European Aviation Safety Agency

30 Nov 2009

NOTICE OF PROPOSED AMENDMENT (NPA) NO 2009-12

DRAFT DECISION OF THE EXECUTIVE DIRECTOR OF THE EUROPEAN AVIATION SAFETY AGENCY

Amending Decision No. 2003/02/RM of the Executive Director of the European Aviation Safety Agency of 17 October 2003 on certification specifications, including airworthiness codes and acceptable means of compliance, for large aeroplanes (« CS-25 »)

"Avionics"

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A. EXPLANATORY NOTE

I. General

1. The purpose of this Notice of Proposed Amendment (NPA) is to envisage amending Certification Specifications for large Aeroplanes (CS-25) as originally issued by Executive Director's Decision 2003/2/RM of 17 October 2003[1] and last amended by Executive Director's Decision 2009/013/R of 14 October 2009[2] (CS-25 Amendment 6). The scope of this rulemaking activity is outlined in Terms of Reference (ToR) 25.037(a) and is described in more detail below.

2. The European Aviation Safety Agency (hereinafter referred to as the Agency) is directly involved in the rule-shaping process. It assists the Commission in its executive tasks by preparing draft regulations, and amendments thereof, for the implementation of the Basic Regulation[3] which are adopted as "Opinions" (Article 19(1)). It also adopts Certification Specifications, including Airworthiness Codes and Acceptable Means of Compliance and Guidance Material to be used in the certification process (Article 19(2)).

3. When developing rules, the Agency is bound to follow a structured process as required by Article 52(1) of the Basic Regulation. Such process has been adopted by the Agency's Management Board and is referred to as "The Rulemaking Procedure"[4].

4. This rulemaking activity is included in the Agency's 4-year Rulemaking Programme for 2010. It implements the rulemaking task 25.037(a): Avionics (see Note below).

5. The text of this NPA is based on harmonised text developed within the ARAC Avionic Systems Harmonisation Working Group (ASHWG) and later developed by the Agency to comply with the rulemaking procedures. It is submitted for consultation of all interested parties in accordance with Article 52 of the Basic Regulation and Articles 5(3) and 6 of the Rulemaking Procedure.

<u>Note</u>: Due to time constraints imposed on the ASHWG in the USA by the Commercial Aviation Safety Team (CAST), the proposed revisions to AC/AMC 25-11 do not address new technologies, such as Enhanced Vision Systems and Synthetic Vision Systems, as originally stipulated in the ASHWG's terms of reference. These tasks will now be undertaken in a second phase of work with EASA participation. EASA rulemaking task 25.037 has therefore been split into 2 parts, with part (b) containing the new technologies and will be added to a future Agency rulemaking programme.

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[1] Decision No 2003/02/RM of the Executive Director of the Agency of 17 October 2003 on Certification Specifications, Including Airworthiness Code and Acceptable Means of Compliance, for Large Aeroplanes (« CS-25 »). Decision as last amended by Decision 2009/010/R of the Executive Director of the Agency of 26 June 2009.

[2] Decision No. 2009/013/R of the Executive Director of the European Aviation Safety Agency of 14 October 2009 on Certification Specifications, Including Airworthiness Code and Acceptable Means of Compliance, for Large Aeroplanes (« CS-25 Amendment 7»).

[3] Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.03.2008, p. 1).

[4] Management Board decision concerning the procedure to be applied by the Agency for the issuing of opinions, certification specifications and guidance material (Rulemaking Procedure), EASA MB 08-2007, 13.6.2007.

II. Consultation

6. To achieve optimal consultation, the Agency is publishing the draft decision of the Executive Director on its Internet site. Comments should be provided within 3 months in accordance with Article 6(4) of the EASA rulemaking procedure. Comments on this proposal should be submitted by one of the following methods:

CRT: Send your comments using the Comment-Response Tool (CRT) available at **http://hub.easa.europa.eu/crt/**.

E-mail: In case the use of CRT is prevented by technical problems, these should be reported to the CRT webmaster and comments sent by e-mail to NPA@easa.europa.eu.

Correspondence: If you do not have access to the Internet or e-mail, you can send your comment by mail to:

Process Support
Rulemaking Directorate
EASA
Postfach 10 12 53
D-50452 Cologne
Germany

Comments should be submitted **by 03 March 2010**. If received after this deadline, they might not be taken into account.

III. Comment response document

7. All comments received in time will be responded to and incorporated in a comment response document (CRD). The CRD will be available on the Agency's website and in the Comment-Response Tool (CRT).

IV. Content of the draft decision

8. This task combines two issues that are interrelated.

9. Alerting Systems

CS-25 contains a certification specification (CS 25.1322) that dictates the colour of warning, caution, advisory, and other message lights that are installed as annunciation displays in the flight deck. As presently written, CS 25.1322 addresses visual alerts only in the form of coloured lights installed in the flight deck. No specifications are stipulated to cover new technologies or the use of alternate media, such as aural tones/voice that can be more effective. CS 25.1322 is therefore considered outdated and does not address the safety concerns associated with today's display systems.

10. Electronic Displays

AMC 25–11, Electronic Display Systems, contains an acceptable means of compliance for the airworthiness approval of electronic display systems. The scope of the AMC is limited and pertains strictly to cathode ray tube (CRT) based electronic display systems used for guidance, control, or decision-making by the flight crew. The AMC is outdated in view of the integrated computer-based display systems used in modern aeroplanes and does not address new technologies such as liquid crystal displays.

11. The envisaged changes to CS-25 (Decision 2003/2/RM) are:

- Deletion and replacement of CS 25.1322: Warning, caution, and advisory lights
- Deletion and replacement of AMC 25.1322: Alerting Systems
- Deletion and replacement of AMC 25-11: Electronic Display Systems

V. Justification

12. CS 25.1322 Title: The title of CS 25.1322 is changed from 'Warning, caution, and advisory lights' to 'Flight crew alerting' to reflect the extended scope. Previously CS 25.1322 addressed only dedicated visual alerting lights, but now includes all flight crew alerting functions, including aural, tactile, other visual display alerting methods, and integrated smart flight crew alerting systems.

13. CS 25.1322(a): Performance based requirements for all flight crew alerting methods are stipulated. These performance based requirements will increase flight safety by defining the alerting elements that should be included in a given alert category, the information content, ease and immediacy of detection, and alert intelligibility, in all foreseeable operating conditions.

14. CS 25.1322(b): Some conditions that generate alerts are more urgent and safety critical than others. CS 25.1322(b) requires the applicant to create a prioritisation hierarchy dependent on the urgency of flight crew awareness and the urgency of flight crew response. By doing so, more urgent alerts can be programmed to be presented first, thereby minimising the delay in flight crew awareness and in taking the appropriate action.

15. CS 25.1322(c): In the case of Warning and Caution alerts, it is often necessary to further prioritise alerts within each category to ensure time critical alerts are given priority and to avoid the presentation of multiple alerts simultaneously. Furthermore, to ensure immediate flight crew awareness of Warning and Caution alerts irrespective of flight crew attentiveness or workload levels, such alerts must use two different senses when presenting the alert to the crew. AMC material gives guidance on best practice for selecting the combinations of alert elements.

16. CS 25.1322(d): A new airworthiness standard is introduced to minimise nuisance effects in the presentation of alerts to the flight crew. A nuisance alert is an alert generated by a system that is functioning as designed, but is inappropriate or unnecessary for the particular condition. For example, the landing gear configuration warning may be automatically inhibited in those flight phases where that warning is clearly unnecessary and would distract the flight crew. Nuisance alerts must be minimised since the flight crew's assessment of a nuisance alert increases their workload, reduces their confidence in the alerting system, and affects their reaction time to legitimate alerts. In addition, CS 25.1322(d)(2) requires a means to suppress an attention getting component of an alert caused by a failure of the alerting function itself, together with a clear and unmistakable indication that the alert has been suppressed. In such a case, the means to suppress an alert must not be readily available to the flight crew such that it could be operated inadvertently or by habitual reflexive action. For example, the action of suppressing an aural alert or extinguishing a flashing master warning or caution light by reaching forward and pressing the alerting light (switch light) is a common acceptable means of suppressing the attention getting component of an alert, but would not be acceptable for suppressing an alert caused by failure of the alerting system.

17. CS 25.1322(e): This paragraph removes the existing ability to deviate from the colour standard for flight crew visual alerts and creates a single and consistent colour standard for alert categories across all future large aeroplane flight decks. As colour coding is used as the primary means for distinguishing between alert categories, this will avoid potential human factors issues associated with pilots flying multiple types. The proposed

colour standard is similar to the existing standard for indicator lights in CS 25.1322(a) and (b), but would now extend to include all visual alerts. The colour "yellow" is added to proposed CS 25.1322(e)(1)(ii) so that either amber or yellow can be used for caution alert indications. Yellow was added because it is commonly used in flight deck displays and is visually similar to amber. The text from current CS 25.1322(c) regarding use of the colour "green" has not been retained because green is used to indicate safe operation, not a flight crew alert. Green is mentioned in proposed § 25.1322(e)(1)(iii) to specify that it cannot be used for an advisory alert.

While colour is considered the primary means to distinguish between alert categories, it is recognised that certain displays, such as head-up displays (HUD) located in the pilot's primary field of view, are monochromatic and are not capable of displaying alerting colours. Since there is an overall safety benefit in displaying alerts on the HUD, visual display coding techniques other than colour need to be used for alerts appearing in the HUD. Proposed CS 25.1322(e)(2) requires that visual monochromatic displays use display features to assist the flight crew in clearly distinguishing between warning, caution, and advisory alert categories. For example, consistent display coding techniques such as location, shape, font style, size, boxing, texture, and other coding methods may be used.

18. CS 25.1322(f): Proposed CS 25.1322(f) would allow the use of the colours red, amber, and yellow for non-alerting functions only if the applicant shows that such use is limited and would not adversely affect flight crew alerting by impairing their ability to interpret and respond to an alert. By standardising the colours used for alerts and by limiting the use of the above colours for other functions on the flight deck, the flight crew will be more likely to both rapidly detect an alert and understand the urgency of the alert.

19. AMC 25.1322: AMC 25.1322 is fully revised and expanded to provide acceptable means of compliance and guidance material for compliance with the new CS 25.1322. While the AMC is not mandatory, it is derived from extensive certification experience and industry best practice.

20. AMC 25-11: AMC 25–11 Electronic Display Systems, contains guidance for demonstrating compliance with CS 25.1322. The scope of the AMC is limited and pertains strictly to cathode ray tube (CRT) based electronic display systems used for guidance, control, or decision making by the flight crew. The guidance is clearly outdated in view of the computer-based and other advanced technological instruments used in modern aeroplanes today.

VI. Harmonisation

21. This task was originally developed jointly under the Avionic Systems Harmonisation Working Group (ASHWG), with the involvement of FAA, JAA and industry specialists. Following submission of the ASHWG's recommendations to FAA/JAA in May 2004 (FAR/JAR 25.1322 & AC/ACJ 25.1322) and in June 2006 (AC/AMC 25-11), and as a result of the creation of EASA, some loss in harmonisation has unavoidably occurred, resulting in the FAA having already published proposals without further coordination.

22. The following is a list of FAA publications equivalent to the contents of this NPA:

EASA (NPA 2009-12)	FAA Equivalent	FAA Status
AMC 25-11	AC 25-11A	Published 21/06/2007
CS 25.1322	FAR 25.1322	NPRM published 09/07/09. (Docket No. FAA 2008-1292)
AMC 25.1322	AC 25.1322-1X	Draft – Not yet published

23. The text of CS 25.1322 proposed in this NPA is different from the text of the associated FAA NPRM. Prior to publication of the NPRM, coordination meetings between FAA and EASA specialists were initiated, with the aim of providing harmonised text between FAA and EASA for both rule and AC/AMC. Consideration has also been given during these discussions to public comments received as part of the NPRM process. The result of these harmonisation discussions proposed to revise the NPRM rule text, primarily to provide greater clarity of the rule and to avoid possible ambiguity. The resulting text now forms the text of CS 25.1322 as part of this NPA. and is expected to be adopted by the FAA.
24. AC/AMC 25.1322, which has also diverged in the intervening period since the ASHWG recommendations, will be subject to a joint FAA/EASA review as part of a post-NPA harmonisation activity. Comments are specifically invited on the differences in presentation and format between FAA draft AC 25.1322-1X and AMC 25.1322.
25. The proposed amendment to AMC 25-11 is based on the published FAA AC 25-11A. Differences with FAA AC 25-11A are mainly reflecting European regulatory and guidance material (e.g. CS-25 instead of FAR 25). However, regarding Chapter 4, Safety Aspects of Electronic Display Systems, it was decided to maintain the original harmonised text in the tables presenting example safety objectives. The rationale for this is that an applicant is assumed to perform a system safety assessment for the particular design and hence the actual hazard classifications may differ significantly from pre-determined hazard classifications due to design and architecture characteristics, crew procedures and other mitigating or aggravating aspects.

VII. Regulatory Impact Assessment:

1. Purpose and intended effect:

a. Issue which the NPA is intended to address

The text of certification specification CS 25.1322 relating to flight crew alerting systems, was first introduced into JAR-25 Change 8 in 1981, and has never been amended since. It was written at the time when discrete warning lights were the normal method of flight crew alerting and is limited to prescribing colour standards associated with the level of alert.

Advances in crew interface and systems technologies have outpaced the existing specifications. Modern flight crew alerting systems include warnings integrated with electronic displays and use other media in addition to lights (e.g. aural tones/voice messages). Furthermore, the existing specifications were developed without addressing the importance of Human Factors and other safety related implementation issues. These issues have highlighted the inadequacy of the specifications, resulting in additional work for applicants and the Agency in developing and showing compliance with Special Conditions, and an adverse effect on certification costs and timescales.

b. Scale of the issue

Human Factors is now generally recognised as being a primary causal factor in between 60-80% of all large aeroplane accidents. Of these, flight crew error and flight crew-flight deck coupling vulnerabilities has been identified as the prime focal area. The JAA Human Factors Harmonisation Working Group (HFHWG) which was tasked by the JAA to research and analyse the broader issues of flight deck Human Factors has identified flight crew alerting systems as a current regulatory deficiency in CS-25. Flight crew alerting as a method of feedback in the flight deck has to be clear and unambiguous in order to be effective in supporting the flight crew's decision making process, hence reducing the risk of flight crew error.

This proposal would affect all new flight deck designs that are certificated to CS-25 and any significant changes to existing designs that include a comprehensive flight deck upgrade.

c. Brief statement of the objectives of the NPA

This proposal aims to amend CS 25.1322 to include certification specifications covering modern technology flight crew alerting systems. CS 25.1322 will be supported by harmonised advisory material (AMC 25.1322 and AMC 25-11).

2. Options:

a. The options identified

Option 1: Do nothing

Certification of flight crew alerting and display systems will be subject to existing specifications, supplemented where necessary by Special Conditions (SC) to address technological developments not covered.

Option 2: Voluntary Implementation

Airframe manufacturers, aircraft modifiers and avionics equipment manufacturers would voluntarily implement the proposed standards. EASA would encourage the industry to adopt the essence of the proposed standards when designing flight crew alerting and display systems.

