advisory Committee (ARAC) working group and the requirements of EASA CS 25.1302, the FAA intends that the proposed rule also include “intentional acts that have unintended consequences” in the consideration of flightcrew errors. An example of such an intentional, good faith error would be a situation in which a valid alert occurs, but the flightcrew does not perform the associated procedure because they believe it to be a nuisance alert rather than a valid alert as defined in § 25.1302(d). Refer to paragraph 5-7 in this AC for showing compliance to § 25.1302(d).

(f) The error discussed in (e) is the intentional act of disregarding a valid alert. In this example, the flightcrew’s misinterpretation of the alert as being a nuisance alert (i.e. it is invalid) may be caused by design deficiencies that lead to frequent nuisance alerts. This is one underlying design deficiency that § 25.1302 is intended to address. While this particular example relates to nuisance alerts, there may be other design characteristics that lead flight crewmembers to make other kinds of intentional errors.

(g) The rule does not include errors committed from decisions, actions, or omissions with malicious or purely contrary intent, (that is, actions intended to have incorrect or unsafe results); or errors arising from a flight crewmember’s obvious, intentional disregard for safety (that is, reckless conduct). Section 25.1302 does not consider errors resulting from acts or threats of violence (for example, actions taken under duress). It is unreasonable to expect that airplane designers would be able to anticipate and prevent these types of actions.

(h) The EASA regulation, CS-25.1302, allows applicants to assume that the flightcrew is “acting in good faith.” While our proposed § 25.1302(d) replaces this term with a more detailed enumeration of exceptions, our intent is the same, and the regulatory effect would be harmonized.

(i) The intent of requiring errors to be manageable only “to the extent practicable” is to address both economic and operational practicability. It is meant to avoid imposing requirements without considering economic feasibility and commensurate safety benefits. It is also meant to address operational practicability, such as the need to avoid introducing error management features into the design that would inappropriately impede flightcrew actions or decisions in normal or non-normal conditions. As an example, we do not intend to require so many guards or interlocks on the means to shut down an engine that the flightcrew would be unable to do this reliably in a timely manner commensurate with the severity of the situation.

(j) Section 25.1302(d) was included because managing errors resulting from flightcrew interaction with equipment that can be reasonably expected in service is an important safety objective. Section 25.1302(d) limits the scope of applicability of this rule to errors for which there is a contribution from, or relationship to, design. However, § 25.1302(d) itself is expected to result in design changes that will contribute to safety. Two examples, among others, are the incorporation of "undo functions" or a cancel button in certain designs.

5-3. Intended Function and Associated Flightcrew Tasks.

a. Section 25.1301(a) requires each item of installed equipment must "be of a kind and design appropriate to its intended function." Section 25.1302 establishes requirements to ensure the design supports flightcrew members' ability to perform all tasks associated with a system's intended function. For the applicant to show compliance with § 25.1302, the intended function of a system and the associated flightcrew tasks expected of the flightcrew must be described.

b. To comply with § 25.1302 the applicant's statement of intended function must be sufficiently specific and detailed that the FAA can evaluate whether that system is appropriate for the intended function(s) and the associated flightcrew tasks. For example, a statement that a new display system is intended to "enhance situation awareness" must be further explained. A wide variety of different displays enhance situation awareness in different ways. Examples are terrain awareness displays, vertical profile displays, and even the primary flight displays. The applicant may also need to provide more detailed descriptions for designs with greater levels of novelty, complexity, or integration.

c. An applicant must describe intended functions and associated tasks for equipment. This type of information is of the level typically provided in a pilot handbook or an operations manual. It would describe indications, controls, and flightcrew procedures. Compliance to § 25.1302 must be shown for:

(1) each item of flightdeck equipment;

(2) flightcrew indications and controls for that equipment; and

(3) individual features or functions of that equipment.

d. As discussed in Chapter 4, novel features may require the applicant provide more detailed information to show compliance, while previously approved systems and features typically require less. Subchapter 4-2 discusses when functions are sufficiently novel that additional scrutiny is required. Applicants should evaluate whether statements of intended function(s) and associated task(s) are sufficiently specific and detailed by using the following questions:

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

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

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

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

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

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

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

5-4. Controls.

a. For purposes of this AC, we define controls as devices the flightcrew manipulates in order to operate, configure, and manage the airplane and its flight control surfaces, systems, and other equipment.

(1) Controls may include such equipment in the flightdeck as:

(a) buttons,

(b) switches,

(c) knobs,

(d) keyboards,

(e) keypads,

(f) touch screens, and

(g) cursor control devices.

(2) Controls may include graphical user interfaces, such as pop-up windows and pull-down menus that provide control functions.

(3) Voice activated controls are also considered in this AC.

b. Applicants must show controls in the proposed design, as defined in §§ 25.777, 25.779, 25.781, 25.1543, and 25.1555 comply with § 25.1302(b).

(1) The proposed means of compliance should be sufficiently detailed to demonstrate that each function, method of control operation, and result of control actuation complies with the requirements. Controls must be shown to:

(a) be clear;

(b) be unambiguous;

(c) be appropriate in resolution and precision;

(d) be accessible;

(e) be usable; and

(f) enable flightcrew awareness, including providing adequate feedback.

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

(a) Physical location of the control.

(b) Physical characteristics of the control (e.g., shape, dimensions, surface texture, range of motion, color).

(c) Equipment or system(s) that the control directly affects.

(d) How the control is labeled.

(e) Available control settings.

(f) Effect of each possible actuation or setting, as a function of initial control setting or other conditions.

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

(h) Location and nature of control actuation feedback.

(3) The discussion below provides additional guidance for design of controls that comply with § 25.1302. It also provides industry accepted best practices.

c. Clear and Unambiguous Presentation of Control-Related Information (§ 25.1302(b)).

(1) Distinguishable and predictable controls.

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

(b) The applicant should evaluate consequences of control activation to show that the consequences are predictable and obvious to each flight crewmember. Such an assessment would include evaluation of the control of multiple displays with a single device and evaluation of shared display areas that flightcrew members access with individual controls. The use of a single control should also be evaluated.

(c) For example, controls can be made distinguishable and predictable by the following differences:

1. Form.
2. Color.
3. Location.
4. Motion.
5. Effect.
6. Labeling.

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

(2) Labeling - §§ 25.1301(a)(2), 25.1543(b), and 25.1555(a).

(a) For the requirements for general marking of controls, see § 25.1555(a). In addition, see guidance on labeling items such as knobs, buttons, symbols, and menus in AC 25-11A, Electronic Flight Deck Displays, Chapter 5, paragraph (c)(2). Section 25.1302(a) and (b) requires that information necessary to accomplish defined tasks be provided precisely and clearly. It also requires the controls be accessible and usable by the flightcrew in a way consistent with the urgency, frequency, and duration of the tasks. Labels should be readable from the flightcrew's normally seated position in all lighting and environmental conditions, if intended for flightcrew use. If a control performs more than one function, labeling should include all intended functions unless the function of the control is obvious. Labels of graphical controls accessed by a cursor device such as a trackball should be included on the graphical display. When menus lead to additional choices such as submenus, the menu label should provide a reasonable description of the next submenu.

(b) The applicant should use standard and/or non-ambiguous abbreviations, nomenclature, or icons to label controls. The labels should be consistent within a function and across the flightdeck. International Civil Aviation Organization (ICAO) Document 8400, Abbreviations and Codes, Sixth Edition, 2004, provides standard abbreviations and is an acceptable basis for selecting labels.

(c) The labeling design should avoid hidden functions such as clicking on empty space on a display to make something happen.

(d) When using icons instead of text labeling, the applicant should show the flightcrew requires only brief exposure to the icon to determine the function of a control and how it operates. Based on experience, the following guidelines for icons have been shown to lead to usable designs.

1 The icon should be analogous to the object it represents.

2 The icon should be in general use in aviation and well known to flightcrews.

3 The icon should be based on established standards, when they exist, and conventional meanings.

(e) In all cases, the applicant should show the use of icons to be at least equivalent to text labels in terms of flightcrew task accomplishment speed and rate of errors made. Alternatively, the applicant should show that icons not equivalent to text labels have no unacceptable effect on safety or flightcrew workload (e.g. incurred task times) and do not confuse the flightcrew.

