Controls associated with the electronic displays covered in this AMC. These controls include hard controls (physical buttons and knobs) and soft controls (virtual or programmable buttons and knobs, generally controlled through a cursor device or line select keys).
Electronic standby displays.
Head-Up Displays (HUD).

Table 2: Topics Outside this AMC

Topics
Display functions not intended for use by the pilot.
In flight entertainment displays.
Flight attendant displays.
Maintenance terminals, even if they are in the flight deck, but not intended for use by the pilots.
Head mounted displays used by pilots.
Displays in the flight crew rest area.
Handheld or laptop items (not installed equipment).
Class I and Class II Electronic Flight Bags.
Electromechanical instruments.
Auditory “displays” (for example, aural alerts), and tactile “displays” (for example, stick shaker).
Flight controls, throttles, and other (hard) controls not directly associated with the electronic displays.

In addition to this AMC, new AMC 25.1302 published in CS-25 Amendment 3, provides acceptable means of compliance with certification specifications associated with the design of flight crew interfaces such as displays, indications, and controls. AMC 25.1322 provides a means of compliance for flight crew alerting systems. The combination of these AMCs is intended to embody a variety of design characteristics and human-centred design techniques that have wide acceptance, are relevant, and can be reasonably applied to large aeroplane certification projects.

Other advisory material is used to establish guidance for specific functionality and characteristics provided by electronic displays. This AMC is not intended to replace or conflict with these existing AMCs but rather provides a top-level view of flight deck displays. Conflicts between this AMC and other advisory material will be resolved on a case-by-case basis in agreement with the Agency.

5. Definitions of Terms Used in this AMC

a. For the purposes of this AMC, a “display system” includes not only the display hardware and software components but the entire set of avionic devices implemented to display information to the flight crew. Hardware and software components of other systems that affect displays, display functions, or display controls should take into account the display aspects of this AMC. For example, this AMC would be applicable to a display used when setting the barometric correction for the altimeter, even though the barometric set function may be part of another system.

b. For the purposes of this AMC, “foreseeable conditions” means the full environment in which the display or the display system is assumed to operate, given its intended function. This includes operating in normal, non-normal, and emergency conditions.

c. Definitions of technical terms used in this AMC can be found in Appendix 3 of this AMC. The acronyms used throughout this document are included in Appendix 4 of this AMC.

6. Background

a. Electronic displays can present unique opportunities and challenges to the design and certification process. In many cases, the demonstration of compliance with Certification Specifications related to the latest flight deck display system capabilities has been subject to a great deal of interpretation by applicants and the Agency. At the time the first electronic displays were developed, they were direct replacements for the conventional electromechanical components. The initial release of AMC 25-11 established an Acceptable Means of Compliance for the approval of Cathode Ray Tube (CRT)-based electronic display systems used for guidance, control, or decision-making by the flight crews of large aeroplanes. This initial release was appropriate for CRTs, but additional specifications were needed to update AMC 25-11 to address new technologies. Additional appendices have been added to address Head-Up Displays (Appendix 6) and Weather Displays (Appendix 7).

b. The FAA and EASA have established a number of specifications intended to improve aviation safety by requiring that the flight deck design have certain capabilities and characteristics. The approval of flight deck displays and display systems has typically been addressed by invoking many specifications that are specific to certain systems, or to specifications with general applicability such as CS 25.1301(a), CS 25.771(a), and CS 25.1523. Thus, this AMC provides acceptable means of compliance and guidance related to these and other applicable airworthiness specifications.

7. - 10. [RESERVED]

CHAPTER 2 ELECTRONIC DISPLAY SYSTEM OVERVIEW

11. General

The following paragraphs provide acceptable means of compliance and guidance that applies to the overall electronic display system. This chapter, together with Chapters 3 through 7 of this AMC, provides compliance objectives and design guidance. Chapter 8 provides general guidance on how to show compliance for approval of electronic display systems. The material in Chapters 2 through 9 and Appendices 1 and 2 of this AMC constitutes an overall method of compliance for the approval of an electronic display system.

a. Design Philosophy.

The applicant should establish, document, and follow a design philosophy for the display system that supports the intended functions (CS 25.1301). The documented design philosophy may be included as part of a system description, certification programme, or other document that is submitted to the Agency during a certification project. The design philosophy should include a high level description of:

(1) General philosophy of information presentation – for example, is a “quiet, dark” flight deck philosophy used or is some other approach used?