Option 3: Rulemaking Action

EASA would amend CS 25.1322 and related AMCs to address the safety concerns associated with current and future flight deck designs and the technologies associated with flight crew alerting.

b. The preferred option selected:

Please see paragraph VII-5 below.

3. Sectors concerned:
Airframe manufacturers, aircraft modifiers, operators and avionics equipment manufacturers will be affected.

4. Impacts:

a. All identified impacts

i. Safety

Option 1

Retains existing rules and procedures and therefore has no safety impact. Modern flight deck alerting system would be subject to Special Conditions developed by the Agency.

Options 2

Safety may be increased. However, without a mandatory status, commercial factors may limit the level of uptake by industry, and lead to different standards being applied.

Option 3

The proposals will increase the minimum safety standard by providing new certification specifications and AMC that are commensurate with industry best practice for the design of flight deck systems and flight crew alerting systems.

ii. Economic

Option 1

No economic impact.

Options 2&3

The new standards and guidance material supports current industry practice. There may be a significant reduction in the certification costs and workload for airframe manufacturers, aircraft modifiers, avionics equipment manufacturers and the Agency, associated with the approval of modern technology flight crew alerting systems.

For airframe manufacturers, aircraft modifiers and avionics equipment manufacturers involved with the design of flight crew alerting systems to earlier technology standards, there may be additional costs incurred should they be required to comply with the intent of the new rule.

Any improvements in safety realised by the introduction of this proposed regulatory change will have the potential to reduce incidents and accidents with an associated economic benefit.

iii. Environmental

No effects on the environment have been identified.

iv. Social

No social impacts have been identified.

v. Other aviation requirements outside EASA scope

This proposal stems from a harmonised activity with the FAA.

FAA published Advisory Circular No. 25-11A *Transport Category Aeroplane Electronic Display Systems,* on 21 June 2007. This forms the basis for the proposed AMC 25-11 in this NPA.

Proposed CS 25.1322 and the associated AMC were originally developed within the ASHWG. FAA has published an NPRM on 09/07/09 (Docket No. FAA 2008-1292), covering the proposed rule change.

vi. Security

No security impacts have been identified.

b. Equity and fairness in terms of distribution of positive and negative impacts among concerned sectors:

Some smaller aircraft modifiers and avionic equipment manufacturers that are not involved with modern flight crew alerting and display systems may be disadvantaged if they are required to comply with the proposed regulatory change.

The proposed regulatory change will result in differences between CS 25.1322 and CS 23.1322, CS 27.1322, CS 29.1322. This may present problems to avionics equipment manufacturers that supply similar equipment to different aircraft categories.

5. Summary and Final Assessment:

a. Comparison of the positive and negative impacts for each option:

Option 1: Do nothing and Option 2 Voluntary Implementation

To adopt the "Do Nothing" or "Voluntary Implementation" approach will result in industry developing flight crew alerting systems and display systems without the benefits of the standardisation afforded by the proposed changes to CS 25.1322 and associated AMCs.

The Agency would still need to develop a Special Condition to cover the inadequate certification specifications, when addressing new flight deck designs and the latest display technologies.

Option 3: Rulemaking Action

Rulemaking action has the potential to improve safety levels and reduce the amount of work involved in compliance demonstration. The economic impact is considered to be positive or marginally negative, depending on whether the proposed rule is applied to a new or modified aircraft. This cost is however considered to be small in relation to the overall costs of the equipment and in relation to potential savings resulting from an increase in safety.

b. Summary describing who would be affected by these impacts and analysing issues of equity and fairness:

The large aircraft industry in general will be affected, including airframe manufacturers, aircraft modifiers, operators, avionic equipment manufacturers and EASA.

Those involved with the design of modern flight crew alerting systems, who have already adopted philosophies similar to those proposed by this change, would benefit from a simplified approval process, leading to economic savings. For those that have not, visibility of the standards acceptable to the Agency will allow pre-planning and any short-term economic burden would be more than off-set by avoidance of certification issues.

There may be indirect effect on manufacturers that design equipment for other aircraft categories i.e. CS-23, CS-27, CS-29.

c. Final assessment and recommendation of a preferred option:

After due consideration the EASA believes that Option 3 Rulemaking Action is to be preferred. The level of technology implemented by the industry in flight crew alerting and displays has surpassed and will continue to develop beyond that embedded in the current certification specifications. Therefore, it is considered necessary that CS-25 should accommodate these developments, as well as anticipate future developments, in order to address the related safety concerns and simplify the approval process.

B. PROPOSALS

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

1. deleted text is shown with a strike through: ~~deleted~~
2. new text is highlighted with grey shading: new
3. ….

   indicates that remaining text is unchanged in front of or following the reflected amendment.

I. CS 25.1322: Flight Crew Alerting

Replace existing CS 25.1322 with the following:

Book 1

SUBPART F - EQUIPMENT

CS 25.1322 Flight Crew Alerting
(See AMC 25.1322)

(a) Flight crew alerts must:
 1) provide the flight crew with the information needed to:
  i) identify non-normal operation or aeroplane system conditions, and
  ii) determine the appropriate action, if any.
 2) be readily and easily detectable and intelligible by the flight crew under all foreseeable operating conditions, including conditions where multiple alerts are provided.
 3) be removed when the alerting condition no longer exists.

(b) Alerts must conform to the following prioritisation hierarchy based on the urgency of flight crew awareness and urgency of flight crew response.
 1) Warning: For conditions that require immediate flight crew awareness and immediate flight crew response.
 2) Caution: For conditions that require immediate flight crew awareness and subsequent flight crew response.
 3) Advisory: For conditions that require flight crew awareness and may require subsequent flight crew response.

(c) Warning and Caution alerts must:
 1) be prioritised within each category, when multiple alerts would cause flight crew confusion, or the sequencing of flight crew response is necessary,
 2) provide timely attention-getting cues through at least two different senses by a combination of aural, visual, or tactile indications.
 3) permit each occurrence of the attention getting cues required by paragraph (c)(2) to be acknowledged and suppressed, unless they are required to be continuous.

(d) The alert function must be designed to minimise the effects of false and nuisance alerts. In particular, it must be designed to:

1) prevent the presentation of an alert that is inappropriate or unnecessary for the particular condition;

2) provide a means to suppress an attention getting component of an alert caused by a failure of the alerting function that interferes with the flight crew's ability to safely operate the aeroplane. This means must not be readily available to the flight crew such that it could be inadvertently operated, or by habitual reflexive action. In this case, there must be a clear and unmistakable annunciation to the flight crew that the alert has been suppressed.

(e) Visual alert indications must:

1) conform to the following colour convention:

i) Red for Warning alert indications.

ii) Amber or yellow for Caution alert indications.

iii) Any colour except red or green for Advisory alert indications.

2) use distinguishable coding techniques for Warning, Caution and Advisory alert indications, if they are shown on monochromatic displays.

(f) Use of the colours red, amber and yellow on the flight deck for functions other than flight crew alerting must be limited and must not adversely affect flight crew alerting.

II. AMC 25.1322: Flight Crew Alerting

Replace existing AMC 25.1322 with the following:

Book 2

SUBPART F - EQUIPMENT

AMC 25.1322
Flight Crew Alerting

Table of Contents

1. PURPOSE

This AMC provides an acceptable means of compliance and guidance for the design and approval of flight crew alerting functions or systems installed in the flight deck of large aeroplanes, for which a new, amended or supplemental type certificate is requested.

2. SCOPE

This AMC applies to the installation, integration, and certification of flight crew alerting functions or systems. It applies to individual aircraft systems that provide flight crew alerting functions that may or may not be integrated with a central alerting system, as well as to systems whose primary function is alerting, such as a central alerting system.

This AMC provides guidance to what is considered an alert. However, what should be alerted to the flight crew is dependent on the specific design and overall flight deck alerting philosophy. For example, the failure of a single sensor in a multi-sensor system in some cases may not necessarily result in an alert condition that the flight crew needs to be aware of. However, for a single sensor system, such a failure would certainly result in an alert. Thus, the applicant should establish the overall flight deck design and alerting philosophy when determining what should be alerted to the flight crew.

3. RELATED CERTIFICATION SPECIFICATIONS

The following list describes certification specifications for flight crew alerting for which this AMC provides an acceptable means of compliance.

CS 25.207	Stall warning

CS 25.253(a)(2)	High-speed characteristics
CS 25.672(a)	Stability Augmentation…
CS 25.679(a)	Control system gust locks
CS 25.699	Lift and drag device indicator
CS 25.703	Take-off warning system
CS 25.729(e)	Retracting mechanism
CS 25.783(e)	Fuselage Doors
CS 25.812(f)(2)	Emergency lighting
CS 25.819(c)	Lower deck service compartments
CS 25.841(b)(6)	Pressurised cabins
CS 25.854(a)	Lavatory fire protection
CS 25.857(b)(3)	Cargo compartment classification
CS 25.857(c)(1)	Cargo compartment classification
CS 25.857(e)(2)	Cargo compartment classification
CS 25.859(e)(3)	Combustion heater fire protection
CS 25.863(c)	Flammable fluid fire protection
CS 25.1019(a)(5)	Oil strainer or filter
CS 25.1165(g)	Engine ignition systems
CS 25.1203(b)(2)	Fire-detector system
CS 25.1203(b)(3)	Fire-detector system
CS 25.1203(f)(1)	Fire-detector system
CS 25.1302	Installed systems and equipment for use by the flight crew
CS 25.1303(c)(1)	Flight and navigation instruments
CS 25.1305(a)(1)	Powerplant instruments
CS 25.1305(a)(5)	Powerplant instruments
CS 25.1305(c)(7)	Powerplant instruments
CS 25.1309(c)	Equipment, systems, and installations
CS 25.1309(d)(4)	Equipment, systems, and installations
CS 25.1322	Warning, caution, and advisory lights
CS 25.1326	Pitot heat indication systems
CS 25.1329	Flight Guidance System
CS 25.1331(a)(3)	Instruments using a power supply
CS 25.1353(c)(6)(ii)	Electrical equipment and installations
CS 25.1419(c)	Ice protection
CS 25.1517(3)	Rough air speed, V_{RA}
CS 25.1549	Powerplant Instruments
CS 25J1305	APU Instruments
CS 25, Appendix I Section 25.6	Installation of an Automatic Take-off Thrust Control System (ATTCS) Powerplant Instruments
CS-AWO 153	Audible Warning of Automatic Pilot Disengagement
CS-AWO 253	Audible Warning of Automatic Pilot Disengagement
CS-AWO 352	Indications and Warnings

4. RELATED DOCUMENTS

Only those documents that were used as reference in developing this AMC are listed.

4.a <u>Federal Aviation Administration Documents</u>

(1) Report DOT/FAA/RD-81/38, II, Aircraft Alerting Systems Standardization Study, Volume II, Aircraft Alerting Systems Design Guidelines. This document can be obtained from the National Technical Information Service, Springfield, Virginia 22166

(2) AC 25-11, Transport Category Aeroplane Electronic Display Systems 7/16/87
(3) Report DOT/FAA/CT-96/1 - GAMA Report No 10, "Recommended Guidelines for Part 23 Cockpit/Flight Deck Design" (September 2000), Section 4, Definitions, Primary Field of View.
(4) AC 25-23 TAWS Terrain Awareness and Warning Systems
(5) AC 25-1309-1A System Design and Analysis
(6) TSO C-151a, Terrain Awareness and Warning Systems
(7) AC 25.1523-1, Minimum Flight Crew & Workload

4.b <u>EASA/NAA Documents</u>

(1) AMC 25-11, Electronic Display Systems
(2) Patterson, R.D. (1982). *Guidelines for Auditory Warning Systems on Civil Aircraft.* Cheltenham, England: Civil Aviation Authority paper 82017.

4.c <u>Industry Documents</u>

(1) Edworthy, J. and Adams, A. (1996). Warning Design: A Research Perspective. Bristol, PA: Taylor & Francis.
(2) Kuchar, J.K. (1996). Methodology for alerting-system performance evaluation. *Journal of Guidance, Control, and Dynamics. 19, 438-444.*
(3) Parasuraman, R., & Riley, V. (1997). Human and Automation: use, misuse, disuse, abuse. *Human Factors, 39,* 216-229.
(4) Satchell, P. (1993). *Cockpit monitoring and alerting systems.* Aldershot, England: Ashgate.
(5) SAE ARP 4033 (Pilot-System Integration), August 1995

5. BACKGROUND

In the past aeroplanes were designed with discrete lights for the alerting function. Now the alerting functions can be integrated with other systems, including electronic display systems, and additional alerting means are available e.g. tactile and aural. This AMC addresses the aspects of integration including prioritisation, commonality between types of alerts, competing simultaneous aural and visual alerts, correlation of aural and visual alerts, potential inhibiting of alerts, and the increased possibility of false or nuisance alerts.

CS-25 often provides references to an alert, such as a warning, to provide flight crew awareness of a certain flight or system condition. Many of these certification specifications were written without recognition of a consistent flight deck alerting philosophy, and may use terms such as "warning" in a generic sense that is not necessarily consistent with the definitions below. This AMC does not intend to conflict with or replace the intent of those certification specifications, but to provide standardisation of crew alerting terminology.

6. DEFINITIONS

Definitions are written to support the content of this AMC and its associated certification specification.

Advisory

The level of alert for conditions that require flight crew awareness and may require subsequent flight crew response

Alert

A generic term used to describe a flight deck indication meant to attract the attention of and identify to the flight crew a non-normal operational or aeroplane system condition. Alerts are classified at levels corresponding to Warning, Caution, and Advisory.

Alert Inhibit

Application of specific logic to prevent the presentation of an Alert.

Alert Message

A visual Alert comprised of text, usually presented on a flight deck display.

Alerting Function

The aircraft function that provides Alerts to the flight crew for non-normal operational or aeroplane system conditions. This includes Warning, Caution and Advisory information.

Alerting Philosophy

The principles. guidance and specifications for implementing Alerting Functions on a flight deck. These typically consider:

- The reason for implementing an Alert
- The level of Alert required for a given condition
- The characteristics of each specific Alert
- Integration of multiple Alerts

Attention Getting Cue

Indication (visual, auditory or tactile/haptic) designed to attract the flight crew's attention in order to obtain the immediate awareness that an Alert condition exists.

Caution

The level of alert for conditions that require immediate flight crew awareness and not immediate but subsequent flight crew response.

Collector Message

An Alert Message that replaces two or more related Alert Messages that do not share a common cause or effect. Example: A "Doors" alert Collector Message is displayed when more than one entry, cargo, or service access door is open at the same time.

Communication Message

A type of message whose initiating conditions are caused by incoming communications, primarily through a data link. This type of message is not a flight crew alert.

(1) **Comm High**: An incoming Communication Message which requires immediate flight crew awareness and immediate flight crew response. (Note: At this time there are no Communication Messages defined that require immediate flight crew response.)

(2) **CommMedium**: An incoming Communication Message which requires immediate flight crew awareness and subsequent flight crew response.