(3) Interaction of multiple controls - § 25.1302(a).

(a) If multiple controls for the flightcrew are provided for a function, § 25.1302 (a) states the applicant should show sufficient information is available to the flightcrew to make them aware of which control is currently functioning. As an example, crewmembers need to know which flight crewmember's input has priority when two cursor control devices can access the same display. Designers should use caution when dual controls can affect the same parameter simultaneously.

d. Accessibility of Controls - § 25.777(a), § 25.777(b) and § 25.1302.

(1) The applicant must show each flightcrew member in the minimum flightcrew, as defined by § 25.1523, has access to and can operate all necessary controls. Accessibility is one

factor in determining whether controls support the intended function of equipment used by the flightcrew. Any control required for flight crewmember operation in the event of incapacitation of other flightcrew member(s), in both normal and non-normal conditions, must be shown to be viewable, reachable, and operable by flightcrew members with the stature specified in § 25.777(c), from the seated position with shoulder restraints on. If shoulder restraints are lockable, this may be shown with shoulder restraints unlocked unless the controls need to be accessed with the restraint locked (e.g., a hard landing or aircraft upset).

(2) Section 25.777(c) requires the location and arrangement of each flightdeck control permit full and unrestricted movement of that control without interference from the flightdeck structure or the flightcrew's clothing.

(3) The layering of information, as with menus or multiple displays, should not hinder the flightcrew in identifying the location of the desired control. Section 25.1302(b) requires information intended for flightcrew use must be provided in a clear and unambiguous form, be accessible, and enable flightcrew awareness. Evaluating location and accessibility requires consideration of more than just the physical aspects of the control function. Location and accessibility also include consideration of where the control functions may be located within various menu layers and how the flight crewmember navigates through those layers to access functions. Accessibility should be shown in conditions of system failures, flightcrew incapacitation, and minimum equipment list dispatch.

(4) Control position and direction of motion must be oriented according to the standards in § 25.777.

e. Use of Controls.

(1) Environmental issues affecting controls - § 25.1301(a) and § 25.1302.

(a) Turbulence or vibration within the aircraft's approved operational envelope and extremes in lighting levels should not prevent the flightcrew from performing all their tasks at an acceptable level of performance and workload.

(b) If the use of gloves is anticipated, the design should account for the effect of their use on the size and precision of controls per §§ 25.1302(b)(2) and (c)(2).

(c) Sensitivity of controls should afford precision sufficient (without being overly sensitive) to perform tasks even in adverse environments as defined for the airplane's operational envelope per §§ 25.1302(c)(2) and (d). Analysis of environmental issues as a means of compliance is not sufficient for new control types or technologies or for novel use of controls that are themselves not new or novel. Tests are required for new control types or technologies, or novel uses of existing controls to determine if they function properly in adverse environments.

(d) The applicant should show the controls required to regain airplane or system control and to continue operating the airplane in a safe manner are identifiable and usable in all environmental conditions, to include dense smoke in the flightdeck and severe vibrations. An example of the latter condition would be after a fan blade loss.

(2) Control-display compatibility - § 25.777(b) states the direction of movement of cockpit controls must meet the requirements of § 25.779. Wherever practicable, the sense of motion involved in the operation of other controls must correspond to the sense of the effect of the operation upon the airplane or upon the part operated. Controls of a variable nature using a rotary motion must move clockwise from the off position, through an increasing range, to the full on position.

(a) To ensure that a control is unambiguous per § 25.1302(b)(1), the relationship and interaction between a control and its associated display or indications should be readily apparent, understandable, and logical. A control input is often required in response to information on a display or to change a parameter setting on a display. The applicant should specifically assess any input device or control that has no obvious "increase" or "decrease" function with regard to flightcrew expectations and its consistency with other controls on the flightdeck. The SAE International (SAE) publication ARP 4102, paragraph 5.3, is an acceptable means of compliance for controls used in flightdeck equipment.

(b) Section 25.777(a) requires each cockpit control must be located to provide convenient operation and to prevent confusion and inadvertent operation. Controls associated with a display, per §§ 25.777(a), 25.1302 (a) and (b)(2), must be located so they do not interfere with the performance of the flightcrew task. Controls whose function is specific to a particular display surface should be mounted near the display or function being controlled. Locating controls immediately below a display is generally preferable. Mounting controls immediately above a display has, in many cases, caused the flight crewmember's hand, when operating the controls, to obscure the view of the display.

(c) Spatial separation between a control and its display may be necessary. This is the case when a system's control is located with others 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 large spatial separation between a control and its associated display, the applicant should show that use of the control for the associated task(s) is acceptable, in accordance with §§ 25.777(a) and 25.1302.

(d) In general, control design and placement should avoid the possibility that visibility of information could be blocked. If range of control movement temporarily blocks the flightcrew's view of information, the applicant should show this information is either not necessary at that time, or is available in another accessible location (§ 25.1302 (b)). Section 25.1302(b)(2) requires information intended for use by the flightcrew be accessible and useable by the flightcrew in a manner consistent with the urgency, frequency, and duration of the flightcrew's tasks.

(e) Annunciations/labels on electronic displays should be identical to labels on related switches and buttons located elsewhere on the flightdeck. If display labels are not identical to related controls, the applicant should show flightcrew members can quickly, easily, and accurately identify associated controls so they can safely perform all the tasks associated with the systems' and equipment's' intended function (§ 25.1302).

f. Adequacy of Feedback - §§ 25.771(a), 25.1301(a) and 25.1302.

(1) Feedback for control operation is necessary to let the flightcrew know the effects of their actions. Each control should provide feedback to the flight crewmember for menu selections, data entries, control actions, or other inputs if awareness is required for safe operation. If the flightcrew input is not accepted by the system, the input failure should be clearly and unambiguously indicated, § 25.1302(b)(1). Such feedback can be visual, auditory, or tactile.

(2) Section 25.1302(b)(3) requires that if feedback/awareness is required for safe operation, it should be provided to inform the flightcrew of the following conditions:

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

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

(c) the action associated with the control has been initiated (the actual state of operation or control value from the operation if it is different from the commanded state); and

(d) The equipment should provide, within the time required for the relevant task, operationally significant feedback of the actuator's position within its range when a control is used to move an actuator through its range of travel. If awareness is required for safe operation, then feedback and awareness must be provided, § 25.1302(b)(3). Examples of information that could appear relative to an actuator's range of travel include trim system positions, and the state of various systems valves.

(3) The type, duration, and appropriateness of feedback will depend on the flightcrew's task and the specific information required for successful operation. As an example, switch position alone is insufficient feedback if the flightcrew must be aware, per § 25.1302(b)(3), of the actual system response or the state of the system as a result of an action that is required.

(4) Keypads should provide tactile feedback for any key depression. In cases when this is omitted, tactile feedback should be replaced with appropriate visual or other feedback that indicates that the system has received the inputs and is responding as expected.

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

(6) To meet the requirements of § 25.1302, the applicant should show that all forms of feedback are obvious and unambiguous to the flightcrew in their performance of all the tasks associated with the intended functions of the equipment.

5-5. Presentation of Information.

a. Introduction.

(1) Applicants should use this AC as a guide to show that information displayed in the proposed design complies with § 25.1302(b). Refer to AC 25-11A for information presentations on electronic displays. The proposed means should be of sufficient detail to show the function, method of control operation, and results comply with the requirements in § 25.1301 and that the results of the presented information are:

(a) clear,

(b) unambiguous,

(c) appropriate in resolution and precision,

(d) accessible,

(e) usable, and

(f) able to provide adequate feedback for flightcrew awareness.