(2) Colour philosophy on the electronic displays – the meaning and intended interpretation of different colours – for example, does magenta always represent a constraint?

(3) Information management philosophy – for example, when should the pilot take an action to retrieve information or is it brought up automatically? What is the intended interpretation of the location of the information?

(4) Interactivity philosophy - for example, when and why is pilot confirmation of actions requested? When is feedback provided?

(5) Redundancy management philosophy – for example, how are single and multiple display failures accommodated? How are power supply and data bus failures accommodated?

b. Human Performance Considerations.

The applicant should establish and document the following human performance elements when developing a display system:

— Flight crew workload during normal and non-normal operations, including emergencies,

— Flight crew training time to become sufficiently familiar with using the display, and

— The potential for flight crew error.

A high workload or excessive training time may indicate a display design that is difficult to use, requires excessive concentration, or may be prone to flight crew errors. Compliance considerations are included in Chapter 8 of this AMC.

c. Addressing Intended Function in the Certification Programme

The certification programme should identify the appropriate CS-25 certification specifications. An important part of the certification programme will be the system description(s) and all intended functions, including attitude, altitude, airspeed, engine parameters, horizontal situation display, etc. To demonstrate compliance with CS 25.1301(a), an applicant must show that the design is appropriate for its intended function. The applicant's description of intended function needs to be sufficiently specific and detailed for the Agency to be able to evaluate that the system is appropriate to its intended function. (CS 25.1302 and associated AMC provide additional information on intended function). General and/or ambiguous intended function descriptions are not acceptable (for example, a function described only as "situation awareness"). Some displays may be intended to be used for situation awareness, but that term needs to be clarified or qualified to explain what type of specific situation awareness will be provided. More detailed descriptions may be warranted for designs that are new, novel, highly integrated, or complex. Many modern displays have multiple functions and applicants should describe each intended function. A system description is one place to document the intended function(s).

Display systems and display components that are not intended for use by the flight crew (such as maintenance displays) should not interfere with the flying duties of the flight crew.

12 - 15. [RESERVED]

CHAPTER 3 ELECTRONIC DISPLAY HARDWARE

16. Display Hardware Characteristics

The following paragraphs provide general guidance and a means of compliance for electronic display hardware with respect to its basic visual, installation, and power bus transient handling characteristics. A more detailed set of display hardware characteristics can be found in the following SAE International (formerly the Society of Automotive Engineers) documents:

— For electronic displays – SAE Aerospace Standards (AS) 8034B, "'Minimum Performance Standard for Airborne Multipurpose Electronic Displays'".

— For head up displays - SAE AS8055, "Minimum Performance Standard for Airborne Head Up Display (HUD)".

— For liquid crystal displays (LCDs) – SAE Aerospace Recommended Practice (ARP) 4256A, "Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft".

NOTE 1: For LCDs, the quantitative criterion in SAE ARP 4256A, paragraph 4.2.6., equation 5, is not considered a reliable predictor of acceptable specular reflectivity characteristics. Accordingly, this aspect of LCD performance should be specifically assessed via flight crew evaluation to establish that there are not internal or external reflections that can result in flight crew distraction or erroneous interpretation of displayed information.

NOTE 2: With regard to the criteria for malfunction indication in SAE ARP 4256A, paragraph 3.4, the Agency has determined that showing the fonts and symbols to be tolerant to the loss of a single column, line, or element is an acceptable alternative to providing a malfunction indication. Proposed designs that do not use fonts and symbols that are tolerant to these faults are acceptable if they meet the criteria in SAE ARP 4256A.

NOTE 3: The applicant should notify the Agency if any visual display characteristics do not meet the guidelines in the applicable SAE documents.

NOTE 4: The most recent revision of the referenced SAE documents should be considered. If there is a conflict between the guidance in an SAE document and AMC 25-11, follow the guidance in AMC 25-11.

a. Visual Display Characteristics

The visual display characteristics of a flight deck display are directly linked to their optical characteristics. Display defects (for example, element defects or stroke tails) should not impair readability of the display or create erroneous interpretation. In addition to the information elements and features identified in Chapter 5 of this AMC, and the visual characteristics in SAE ARP 4256A, SAE AS 8034B, and 8055 described above, the display should meet the criteria for the following characteristics. These characteristics are independent of the proposed display technology.

(1) Physical Display Size. A display should be large enough to present information in a form that is usable (for example, readable or identifiable) to the flight crew from the flight crew stationin all foreseeable conditions, relative to the operational and lighting environment and in accordance with its intended function(s).