(3) **Comm Low**: An incoming Communication Message which requires flight crew awareness and future flight crew response.

False Alert

An incorrect or spurious Alert caused by a failure of the alerting system including the sensor.

Failure Flag

One local means of indicating the failure of a displayed parameter.

Flashing

Short term flashing symbols (approximately 10 seconds) or flash until acknowledge.

Master Aural Alert

An aural indication used to attract the flight crew's attention that is specific to an Alert urgency level (e.g. Warning, Caution).

Master Visual Alert

A visual indication used to attract the flight crew's attention that is specific to an Alert urgency level (e.g. Warning, Caution).

Normal Condition

Any fault-free condition typically experienced in normal flight operations. Operations typically well within the aircraft flight envelope and with routine atmospheric and environmental conditions.

Nuisance Alert

An Alert generated by a system that is functioning as designed but which is inappropriate or unnecessary for the particular condition.

Primary field of view

Primary Field-of-View is based upon the optimum vertical and horizontal visual fields from the design eye reference point that can be accommodated with eye rotation only. The description below provides an example of how this may apply to head-down displays.

With the normal line-of-sight established at 15 degrees below the horizontal plane, the values for the vertical (relative to normal line-of-sight forward of the aircraft) are +/-15 degrees optimum, with +40 degrees up and -20 degrees down maximum.

For the horizontal visual field (relative to normal line-of-sight forward of the aircraft), the values are +/-15 degrees optimum, and +/-35 degrees maximum.

Status

A specific aircraft system condition that is recognised using a visual indication, but does not require an alert and does not require flight crew response. These types of messages are sometimes used to determine aeroplane dispatch capability for subsequent flights.

Tactile/haptic Information

Indication means where the stimulus is via physical touch, force feedback or vibration (e.g. stick shaker).

Time-Critical Warning

A subset of Warning. The highest level of Warning for conditions that require immediate flight crew response to maintain the safe operation of the aeroplane. Examples of Time-Critical Warnings include:

- Predictive and Reactive Windshear Warning
- Terrain Awareness Warning (TAWS)
- TCAS Resolution Advisory
- Overspeed Warning
- Low Energy Warning

Umbrella Message

An Alert Message that is presented in lieu of two or more Alert Messages that share a common cause. Example: A single Engine Shutdown message in lieu of the multiple messages for electrical generator, generator drive, hydraulic pump and bleed air messages which would otherwise have been displayed.

Unique Tones (Unique Sounds)

An aural indication that is dedicated to specific Alerts. (e.g. fire bell, overspeed)

Visual Alert Information

A visual indication that presents the flight crew with data on the exact nature of the alerting situation. For an Advisory level Alert, it also provides the awareness.

Voice Information

Aural means for informing the flight crew of the nature of a specific condition.

Warning

The level of Alert for conditions that require immediate flight crew awareness and immediate flight crew response.

7. GENERAL

The purpose of alerting functions on aeroplanes is to get the attention of the flight crew, and inform the flight crew of specific aeroplane system conditions and certain operational events that require their awareness. The ability of the alerting function to accomplish its purpose is effected not only by the alert presentation itself, but also by the sensed condition and information processing for which the alert presentation was initiated. The alert presentation, condition sensing and information processing for the alert should all be designed to support the purpose of the alerting function.

Only aeroplane system conditions and operational events that require flight crew awareness to support a flight crew response should cause an alert. Conditions and events that do not require flight crew awareness should not cause an alert.

For all alerts which are presented to the flight crew, the action or accommodation for that alert must be either intuitive or a specific procedure must be provided to assist the flight crew in accomplishing corrective or compensatory action. Appropriate flight crew action for flight crew alerts are normally defined by aeroplane procedures (i.e. in checklists), and are trained as part of a flight crew training curriculum or considered basic airmanship.

The presentation of all alerting signals should be accomplished using a consistent Alerting Philosophy.

7.a Alert Presentation Elements

An alert typically includes one or more of the following presentation elements:

- Master Visual Alert
- Visual Alert Information
- Master Aural Alert
- Voice Information
- Unique Tone (Unique Sound)
- Tactile/haptic Information
- Failure Flag

Logic should be incorporated to ensure that the alerting functions are coordinated and provide the proper presentation format for each urgency level. For example, the onset of the Master Visual Alert should occur simultaneously with the onset of the Master Aural Alert.

To maintain the effectiveness of visual alerting, consistent use of the colours red and amber/yellow should be implemented throughout the flight deck. Colours used for Master Caution and Master Warning should match colours for their respective Caution and Warning visual alerts.

To maintain the effectiveness of voice alerting, the use of Voice Information as an alert element should be limited. When practical, the Voice Information should be identical to any alphanumeric message presented on an information display. However, as a minimum the voice and alphanumeric messages should be compatible and readily understandable.

A single alert element (e.g. failure flag on a primary flight displays), may be accepted as complying with CS 25.1322 (c)(2) provided that it has sufficient attention getting characteristics by itself.

7.b Functional Components for each type of alert

(1) Warning:

The alert elements used for Warnings typically include:

- Master Visual Alert, AND
- Visual Alert Information, AND
- Master Aural Alert or Voice Information or Unique Tone

Note: Voice Information may be preceded by a Master Aural Alert

It is recognised that in a limited number of cases a Master Visual Alert and Master Aural Alert may not be required. For example, Visual Information presented in the pilot's primary forward field of view may be acceptable in place of a Master Visual Alert if it provides sufficient attention-getting characteristics.

For Time-critical Warnings, the alerting elements described above should be supplemented with additional alerting elements to provide immediate flight crew awareness of the specific condition without further reference to other indications in the flight deck. The alerting elements for Time-Critical Warnings should include:

- Unique Voice Information and/or Unique Tone for each condition, AND

Unique Visual Alert Information in both pilots' primary forward field of view for each condition.

Note: For Time-critical Warnings, the use of a Master Visual Alert is not required. However, if the Master Visual Alert is used, it should aid in the overall attention-getting characteristics and should not distract the flight crew from the time-critical condition.

(2) Caution

The alert elements used for Caution are typically identical to those used for Warnings, as both require immediate flight crew awareness.

Some Caution level alerts are related to conditions that are precursors to potential Time-Critical Warning conditions. In these cases, the alerting elements associated with the Caution should be consistent with the elements for related Time-Critical Warnings. For example, a TCAS II Traffic condition, which can be a precursor to a TCAS II Resolution Advisory condition, may not have an associated Master Visual Alert ("master caution") and is acceptable because the TCAS Traffic Voice Information alone provides the characteristic of a Caution.

(3) Advisory

The alert elements used for Advisory typically include:

- Visual Alert Information - Advisory information may be located in an area where the flight crew is expected to periodically scan for information

Note: Advisory information does not require immediate flight crew awareness and therefore does not require an attention getting Master Visual Alert or Master Aural Alert.

Aural or visual information such as maintenance messages, information messages, and other status messages associated with conditions that do not require an alert may be presented to the flight crew, but the presentation of this information should not interfere with the alerting function or its use.

7.c Alerting System Reliability and Integrity

The alerting functions or system should be designed to avoid False Alerts and Nuisance Alerts, while providing reliable alerts to the flight crew when needed.

For establishing compliance of the alerting functions or system with CS 25.1309, both the failure to operate when required and false operation should be considered.

When applying CS 25.1309 to a particular function or system that has an associated flight crew alert, both the failure of the function/system and a failure of its associated alert should be assessed. This should include assessing the effect of a single (common mode) failure that could cause the loss or failure of a system function and the loss of any associated alerting function.

When assessing compliance with CS 25.1309, particular attention should be paid to the following:

- Availability of the flight crew alerting functions; although the individual assessment of not presenting an alert for a given system when required may lead to a specific consequence, the impact of a larger or a complete failure of the crew alerting function may lead to a more severe consequence, and should be assessed.
-
- Integrity of the alerting system driving the flight crew's confidence. Since the individual assessment of a False Alert or Nuisance Alert for a given system may lead to a specific consequence, the impact of frequent False Alerts or Nuisance Alerts increases the flight crew’s workload, reduces the flight crew’s confidence in the alerting function, and affects their reaction in case of a real alert.

8. MANAGEMENT OF ALERTS

8.a Prioritisation

The objective of prioritisation is to provide the most urgent alert to the flight crew first.

(1) General Guidelines

Alerts must be prioritised based upon urgency of flight crew awareness and urgency of flight crew response. A Warning has the highest priority, followed by a Caution and then an Advisory.

A prioritisation scheme should be established for all alerts presented throughout the flight deck. Prioritisation within each category (Warning, Caution) may also be necessary. For example, JAA TGL-12 (TAWS) identifies situations where prioritisation within alert categories is necessary. The prioritisation scheme, as well as the rationale for prioritisation should be documented and evaluated.

Documentation should include the results of analysis showing that any alerts delayed or inhibited as the result of the prioritisation scheme do not adversely impact safety.

(2) Multiple Aural Alerts

Aural alerts should be prioritised so that only one aural alert is presented at a time. However, if more than one aural alert is presented at the same time, each should be clearly distinguishable and intelligible to the flight crew.

When aural alerts are provided, an active alert should be completed before initiating another aural alert. However, active aural alerts may be interrupted by alerts from higher urgency levels if the delay to annunciate the higher priority alert would impact the timely response of the flight crew. If the interrupted alert condition is still active, it may be repeated once the higher urgency alert is completed.

(3) Multiple Visual Alerts

Since two or more visual alerts can occur at the same time, it should be shown that each alert is clearly recognisable to the flight crew.

Visual Alert Information should be prioritised between levels. When multiple alerts exist in a specific level (i.e. multiple Warnings, multiple Cautions), a means for the flight crew to determine the most recent or most urgent alert should be provided. For example, the most recent or highest priority alert may be listed at the top of its own category.

8.b Alert Inhibits

Alert Inhibits are used to prevent the presentation of an alert which is inappropriate or unnecessary for the particular phase of operation.

Alert Inhibits are techniques that can be used to avoid multiple simultaneous alerts, alert information overload and display clutter. Alerts may be inhibited automatically or manually by the flight crew.

The presentation of alerts should be inhibited under certain conditions where:

- The alert could cause a hazard if the flight crew was distracted by or responded to the alert.
- The alert contributes to display clutter
- The alert provides unnecessary information or awareness of aeroplane conditions

A number of consequential alerts may be combined into a single higher-level alert (e.g. Umbrella Message).

For certain operational conditions not recognised by the alerting functions, a means may be provided for the flight crew to inhibit a potential alert that would be expected to occur as the result of the specific operation (e.g. preventing a landing configuration alert for a different landing flap setting). There should be a clear and unmistakable indication that an alert has been manually inhibited by the flight crew, for as long as the inhibit exists.

8.c Clear / Recall of Alert Messages

Clearing Alert Messages from the current display allows the flight crew to remove a potential source of distraction. If a message can be cleared, the system should provide the ability to recall any cleared Alert Message that has been acknowledged where the condition still exists.

There should be a means to identify if alerts are stored (or otherwise not in view), either through a positive indication on the display or through normal flight crew procedures.

8.d Considerations for interface or integration with other systems (ex. checklist, synoptics, switches, discrete lamps)

All annunciations and indications used to present an alert should be consistent with wording, colour, position, or other attributes they may share. Any other information (e.g. synoptic pages) associated with the alert condition should facilitate the flight crew's ability to identify the alert condition and determine any correct action.

Information conveyed by the alerting function or system should lead the flight crew to the correct checklist procedure to facilitate the correct flight crew action. Some alerts may not have an associated checklist procedure because the correct flight crew action is covered by training or basic airmanship (e.g. autopilot disconnect, Time-Critical Warnings).

8.e Colour standardisation

CS 25.1322(f) requires that "*The use of the colours red, amber and yellow on the flight deck for functions other than flight crew alerting must be limited and must not adversely affect flight crew alerting.*"

This applies to the use of these colours on both alerting functions and non-alerting functions including displays and other indications. The objective is to limit the use of red and amber/yellow within the flight deck so that these colours always provide an indication of immediacy of response commensurate with the associated hazard.

For discrete lights and indicators, the use of red and amber/yellow should be limited exclusively to flight crew alerting functions. However, the use of red and amber/yellow for non-alerting functions may also be appropriate in the flight deck. Agency approval can be expected if any of the following guidelines are met:

A. Red may be used (on both alerting and non-alerting functions) for conditions that require immediate flight crew awareness and immediate flight crew response.
B. Amber/yellow may be used (on both alerting and non-alerting functions) for conditions that require immediate flight crew awareness and subsequent flight crew response.
C. If the colours red or amber/yellow are proposed to be used in any other way, the following should be considered:
    1. The use of red and amber/yellow is appropriate to the task and context of use;
    2. The proposed use does not affect the attention getting qualities of the alerting functions across the flight deck.

Examples of acceptable uses of red and amber/yellow related to the paragraphs above typically include:

- Engine and airframe limit indications;
- Failure flags;
- Electronic checklist elements that correlate to an alert;

- Indications that correlate to an associated alert;
- Weather radar;
- Approaching terrain associated with a terrain awareness warning

It is appropriate to use red or amber/yellow failure flags and system indicators for failures/exceedances associated with hazard conditions requiring immediate flight crew awareness. In these cases, the colour should be selected based on the level of urgency. For example, it is appropriate to have the EGT engine limit as red because in the event of an exceedance, this condition requires immediate flight crew awareness and immediate flight crew response. However, it would not be appropriate to use a red flag to indicate the loss of weather radar data, because immediate flight crew response is not required.

8.f Suppression of False Alerts

Pulling circuit breakers should not be the prime means by which the flight crew suppress an alert.

9. CERTIFICATION TEST AND EVALUATION CONSIDERATIONS

Because alerting functions or systems vary in complexity, level of integration and number and types of alerts, these functions may raise specific certification issues. Thus it is recommended that an applicant develops a plan to establish and document how issues will be identified, tracked, and resolved throughout the life cycle of the project. Applicants typically use the certification programme for this purpose. For addressing human factors/pilot interface issues applicants should refer to CS 25.1302 and AMC 25.1302.

It is recommended that the applicant documents the means of compliance with the appropriate certification specifications, as well as document compliance to and/or divergence from this AMC. Additionally, rationale should be provided for decisions regarding new or novel features in the design of the alerting functions or system. This will facilitate the certification evaluation in that it enables the Agency to focus on evaluating areas where the proposed functions diverge from the accepted means of compliance and have new or novel features. Thus, areas where the applicant has demonstrated compliance with this AMC would typically receive less scrutiny.

The type of certification evaluation will vary depending upon the complexity, degree of integration, and specifics of the alerting function or system proposed. The evaluation should include an assessment of acceptable performance of the intended functions, including the human-machine interface, and acceptability of failure scenarios of the alerting function. The scenarios should reflect the expected operational use of the functions. The compliance demonstration of the performance and integrity aspects will typically be accomplished by a combination of the following methods:

- Analysis
- Laboratory Test
- Simulation
- Flight Test

The certification programme should include evaluations of the alerts in isolation and combination throughout appropriate phases of flight and manoeuvres, as well as representative environmental and operational conditions. The alerting functions as a whole needs to be evaluated in a representative flight deck environment. Representative simulators can be used to accomplish the evaluation of some human factors and workload studies. The level and fidelity of the simulator used should be commensurate with the certification credit being sought and its use should be agreed with the Agency. The assessment of the alerts may be conducted in a laboratory, simulator or in the actual aircraft. Certain elements of the alerting functions or system may have to be validated in the actual aircraft. The evaluation should be conducted by a representative population of pilots of various background and expertise.