(2) Presentation of information to the flightcrew can be visual (for instance, on an LCD), auditory (a “talking” checklist), or tactile (for example, the “feel” of the control). Information presented on the integrated flightdeck, regardless of the medium used, must meet all of the requirements in § 25.1302 as stated above. For visual displays, this AC addresses mainly display format issues and not display hardware characteristics. The following provides design considerations for requirements found in §§ 25.1301(a), 25.1302, and 25.1543(b).

b. Clear and Unambiguous Presentation of Information.

(1) Qualitative and quantitative display formats - §§ 25.1301(a) and 25.1302.

(a) Applicants should show, per § 25.1302(b), that display formats include the type of information the flightcrew needs for the task, specifically with regard to the speed and precision of reading required. The information can 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.

(b) If the flightcrew’s only way to determine non-normal values is by monitoring display values presented on the display, the equipment should offer qualitative display formats. Qualitative display formats convey rate and trend information better than quantitative (e.g. digital) presentations. If a qualitative display is not practical, the applicant should show the flightcrew can perform the tasks for which the information is used. Quantitative presentation of information is better for tasks requiring precise values. Refer to § 25.1322 and AC 25.1322 when a non-normal value is associated with a flightcrew alert.

(c) Digital readouts or present value indices incorporated into qualitative displays should not make the scale markings or graduations unusable as they pass the present value index. Scale markings should be clear throughout all values presented in the readout.

(2) Characters, fonts, lines, and scale markings - §§ 25.1301(a)(2) and 25.1543(b). The applicable flightcrew members, seated at their stations and using normal head movement, must be able to see and read display format features such as fonts, symbols, icons, and markings so they can safely perform their tasks. In some cases, cross-flight-deck readability may be required to meet the intended function (§ 25.1301(a)) that both pilots must be able to access and read the display. Examples of situations where this might be needed are cases of display failure or when cross checking flight instruments. Readability must be maintained in sunlight viewing conditions per § 25.773(a) and under other adverse conditions such as vibration and turbulence. Figures and letters should not extend below the visual angles defined in SAE ARP 4102-7 at the design eye position of the flight crewmember who normally uses the information.

(3) Color - § 25.1302.

(a) Avoid using many different colors to convey meaning on displays. If thoughtfully used, however, color can be very effective in minimizing display interpretation workload and response time. Color can be used to group logical electronic display functions or data types. A common color philosophy across the flightdeck is desirable, although deviations may be approved with acceptable justification. Information for color coding on flightdeck electronic displays is provided in AC 25-11A, Electronic Flight Control Displays.

(b) For visual alerts on multicolor displays, the colors red, amber, and yellow should be used consistently throughout the flight deck to maintain the effectiveness of an alert. The applicant must limit the use of red, yellow, and amber for functions other than flightcrew alerting, so that misuse does not adversely affect flightcrew alerting per § 25.1322(f). Extensive use of red, yellow, and amber diminishes the attention-getting characteristics of warnings and cautions. This includes alert color consistency among propulsion, flight, navigation, and other displays and indications used on the flight deck.

(c) Applicants should show the chosen color set is not susceptible to confusion or misinterpretation due to differences in color usage between displays. Improper color coding increases response times for display item recognition and selection, and increases likelihood of errors in situations where the speed of performing a task is more important than accuracy.

(d) Color, when used for task essential information, should be in addition to other coding characteristics, such as texture or differences in luminance to present information. AC 25-11A, Electronic Flight Control Displays, contains recommended color sets for specific display features.

(e) To meet the requirements in § 25.1302(b) applicants should show that layering information on a display does not add to confusion and clutter as a result of the color standards and symbols used. Avoid designs requiring flightcrew members to manually reduce the clutter of such displays.

(4) Symbology, text, and auditory messages

(a) Designs can base many elements of electronic display formats on established standards and conventional meanings. ICAO 8400 provides abbreviations and is one standard that could be applied to flightdeck text. SAE ARP 4102-7, Appendix A-C, and SAE ARP 5289 are acceptable standards for avionics display symbols.

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

(c) Applicants should give careful attention to symbol priority when displaying one symbol overlaying another symbol by editing out the secondary symbol, to ensure higher priority symbols remain viewable.

(d) New symbols, a new design, or a new symbol for a function historically associated with another symbol, should be tested for flightcrew comprehension, retention, and ability to distinguish from other symbols.

(e) The applicant should show display text and auditory messages are distinct and meaningful for the information presented. Section 25.1302 requires information intended for the flightcrew must be provided in a clear and unambiguous format in a resolution and precision appropriate to the task and that the information conveys the intended meaning. Equipment should display standard and/or non-ambiguous abbreviations and nomenclature, which should be consistent within a function and across the flightdeck.

c. Accessibility and Usability of Information.

(1) Accessibility of information - § 25.1302.

(a) Information intended for the flightcrew must be accessible and useable by the flightcrew in a manner consistent with the urgency, frequency, and duration of their tasks, per § 25.1302(b)(2). The flightcrew may, at certain times, need some information immediately. Other information may not be necessary during all phases of flight. The applicant should show the flightcrew can access and manage (configure) all necessary information on the dedicated and multifunction displays for the phase of flight. The applicant should show any information required for continued safe flight and landing is accessible in the relevant degraded display modes following failures, as defined by § 25.1309(d)(1), (2), (3), and (4). The applicant must show, per § 25.1302(b), that supplemental information does not displace or otherwise interfere with required information.

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

(2) Clutter - § 25.1302.

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

(b) Display options that automatically hide information for the purpose of reducing visual clutter may hide needed information from the flight crewmember. If equipment uses automatic de-selection of data to enhance the flight crewmember's performance in certain emergency conditions, the applicant must show, per § 25.1302(a), that it provides the information the flight crewmember needs. The use of part-time displays depends not only on the removal of clutter from the information, but also on the availability and criticality of the display. Therefore, when designing such features, the applicant should follow the guidance in AC 25-11A, Electronic Flight Control Displays.

(c) Because auditory information presentation is transient, designers should be careful to avoid the potential for competing auditory presentations that may conflict with each other and hinder interpretation. Prioritization and timing may be useful for avoiding this potential problem.

(d) Prioritize information according to task criticality. Lower priority information should not mask higher priority information. Higher priority information should be available, readily detectable, easily distinguishable, and usable per § 25.1302(b). For information on alerting priority, see § 25.1322 and AC 25.1322, Flight Crew Alerting.

(3) System response to control input - § 25.1302. Long or variable response times between control input and system response can adversely affect system usability. The applicant must show, per § 25.1302(a), that response to control input, such as setting values, displaying parameters, or moving a cursor symbol on a graphical display, is fast enough to allow the flightcrew to complete the task in an acceptable amount of time. For actions requiring noticeable system processing time, equipment must indicate system response is pending if awareness is required for safe operation, as stated in § 25.1302(b)(3).

5-6. System Behavior.

a. Introduction.

(1) As described in subchapter 5-2, § 25.1302(c) states installed equipment must be designed so that behavior of the equipment operationally relevant to the flightcrew's tasks is:

(a) predictable and unambiguous, and

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

(2) The requirement for operationally relevant system behavior to be predictable and unambiguous will enable a qualified flightcrew to know what the system is doing and why. This means a flightcrew should have enough information about what the system will do under foreseeable circumstances as a result of their action or a changing situation that they can operate the system safely, § 25.1302(b)(c). This requirement distinguishes system behavior from the functional logic within the system design, much of which the flightcrew does not know or need to know.

(3) If flightcrew intervention is part of the intended function, or part of non-normal procedures for the system, the flight crewmember may need to take some action, or change an input to the system. The system must be designed accordingly, per § 25.1302(c). The requirement for flightcrew intervention capabilities recognizes this reality.

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

(5) Some automated systems involve tasks that require flightcrew attention for effective and safe performance. Examples include the FMS 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 are not covered by § 25.1302(c). Examples include Full Authority Digital Engine Controls (FADEC) and yaw dampers. Specific detailed guidance for automatic systems can be found in relevant paragraphs of part 25.

(6) Service experience shows automated system behavior that is excessively complex or dependent on logical states or mode transitions the flightcrew does not understand or expect can lead to flightcrew confusion. Design characteristics such as these have been determined to contribute to incidents and accidents.