(2) Resolution and Line Width. The resolution and minimum line width should be sufficient to support all the displayed images such that the displayed information is visible and understandable without misinterpretation from the flight crew station in all foreseeable conditions, relative to the operational and lighting environment.

(3) Luminance. Information should be readable over a wide range of ambient illumination under all foreseeable conditions relative to the operating environment, including but not limited to:

— Direct sunlight on the display,

— Sunlight through a front window illuminating white shirts (reflections),

— Sun above the forward horizon and above a cloud deck in a flight crew member's eyes, and

— Night and/or dark environment.

(a) For low ambient conditions, the display should be dimmable to levels allowing for the flight crew's adaptation to the dark, such that outside vision and an acceptable presentation are maintained.

(b) Automatic luminance adjustment systems can be employed to decrease pilot workload and increase display life. Operation of these systems should be satisfactory over a wide range of ambient light conditions, including the extreme cases of a forward low sun and a quartering rearward sun shining directly on the display.

1. Some manual adjustment should be retained to provide for normal and non-normal operating differences so that the luminance variation is not distracting and does not interfere with the flight crew's ability to perform their tasks.

2. Displays or layers of displays with uniformly filled areas conveying information such as weather radar imagery should be independently adjustable in luminance from overlaid symbology. The range of luminance control should allow detection of colour differences between adjacent small filled areas no larger than 5 milliradians in principal dimension; while at this setting, overlying map symbology, if present, should be discernible.

(c) Display luminance variation within the entire flight deck should be minimised so that displayed symbols, lines, or characters of equal luminance remain uniform under any luminance setting and under all foreseeable operating conditions.

(4) Contrast Ratio

(a) The display's contrast ratio should be sufficient to ensure that the information is discernable under the whole ambient illumination range from the flight crew station under all foreseeable conditions relative to the operating environment.

(b) The contrast between all symbols, characters, lines, and their associated backgrounds should be sufficient to preclude confusion or ambiguity of any necessary information.

(5) Chromaticity

(a) The display chromaticity differences, in conjunction with luminance differences, should be sufficient to allow graphic symbols to be discriminated from each other, from their backgrounds (for example, external scene or image background) and background shaded areas, from the flight crew station, in all foreseeable conditions relative to the lighting environment. Raster or video fields (for example, non-vector graphics such as weather radar) should allow the image to be discriminated from overlaid symbols, and should allow the desired graphic symbols to be displayed. See SAE AS 8034A, sections 4.3.3 and 4.3.4, for additional guidance.

(b) The display should provide chromaticity stability over the foreseeable conditions relative to the range of operating temperatures, viewing envelope, image dynamics, and dimming range, such that the symbology is understandable and is not misleading, distracting, or confusing.

(6) Grey Scale

(a) The number of shades of gray and the difference between shades of gray that the display can provide should be adequate for all image content and its use, and should accommodate all viewing conditions.

(b) The display should provide sufficient gray scale stability over the foreseeable range of operating temperatures, viewing envelope, and dimming range, such that the symbology is understandable and is not misleading, distracting, or confusing.

(7) Display Response. The dynamic response of the display should be sufficient to present discernable and readable information that is not misleading, distracting, or confusing. The response time should be sufficient to ensure dynamic stability of colours, line widths, gray scale, and relative positioning of symbols. Undesirable display characteristics, such as smearing of moving images and loss of luminance, should be minimised so that information is still readable and identifiable under all foreseeable conditions, not distracting, and does not lead to misinterpretation of data.

(8) Display Refresh Rate. The display refresh rate should be sufficient to prevent flicker effects that result in misleading information or difficulty in reading or interpreting information. The display refresh rate should be sufficient to preclude the appearance of unacceptable flicker.

(9) [RESERVED]

(10) Display Defects. Display defects, such as element defects and stroke tails, resulting from hardware and graphical imaging causes should not impair readability of the displays or induce or cause erroneous interpretation. This is covered in more detail in SAE ARP 4256A, SAE AS 8034B, and 8055.

(11) [RESERVED]

(12) Flight Deck Viewing Envelope. The size of the viewing envelope should provide visibility of the flight deck displays over the flight crew's normal range of head motion, and support cross-flight deck viewing if necessary; for example, when it is required that the captain be able to view and use the first officer's primary flight information.

b. Installation

(1) Flight deck display equipment and installation designs should be compatible with the overall flight deck design characteristics (such as flight deck size and shape, flight crew member position, position of windows, external luminance, etc.) as well as the aeroplane environment (such as temperature, altitude, electromagnetic interference, and vibration).