Some specific aspects that should be considered during the evaluation(s) include:

- Visual, aural, and tactile/haptic aspects of the alert(s)
- The effectiveness of the intended alerting function and its impact on human/machine integration, flight crew workload, and the potential for flight crew errors and confusion
- Normal and emergency cancellation logic and accessibility of related controls
- Proper integration with other systems, including labelling
- Acceptability of operation during failure modes
- Compatibility with other displays and controls
- The absence of False Alerts, prevention of Nuisance Alerts and the potential for interference with other systems
- Inhibition of alerts for specific phases of flight (e.g., take-off and landing) and for specific aeroplane configurations (e.g. abnormal flaps and gear).

Evaluations may also be useful to verify the chromaticity (e.g., red looks red, amber looks amber) and that colours can be distinguished reliably from each other under the expected lighting levels. These evaluations can be affected by the development state of the equipment being used. Therefore, final evaluation with qualified production hardware may be required.

10 APPLICABILITY TO CHANGED PRODUCTS

10.a Purpose

This paragraph addresses the integration of flight crew alerting functions associated with changes to existing aeroplanes that have already been type certificated.

Any change affecting alerting functions should be compatible with the aircraft flight deck alerting philosophy.

10.b Visual Alerts

(1) Master Visual Alert. A determination should be made in accordance with paragraph 7.b of this AMC if any added system features alerts that require activation of a Master Visual Alert.

(2) The existing aircraft alerting functions or system may not be able to facilitate the integration of additional aircraft systems and associated alerts due to limitations in the system inputs, incompatible technologies between the aircraft and the system being added, or economic considerations. In this case, the following should be considered:

(i) The incorporation of an additional Master Visual Alert is discouraged. However, if it is not feasible to interface with the existing Master Visual Alert, an additional Master Visual Alert may be installed, provided that it does not delay the flight crew's response time for recognising and responding to the alert.

(ii) New alerts should be integrated with existing alerting functions or system where possible. If these alerts cannot be integrated, dedicated indications or an additional alerting display system may be added.

(iii) It is permissible for some failure flags not to be integrated with the existing alerting functions.

(iv) A failure flag may be accepted as complying with CS 25.1322(c)(2) provided that it has sufficient attention getting characteristics by itself.

10.c Aural Alerts

(1) A determination should be made in accordance with this AMC, if the added system will require activation of an aural alert.

(2) If possible this new aural alert should be integrated with the existing aural alerting functions or system. If this is not possible, separate aural alerting functions or system may be introduced provided that all of the following have been considered:

(i) A means is provided to set a prioritisation scheme in place between existing aural alerts and the new aural alerts such that each alert is recognised and can be acted upon in the time frame appropriate for the alerting situation.

(ii) Each individual alert can be understood and acted upon. This may require a demonstration of any likely combination of simultaneous alerts.

(iii) The material provided in this AMC should be utilised in determining the prioritisation for the integration of new aural alerts with existing aural alerts

10.d Special Considerations for Head-Up Displays (HUDs)

A HUD, when used as Primary Flight Display (PFD), should provide the equivalent alerting indications as a head-down display (HDD). Alerts that require continued flight crew awareness on the PFD should be presented on the HUD (e.g., TCAS, Windshear, and Ground Proximity Warning alerts). In addition, if the Master Visual Alert does not provide a sufficient attention getting cue to the pilot while using the HUD, the HUD should provide equivalent cues.

An alert that is presented on a HUD may include attributes which are different than those presented on a HDD. To the extent that current HUDs are single colour devices, Cautions and Warnings should be emphasised with the appropriate use of attention-getting properties such as flashing, outline boxes, brightness, size, and/or location. Report No. DOT/FAA/RD-81/38, II stresses the importance of preserving the distinguishing characteristics of Caution and Warning alerts. Where multi-colour HUD symbols are used for alerts, consideration should be given to ensure consistency between the HUD and the HDD.

For dual HUD installations, each HUD should provide attention getting cues equivalent to those provided on the on-side HDDs.

APPENDIX A: EXAMPLES OF VISUAL ALERTING ELEMENTS

Examples are included in this AMC to help the reader through the detailed design of alerting functions or systems. They are based on experience of existing and recommended alerting functions or systems that comply with the certification specifications. The extent to which these examples are applied to a specific certification project will vary, depending on the types of alerts that are presented, and the level of integration associated with them.

Visual alert elements may include:

- Master Visual Alert
- Visual Alert Information
- Visual Alert Information For Time-Critical Warning
- Failure Flags

A.1 Master Visual Alert

(1) Number & Location

A Master Visual Alert for Warnings ("master warning") and a Master Visual Alert for Cautions ("master caution") should be installed at each pilot's station and located directly in front of each pilot in their primary field of view.

(2) Onset/Duration/Cancellation

The onset of a Master Visual Alert should occur in a timeframe appropriate for the alerting condition and the desired response.

The onset of a Master Visual Alert should occur simultaneously with the onset of its related Master Aural Alert or Unique Tone, and its related Visual Alert Information. Any delays between the onset of the Master Visual Alert and its related Master Aural Alert or Unique Tone, and its Visual Alert Information should not cause flight crew distraction or confusion.

The onset of Master Visual Alerts for the same condition (Warnings, Cautions) should occur simultaneously at each pilot's station.

The Master Visual Alert should remain on until it is cancelled either manually by the flight crew, or automatically when the alerting situation no longer exists.

Upon cancellation, the alerting mechanisms should be reset to annunciate any subsequent fault condition.

(3) Attention-getting visual characteristics

In addition to colour, steady state or Flashing Master Visual Alerts may be used, as long as the method employed provides positive attention-getting characteristics. If Flashing is used, all Master Visual Alerts should be synchronous to avoid any unnecessary distraction.

(4) Brightness

Master Visual Alerts should be bright enough to attract the attention of the flight crew in all ambient light conditions.

Manual dimming should not be provided unless the minimum setting retains adequate attention-getting qualities when flying under all ambient light conditions.

(5) Display/Indicator Size and Character Dimensions

Any character types, sizes and fonts should be designed so that the Master Visual Alerts are legible and understandable at each pilot's station where they are installed and should provide suitable attention-getting characteristics.

(6) Test function

To comply with CS 25.1309, provisions may need to be included to test/verify the operability of the Master Visual Alerts.

A.2 Visual Alert Information

(1) Number & Location

The number of displays that provide Warning, Caution, and Advisory alerts should be determined by a combination of ergonomic, operational and reliability criteria, as well as any flight deck physical space constraints.

(2) The Visual Alert Information should be located so that both pilots are able to readily identify the alert condition.

(3) All Warning and Caution Visual Alert Information linked to a Master Visual Alert should be grouped together on a single dedicated display area. There may be a separate area for each pilot. Advisory alerts may also be presented on the same display area. The intent is to provide an intuitive and consistent location for the display of information.

(4) Format

A consistent philosophy should be provided for the format of Visual Alert Information to unambiguously indicate the alert condition. The objectives of the corresponding text message format are to direct the flight crew to the correct checklist procedure, and to minimise the risk of flight crew error.

The alerting philosophy should describe the format for Visual Alert Information. A consistent format should be used.

A format philosophy should include the following three elements:

- The general heading of the alert, (e.g. HYD, FUEL)
- the specific subsystem or location (e.g. L-R, 1-2), and,
- the nature of the condition (e.g. FAIL, HOT, LOW)

For any given message, the available space on a single page should be able to present the entire text on a single defined area to encourage short and concise messages. Additional lines may be used provided the Visual Alert Information is clear and unambiguous.

If alerts are presented on a limited display area, an overflow indication should be used to inform the flight crew that additional alerts may be called up for review. A memory indication should be used to indicate the number and urgency level of the alerts that have been stored.

A “Collector Message” is a technique that can be used to resolve problems of insufficient display space, prioritisation of multiple alert conditions, Visual Alert Information overload and display clutter.

Collector Messages should be used where the procedure or action is different for the multiple fault condition than the procedure or action for the individual messages being collected. Example: Non-normal procedures for loss of a single hydraulic system on its own are different to non-normal procedures for loss of two hydraulic systems. The messages that are “collected” should be inhibited.

An alphanumeric font should be of a sufficient thickness and size to be readable when users are seated at the normal viewing distance from the screen.

NOTE: Minimum character height of 1/200 of viewing distance has been shown to be acceptable (e.g. a viewing distance of 0.91 m (36 inches) requires a 4.57 mm (0.18 inch) character height on the screen)(DOD-CM-400-18-05, p 12-1).

NOTE: Arial and Sans serif fonts have been shown to be acceptable for visual alert text. The size of numbers and letters required to achieve acceptable readability may depend on the display technology used. Stroke width between 10% and 15% of character height appears to be best for word recognition on text displays and extensions of descending letters and ascending letters should be about 40% of letter height.

(5) Luminance

The Visual Alert Information should be bright enough so that both pilots are able to readily identify the alert condition in all ambient light conditions.

The luminance of the Visual Alert Information display may be adjusted automatically as ambient lighting conditions on the flight deck change. A manual override control may be provided to enable the pilots to adjust display luminance.

A.3 Visual Alert Information For Time-Critical Warning

(1) Number & Location

Visual Alert Information for Time-Critical Warnings should be provided directly in front of each pilot within their primary field of view.

Note: The Primary Flight Display (PFD) is used as a practical and preferred display to use as the Time-Critical Warning display. Integration of time critical information into the PFD may vary depending on the exact nature of the warning. For example, a dedicated location on the PFD may be used both as an attention-getting function and a visual information display by displaying alerts such as “WINDSHEAR”, “SINK RATE”, “PULL UP”, “TERRAIN AHEAD”, “CLIMB, CLIMB” etc. In addition, graphic displays of target pitch attitudes for TCAS RAs and Terrain may also be included.

(2) Format

Visual Alert Information for Time-Critical Warnings should be consistent with the corresponding Time-Critical Warning aural information.

Visual Alert Information for Time-Critical Warnings may be presented as a text message (for example, “WINDSHEAR”). Certain Visual Alert Information for Time-Critical Warnings, including guidance, may be presented graphically (for example, TCAS Resolution Advisory).

Text messages that are used for Visual Alert Information for Time-Critical Warnings should be red.

The Visual Alert Information for Time-Critical Warnings should be erased when corrective actions have been taken, or when the alerting situation no longer exists

A.4 Failure Flags

The use of failure flags on flight deck instruments is a means of indicating failures of displayed parameters or their data source. In the sense that these flags indicate failures of aeroplane systems, they have been displayed using colours that are the same as for flight crew alerts. Failure flags are typically associated with only single instrument displays and as such do not necessarily satisfy all of the guidance material for flight crew alerts in general. However, in the integrated environment of the flight deck it is appropriate to display instrument failure flags in a colour consistent with the alerting system, as part of the alerting function (see paragraph 8.e). Conditions that set failure flags may also generate flight crew alerts and the subsequent flight deck indications should be consistent.

APPENDIX B: EXAMPLES OF AURAL ALERTING ELEMENTS

Examples are included in this AMC to help the reader through the detailed design of alerting functions or systems. They are based on experience of existing and recommended alerting functions or systems that comply with the certification specifications. The extent to which these examples are applied to a specific certification project will vary, depending on the types of alerts and the level of integration associated with them.

Aural alert elements may include:

- Unique Tones, including Master Aural Alerts
- Voice Information

B.1 Master Aural Alert and Unique Tones

The applicant should establish a matched set of tones for flight crew aural alerting. The characteristics of each Unique Tone, including Master Aural Alerts, should be clearly distinguishable by means of frequency, sequence, intensity, etc.

(1) Frequency

Aural signals composed of at least two different frequencies or aural signals composed of only one frequency that contain different characteristics (e.g. spacing) have been found to be acceptable.

To minimise masking, frequencies different from those that dominate background noise should be used.

(2) Intensity

The aural alerting must be audible to the flight crew in the worst-case (ambient noise) flight conditions whether or not the flight crew is wearing headsets (taking into account their noise attenuation characteristics). The aural alerting should not be so loud and intrusive as to interfere with the flight crew taking the required action.

The minimum volume achievable by any adjustment (manual or automatic) (if provided) of aural alerts should be adequate to ensure it can be heard by the flight crew if the level of flight deck noise subsequently increases.

Automatic volume control is recommended to maintain an acceptable signal-to-noise ratio.

(3) Number of Tones

The number of Unique Tones (including Master Aural Alerts), should be limited, based on the ability of the flight crew to readily obtain information from each alert and tone. Previous research has concluded that this number should be limited to less than 10.

In general, one Unique Tone for master warning and one Unique Tone for master caution should be provided. A master aural tone for advisories is not recommended.

(4) Onset/Duration

It is recommended that the onset and offset of any aural alert or Unique Tone be ramped to avoid startling the flight crew.

The onset of the Master Aural Alert or Unique Tone should occur in a timeframe appropriate for the alerting condition and the desired response. Any delays between the onset of the Master Aural Alert or Unique Tone and its related visual alert should not cause flight crew distraction or confusion.

If more than one source of the Master Aural Alert or Unique Tone is provided, the Master Aural Alert or Unique Tone for the same condition should occur simultaneously and synchronously at each pilot's station. Any timing differences should not be distracting nor should they interfere with identification of the aural alert or Unique Tone.

Signal duration of the Master Aural Alert and Unique Tones should vary, depending on the alert urgency level and the type of response desired.

Unique Tones associated with Time-Critical Warnings should be repeated and non-cancellable until the alerting condition no longer exists (e.g. stall warning), unless it interferes with the flight crew's ability to respond to the alerting condition.

Unique Tones associated with Warnings should be repeated and non-cancellable if the flight crew needs continuous awareness that the condition still exists, to support the flight crew in taking corrective action (ref. CS 1303.c.(1), Flight and Navigation Instruments, and CS 25.729.e, Retracting Mechanism).

If the flight crew does not need continuous aural indication that the condition still exists, then Unique Tones associated with Warnings should either:

(i) be repeated and cancellable by the flight crew if a positive acknowledgement of the alert condition is required (e.g. Fire bell, abnormal autopilot disconnect), or
(ii) not be repeated.

Master Aural Warnings should be repeatable until the flight crew acknowledges the warning condition or when the warning condition no longer exists.

For Master Aural Alerts associated with Cautions and Unique Tones associated with a Caution, the sound should be limited in duration or can be continuous until the flight crew manually cancels it, or when the Caution condition no longer exists.

Unique Tones that are neither associated with a Warning nor a Caution (e.g. certain advisories, altitude alert, SELCAL), should be limited in duration.

(5) Cancellation

For Caution level alerts, the Master Aural Alert and Unique Tone should continue through one presentation and cancel automatically.