(7) Subchapter 5-6 provides guidance material for showing compliance with these design considerations for requirements found in §§ 25.1302(c), 25.1301(a), 25.1309(c), or any other relevant sections of part 25.

b. System Function Allocation.

(1) To meet the general requirements of § 25.1302, the applicant must show that functions of the proposed design are allocated so that:

(a) the flightcrew can be expected to complete their allocated tasks successfully in both normal and non-normal operational conditions, within the bounds of acceptable workload and without requiring undue concentration, exceptional skill or strength, or causing undue fatigue (see § 25.1523, part 25 Appendix D, and AC 25.1523 for workload evaluation). Flightcrew population demographics should be considered (for example age and gender) when determining exceptional strength;

(b) the flightcrew's interaction with the system enables them to understand the situation, and enables timely detection of failures and flightcrew intervention when appropriate; and

(c) task sharing and distribution of tasks among flightcrew members and the system during normal and non-normal operations is considered.

c. System Functional Behavior.

(1) A system's behavior results from the interaction between the flightcrew and the automated system. The system's behavior should be determined by:

(a) the system's functions and the logic that governs its operation; and

(b) the user interface, which consists of the controls and information displays that communicate the flightcrew's inputs to the system and provide feedback on system behavior to the flightcrew.

(2) The design should consider both the system's functions and the user interface together. This approach should avoid a design in which the functional logic that governs system behavior can have an unacceptable effect on flightcrew performance, see § 25.1302(c). Examples of system functional logic and system behavior issues that may be associated with errors and other difficulties for the flightcrew include the following:

(a) Complexity of the flightcrew interface for both control actuation and data entry, and complexity of the corresponding system indications provided to the flightcrew.

(b) Inadequate understanding and inaccurate expectations of system behavior by the flightcrew following mode selections and transitions.

(c) Inadequate understanding and incorrect expectations by the flightcrew of what the system is preparing to do next and how it is behaving.

(3) The system or system mode behavior must be predictable and unambiguous, per § 25.1302(c)(1).

(a) Behavior that is ambiguous or unpredictable to the flightcrew can cause or contribute to flightcrew errors. It can also potentially degrade the flightcrew's ability to perform their tasks in both normal and non-normal conditions. Certain design considerations have been found to minimize flightcrew errors and other flightcrew performance problems as discussed below.

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

1 The design should be simple.

2 Mode annunciation should be clear and unambiguous. As an example, a mode engagement or arming selection by the flightcrew should result in annunciation, indication, or display feedback adequate to make the flightcrew aware of the effects of their action. Additionally, any change in the mode as a result of the aircraft's changing from one operational mode (for instance, on an approach) to another should be clearly and unambiguously annunciated and fed back to the flightcrew.

3 Methods of mode arming, engagement and de-selection should be accessible and usable. For example, the flightcrew actions necessary to arm, engage, disarm, or disengage an autopilot mode should not be dependent on the mode the system is in. Requiring a different flightcrew action for each mode could contribute to errors. For specific guidance on flight guidance system modes, see AC 25.1329-1B, Approval of Flight Guidance Systems.

4 Uncommanded mode changes and reversions should have sufficient annunciation, indication, or display information to provide awareness of uncommanded changes of the engaged or armed mode of a system (§ 25.1302(b)(3)).

5 The current mode should remain identified and displayed at all times.

(c) Formal descriptions of modes typically define them as mutually exclusive, so that a system cannot be in more than one mode at a time. A map depiction can be in "north up" mode or "track up" mode, but not in both modes at the same time.

(4) Flightcrew Intervention - § 25.1302(c)(2).

(a) Applicants should propose how they will show their design will allow the flightcrew to intervene in the operation of the system without compromising safety. The means of showing compliance should include descriptions of how the intervention of functions and conditions is possible.

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

(5) Controls for Automated Systems.

(a) Automated systems can perform various tasks selected by and supervised by the flightcrew. Controls should be provided for managing functionalities of such a system or set of systems. The design of such "automation specific" controls per § 25.1302 should enable the flightcrew to do the following:

1 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, new flight trajectory) should not interfere with, or be confused with, the task currently being executed by the automated system.

2 Activate the appropriate system function and clearly understand what is being controlled and what the flightcrew expects. For example, the flightcrew must clearly understand they can set either vertical speed or flight path angle when they operate a vertical speed indicator.

3 Manually intervene in any system function, as required by 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.

(a) Automated systems may perform various tasks with minimal flightcrew interventions, but under supervision of the flightcrew. To ensure effective supervision and maintain flightcrew awareness of system state and system "intention" for safe operation (future states), displays should, per § 25.1302(b)(3,), provide recognizable feedback on the following:

1 Entries made by the flightcrew into the system, so the flightcrew can detect and correct errors.

2 The present state of the automated system or mode of operation (i.e., "What is it doing?").

3 Actions taken by the system to achieve or maintain a desired state (i.e., "What is it trying to do?").

4 Future states scheduled by the automated system (i.e., "What is it going to do next?").

5 Transitions between system states.

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

(a) Indications of commanded and actual values should enable the flightcrew to determine whether the automated systems will perform according to their expectations, as stated in § 25.1302(c)(1).

(b) If the automated system nears its operating limit, or is operating abnormally, or can't operate at a selected level, it must inform the flightcrew of its operating limitations, § 25.1309(c)(2).

(c) The automated system must, per § 25.1302(b)(3), support flightcrew coordination and cooperation by ensuring shared awareness of system status and flightcrew inputs to the system, if required for safe operation.

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

5-7. Flightcrew Error Management.

a. Showing compliance with § 25.1302(d).

(1) It is important to recognize flightcrews will make errors, even when they are well trained, experienced, rested, and are using well-designed systems. To address this reality, § 25.1302(d) states that—

To the extent practicable, installed equipment must incorporate means to enable the flightcrew to manage errors resulting from the kinds of flightcrew interactions with the equipment that can be reasonably expected in service. This sub-paragraph (d) does not apply to any of the following:

(a) skill-related errors associated with manual control of the airplane;

(b) errors that result from decisions, actions, or omissions committed with malicious intent;

(c) errors arising from a flight crewmember's reckless decisions, actions, or omissions reflecting a substantial disregard for safety; and

(d) errors resulting from acts or threats of violence, including actions taken under duress.

(2) To comply with the § 25.1302(d) requirement that a design enables the flightcrew to "manage errors," to the extent practicable, the installed equipment design should meet the following criteria:

(a) Enable the flightcrew to detect (see subchapter 5-7b), and/or recover from errors (see subchapter 5-7c);

(b) Ensure effects of flightcrew errors on the airplane functions or capabilities are evident to the flightcrew and continued safe flight and landing is possible (see subchapter 5-7d);

(c) Discourage flightcrew errors by using switch guards, interlocks, confirmation actions, or similar means, and

(d) Preclude the effects of errors through system logic and/or redundant, robust, or fault tolerant system design (see subchapter 5-7e).

(3) The criteria in 5-7a.(2):

(a) Recognize and assume flightcrew 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; and

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

(4) As discussed previously in subchapter 5-2, compliance with § 25.1302(d) is not intended to require consideration of errors resulting from acts of violence or threats of violence. Additionally, the requirement is intended to require consideration of only those errors that are design-related.

(5) Errors from design-related problems are within the scope of this regulatory and advisory material. One example is a design that is incompatible with the procedure by which it is used. Other design examples are indicators and controls that are complex and inconsistent with each other or other systems on the flightdeck.

(6) When demonstrating compliance, the applicant should evaluate flightcrew tasks in both normal and non-normal conditions, considering that many of the same design characteristics are relevant in either case (see §§ 25.1523, and 25.1585). For example, under non-normal conditions, the flying tasks required for normal conditions such as navigation, communication and monitoring, are generally still present, although they may be more difficult to carry out. Therefore, tasks associated with the non-normal conditions should be considered additive. The applicant should not expect the possible errors considered to be different from those that would occur in normal conditions, but any evaluation should account for the change in expected tasks.