(2) European Organisation for Civil Aviation Electronics (EUROCAE) ED-14 Environmental Conditions and Test Procedures for Airborne Equipment, at the latest revision, provides information that may be used for an acceptable means of qualifying display equipment for use in the aeroplane environment.

(3) [RESERVED]

(4) The installation of the display equipment must not adversely affect its readability and the external scene visibility of the flight crew under all foreseeable conditions relative to the operating and lighting environment (CS 25.1321(a), CS 25.773(a)(1)).

(5) The installation of the display equipment must not cause glare or reflection, either on the displays or on the flight deck windows, that could interfere with the normal duties of the minimum flight crew (CS 25.773(a)(2)) under all foreseeable conditions.

(6) If the display system design is dependent on cross-flight deck viewing for its use, the installation should take into account the viewing angle limitations of the display units, the size of the displayed information, and the distance of the display from each flight crew member.

(7) When a display is used to align or overlay symbols with real-world external data (for example, HUD symbols), the display should be installed such that the positioning accuracy of these symbols is maintained during all phases of flight. Appendix 6 to this AMC and SAE ARP 5288, Transport Category Aeroplane Head Up Display (HUD) Systems, provides additional details regarding the symbol positioning accuracy for conformal symbology on an HUD.

(8) The display system components should not cause physical harm to the flight crew under foreseeable conditions relative to the operating environment (for example, turbulence or emergency egress, bird strike, hard landing, and emergency landing).

(9) The installed display must not visually obstruct other controls and instruments or prevent those controls and instruments from performing their intended function (CS 25.1301).

(10) The display system must not be adversely susceptible to electromagnetic interference from other aeroplane systems (CS 25.1431) under all foreseeable conditions.

(11) The display components should be installed in such a way that they retain mechanical integrity (secured in position) for all foreseeable conditions relative to the flight environment.

(12) Liquid spill on or breakage of a display system component in the flight deck should not result in a hazard.

c. Power Bus Transient. EUROCAE document ED-14, at the latest revision, provides information that may be used for an acceptable means of qualifying display equipment such that the equipment performs its intended function when subjected to anomalous input power. SAE ARP 4256A, Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft, provides additional information for power transient recovery (specifically for the display unit).

(1) Flight deck displays and display systems should be insensitive to power transients caused by normal load switching operation of the aeroplane, in accordance with their intended function.

(2) The electronic attitude display should not be unusable or unstable for more than one second after electrical bus transients due to engine failure. Only displays on one side of the aeroplane should be affected by an engine failure. Recognisably valid pitch and roll data should be available within one second on the affected

displays and any effects lasting beyond one second should not interfere with the ability to obtain quick glance valid attitude. For most aeroplanes an engine failure after take-off will simultaneously create a roll acceleration, new pitch attitude requirements, and an electrical transient. Attitude information is paramount; if there is an engine failure, transfer to standby attitude or transfer of control of the aeroplane to the other pilot cannot be reliably accomplished in a timely enough manner to prevent an unsafe condition. In testing this failure mode, experience has shown that switching the generator off at the control panel may not result in the longest electrical transient. One practical way to simulate this failure is with a fuel cut which will allow the generator output voltage and frequency to decrease until the bus control recognises the failure. Other engine failure conditions may be more critical (such as sub-idle stalls) which cannot be reasonably evaluated during flight test. Analysis should identify these failure modes and show that the preceding criteria are met.

(3) Non-normal bus transients (for example, generator failure) should not initiate a power up initialisation or cold start process.

(4) The display response to a short term power interrupt (<200 milliseconds) should be such that the intended function of the display is not adversely affected.

(5) Following in-flight long term power interrupts (>200 milliseconds), the display system should quickly return to operation in accordance with its intended function, and should continue to permit the safe control of the aeroplane in attitude, altitude, airspeed, and direction.

(6) The large electrical loads required to restart some engine types should not affect more than one pilot's display during the start sequence.