If there is any tone associated with an Advisory, it should be presented once and then cancelled automatically.

An aural alert should automatically be re-armed after cancellation. However, if there is a clear and unmistakable annunciation in each pilot's forward field of view that the aural alerts are cancelled, manual re-arming is acceptable.

B.2 Voice Information

NOTE: The purpose for using Voice Information is to indicate conditions that demand immediate flight crew awareness of a specific condition without further reference to other indications in the flight deck.

Voice Information may be applied:

- To limit the number of Unique Tones
- To transfer workload from the visual to the auditory channel
- To enhance the identification of an abnormal condition, and effectively augment the visual indication.
- To provide information to the flight crew where a voice message is preferable to other methods
- Where awareness of the alert must be assured no matter where the pilot's eyes are pointed

(1) Voice Characteristics

The voice characteristics should be distinctive and intelligible.

Voice characteristics should include attention-getting qualities appropriate for the level of the alert.

(2) Voice Inflection

Voice inflection has been used in the past to indicate a sense of urgency. However, an alarming tone indicating tension or panic is not recommended, since it may be inappropriately interpreted by flight crews of differing cultures. Depending on the alerting condition, advising and commanding inflections may be used to facilitate corrective action, but the content of the message itself should be sufficient.

(3) Intensity

The aural alerting must be audible to the flight crew in the worst-case (ambient noise) flight conditions whether or not the flight crew is wearing headsets (taking into account their noise attenuation characteristics). The aural alerting should not be so loud and intrusive as to interfere with the flight crew taking the required action.

The minimum volume achievable by any adjustment (manual or automatic) (if provided) of aural alerts should be adequate to ensure it can be heard by the flight crew if the level of flight deck noise subsequently increases.

Automatic volume control is recommended to maintain an acceptable signal-to-noise ratio.

(4) Onset/Duration

The onset of the Voice Information should occur in a timeframe appropriate for the alerting condition and the desired response.

The onset of the Voice Information should occur simultaneously with the onset of its related Visual Alert Information. Any synchronisation delays should not cause flight crew distraction or confusion.

If more than one source of the Voice Information is provided for the same condition, they should occur simultaneously and synchronously at each pilot's station so that intelligibility is not affected.

Voice Information associated with Time-Critical Warnings should be repeated and non-cancellable until the alerting condition no longer exists (e.g. terrain warning). However, Voice Information associated with Time-Critical Warnings should *not* be repeated if they interfere with the flight crew's ability to respond to the alerting condition (e.g. windshear warning, TCAS resolution advisory).

Voice Information associated with Warnings should be repeated and non-cancellable if the flight crew needs continuous awareness that the condition still exists, to support the flight crew in taking corrective action. However, Voice Information associated with Warnings should be repeated and cancellable if the flight crew does not need continuous aural indication that the condition still exists (e.g. Cabin Altitude Warning, Autopilot Disconnect).

Upon cancellation the alert should be reset to annunciate any subsequent alert condition.

For voice alerts associated with a Caution, the corresponding Voice Information should be limited in duration (e.g. TCAS Traffic Advisory, Windshear Caution), or can be continuous until the flight crew manually cancels it or the Caution condition no longer exists.

(5) Voice Information Content

The content of the Voice Information should consider the flight crew's ability to understand the spoken language.

It may be acceptable to consider the use of languages other than aviation English (either replaced entirely or alternating with a native language).

For Time-Critical Warnings, the content and vocabulary of Voice Information should express the immediacy of flight crew response and provide intuitive identification of the alerting condition. In some cases, it may also be necessary to include guidance or instruction information.

For Warnings and Cautions the content of Voice Information should provide an indication of the nature of the alerting condition.

The content of Voice Information should be consistent with any related visual information display.

Voice Information that uses more than one word should be structured to avoid incorrect or misleading information if one or more words are missed (e.g. the word "don't" at the beginning of a voice message should be avoided).

Voice Information messages should be designed to minimise confusion with each other.

III. AMC 25-11: Electronic Flight Deck Displays

Replace existing AMC 25-11 with the following:

Book 2
GENERAL
ACCEPTABLE MEANS OF COMPLIANCE - AMC

AMC 25-11
Electronic Flight Deck Displays

Content

CHAPTER 1
BACKGROUND

1. What is the purpose of this AMC?

This AMC provides an acceptable means of compliance for demonstrating compliance with certain certification specifications of CS-25, as well as general guidance for the design, installation, integration, and approval of electronic flight deck displays, components, and systems installed in large aeroplanes.

2. Who does this AMC apply to?

a. The acceptable means of compliance and guidance provided in this document is directed to aeroplane and avionics manufacturers, modifiers, and operators of large aeroplanes.

b. This material describes acceptable means, but not the only means, for demonstrating compliance with the applicable certification specifications. The Agency will consider other methods of demonstrating compliance that an applicant may elect to present. While these guidelines are not mandatory, they are derived from extensive Agency and industry experience in determining compliance with the relevant certification specifications. Applicants for a European Technical Standard Order (ETSO) approval should consider following this AMC when the ETSO does not provide adequate or appropriate specifications.

3. [RESERVED]

4. General

This AMC applies to the design, integration, installation, and certification approval of electronic flight deck displays, components, and systems for large aeroplanes. As a minimum this includes:

- General airworthiness considerations,
- Display system and component characteristics,
- Safety and criticality aspects,
- Functional characteristics,
- Display information characteristics,
- Guidance to manage display information,
- Flight crew interface and interactivity, and
- Airworthiness approval (means of compliance) considerations.

Table 1, below, lists the topics included in this AMC. Table 2, below, lists the topics not included in this AMC.

Table 1: Topics Covered in this AMC

Topics
Electronic pilot displays – including single function and multi-function displays.
Display features and functions that are intended for use by the pilot.
Display functions not intended for use by the pilot if they may interfere with the pilot's flying duties.
Display aspects of Class III Electronic Flight Bag (installed equipment).
Controls associated with the electronic displays covered in this AC. 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, showing 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.

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,
- 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) 8034A, *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 FAA 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 FAA certification engineer 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 AC 25-11A, follow the guidance in AC 25-11A.

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 8034A, and SAE AS 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 station in 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.

(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 8034A, and SAE AS 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) RTCA DO-160E, *Environmental Conditions and Test Procedures for Airborne Equipment*, and European Organisation for Civil Aviation Electronics (EUROCAE) ED-14E, *Environmental Conditions and Test Procedures for Airborne Equipment*, provide 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 positioning accuracy of these symbols is maintained during all phases of flight. SAE ARP 5288, *Transport Category Aeroplane Head Up Display (HUD) Systems*, provides additional details regarding the symbol positioning accuracy for conformal symbology on a 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).

(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. RTCA DO-160E and EUROCAE document ED-14E provide 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:
  - o Partial loss of data, or
  - o 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:
  - o Controlled flight into terrain,
  - o Loss of control of the aeroplane during flight and/or during critical

flight phases (approach, take-off, go-around, etc.),

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

- Effects on the flight crew's ability to control the engines, such as:
  - o Those effects resulting in shutting down a non-failed engine in response to the failure of a different engine, and
  - o 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).

- Protections provided by other systems (for example, flight envelope protection or augmentation systems).

(2) The mitigation means should be described in the safety analysis/assessment document or by reference to another document (for example, a system description document). The continued performance of the mitigation means, in the presence of the failure conditions, should also be identified and assured.

(3) The safety assessment should include the rationale and coverage of any display system protection and monitoring philosophies used in the design. The safety assessment should also include an evaluation of each of the identified display system failure conditions and an analysis of the exposure to common mode/cause or cascade failures in accordance with AMC 25.1309. Additionally, the safety assessment should justify and describe any functional partitioning schemes employed to reduce the effect of integrated component failures or functional failures.

d. Validation of the Classification of Failure Conditions and Their Effects.

There may be situations where the severity of the effect of the failure condition identified in the safety analysis needs to be confirmed. Laboratory, simulator, or flight test may be appropriate to accomplish the confirmation. The method of validating the failure condition classification will depend on the effect of the condition, assumptions made, and any associated risk. If flight crew action is expected to cope with the effect of a failure condition, the information available to the flight crew should be useable for detection of the failure condition and to initiate corrective action.

e. System Safety Guidelines.

(1) Experience from previous certification programmes has shown that a single failure due to a loss or malfunction of the display system, a sensor, or some other dependent system, which causes the misleading display of primary flight information, may have negative safety effects. It is recommended that the display system design and architecture implement monitoring of the primary flight information to reduce the probability of displaying misleading information.

(2) Experience from previous certification programmes has shown that the combined failure of both primary displays with the loss of the standby system can result in failure conditions with catastrophic effects.

(3) When an integrated standby display is used to provide a backup means of primary flight information, the safety analysis should substantiate that common cause failures have been adequately addressed in the design, including the design of software and complex hardware. In particular, the safety analysis should show that the independence between the primary instruments and the integrated standby instruments is not violated because the integrated standby display may interface with a large number of aeroplane components, including power supplies, pitot static ports, and other sensors.

(4) There should be a means to detect the loss of or erroneous display of primary flight information, either as a result of a display system failure or the failure of an associated sensor. When loss or malfunction of primary flight information is detected, the means used to indicate the lost or erroneous information should ensure that the erroneous information will not be used by the flight crew (for example, removal of the information from the display or placement of an "X" through the failed display).

(5) The means used to indicate the lost or erroneous information, when it is detected, should be independent of the failure mechanism. For example, the processor that originates the erroneous parameter should not be the same processor that annunciates or removes the erroneous parameter from the display. Common mode failures of identical processor types should be considered (for example, common mode failures may exist in a processor used to compute the display parameters and an identical processor used for monitoring and annunciating failures.)

(6) A catastrophic failure condition should not result from the failure of a single component, part, or element of a system. Failure containment should be provided by the system design to limit the propagation of the effects of any single failure and preclude catastrophic failure conditions. In addition, there should not be a common cause failure that could affect both the single component, part, or element and its failure containment provisions.

(7) For safety-critical display parameters, there should be a means to verify the correctness of sensor input data. Range, staleness, and validity checks should be used where possible.

(8) The latency period induced by the display system, particularly for alerts, should not be excessive and should take into account the criticality of the alert and the required crew response time to minimise propagation of the failure condition.

(9) For those systems that integrate windowing architecture into the display system, a means should be provided to control the information shown on the displays, such that the integrity of the display system as a whole will not be adversely impacted by anomalies in the functions being integrated. This means of controlling the display of information, called window manager in this AMC, should be developed to the software assurance level at least as high as the highest integrity function of any window. For example, a window manager should be level "A" if the information displayed in any window is level "A" (see RTCA DO-178B). SAE ARP 4754, *Certification Consideration for Highly-Integrated or Complex Aircraft Systems*, provides a recommended practice for system development assurance.

(10) System Safety Assessment Guidelines. The complete set of failure conditions to be considered in the display system safety analysis and the associated safety objective are established during the system safety assessment, and agreed upon by the applicant and the approving civil airworthiness agency. The safety assessment should consider the full set of display system intended functions as well as display system architecture and design philosophy (for example, failure modes, failure detection and annunciation, redundancy management, system and component independence and isolation). The system safety analysis is required by CS 25.1309, and indirectly by other specifications, including CS 25.901, CS 25.903, and CS 25.1333.

The following tables provide examples of failure conditions and associated safety objectives common to numerous display systems that are already certified. These tables are provided to identify a set of failure conditions that need to be considered; however, these are only examples. These examples do not replace the need for a system safety assessment and are not an exhaustive list of failure conditions. For these example failure conditions, additional functional capabilities or less operational mitigation may result in higher safety objectives, while reduced functional capability or increase operational mitigation may result in lower safety objectives.

1 Attitude (Pitch and Roll). The following table lists examples of safety objectives for attitude related failure conditions.

Table 3
Example Safety Objectives for
Attitude Failure Conditions

Failure Condition	Safety Objective
Loss of all attitude displays, including standby display	Extremely Improbable
Loss of all primary attitude displays	Remote - Extremely Remote (*)
Display of misleading attitude information on both primary displays	Extremely Improbable
Display of misleading attitude information on one primary display	Extremely Remote
Display of misleading attitude information on the standby display	Remote
Display of misleading attitude information on one primary display combined with a standby failure (loss of attitude or incorrect attitude)	Extremely Improbable (**)

(*) System architecture and functional integration should be considered in determining the classification within this range. This failure may result in a sufficiently large reduction in safety margins to warrant a hazardous classification.

(**) Consistent with the “Loss of all attitude display, including standby display” safety objective, since the flight crew may not be able to identify the correct display. Consideration will be given to the ability of the flight crew to control the aeroplane after a loss of attitude primary display on one side in some flight phases (for example, during take-off).

2 Airspeed. The following table lists examples of safety objectives for airspeed related failure conditions.

Table 4

Example Safety Objectives for
Airspeed Failure Conditions

Failure Condition	Safety Objective
Loss of all airspeed displays, including standby display	Extremely Improbable
Loss of all primary airspeed displays	Remote - Extremely Remote(*)
Display of misleading airspeed information on both primary displays, coupled with loss of stall warning or loss of over-speed warning	Extremely Improbable
Display of misleading airspeed information of the standby display (primary airspeed still available)	Remote
Display of misleading airspeed information on one primary display combined with a standby failure (loss of airspeed or incorrect airspeed)	Extremely Improbable (**)

(*) System architecture and functional integration should be considered in determining the classification within this range. This failure may result in a sufficiently large reduction in safety margins to warrant a hazardous classification.

(**) Consistent with the "Loss of all airspeed display, including standby display" safety objective, since the flight crew may not be able to separate out the correct display.

3 **Barometric Altitude.** The following table lists examples of safety objectives for barometric altitude related failure conditions.

Table 5
Example Safety Objectives for
Barometric Altitude Failure Conditions

Failure Condition	Safety Objective
Loss of all barometric altitude displays, including standby display	Extremely Improbable
Loss of all barometric altitude primary displays	Remote - Extremely Remote(*)
Display of misleading barometric altitude information on both primary displays	Extremely Improbable

Display of misleading barometric altitude information on the standby display (primary barometric altitude still available)	Remote
Display of misleading barometric altitude information on one primary display combined with a standby failure (loss of altitude or incorrect altitude)	Extremely Improbable (**)

(*) System architecture and functional integration should be considered in determining the classification within this range. This failure may result in a sufficiently large reduction in safety margins to warrant a hazardous classification.

(**) Consistent with the "Loss of all barometric altitude display, including standby display" safety objective since the flight crew may not be able to separate out the correct display. Consideration should be given that barometric setting function design is commensurate with the safety objectives identified for barometric altitude.

4 **Heading.** The following table lists examples of safety objectives for heading related failure conditions.

(aa) The standby heading may be provided by an independent integrated standby or the magnetic direction indicator.

(bb) The safety objectives listed below can be alleviated if it can be demonstrated that track information is available and correct.