(7) To show compliance with § 25.1302(d), an applicant may employ any of the general types of methods of compliance discussed in Chapter 6 by itself or in combination. These methods should be consistent with an approved certification plan as discussed in Chapter 4, 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 related references

to understand error occurrence. A brief summary of those methods and how they can be applied to address flightcrew error considerations follows.

(a) Statement of similarity (subchapter 6-4): A statement of similarity may be used to show the design has sufficient certification precedent to allow the ACO to conclude the flightcrew's ability to manage errors is not significantly changed. Applicants may also use service experience data to identify errors known to commonly occur for similar flightcrew interfaces or system behavior. As part of showing compliance, the applicant should identify steps taken in the new design to avoid or mitigate similar errors.

(b) Design descriptions (subchapter 6-4): Applicants may structure design descriptions and rationale to show how various types of errors are considered in the design and how they are addressed, mitigated, or managed. Applicants can also use a description of how the design adheres to an established and valid design philosophy to show the design enables flightcrews to manage errors.

(c) Calculation and engineering analysis (subchapter 6-4): As one means of showing compliance with § 25.1302(d), an applicant may document means of error management through analysis of controls, indications, system behavior, and related flightcrew tasks. The applicant should understand what potential errors can occur and ways the flightcrew can manage those errors in order to document error management. In most cases, the probability of flightcrew errors can't be predicted. If an applicant chooses to use a quantitative approach, the validity of the approach should be established.

(d) Evaluations, demonstrations, and tests (subchapter 6-4): For compliance purposes, evaluations 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, demonstrations, or tests. In that way, any discrepancy in those expectations can be discussed and explained in the analysis of the results.

(8) As discussed further in Chapter 6, these evaluations, demonstrations, or tests should use appropriate scenarios that reflect intended function and tasks, including use of the equipment in both normal and non-normal conditions. Scenarios should consider flightcrew errors. The use of inappropriate scenarios can result in incorrect conclusions. If no errors occur during an evaluation, it may only mean 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:

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

(b) The scenarios are unrealistically challenging; or

(c) Not enough training occurred prior to the evaluation.

(9) In such evaluations, it is not feasible to establish criteria for error frequency.

b. Error Detection.

(1) Applicants should design equipment to provide information so the flightcrew can become aware of an error or a system/airplane state resulting from a system action. Applicants should show that this information is available to the flightcrew, is adequately detectable, and that it shows a clear relationship between flightcrew action and the error so recovery can be made in a timely manner, per § 25.1302(b)(2).

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

(a) Indications provided to the flightcrew during normal monitoring tasks.

1 As an example, if an incorrect knob was used, resulting in an unintended heading change, the change could be detected through the display of target values. Presentation of a temporary flight plan for flightcrew review before accepting it would be another way of providing an opportunity of detecting errors.

2 Indications on instruments in the primary field of view used during normal operation 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 airplane state information such as altitude or heading. Other locations for the information may be appropriate depending on the flightcrew's tasks, such as on the control-display unit when the task involves dealing with a flight plan (see subchapter 5-5).

(b) Flightcrew indications that provide information of an error or a resulting airplane system condition. See § 25.1322 and AC 25.1322, Flight Crew Alerting, for flightcrew alerting requirements and guidance

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

2 If flightcrew 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 flightcrew to identify and correct the error, then the alert in combination with the additional information would be sufficient to comply with § 25.1302(d) for that error.

3 An error detectable by the system should provide an alert and provide sufficient information that a flightcrew error has occurred, such as in the case of a takeoff 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 flightcrew 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.

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

(c) "Global" alerts cover a multitude of possible errors by annunciating external hazards, or the airplane envelope, or operational conditions. Examples include monitoring systems such as Terrain Awareness Warning System (TAWS) and Traffic Alert and Collision Avoidance System (TCAS). An example would be a TAWS alert resulting from turning the wrong direction in a holding pattern in mountainous terrain.

(3) The applicant should consider the following when establishing whether the information is available to the flightcrew, whether it is adequately detectable, and whether it is clearly related to the error:

(a) Effects of some errors are easily and reliably determined by the system because of its design, and some are not. For errors the system cannot sense or detect, the design and arrangement of the information monitored and scanned by the flightcrew can facilitate error detection. An example would be alignment of engine speed indicator needles in the same direction during normal operation. Failure of the needles to align in the same direction during normal operation would indicate a problem with one of the engines, since one engine would be going at a different speed than the other engine.

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

(c) Some information, such as that provided by powerplant instruments, must be clearly indicated and readily available, as stated in § 25.1549. Guidance is provided in AC 20-88A, Guidelines on the Marking of Aircraft Powerplant Instruments (displays).

(4) In some cases, (see part 6-4) piloted evaluations may be needed to assess whether the information provided is available and detectable since design descriptions related to error detection may not be adequate.

c. Error Recovery.

(1) Assuming the flightcrew detects errors or their effects, the next logical step is to ensure the error can be reversed, or the effect of the error can be mitigated in some way so the airplane remains in, or is returned to, a safe state.

(2) To establish in an acceptable means that an error can be recovered, you must show that:

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

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

(3) To establish the adequacy of controls and indications that facilitate error recovery, a statement of similarity or a design description of the system and flightcrew interface may be sufficient. For simple or familiar types of system interfaces, or systems that are not novel, even if complex, a statement of similarity or design description of the flightcrew interfaces and procedures associated with indications may be an acceptable means of compliance.

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

d. Error Effects.

(1) Another means of mitigating the effects of errors is to ensure effects of the error or relevant effects on airplane state:

(a) are evident to the flightcrew, and

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

(2) Piloted evaluations in the airplane or in simulation may be relevant if flightcrew performance issues are in question for determining whether a state following an error permits continued safe flight and landing. Evaluations and/or analyses should be used to show that, following an error, the flightcrew has the information in an effective form and has the airplane control capability necessary to continue safe flight and landing.

e. Precluding Errors and Error Effects.

(1) The design should provide a way to discourage irreversible errors that have potential safety implications. Acceptable ways to discourage errors include switch guards, interlocks, or multiple confirmation actions. As an example, generator drive controls on many airplanes have guards over the switches to discourage inadvertent actuation, because once the drives are disengaged, they cannot be re-engaged while in flight or with the engine running. An example of multiple confirmations would be the presentation of a temporary flight plan that the flightcrew can review before accepting.

(2) Another way of avoiding flightcrew error is to design systems to remove misleading or inaccurate information, which might result from sensor failures, or from inadequate displays. An example would be a system that removes 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 invalid.

(3) The applicant should avoid applying an excessive number of protections for a given error. Excessive use of protections could have unintended safety consequences. They might hamper the flightcrew members’ ability to use judgment and take actions in the best interest of safety in situations not predicted by the applicant. If protections become a nuisance in daily operation, flightcrews may circumvent them. This could have further effects not anticipated by the operator or by the designer.

5-8. Integration.

a. Introduction.

(1) Many systems, such as the Flight Management System, (FMS), are integrated physically and functionally into the flightdeck and will interact with other flightdeck systems. It is important to consider a design not just in isolation, but in the context of the overall flightdeck. 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 multifunction display, as well as consistency with the rest of the flightdeck’s equipment.

(2) Section 25.1302 requires that *“…installed equipment, individually and in combination with other such equipment, is designed so that qualified flightcrew members trained in its use can safely perform all tasks associated with the equipment’s function ..*.… To comply with this integration requirement, all flightdeck equipment must be usable by the flightcrew to perform all tasks associated with the intended functions, in any combination reasonably expected in service. Flightdeck equipment includes interfaces to airplane systems the flightcrew interacts with, such as controls, displays, indications, and annunciations.

(3) Analyses, evaluations, tests, and other data developed to establish compliance with each of the specific requirements in § 25.1302(a) through (d) should address integration of new

or novel design features or equipment with previously approved features or equipment as well as with other new items. It should include consideration of the following integration factors:

(a) consistency,

(b) consistency trade-offs,

(c) flightdeck environment, and

(d) integration related workload and error.

b. Consistency.