17. – 20. [RESERVED]

CHAPTER 4. SAFETY ASPECTS OF ELECTRONIC DISPLAY SYSTEMS

21. General. This chapter provides additional guidance and interpretative material for applying CS 25.1309 and CS 25.1333(b) to the approval of display systems. Using electronic displays and integrated modular avionics allows designers to integrate systems to a much higher degree than was practical with previous flight deck components. Although operating the aeroplane may become easier as a result of the integration, evaluating the conditions in which the display system could fail and determining the severity of the resulting failure effects may become more complex. The evaluation of the failure conditions should identify the display function and include all causes that could affect that function's display and display equipment. CS 25.1309 defines the basic safety specifications for the airworthiness approval of aeroplane systems

a. Identification of Failure Conditions. One of the initial steps in establishing compliance with CS 25.1309 is identifying the failure conditions that are associated with a display or a display system. The following paragraphs provide material that may be useful in supporting this initial activity. The analysis of the failure condition should identify the impacted functionality, the effect on the aeroplane and/or its occupants, any considerations related to phase of flight, and identify any flight deck indication, flight crew action, or other relevant mitigation means.

(1) The type of display system failure conditions will depend, to a large extent, on the architecture (Integrated Modular Avionics, Federated System, Non-Federated

System, etc.), design philosophy, and implementation of the system. Types of failure conditions include:

— Loss of function (system or display).

— Failure of display controls – loss of function or malfunction such that controls perform in an inappropriate manner, including erroneous display control.

— Malfunction (system or display) that leads to:

— Partial loss of data, or

— Erroneous display of data that is either:

— Detected by the system (for example, flagged or comparator alert), and/or easily detectable by the flight crew; or

— Difficult to detect by the flight crew or not detectable and assumed to be correct (for example, "Misleading display of ….").

(2) When a flight deck design includes primary and standby displays, consider failure conditions involving the failure of standby displays in combination with the failure of primary displays. The flight crew may use standby instruments in two complementary roles following the failure of primary displays:

(a) Redundant display to cope with failure of main instruments, or

(b) Independent third source of information to resolve inconsistencies between primary instruments.

(3) When the display of erroneous information is caused by failure of other systems which interface with the display system, the effects of these failures may not be limited to the display system. Associated failure conditions may be dealt with at the aeroplane level or within the other systems' safety assessment, as appropriate, in order to assess the cumulative effect.

b. Effects of Display Failure Conditions. The effects of display system failure conditions on safe operations are highly dependent on pilot skills, flight deck procedures, phase of flight, type of operations being conducted, and instrument or visual meteorological conditions.

(1) Based on previous aeroplane certification programmes, paragraph 21e of this AMC shows examples of safety objectives for certain failure conditions. These safety objectives do not preclude the need for a safety assessment of the actual effects of these failures, which may be more or less severe depending on the design. Therefore, during the CS 25.1309 safety assessment process, the Agency will need to agree with the applicant's hazard classifications for these failure conditions in order for the assessment to be considered valid.

(2) When assessing the effects that result from a display failure, consider the following, accounting for phases of flight when relevant:

— Effects on the flight crew's ability to control the aeroplane in terms of attitude, speed, accelerations, and flight path, potentially resulting in:

— Controlled flight into terrain,

— Loss of control of the aeroplane during flight and/or during critical flight phases (approach, take-off, go-around, etc.),

— Inadequate performance capability for phase of flight, including:
  — Loss of obstacle clearance capability, and
  — Exceeding take-off or landing field length.
— Exceeding the flight envelope,
— Exceeding the structural integrity of the aeroplane, and
— Causing or contributing to pilot induced oscillations.

— Effects on the flight crew's ability to control the engines, such as:
  — Those effects resulting in shutting down a non-failed engine in response to the failure of a different engine, and
  — Undetected, significant thrust loss.
— Effects on the flight crew's management of the aeroplane systems.
— Effects on the flight crew's performance, workload and ability to cope with adverse operating conditions.
— Effects on situation awareness; for example, the specific effects must be identified, such as situation awareness related to navigation or system status.
— Effects on automation if the display is used as a controlling device.

(3) When the display system is used as a control device for other aeroplane systems, consider the cumulative effect of a display system failure on all of the controlled systems.

c. Mitigation of Failure Conditions

(1) When determining mitigation means for a failure condition consider the following:

— Protection against common mode failures.
— Fault isolation and reconfiguration.
— Redundancy (for example, heading information may be provided by an independent integrated standby and/or a magnetic direction indicator).
— Availability of, level of, timeliness of, and type of, alert provided to the flight crew.
— The flight phase and the aircraft configuration.
— The duration of the condition.
— The aircraft motion cues that may be used by the flight crew for recognition.
— Expected flight crew corrective action on detection of the failure, and/or operational procedures.
— In some flight phases, ability of the flight crew to control the aeroplane after a loss of primary attitude display on one side.
— The flight crew's ability to turn off a display (for example, full bright display at night).