Table 6
Example Safety Objectives for
Heading Failure Conditions

Failure Condition	**Safety Objective**
Loss of stabilised heading in the flight deck	Remote
Loss of all heading displays in the flight deck	Extremely Improbable
Display of misleading heading information on both pilots' primary displays	Remote - Extremely Remote(*)
Display of misleading heading information on one primary display combined with a standby failure (loss of heading or incorrect heading)	Remote – Extremely Remote(*)

(*) System architecture and functional integration should be considered in determining the classification within this range. This failure may result in a sufficiently large reduction in safety margins to warrant a hazardous classification.

(**) This assumes the availability of an independent, non-stabilised heading required by CS 25.1303 (a)(3).

5 Navigation and Communication (Excluding Heading, Airspeed, and Clock Data). The following table lists examples of safety objectives for navigation and communication related failure conditions.

Table 7
Example Safety Objectives for
Certain Navigation and Communication
Failure Conditions

Failure Condition	**Safety Objective**
Loss of display of all navigation information	Remote(*)
Non-restorable loss of display of all navigation information coupled with a total loss of communication functions	Extremely Improbable
Display of misleading navigation information simultaneously to both pilots	Remote – Extremely Remote
Loss of all communication functions	Remote

(*) “All” means loss of all navigation information, excluding heading, airspeed, and clock data. If any or all of the latter information is also lost then a higher classification may be warranted.

6 Other Parameters (Typically Shown on Electronic Display Systems). The following table lists examples of safety objectives for failure conditions related to other parameters typically shown on electronic display systems.

Table 8
Example Safety Objectives for
Failure Conditions of Other Parameters

Failure Condition	**Safety Objective**
Display of misleading flight path vector information to one pilot	Remote (*)
Loss of all vertical speed displays	Remote
Display of misleading vertical speed information to both pilots	Remote
Loss of all slip/skid indication displays	Remote
Display of misleading slip/skid indication to both pilots	Remote

Display of misleading weather radar information	Remote (**)
Total loss of flight crew alerting displays	Remote
Display of misleading flight crew alerting information	Remote
Display of misleading flight crew procedures	Remote – Extremely Improbable (****)
Loss of the standby displays	Remote

(*) The safety objective may be more stringent depending on the use and on the phase of flight.

(**) Applicable to the display part of the system only.

(***) Applicable to the general case, however, some cases could be more severe. Additional guidance is in the ARAC recommendations for proposed AMC 25.1322.

(****) To be evaluated depending on the particular procedures and associated situations.

7 Engine. Table 9, below, lists examples of generally accepted safety objectives for engine related failure conditions. Appendix 2 of this AMC provides additional guidance for powerplant displays.

(aa) The term “required engine indications” refers specifically to the engine thrust/power setting parameter (for example, engine pressure ratio, fan speed, or torque) and any other engine indications that may be required by the flight crew to maintain the engine within safe operating limits (for example, rotor speeds or exhaust gas temperature).

(bb) The information in Table 9 is based on the premise that the display failure occurs while operating in an autonomous engine control mode. Autonomous engine control modes, such as those provided by full authority digital engine controls, protect continued safe operation of the engine at any thrust lever setting. Hence, the flight deck indications and associated flight crew actions are not the primary means of protecting safe engine operation.

(cc) Where the indications serve as the primary means of assuring continued safe engine operation, the hazard classification may be more severe. For example, under the table entry “Loss of one or more required engine indications on more than one engine,” the hazard classification would change to “Catastrophic” and the probability would change to “Extremely Improbable.”

(dd) Each of the general failure condition descriptions provided in Table 9 represents a set of more specific failure conditions. The hazard classifications and probabilities provided in Table 9 represent the most severe outcome typically associated with any failure condition within the set. If considered separately, some of the specific failure conditions within each set would likely have less severe hazard classifications and probabilities.

Table 9
Example Safety Objectives for
Engine Failure Conditions

Failure Condition	**Safety Objective**
Loss of one or more required engine indications for a single engine	Remote
Misleading display of one or more required engine indications for a single engine	Remote
Loss of one or more required engine indications for more than one engine	Remote - Extremely Remote(*****)
Misleading display of any required engine indications for more than one engine	Extremely Remote - Extremely Improbable(******)

(*****) The worst anticipated outcomes associated with this class of failure may often be driven by consideration of the simultaneous loss of all required engine indications. In any case, those outcomes will typically include both a high speed take-off abort and loss of the backup means to assure safe engine operations. High speed aborts have typically been classified as “hazardous” by the Agency due to the associated impacts on both flight crew workload and safety margins. Since any number of single failures or errors can defeat the protections of a typical autonomous engine control, losing the ability to backup the control is considered a sufficiently large reduction in the safety margins to also warrant a “hazardous” classification. Hence the “Extremely Remote” design guideline was chosen.

(******) If the power setting parameter is indicating higher than actual during take-off, this can lead directly to a catastrophe, either due to a high speed runway overrun or impacting an obstacle after take-off. This classification has been debated and sustained by the Agency numerous times in the past. Hence the “Extremely Improbable” probability is listed.

8 Use of Display Systems as Controls. Hazard classifications and safety objectives are not provided for display systems used as controls because the failure conditions are dependant on the functions and systems being controlled or on alternative means of control. The use of display systems as controls is described in Chapter 7 of this AMC. The following table lists the failure conditions when display systems are used as controls.

Table 10
Failure Conditions for Display Systems Used as Controls

Failure Condition	**Safety Objective**
Total loss of capability to use the display system as a control	Depends on system being controlled.
Undetected erroneous input from the display system as a control	Depends on system being controlled.

22.– 30. [RESERVED]

CHAPTER 5.
ELECTRONIC DISPLAY INFORMATION ELEMENTS AND FEATURES

31. Display Information Elements and Features. This chapter provides guidance for the display of information elements including text, labels, symbols, graphics, and other depictions (such as schematics) in isolation and in combination. It covers the design and format of these information elements within a given display area. Chapter 6 of this AMC covers the integration of information across several display areas in the flight deck, including guidance on flight deck information location, display arrangement, windowing, redundancy management, and failure management.

a. General.

(1) The following list provides objectives for each display information element, in accordance with its intended function:

- Each flight, navigation, and powerplant instrument for use by any pilot must be plainly visible to him from his station with the minimum practicable deviation from his normal position and line of vision when he is looking forward along the flight path (CS 25.1321(a)).
- The displayed information should be easily and clearly discernable, and have enough visual contrast for the pilot to see and interpret it. Overall, the display should allow the pilot to identify and discriminate the information without eyestrain. Refer to paragraph 16a(4) of this AMC for additional guidance regarding contrast ratio.
- For all display configurations, all foreseeable conditions relative to lighting should be considered. Foreseeable lighting considerations should include failure modes such as lighting and power system failure, the full range of flight deck lighting and display system lighting options, and the operational environment (for example, day and night operations). If a visual indicator is provided to indicate a malfunction of an instrument, it must be effective under all foreseeable lighting conditions (CS 25.1321(e)).
- Information elements (text, symbol, etc.) should be large enough for the pilot to see and interpret in all foreseeable conditions relative to the operating environment and from the flight crew station. If two or more pilots need to view the information, the information elements should also be discernable and interpretable over these viewing distances.

- The pilots should have a clear, unobstructed, and undistorted view of the displayed information.
- Information elements should be distinct and permit the pilots to immediately recognise the source of the information elements when there are multiple sources of the same kind of information. For example, if there are multiple sources for vertical guidance information, then each informational element should be distinct so the flight crew can immediately recognise the source of the vertical guidance.

(2) Factors to consider when designing and evaluating the viewability and readability of the displayed information include:

- Position of displayed information: Distance from the design eye position (DEP) is generally used. If cross-flight deck viewing of the information is needed, distance from the offside DEP, accounting for normal head movement, should be used. For displays not mounted on the front panel, the distance determination should include any expected movement away from the DEP by the flight crew.
- Vibrations: Readability should be maintained in adverse conditions, such as vibration. One possible cause of vibration is sustained engine imbalance. AMC 25-24, *Sustained Engine Imbalance*, provides readability guidance for that condition.

- Visual Angles: Account for both the position of the displayed information as well as font height. SAE ARP 4102/7, *Electronic Displays,* provides additional information on this subject.
- Readability of Display Information: The Illuminating Engineering Society classifies three main parameters that affect readability: luminance, size, and contrast. Size is the combination of font size and distance from the display.

b. Consistency. Display information should be presented so it is consistent with the flight deck design philosophy in terms of symbology, location, control, behaviour, size, shape, colour, labels, dynamics and alerts. Consistency also applies to the representation of information on multiple displays on the same flight deck. Display information representing the same thing on more than one display on the same flight deck should be consistent. Acronyms and labels should be used consistently, and messages/annunciations should contain text in a consistent way. Inconsistencies should be evaluated to ensure that they are not susceptible to confusion or errors, and do not adversely impact the intended function of the system(s) involved.

c. Display Information Elements

(1) **Text.** Text should be shown to be distinct and meaningful for the information presented. Messages should convey the meaning intended. Abbreviations and acronyms should be clear and consistent with established standards. For example, International Civil Aviation Organization (ICAO) document 8400, *Procedures for Air Navigation Services ICAO Abbreviations and Codes*, provides internationally recognised standard abbreviations and airport identifiers.

(a) Regardless of the font type, size, colour, and background, text should be readable in all foreseeable lighting and operating conditions from the flight crew station (CS 25.1321(a)). General guidelines for text are as follows:

- Standard grammatical use of upper and lower case letters is recommended for lengthy documentation and lengthy messages. Using this format is also helpful when the structure of the text is in sentence form.
- The use of only upper case letters for text labels is acceptable.
- Avoid contractions, such as "can't" instead of "cannot."
- Break lines of text only at spaces or other natural delimiters.
- Avoid abbreviations and acronyms where practical.
- SAE ARP 4102/7, *Electronic Displays*, provides guidelines on font sizes that are generally acceptable.

(b) The choice of font also affects readability. The following guidelines apply:

- To facilitate readability, the font chosen should be compatible with the display technology. For example, serif fonts may become distorted on some low pixel resolution displays. However, on displays where serif fonts have been found acceptable, they have been found to be useful for depicting full sentences or larger text strings.
- Sans serif fonts (for example, Futura or Helvetica) are recommended for displays viewed under extreme lighting conditions.

(2) **Labels.** Labels may be text or icons. The following paragraphs provide guidance on labelling items such as knobs, buttons, symbols, and menus. This guidance applies to labels that are on a display, label a display, or label a display control. CS 25.1555(a) requires that each flight deck control, other than controls whose function is obvious, must be plainly marked as to its function and method of operation. Controls whose functions are not obvious should be marked or identified so that a flight crew member with little or no familiarity with the aeroplane is able to rapidly, accurately, and consistently identify their functions.

(a) Text and icons should be shown to be distinct and meaningful for the function(s) they label. Standard or non-ambiguous symbols, abbreviations, and nomenclature should be used; for example, in order to be distinct from barometric altitude, any displayed altitude that is geometrically derived should be labelled "GSL."

(b) If a control performs more than one function the labels should include all intended functions, unless the function of the control is obvious. Labels of graphical controls accessed via a cursor control device should be included on the graphical display.

(c) The following are guidelines and recommendations for labels:

- Data fields should be uniquely identified either with the unit of measurement or a descriptive label. However, some basic "T" instruments have been found to be acceptable without units of measurement.
- Labels should be consistent with related labels located elsewhere in the flight deck.
- When a control or indication occurs in multiple places (for example, a "Return" control on multiple pages of a flight management function), the label should be consistent across all occurrences.

(d) Labels should be placed such that:

- The spatial relationships between labels and the objects they reference are clear.

- Labels for display controls are on or adjacent to the controls they identify.
- Labels for display controls are not obstructed by the associated controls.
- Labels are oriented to facilitate readability. For example, the labels continuously maintain an upright orientation or align with an associated symbol such as a runway or airway.
- On multi-function displays, a label should be used to indicate the active function(s), unless its function is obvious. When the function is no longer active or being displayed, the label should be removed unless another means of showing availability of that function is used. For example, greying out an inactive menu button.

(e) When using icons instead of text labels, only brief exposure to the icon should be needed in order for the flight crew to determine the function and method of operation of a control. The use of icons should not cause flight crew confusion.

(3) Symbols.

(a) Electronic display symbol appearance and dynamics should be designed to enhance flight crew comprehension and retention, and minimise flight crew workload and errors in accordance with the intended function. The following list provides guidance for symbol appearance and dynamics:

- Symbols should be positioned with sufficient accuracy to avoid interpretation errors or significantly increase interpretation time.
- Each symbol used should be identifiable and distinguishable from other related symbols.
- The shape, dynamics, and other symbol characteristics representing the same function on more than one display on the same flight deck should be consistent.
- Symbol modifiers used to convey multiple levels of information should follow depiction rules clearly stated by the applicant. Symbol modifiers are changes to easily recognised baseline symbols such as colours, fill, and borders.
- Symbols that represent physical objects (for example, navigational aids and traffic) should not be misleading as to the object's physical characteristics (including position, size, envelope, and orientation).

(b) Within the flight deck, avoid using the same symbol for different purposes, unless it can be shown that there is no potential for misinterpretation errors or increases in flight crew training times.

(c) It is recommended that standardised symbols be used. The symbols in the following SAE documents have been found to be acceptable for compliance to the regulations:

- SAE ARP 4102/7, *Electronic Displays*, Appendices A through C (for primary flight, navigation, and powerplant displays);
- SAE ARP 5289, *Electronic Aeronautical Symbols*, (for depiction of navigation symbology); and

- SAE ARP 5288, *Transport Category Aeroplane Head Up Display (HUD) Systems*, (for HUD symbology).

(4) Indications. The following paragraphs provide guidance on numeric readouts, gauges, scales, tapes and graphical depictions such as schematics. Graphics related to interactivity are discussed in paragraph 31e of this chapter and Chapter 7 of this AMC. Graphics and display indications should:

- Be readily understood and compatible with other graphics and indications in the flight deck.
- Be identifiable and readily distinguishable.
- Follow the guidance for viewability presented in paragraphs 31a, 31b, 31c(1), and 31c(2) of this chapter.

(a) Numeric Readouts. Numeric readouts include displays that emulate rotating drum readouts where the numbers scroll, as well as displays where the digit locations stay fixed.

1 Data accuracy of the numeric readout should be sufficient for the intended function and to avoid inappropriate flight crew response. The number of significant digits should be appropriate to the data accuracy. Leading zeroes should not be displayed unless convention dictates otherwise (for example, heading and track). As the digits change or scroll, there should not be any confusing motion effects such that the apparent motion does not match the actual trend.

2 When a numeric readout is not associated with any scale, tape, or pointer, it may be difficult for pilots to determine the margin relative to targets or limits, or compare between numeric parameters. A scale, dial, or tape may be needed to accomplish the intended flight crew task.

3 For North, numeric readouts of heading should indicate 360, as opposed to 000.

(b) Scales, Dials, and Tapes. Scales, dials, and tapes with fixed and/or moving pointers have been shown to effectively improve flight crew interpretation of numeric data.

1 The displayed range should be sufficient to perform the intended function. If the entire operational range is not shown at any given time, the transition to the other portions of the range should not be distracting or confusing.