(1) The applicant should consider consistency within a given system and across the flightdeck. Inconsistencies may result in vulnerabilities, such as increased workload and errors, especially during stressful situations. For example, in some FMS's, the format for entering latitude and longitude differs across the display pages. This may induce flightcrew errors, or at least increase flightcrew workload. Additionally, errors may result if latitude and longitude are displayed in a format that differs from formats on the most commonly used paper charts. Because of this, it is desirable to use formats consistent with other media whenever possible. Although trade-offs exist, as discussed in the next paragraph, the following are design attributes to consider for consistency within and across systems:

(a) Symbology, data entry conventions, formatting, color philosophy, terminology, and labeling.

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

(c) Information presented with other information of the same type used in the flightdeck. As an example, navigation symbols used on other flightdeck systems or on commonly used paper charts could be used on electronic map displays.

(d) The operational environment. For example, it is important that an FMS should be consistent with the operational environment, so the order of the steps required to enter a clearance into the system is consistent with the order in which they are given by air traffic management.

(2) One way the applicant can achieve consistency within a given system, as well as within the overall flightdeck, is to adhere to a comprehensive flightdeck design philosophy. Another way is to standardize aspects of the design by using accepted, published industry standards such as the labels and abbreviations recommended in ICAO 8400/5. The applicant might standardize symbols used to depict navigation aids, such as Very High Frequency Omnidirectional Range (VOR) beacons, by following the conventions recommended in SAE document ARP 5289. On the other hand, inappropriate standardization, rigidly applied, can be a barrier to innovation and product improvement. Standardization could also result in a standard to the lowest common denominator. Thus, guidance in this paragraph promotes consistency rather than rigid standardization.

c. Consistency Trade-offs.

(1) While strongly encouraged, the FAA recognizes it is not always possible to provide a consistent flightcrew interface. Despite conformance with a flightdeck design philosophy, principles of consistency, etc., it is possible to negatively impact flightcrew workload. As an example, all the auditory alerts in a design may adhere to a flightdeck alerting philosophy, but the number of alerts may be unacceptable. Consistent format across the flightdeck may not work when individual task requirements necessitate 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, the applicant should show that the interface design is compatible with the requirements of the piloting task and that it can be used individually and in combination with other interfaces without interference to either system or function. Additionally:

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

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

(c) The applicant should provide a rationale for instances where a system's design diverges from the flightdeck design philosophy. Consider any impact on workload and errors as a result of this divergence.

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

d. Flightdeck Environment.

(1) The physical configuration of the airplane and its operating environment influence the integration and placement of the flightdeck system. The system is subject to influences on the flightdeck such as turbulence, noise, ambient light, smoke, and vibrations (e.g., as may result from ice or fan blade loss). System design should recognize the effect of such influences on usability, workload, and flightcrew task performance. Turbulence and ambient light, for example, may affect readability of a display. Flightdeck noise may affect audibility of aural alerts. The applicant should also consider the impact of the flightdeck environment for non-normal situations, such as recovering from an unusual attitude or regaining control of the airplane or system. Also refer to AC 25-11A for guidance on information display usability.

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

(a) Access and reach (to controls).

(b) Visibility and readability of displays and labels.

(c) An example of poor physical integration that affects visibility and readability is a required traffic avoidance system obscured by thrust levers in their normal operating position.

(d) Task-oriented location and grouping of human-machine interaction elements.

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 flightcrew workload and its subsequent impact on error management. Systems should be designed and evaluated, both in isolation and in combination with other flightdeck systems, to ensure the flightcrew is able to detect, reverse, or recover from errors, § 25.1302(d). This process may be challenging when integrating systems that employ different kinds of automated systems or have a high degree of interaction and dependency on other flightdeck systems.

(2) Applicants should show the integrated design does not adversely impact workload, errors, or safe flightcrew performance per § 25.1302 given the context of the entire flight regime. Examples of such impacts would be increased time to:

(a) interpret a function,

(b) make a decision, or

(c) take appropriate actions.

(3) Because each new system integrated into the flightdeck may have a positive or negative effect on workload, each must be evaluated both in isolation and in combination with the other systems for compliance with § 25.1523. This is to ensure the overall workload is acceptable, i.e., that performance of flight tasks is not adversely impacted and the flightcrew's detection and interpretation of information does not lead to unacceptable response times. Special attention should be paid to part 25 Appendix D and, specifically, compliance for items that the appendix lists as (b), workload factors. These include "accessibility, ease, and simplicity of operation of all necessary flight, power, and equipment controls."

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

(a) Presenting the same information in two different formats. Presenting altitude information concurrently in tape and round-dial formats, for example, may increase workload. Yet different formats may be suitable depending on the design and the flightcrew task. An analog display of engine revolutions-per-minute can facilitate a quick scan, whereas a digital numeric display can facilitate precise inputs. The applicant is responsible for demonstrating compliance with § 25.1523 and showing that differences in the formats of information presented do not result in unacceptable workload levels.

(b) Presenting conflicting information. Systems may exhibit minor differences between each flight crewmember station, but all such differences should be evaluated specifically to ensure that the potential for interpretation error is minimized, or that a method exists for the flightcrew to detect incorrect information, or that the effects of these errors can be precluded such as a baro-altimeter that is set wrong.

Chapter 6. Means of Compliance.

6-1. Overview.

This chapter discusses considerations in selecting and applying means of compliance in addressing human performance issues. These means of compliance are generic and have been used in certification programs. The acceptable means of compliance to be used on any given project should be determined on a case-by-case basis, driven by the specific compliance issues. The applicant should develop and propose a means of compliance acceptable to the FAA, part 21. Uses and limitations of each type of compliance means are provided in subchapter 6-4.

6-2. Selecting Means of Compliance.

a. The means of compliance discussed in subchapter 6-4 include:

(1) statements of similarity,

(2) design description,

(3) calculations/analysis,

(4) evaluations, and

(5) tests.

b. No generic method can determine the appropriate means of compliance for a specific project. The choice of an appropriate compliance means, or combination of several different means, depends on a number of factors specific to a project.

c. Some certification projects may need more than one way of demonstrating compliance with a particular requirement. When it is not possible to flight test a conformed airplane, for example, a combination of design review and part-task simulation evaluation may be proposed.

d. Answering the following questions will aid in selecting the means of compliance.

(1) With which means of compliance will it be possible to gather the required certification data?

(2) Will a single means of compliance provide all of the data or will several means be used in series or in parallel?

(3) What level of fidelity of the facility (test apparatus) is required to collect the required data? (Fidelity means to represent the function and behavior of the installed system.)

(4) Who will be the participants?

(5) What level of training is required prior to acting as a participant?

(6) How will data from an evaluation be presented to show compliance?

(7) Will results of a demonstration be submitted for credit?

(8) If a test is required, what degree of conformity for the test will be needed?

6-3. Discussion and Agreement with the FAA on Compliance Demonstrations.

The applicant's proposal for means of compliance should be coordinated with the FAA to ensure all aspects necessary for desired credit towards certification are achieved (refer to §§ 21.15 and 21.17). The proposal should include the planned scenarios, the necessary types of human performance issues to be explored, or the conditions under which the test will be conducted so it provides a realistic environment for the evaluation.

6-4. Description of Means of Compliance.

The general means of compliance acceptable for use in demonstrating compliance related to flightdeck design are described in the following paragraphs.

a. Statement of similarity.

(1) Description: a statement of similarity is a description of the system to be approved, and a description of a previously approved system, which details the physical, logical, and operational similarities of the two systems as they relate to compliance with the requirements.

(2) Deliverable: a statement of similarity should be part of the certification report.

(3) Participants: not applicable.

(4) Conformity: not applicable.

(5) Uses: it may be possible to substantiate the adequacy of a design by comparing it to previously certificated systems that have shown they are robust with respect to their lack of contribution to flightcrew error and/or are robust in their ability to allow flightcrews to manage the situation should an error occur. This process avoids unnecessary repetition of effort to justify the safety of such systems.

(6) Limitations: the applicant should be careful when using a statement of similarity to show compliance. The flightdeck should be evaluated as a whole, not as merely a set of individual functions or systems. Two functions or features previously approved on separate airplanes may be incompatible when combined on a single flightdeck. Also, changing one

feature in a flightdeck may necessitate corresponding changes in other features, to maintain consistency and prevent confusion.

(7) Example: if the cursor control device in a new airplane is identical in design to that in an existing airplane, a statement of similarity may be an acceptable way to show compliance with § 25.1555(a), if other relevant airplane characteristics are also similar (e.g. flight deck geometry, flightcrew interfaces using the cursor, vibration conditions, etc.).

b. Design description. The applicant may elect to show the design meets requirements of a specific rule by describing the design. Applicants have traditionally used drawings, configuration descriptions, and/or design philosophy to show compliance. Selection of participants and conformity are not relevant to this means of compliance.

(1) Drawings.

(a) Description: these may be layout drawings or engineering drawings, or both, which depict the geometric arrangement of hardware or display graphics.

(b) Deliverable: the drawing, which may be part of a certification report.

(c) Uses: the applicant may use drawings for very simple certification programs when the change to the flightdeck may be very simple and straightforward. Drawings may also be used to support findings of compliance for more complex interfaces.

(d) Limitations: the use of drawings is limited to physical arrangements and graphical concerns.

(2) Configuration description.

(a) Description: a configuration description should be a description of the layout, general arrangement, direction of movement, etc., of the regulated item. It may also be a reference to documentation, giving such a description (for example from a different project with a similar layout). It should be used to show the relative locations of flight instruments, groupings of control functions, allocation of color codes to displays and alerts, etc.

(b) Deliverable: the deliverable is a text explanation and, if appropriate, visual display of the certification item, which explains the functional aspects of the flightcrew interface with the system.

(c) Uses: configuration descriptions are generally less formalized 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 final confirmation of compliance is found through other means, such as demonstrations or tests. The background information provided by configuration descriptions may significantly reduce the complexity and/or risk associated with demonstrations or tests. The applicant will have already communicated how a system works with the configuration description and any discussions or assumptions may have already been coordinated.

(d) Limitations: configuration descriptions may provide enough information to allow a finding of compliance with a specific requirement. More often, though, they provide important background information, while final confirmation of compliance is found by other means, such as demonstrations or tests. Background information provided by configuration descriptions may significantly reduce the complexity and/or risk associated with the demonstrations or tests.

(3) Design philosophy.

(a) Description: an overall safety-centered philosophy as explained in detail in the design specifications for the product, system, or flightdeck can be used to demonstrate a design philosophy.

(b) Deliverable: a text description of the certification item and/or a text description of the functional aspects of the flightcrew interface with the system, including figures and drawings as appropriate, and their relationship to the overall design philosophy.

(c) Uses: a design philosophy documents the ability of a design to meet requirements of a specific rule.

(d) Limitations: in most cases, this means of compliance will not be sufficient as the sole means to demonstrate compliance.

(e) Example: design philosophy may be used as a means of compliance when a new alert is added to the flightdeck if the new alert is consistent with the acceptable existing alerting philosophy.

c. Calculation/analysis.

(1) Description: calculations or engineering analyses may be analytical assessments, which do not require direct participant interaction with a physical representation of the equipment.

(2) Deliverable: a report with detailed results and conclusions that includes a thorough analysis with its components, evaluation assumptions, and the basis for decision making.

(3) Participants: conducted by the applicant.

(4) Conformity: not applicable.

(5) Uses: provides a systematic evaluation of specific or overall aspects of the human interface part of the product, system, and flightdeck. May be specified by guidance material.

(6) Limitations: the applicant should carefully consider the validity of the assessment technique if the analyses are not based on advisory material or accepted industry standard methods. The FAA may ask the applicant to validate any computational tools used in such analyses. If analysis involves comparing measured characteristics to recommendations derived from pre-existing research, either internal or public domain, the FAA may ask the applicant to justify the applicability of data to the project.

(7) Example: an applicant may conduct a vision analysis to demonstrate the flightcrew has a clear and undistorted view out the windows. Similarly, an analysis may also demonstrate flight, navigation, and powerplant instruments are plainly visible from the flightcrew member station. The applicant may need to validate results of the analysis in ground or flight tests.

d. Evaluations. The applicant may use a wide variety of part-task to full-installation representations of the product/system or flightdeck for evaluations. All of these have two characteristics in common. First, the representation of the human interface and the system interface do not necessarily conform to the final documentation. Second, the certification official is generally not present. The table below addresses mock-ups, part-task simulations, full simulations, and in-flight evaluations that typically make up this group of compliance means. A mock-up is a full-scale, static representation of the physical configuration that includes fit and form. It does not include functional aspects of the flightdeck and its installed equipment.

(1) Description: evaluations are assessments of the design conducted by the applicant (or their agent), who then provides a report of the results to the FAA.

(2) Deliverable: a report, delivered to the FAA.

(3) Participants: applicant and possibly the FAA.

(4) Facilities: an evaluation may be conducted in a mock-up, on a bench, in a laboratory, simulator, or aircraft.

(5) Conformity: not required.

(6) Mock-up evaluation: the applicant may use mock-ups as representations of the design, allowing participants to physically interact with the design. Three-dimensional representations of the design in a computer aided design (CAD) system, in conjunction with three-dimensional models of the flightdeck occupants, have also been used as “virtual” mock-ups for certain limited types of evaluations. Reach assessments, for example, can use either type of mock-up.

(7) Example of a mock-up evaluation: one example might be an analysis to demonstrate that controls are arranged so flightcrew members from 1.58 m (5 ft., 2 inches) to

1.91 m (6 ft., 3 inches) in height can reach all the controls. This analysis should also consider differences in anatomy, such as functional arm reach, leg length, and other relevant body measurements. It may use computer generated data based on engineering drawings. The applicant may demonstrate results of the analysis in the actual aircraft.

(8) Bench or laboratory evaluation: the applicant may conduct an evaluation using devices that emulate the flightcrew interfaces for a single system or for a related group of systems. The applicant can use flight hardware, simulated systems, or combinations of them.

(9) Example of a bench or laboratory evaluation: a bench evaluation for an integrated system could be conducted with an avionics suite installed in a mock-up of a flightdeck, with the main displays and autopilot controllers included. Such a tool may be valuable during development and valuable for providing system familiarization to the FAA. In a highly integrated architecture, however, it may be difficult or impossible to assess how well the avionics system will fit into the overall flightdeck without more complete simulation or use of the actual airplane.

(10) Simulator evaluation: a simulator evaluation uses devices that present an integrated emulation of the flightdeck and the operational environment by using flight hardware, simulated systems, or combinations of them. The devices may also be “flown,” with response characteristics that replicate, to some extent, the responses of the airplane. The simulation of functional requirements and the physical fidelity of the requirements, or degree of realism, will typically depend on the configurations, functions, tasks, and equipment being evaluated.

(11) Aircraft evaluation: an evaluation conducted in the actual aircraft.

(12) These evaluation activities result in better designs that are more likely to comply with the applicable requirements.

(13) Limitations: evaluations are limited by the extent to which the facilities actually represent the flightdeck configuration and realistically represent flightcrew tasks. As flightdeck systems become more integrated, part-task evaluations may become less useful as a means of compliance, even though their utility as engineering tools may increase.

e. Tests. Tests are means of compliance conducted in a manner very similar to evaluations described above, with one significant difference. Tests require an actual conforming product/system and system interface. A test may be conducted on a bench, in a laboratory, in a simulator, or on an airplane.

(1) Description: tests are assessments of the design conducted with the FAA certifying official present.

(2) Deliverable: a report is delivered to the FAA.

(3) Participants: applicant and possibly the FAA.

(4) Facilities: a test may be conducted on a bench or in a laboratory, simulator, or an aircraft.

(5) Conformity: the product/system, flightdeck, and/or system interface being evaluated must be conformed to show compliance per part 21. A simulator must be conformed per § 60.13.