2 Scale resolution should be sufficient to perform the intended task. Scales may be used without an associated numeric readout if alone they provide sufficient accuracy for the intended function. When numeric readouts are used in conjunction with scales, they should be located close enough to the scale to ensure proper association, yet not detract from the interpretation of the graphic or the readout.

3 Delimiters, such as tick marks, should allow rapid interpretation without adding unnecessary clutter. Markings and labels should be positioned such that their meaning is clear yet they do not hinder interpretation. Pointers and indexes should not obscure the scales or delimiters such that they can no longer be interpreted. Pointers and indexes should be positioned with sufficient accuracy for their intended function. Accuracy includes effects due to data resolution, latency, graphical positioning, etc.

(c) **Other Graphical Depictions.** Depictions include schematics, synoptics, and other graphics such as attitude indications, moving maps, and vertical situation displays.

1 To avoid visual clutter, graphic elements should be included only if they add useful information content, reduce flight crew access or interpretation time, or decrease the probability of interpretation error.

2 To the extent it is practical and necessary, the graphic orientation and the flight crew's frame of reference should be correlated. For example, left indications should be on the left side of the graphic and higher altitudes should be shown above lower altitudes.

3 If there are multiple depictions, such as "thumbnail" or overlaid depictions, the orientation (for example, heading up, track up, North up, etc.) should be the same for each depiction. This does not apply to other systems where the captain and first officer may select different presentations of the same information and are used exclusively by that flight crew member.

4 Graphics that include 3-Dimensional effects, such as raised buttons or the aeroplane flight path in a perspective view, should ensure that the symbol elements used to achieve these effects will not be incorrectly interpreted.

(5) Colour Coding.

(a) If colour is used for coding at least one other distinctive coding parameter should be used (for example, size, shape, location, etc.). Normal aging of the eye can reduce the ability to sharply focus on red objects, or discriminate blue from green. For pilots with such a deficiency, display interpretation workload may be unacceptably increased unless symbology is coded in more dimensions than colour alone. However, the use of colour alone for coding information has been shown to be acceptable in some cases, such as weather radar and terrain depiction on the lateral view of the navigation display.

(b) To ensure correct information transfer, the consistent use and standardisation of colour is highly desirable. In order to avoid confusion or interpretation error, there should not be a change in how the colour is perceived over all foreseeable conditions. Colours used for one purpose in one information set should not be used for an incompatible purpose that could create a misunderstanding within another information set. In particular, consistent use and standardisation for red and amber or yellow, per CS 25.1322, is required to retain the effectiveness of flight crew alerts. A common application is the progression from green to amber to red, representing increasing degrees of threat, potential hazard, safety criticality, or need for flight crew awareness or response. Inconsistencies in the use of colour should be evaluated to ensure that they are not susceptible to confusion or errors, and do not adversely impact the intended function of the system(s) involved.

(c) If colour is used for coding it is considered good practice to use six colours or less for coding parameters. Each coded colour should have sufficient chrominance separation so it is identifiable and distinguishable in all foreseeable lighting and operating conditions and when used with other colours. Colours should be identifiable and distinguishable across the range of information element size, shape, and movement. The colours available for coding from an electronic display system should be carefully selected to maximise their chrominance separation. Colour combinations that are similar in luminance should be avoided (for example, Navy blue on black or yellow on white).

(d) Other graphic depictions such as terrain maps and synthetic vision presentations may use more than six colours and use colour blending techniques to represent colours in the outside world or to emphasize terrain features. These displays are often presented as background imagery and the colours used in the displays should not interfere with the flight crew interpretation of overlaid information parameters as addressed in paragraph 31c(5)(e)1 of this chapter.

(e) The following table depicts previously accepted colour coding and the functional meaning associated with each colour. The use of these colours is recommended for electronic display systems with colour displays.

Table 11
Recommended Colours for Certain Functions

Feature	**Colour**
Warnings	Red
Flight envelope and system limits, exceedances	Red or Yellow/Amber as appropriate (see above)
Cautions, non-normal sources	Yellow/Amber
Scales, dials, tapes, and associated information elements	White*
Earth	Tan/Brown
Sky	Blue/Cyan
Engaged Modes/Normal Conditions	Green
Instrument landing system deviation pointer	Magenta
Divisor lines, units and labels for inactive soft buttons	Light Gray

* Use of the colour green for tape elements (for example airspeed and altitude) has also been found acceptable if the colour green does not adversely affect flight crew alerting.

(f) The following table depicts display features that should be allocated a colour from either Colour Set 1 or Colour Set 2.

Table 12

Specified Colours for Certain Display Features

Display Feature	Colour Set 1	Colour Set 2
Fixed reference symbols	White	Yellow*
Current data, values	White	Green
Armed modes	White	Cyan
Selected data, values	Green	Cyan
Selected heading	Magenta**	Cyan
Active route/flight plan	Magenta	White

* Use of the colour yellow for functions other than flight crew alerting should be limited and should not adversely affect flight crew alerting.

** In Colour Set 1, magenta is intended to be associated with those analogue parameters that constitute “fly to” or “keep centred” type information.

(g) The following colour pairs should be avoided:

- Saturated red and blue,
- Saturated red and green,
- Saturated blue and green,
- Saturated yellow and green,
- Yellow on purple,
- Yellow on green,
- Yellow on white,
- Magenta on green,
- Magenta on black (although this may be acceptable for lower criticality items),
- Green on white,
- Blue on black, and
- Red on black.

For further information on this subject see the FAA report *Human Factors Design Guide Update (Report Number DOT/FAA/CT-96/01): A Revision to Chapter 8 - Human Interface Guidelines.*

(h) When background colour is used (for example, grey), it should not impair the use of the overlaid information elements. Labels, display-based controls, menus, symbols, and graphics should all remain identifiable and distinguishable. The use of background colour should conform to the overall flight deck philosophies for colour usage and information management. If texturing is used to create a background, it should not result in loss of readability of the symbols overlaid on it, nor should it increase visual clutter or pilot information access time. Transparency is a means of seeing a background information element through a foreground one – the use of transparency should be minimised because it may increase pilot interpretation time or errors.

(i) Requiring the flight crew to discriminate between shades of the same colour for distinct meaning is not recommended. The use of pure blue should not be used for important information because it has low luminance on many display technologies (for example, CRT and LCD).

(j) Any foreseeable change in symbol size should ensure correct colour interpretation; for example, the symbol needs to be sufficiently large so the pilot can interpret the correct colour.

d. Dynamic (Graphic) Information Elements on a Display.

(1) General. The following paragraphs cover the motion of graphic information elements on a display, such as the indices on a tape display. Graphic objects that translate or rotate should do so smoothly without distracting or objectionable jitter, jerkiness, or ratcheting effects. Data update rates for information elements used in direct aeroplane or powerplant manual control tasks (such as attitude, engine parameters, etc.) equal to or greater than 15 Hertz have been found to be acceptable. Any lag introduced by the display system should be consistent with the aeroplane control task associated with that parameter. In particular, display system lag (including the sensor) for attitude which does not exceed a first order equivalent time constant of 100 milliseconds for aeroplanes with conventional control system response is generally acceptable.

(2) Movement of display information elements should not blur, shimmer, or produce unintended dynamic effects such that the image becomes distracting or difficult to interpret. Filtering or coasting of data intended to smooth the motion of display elements should not introduce significant positioning errors or create system lag that makes it difficult to perform the intended task.

(3) When a symbol reaches the limit of its allowed range of motion, the symbol should either slide from view, change visual characteristics, or be self-evident that further deflection is impossible.

(4) Dynamic information should not appreciably change shape or colour as it moves. Objects that change sizes (for example, as the map range changes) should not cause confusion as to their meaning and should remain consistent throughout their size range. At all sizes the objects should meet the guidance of this chapter as applicable (that is, the objects should be discernable, legible, identifiable, placed accurately, not distracting, etc.).

e. Sharing Information on a Display. There are three primary methods of sharing information on a given display. First, the information may be overlaid or combined, such as when traffic alert and collision avoidance system (TCAS) information is overlaid on a map display. Second, the information can be time shared so that the pilot toggles between functions, one at a time. Third, the information may be displayed in separate physical areas or windows that are concurrently displayed. Regardless of the method of information sharing, care should be taken to ensure that information that is out prioritised, but is needed, can be recovered, and that it will not be needed more quickly than it can be recovered.

(1) Overlays and Combined Information Elements. The following guidelines apply:

- When information is graphically overlaid over other information (for example, an aeroplane symbol over a waypoint symbol) in the same location on a display, the loss of information availability, information access times, and potential for confusion should be minimised.

- When information obscures other information it should be shown that the obscured information is either not needed when it is obscured or can be rapidly recovered. Needed information should not be obscured. This may be accomplished by protecting certain areas of the display.
- If information is integrated with other information on a display, the projection, the placement accuracy, the directional orientation and the display data ranges should all be consistent (for example, when traffic or weather is integrated with navigation information). When information elements temporarily obscure other information (for example, pop-up menus or windows), the resultant loss of information should not cause a hazard in accordance with the obscured information's intended function.

(2) **Time Sharing.** The following guidelines apply:

- Guidance on Full-time vs. Part-time Displays (see paragraph 36c(3) of this AMC).
- Any information that should or must be continuously monitored by the flight crew should be displayed at all times (for example, attitude).
- Whether or not information may be time shared depends on how easily it can be retrieved in normal, non-normal, and emergency operations. Information for a given performance monitoring task may be time shared if the method of switching back and forth does not jeopardise the performance monitoring task.
- Generally, system information, planning, and other information not necessary for the pilot tasks can be time shared.

(3) **Separating Information Visually.** When different information elements are adjacent to each other on a display, the elements should be separated visually so the pilots can easily distinguish between them. Visual separation can be achieved with, for example, spacing, delimiters, or shading in accordance with the overall flight deck information management philosophy. Required information presented in reversionary or compacted display modes following a display failure should still be uncluttered and still allow acceptable information access time.

(4) **Clutter and De-Clutter.**

(a) A cluttered display presents an excessive number or variety of symbols, colours, and/or other unnecessary information and, depending on the situation, may interfere with the flight task or operation. A cluttered display causes increased flight crew processing time for display interpretation, and may detract from the interpretation of information necessary to navigate and fly the aeroplane. Information should be displayed so that clutter is minimised.

(b) To enhance pilot performance a means should be considered to de-clutter the display. For example, an attitude indicator may automatically de-clutter when the aeroplane is at an unusual attitude to aid the pilot in recovery from the unusual attitude by removing unnecessary information and retaining information required for the flight crew to recover the aeroplane.

f. Annunciations and Indications.

(1) General. Annunciations and indications include annunciator switches, messages, prompts, flags, and status or mode indications which are either on the flight deck display itself or control a flight deck display. Reference: CS 25.1322 and the associated AMC for information regarding specific annunciations and indications such as warning, caution, and advisory level alerts.

(a) Annunciations and indications should be operationally relevant and limited to minimise the adverse effects on flight crew workload.

(b) Annunciations and indications should be clear, unambiguous, timely, and consistent with the flight deck design philosophy. When an annunciation is provided for the status or mode of a system, it is recommended that the annunciation indicate the actual state of the system and not just the position or selection of a switch. Annunciations should only be indicated while the condition exists.

(2) Location. Annunciations and indications should be consistently located in a specific area of the electronic display. Annunciations that may require immediate flight crew awareness should be located in the flight crew's forward/primary field of view.

(3) Managing Messages and Prompts.

(a) The following general guidance applies to all messages and prompts:

- When messages are currently being displayed and there are additional messages in the queue that are not currently displayed, there should be an indication that the additional messages exist.
- Within levels of urgency, messages should be displayed in logical order. In many cases the order of occurrence of events has been found to be the most logical way to place the messages in order.
- Reference the ARAC recommendations for revising CS 25.1322 and the associated guidance material for information on warning, caution, and advisory alerts.

(b) A text change by itself should not be used as an attention-getting cue (for example, to annunciate mode changes).

(4) Blinking. Blinking information elements such as readouts or pointers are effective methods of annunciation. However, the use of blinking should be limited because it can be distracting and excessive use reduces the attention getting effectiveness. Blinking rates between 0.8 and 4.0 Hertz should be used, depending on the display technology and the compromise between urgency and distraction. If blinking of an information element can occur for more than approximately 10 seconds, a means to cancel the blinking should be provided.

g. Use of Imaging. This paragraph provides guidance on the use of images which depict a specific portion of the aeroplane environment. These images may be static or continuously updated. Imaging includes weather radar returns, terrain depictions, forecast weather maps, video, enhanced vision displays, and synthetic vision displays. Images may be generated from databases or by sensors.

(1) Images should be of sufficient size and include sufficient detail to meet the intended function. The pilots should be able to readily distinguish the features depicted. Images should be oriented in such a way that their presentation is easily interpreted. All images, but especially dynamic images, should be located or controllable so they do not distract the pilots from required tasks. The source and intended function of the image and the level of operational approval for using the image should be provided to the pilots. This can be accomplished using the aeroplane flight manual, image location, adequate labelling, distinct texturing, or other means.

(2) Image distortion should not compromise image interpretation. Images meant to provide information about depth (for example, 3-Dimensional type perspective displays) should provide adequate depth information to meet the intended function.

(3) Dynamic images should meet the guidance in paragraph 31d of this chapter, above. The overall system lag time of a dynamic image relative to real time should not cause flight crew misinterpretation or lead to a potentially hazardous condition. Image failure, freezing, coasting or colour changes should not be misleading and should be considered during the safety analysis.

(4) When overlaying coded information elements over images, the information elements should be readily identifiable and distinguishable for all foreseeable conditions of the underlying image and range of motion. The information elements should not obscure necessary information contained in the image. The information should be depicted with the appropriate size, shape, and placement accuracy to avoid being misleading. They should retain and maintain their shape, size, and colour for all foreseeable conditions of the underlying image and range of motion.

(5) When fusing or overlaying multiple images, the resultant combined image should meet its intended function despite any differences in image quality, projection, data update rates, sensitivity to sunlight, data latency, or sensor alignment algorithms. When conforming an image to the outside world, such as on a HUD, the image should not obscure or significantly hinder the flight crew's ability to detect real world objects. An independent brightness control of the image may help satisfy this guideline. Image elements that correlate or highlight real world objects should be sufficiently coincident to avoid interpretation error or significantly increase interpretation time.

32. – 35. [RESERVED]

CHAPTER 6.

ORGANISING ELECTRONIC DISPLAY INFORMATION ELEMENTS

36. Organising Information Elements.

a. General. This chapter provides guidance for integrating information into the flight deck related to managing the location of information, arranging the display, windowing, configuring and reconfiguring the display, and selecting the sensors across the flight deck displays. The following paragraphs include guidance for various flight deck configurations from dedicated electronic displays for the attitude director indicator and the horizontal situation indicator to larger display sizes which use windowing techniques to display various functionalities on one display area. In some flight decks the primary flight information and the navigation display are examples of information that is displayed using windowing techniques. Chapter 5 of this AMC provides guidance for information elements including: text, labels, symbols, graphics, and other depictions (such as video) in isolation and combination.

b. Types and Arrangement of Display Information. This paragraph provides guidance for the arrangement and location of categories of information. The categories of information include:

- Primary flight information including attitude, airspeed, altitude, and heading.
- Powerplant information which covers functions relating to propulsion.
- Other information.