(6) Bench or laboratory test: this type of testing is usually confined to showing components perform as designed. Bench tests are usually not enough to stand alone as a means of compliance. They can, however, provide useful supporting data in combination with other means.

(7) Example of a bench or laboratory test: the applicant might show visibility of a display under the brightest of expected lighting conditions with a bench test, provided there is supporting analysis to define the expected lighting conditions. Such supporting information might include a geometric analysis to show potential directions from which the sun could shine on the display, with calculations of expected viewing angles. These conditions might then be reproduced in the laboratory.

(8) Conformity related to a bench or laboratory test: the part or system must be conformed to show compliance, per part 21.

(9) Simulator test: a simulator test uses devices that present an integrated emulation of the flightdeck and the operational environment by using flight hardware and software, simulated systems, or combinations of these. The devices may also be "flown," with response characteristics that replicate the responses of the airplane. The applicant should determine the physical and functional fidelity requirements of the simulation as a function of the issue under evaluation.

(10) Simulator test conformity and fidelity issues: only conforming parts of the flightdeck may be used for simulator tests. Applicants may use a flightcrew training simulator to validate most of the normal and emergency procedures for the design, and any workload effects of the equipment on the flightcrew. If the flightdeck is fully conforming, and the avionics are driven by conforming hardware and software, then the applicant may conduct and use integrated avionics tests to show compliance. Not all aspects of the simulation must have a high level of fidelity for any given compliance issue (see § 60.11). Fidelity requirements can be assessed in consideration of the issue being evaluated.

(11) Airplane test: airplane tests may be conducted either on the ground or in flight.

(12) Example of an airplane test: an example of a ground test is an evaluation of the potential for reflections on displays. Such a test usually involves covering the flightdeck windows to simulate darkness and setting the flightdeck lighting to desired levels. This particular test may not be possible in a simulator because of differences in the light sources,

display hardware, and/or window construction. Flight testing during certification is the final demonstration of the design. These tests are conducted on a conforming airplane during flight. The airplane and its components (flightdeck) 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 evaluations that can be conducted safely. Flight testing may be used to validate and verify other tests previously conducted during the development and certification program. It is often best to use flight testing as final confirmation of the data collected that used other means of compliance, including analyses and evaluations.

(13) Limitations of flight tests: flight tests may be limited by the extent to which flight conditions of particular interest such as weather, failure, or unusual attitudes can be found or produced, and then safely evaluated in flight. Also, note that flight testing on the airplane provides the least control over conditions of any of the means of compliance. The FAA and the applicant should thoroughly discuss how and when flight tests and their results will be used to show compliance.

Appendix A. Related Documents.

A-1. Additional Requirements.

The following is a list of requirements, means of compliance, and other documents relevant to flightdeck design and flightcrew interfaces which may be useful when reviewing this AC.

Table A-1. Part 25 Requirements.

Part 25 Requirements	General topic
§ 25.771(a)	Unreasonable concentration or fatigue
§ 25.771(c)	Equipment controllable from either pilot seat
§ 25.773	Pilot compartment view
§ 25.777(a)	Location of cockpit controls and inadvertent operation
§ 25.777(b)	Direction of movement of cockpit controls
§ 25.777(c)	Full and unrestricted movement of controls
§ 25.1301(a)	Intended function of installed systems
§ 25.1302	Flightcrew error
§ 25.1303	Flight and navigation instruments
§ 25.1309(a)	Intended function of required equipment under all operating conditions
§ 25.1309(c)	Unsafe system operating conditions. System design to minimize flightcrew errors which could create additional hazards
§ 25.1321	Visibility of instruments
§ 25.1322	Warning, caution, and advisory lights
§ 25.1329	Autopilot, flight director, and autothrust
§ 25.1523	Minimum flightcrew and workload
§ 25.1543(b)	Visibility of instrument markings
§ 25.1555(a)	Control markings
§ 25.1549	Powerplant and auxiliary power unit instruments
Part 25 Appendix D	Criteria for determining minimum flightcrew

A-2. Orders and Policy Related to this AC.

a. Policy Memo ANM-99-2, Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Transport Airplane Flightdecks, dated 09/29/1999.

b. Policy Memo PS-ANM100-01-03A, Factors to Consider When Reviewing an Applicant's Proposed Human Factors Methods of Compliance for Flightdeck Certification, dated 02/07/2003.

A-3. FAA Advisory Circulars Referenced in this AC.

AC Number	AC Title
25-11A	Electronic Flight Deck Displays
20-88A	Marking of Aircraft Powerplant Instruments
25.1322	Flight Crew Alerting
25.1329-1B	Approval of Flight Guidance Systems

A-4. Other Documents.

The following is a list of other documents relevant to flightdeck design and flightcrew interfaces. Some contain special constraints and limitations, particularly those that are not aviation specific. For example, International Standard Organization (ISO) 9241-4 has much useful guidance that is not aviation specific. When using that document, applicants should consider environmental factors such as the intended operational environment, turbulence, and lighting as well as cross-flightdeck side reach.

a. SAE International.

(1) SAE ARP 4033, Pilot-System Integration, August 1995.

(2) SAE ARP 5289A, Electronic Aeronautical Symbols, August 2011.

(3) SAE ARP 4102/7, Electronic Displays, November 1998.

b. FAA.

(1) FAA Human Factors Team report on: The Interfaces Between Flightcrews and Modern Flightdeck Systems, 1996.

c. Department of Transportation (DOT).

(1) DOT/FAA/RD –93/5: Human Factors for Flightdeck Certification Personnel, 1993.

d. International Civil Aviation Organization (ICAO).

(1) ICAO 8400/5, Procedures for Air Navigation Services ICAO Abbreviations and Codes. Ed 8 - 2010.

(2) ICAO Human Factors Training Manual: DOC 9683 – AN/950, 1998.

(3) International Standards ISO 9241-4, Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs), 1998.

Appendix B. Definitions.

B-1. Acronyms.

AC	Advisory Circular
ACO	Aircraft Certification Office
AMC	Acceptable Means of Compliance
ARAC	Aviation Rulemaking Advisory Committee
DOT	Department of Transportation
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FADEC	Full Authority Digital Engine Controls
FMS	Flight Management System
ICAO	International Civil Aviation Organization
ISO	International Standards Organization
MOC	Means of Compliance
SAE	SAE International
STC	Supplemental Type Certificate
TAWS	Terrain Awareness Warning System
TC	Type Certificate
TCAS	Traffic Alert and Collision Avoidance System
TSO	Technical Standards Order
VOR	Very High Frequency Omnidirectional Range

B-2. Terms and Definitions.

(a) Aircraft Interface - an electronics unit that provides the electrical connections between the display in the cockpit and the aircraft controls

(b) Annunciators Indications – Separate alerting instruments that get the attention of the operators when they are diverted from the primary display.

(c) Conformity – Official verification that the flightdeck/system/product conforms to the type design data.

(d) Consistency – Presentation of similar information in multiple locations or modes in the same way to minimize flightcrew error.

(e) Control Device (Flightdeck Control) – Devices the flightcrew manipulates in order to operate, configure, and manage the airplane and its flight control surfaces, systems, and other equipment.

(f) Cursor Control Device – Control device for interacting with virtual controls, typically used with a graphical user interface on an electro-optical display.

(g) Design Philosophy – A high-level description of human-centered design principles that guide the designer and aid in ensuring that a consistent, coherent user interface is presented to the flightcrew.

(h) Display – Device (typically visual, but may be auditory or tactile) that transmits data or information from the airplane systems to the flightcrew.

(i) Flightcrew – Group of trained and checked professional persons who's assigned task is to operate the airplane safely as set forth in § 25.1523 and in appendix D to part 25.

(j) Interface - The layout of an application's graphic or textual controls in conjunction with the way the application responds to user activity, or an electrical circuit linking one device, especially a computer, with another.

(k) Multifunction Control – A control device that can be used for multiple functions as opposed to a control device with a single dedicated function.

(l) Task Analysis – A formal analytical method used to describe the nature and relationship of tasks involving a human operator.