(1) Placement - General Information. The position of a message or symbol within a display conveys meaning to the pilot. Without the consistent or repeatable location of a symbol in a specific area of the electronic display interpretation error and response times may increase. The following information should be placed in a consistent location under normal conditions:

- Primary flight information (see paragraph 36b(3) in this chapter and Appendix 1 of this AMC).
- Powerplant information (see paragraph 36b(4) in this chapter and Appendix 2 of this AMC).
- Flight crew alerts – each flight crew alert should be displayed in a specific location or a central flight crew alert area.
- Autopilot and flight director modes of operation.
- Lateral and vertical path deviation indicators.
- Radio altitude indications.
- Failure flags should be presented in the location of the information they reference or replace.
- Data labels for navigation, traffic, aeroplane system, and other information should be placed in a consistent position relative to the information they are labelling.
- Supporting data for other information, such as bugs and limit markings, should be consistently positioned relative to the information they support.
- Features on electronic moving map displays (for example, VORs, waypoints, etc.) relative to the current aeroplane position. In addition, the features should be placed on a constant scale for each range selected.
- Segment of flight information relative to similar information or other segments.

(2) Placement - Controls and Indications. When a control or indication occurs in multiple places (for example a “Return” control on multiple pages of a flight management function), the control or indication should be located consistently for all occurrences.

(3) Arrangement - Basic T Information.

(a) CS 25.1321(b) includes specifications for the “Basic T” arrangement of certain information required by CS 25.1303(b).

(b) The following paragraphs provide guidance for the Basic T arrangement. This guidance applies to single and multiple display surfaces.

1 The Basic T information should be displayed continuously, directly in front of each flight crew member under normal (that is, no display system failure) conditions. CS 25.1321(b) requires that flight instruments required by CS 25.1303 must be grouped on the instrument panel and centred as nearly as practicable about the vertical plane of the pilot's forward vision.

2 The Basic T arrangement applies to the primary display of attitude, airspeed, altitude, and direction of flight. Depending on the flight deck design, there may be more than one indication of the Basic T information elements in front of a pilot. For example, heading information may appear on back-up displays, HUDs, and moving map displays. The primary airspeed, altitude, and direction indications are the respective display indications closest to the primary attitude indication.

3 The primary attitude indication should be centred about the plane of the flight crew’s forward vision. This should be measured from the DEP at the flight crew station. If located on the main instrument panel, the primary attitude indication must be in the top centre position (CS 25.1321(b)). The attitude indication should be placed so that the display is unobstructed under all flight conditions. Refer to SAE ARP 4102/7 for additional information.

4 The primary airspeed, altitude, and direction of flight indications should be located adjacent to the primary attitude indication. Information elements placed within, overlaid, or between these indications, such as lateral and vertical deviation, are acceptable when they are relevant to respective airspeed, altitude, or directional indications used for accomplishing the basic flying task, and are shown to not disrupt the normal crosscheck or decrease manual flying performance.

5 The instrument that most effectively indicates airspeed must be adjacent to and directly to the left of the primary attitude indication (CS 25.1321(b)). The centre of the airspeed indication should be aligned with the centre of the attitude indication. For airspeed indications, vertical deviations have been found acceptable up to 15 degrees below to 10 degrees above when measured from the direct horizontal position of the aeroplane waterline reference symbol. For tape type airspeed indications, the centre of the indication is defined as the centre of the current airspeed status reference.

6 Parameters related to the primary airspeed indication, such as reference speeds or a mach indication, should be displayed to the left of the primary attitude indication.

7 The instrument that most effectively indicates altitude must be located adjacent to and directly to the right of the primary attitude indication (CS 25.1321(b)). The centre of the altitude indication should be aligned with the centre of the attitude indication. For altitude indications, vertical deviations have been found acceptable up to 15 degrees below to 10 degrees above when measured from the direct horizontal position of the aeroplane waterline reference symbol. For tape type altitude indications, the centre of the indication is defined as the centre of the current altitude status reference.

8 Parameters related to the primary altitude indication, such as the barometric setting or the primary vertical speed indication, should be displayed to the right of the primary altitude indication.

9 The instrument that most effectively indicates direction of flight must be located adjacent to and directly below the primary attitude indication (CS 25.1321(b)). The centre of the direction of flight indication should be aligned with the centre of the attitude indication. The centre of the direction of flight indication is defined as the centre of the current direction of flight status reference.

10 Parameters related to the primary direction of flight indication, such as the reference (that is, magnetic or true) or the localiser deviation should be displayed below the primary attitude indication.

11 If applicants seek approval of alternative instrument arrangements by equivalent safety under Part 21A.21(c)2, the Agency will normally require well-founded research, or relevant service experience from military, foreign, or other sources to substantiate the applicants' proposed compensating factors.

(4) Arrangement - Powerplant Information.

(a) Required engine indications necessary to set and monitor engine thrust or power should be continuously displayed in the flight crew's primary field of view, unless the applicant can demonstrate that this is not necessary (see the guidance in paragraph 36c(3) of this chapter and Appendix 2 of this AMC). The automatically selected display of powerplant information should not suppress other information that requires flight crew awareness.

(b) Powerplant information must be closely grouped (in accordance with § 25.1321) in an easily identifiable and logical arrangement which allows the flight crew to clearly and quickly identify the displayed information and associate it with the corresponding engine. Typically, it is considered to be acceptable to arrange parameters related to one powerplant in a vertical manner and, according to powerplant position, next to the parameters related to another powerplant in such a way that identical powerplant parameters are horizontally aligned. Generally, place parameter indications in order of importance with the most important one at the top. Typically, the top indication is the primary thrust setting parameter.

(5) Arrangement - Other Information (For Example, Glideslope and Multi-Function Displays).

(a) Glideslope or glidepath deviation scales should be located to the right side of the primary attitude indication. If glideslope deviation data is presented on both an electronic horizontal situation indicator and an electronic attitude direction indicator, the information should appear in the same relative location on each indicator.

(b) When the glideslope pointer is being driven by a RNAV (area navigation) system with VNAV (vertical navigation) or ILS (instrument landing system) look-alike functionality, the pointer should not be marked "GS" or "glideslope."

(c) Navigation, weather, and vertical situation display information is often displayed on multi-function displays. This information may be displayed on one or more physical electronic displays, or on several areas of one larger display. When this information is not required to be displayed continuously, it can be displayed part-time, but the displayed information should be easily recoverable to the flight crew when needed. For guidance on part-time displays see paragraph 36c(3) of this chapter.

(d) Other information should not be located where the primary flight information or required powerplant information is normally presented. See paragraphs 36b(1) and 36b(3) of this chapter for primary flight information guidance. See paragraphs 21e(10) and 36b(4) of this AMC for powerplant information guidance.

c. Managing Display Information. The following paragraphs address managing and integrating the display of information throughout the flight deck. This includes the use of windows to present information and the use of menus to manage the display of information.

(1) Window. A window is a defined area which can be present on one or more physical displays. A window that contains a set of related information is commonly referred to as a format. Multiple windows may be presented on one physical display surface and may have different sizes. Guidelines for sharing information on a display, using separate windows, are as follows:

- The window(s) should have fixed size(s) and location(s).
- Separation between information elements within and across windows should be sufficient to allow the flight crew to readily distinguish separate functions or functional groups (for example, powerplant indication) and avoid any distractions or unintended interaction.
- Display of selectable information, such as a window on a display area, should not interfere with or affect the use of primary flight information.
- For additional information regarding the display of data on a given location, data blending, and data over-writing (see ARINC Specification 661).

(2) Menu.

(a) A menu is a displayed list of items from which the flight crew can choose. Menus include drop-down and scrolling menus, line select keys on a multi-function display, and flight management system menu trees. An option is one of the selectable items in a menu. Selection is the action a user makes in choosing a menu option, and may be done by pointing (with a cursor control device or other mechanism), entering an associated option code, or activating a function key.

(b) The hierarchical structure and organisation of the menus should be designed to allow the flight crew to sequentially step through the available menus or options in a logical way that supports their tasks. The options provided on any particular menu should be logically related to each other. Menus should be displayed in consistent locations, either a fixed location or a consistent relative location, so that the flight crew knows where to find them. At all times the system should indicate the current position within the menu and menu hierarchy.

(c) The number of sub-menus should be designed to assure timely access to the desired option without over-reliance on memorisation of the menu structure. The presentation of items on the menu should allow clear distinction between items that select other menus and items that are the final selection.

(d) The number of steps required to choose the desired option should be consistent with the frequency, importance, and urgency of the flight crew's task.

(e) When a menu is displayed it should not obscure required information.

(3) Full-time vs. Part-time Display of Information. Some aeroplane parameters or status indications are required to be displayed by the specifications (for example, powerplant information required by CS 25.1305), yet they may only be necessary or required in certain phases of flight. If it is desired to inhibit some parameters from full-time display, a usability level and functionality equivalent to a full-time display should be demonstrated.

(a) When determining if information on a display can be part-time, consider the following criteria:

- Continuous display of the parameter is not required for safety of flight in all normal flight phases.
- The parameter is automatically displayed in flight phases where it is required, when its value indicates an abnormal condition, or when it would be relevant information during a failure condition.
- Display of the inhibited parameter can be manually selected by the flight crew without interfering with the display of other required information.
- If the parameter fails to be displayed when required, the failure effect and compounding effects must meet the specifications of all applicable specifications (for example, CS 25.1309).
- The automatic or requested display of the inhibited parameter should not create unacceptable clutter on the display. Also, simultaneous multiple "pop-ups" should not create unacceptable clutter on the display.
- If the presence of a new parameter is not sufficiently self-evident, suitable alerting or other annunciations should accompany the automatic presentation of the parameter.

(b) Pop-up Display of Information.

1 Certain types of information, such as terrain and TCAS, are required by operating rules to be displayed, yet they are only necessary or required in certain phases of flight (similar to the part-time display of required aeroplane parameters, (see paragraph 36b(3) of this chapter)) or under specific conditions. One method commonly employed to display this information is called "automatic pop-up." Automatic pop-ups may be in the form of an overlay, such as a TCAS overlay on the moving map, or in a separate window as a part of a display format. Pop-up window locations should not obscure required information.

2 Consider the following criteria for displaying automatic pop-up information:

- Information is automatically displayed when its value indicates a predetermined condition, or when the associated parameter reaches a predetermined value.
- Pop-up information should appropriately attract the flight crew's attention while minimising task disruption.
- If the flight crew deselects the display of the automatic pop-up information, then another automatic pop-up should not occur until a new condition/event causes it.
- If an automatic pop-up condition is activated and the system is in the wrong configuration or mode to display the information, and the system configuration cannot be automatically changed, then an annunciation should be displayed in the colour associated with the nature of the alert, prompting the flight crew to make the necessary changes for the display of the information. This guidance differs from the part-time display of information required by CS-25 because the required information should be displayed regardless of the configuration.
- If a pop-up(s) or simultaneous multiple pop-ups occur and obscure information, it should be shown that the obscured information is not relevant or necessary for the current flight crew task. Additionally, the pop-ups should not cause a misleading presentation.
- If more than one automatic pop-up occurs simultaneously on one display area, for example a terrain and TCAS pop-up, then the system should prioritise the pop-up events based on their criticality. Pop-up display orientation should be in track-up or heading-up.
- Any information to a given system that is not continuously displayed, but the safety assessment determines it is necessary to be presented to the flight crew, should automatically pop-up or otherwise indicate that its display is required.

d. Managing Display Configuration. The following paragraphs address managing the information presented by an electronic display system and its response to failure conditions and flight crew selections. The following paragraphs also provide guidance on the acceptability of display formats and their required physical location on the flight deck, both during normal flight and in failure modes. Manual and automatic system reconfiguration and source switching are also addressed.

(1) **Normal Conditions.** In normal conditions (that is, non-failure conditions) there may be a number of possible display configurations that may be selected manually or automatically. All possible display configurations available to the flight crew should be designed and evaluated for arrangement, visibility, and interference.

(2) **System Failure Conditions (Reconfiguration).** The following paragraphs provide guidance on manual and automatic display system reconfiguration in response to display system failures. Arrangement and visibility specifications also apply in failure conditions. Alternative display locations used in non-normal conditions should be evaluated by the Agency to determine if the alternative locations meet the criteria for acceptability.

(a) Moving display formats to different display locations on the flight deck or using redundant display paths to drive display information is acceptable to meet availability and integrity specifications.

(b) In an instrument panel configuration with a display unit for primary flight information positioned above a display unit for navigation information, it is acceptable to move the primary flight information to the lower display unit if the upper display unit fails.

(c) In an instrument panel configuration with a display unit for primary flight information positioned next to a display unit for navigation information, it is acceptable to move the primary flight information to the display unit directly adjacent to it if the preferred display unit fails. It is also acceptable to switch the navigation information to a centrally located auxiliary display (multi-function display).

(d) If several possibilities exist for relocating the failed display, a recommended flight crew procedure should be considered and documented in the aeroplane flight manual.

(e) It is acceptable to have manual or automatic switching capability (automatic switching is preferred) in case of system failure; however, the ARAC recommendation for revising § 25.1333(b) requires that the equipment, systems, and installations must be designed so that sufficient information is available to assure control of the aeroplane's airspeed, altitude, heading, and attitude by one of the pilots without additional flight crew action, after any single failure or combination of failures that is not assessed to be extremely improbable.

(f) The following means to reconfigure the displayed information are acceptable:

- Display unit reconfiguration. Moving a display format to a different location (for example, moving the primary flight information to the adjacent display unit) or the use of a compacted format may be acceptable.
- Source/graphic generator reconfiguration. The reconfiguration of graphic generator sources either manually or automatically to accommodate a failure may be acceptable. In the case where both the captain and first officer's displays are driven by a single graphic generator source, there should be clear, cautionary alerting to the flight crew that the displayed information is from a single graphic generator source.

1 In certain flight phases, manual reconfiguration may not satisfy the need for the pilot controlling the aeroplane to recover primary flight information without delay. Automatic reconfiguration might be necessary to ensure the timely availability of information that requires immediate flight crew member action.

2 When automatic reconfiguration occurs (for example, display transfer), it should not adversely affect the performance of the flight crew and should not result in any trajectory deviation.

3 When the display reconfiguration results in the switching of sources or display paths that is not annunciated and is not obvious to the flight crew, care should be taken that the flight crew is aware of the actual status of the systems when necessary, depending on flight deck philosophy.

e. Methods of Reconfiguration.

(1) Compacted Format.

(a) The term "compacted format," as used in this AMC, refers to a reversionary display mode where selected display components of a multi-display configuration are combined in a single display format to provide higher priority information following a display failure. The “compacted format” may be automatically selected in case of a primary display failure, or it may be manually (automatic selection preferred) selected by the flight crew. Except for training purposes, the “compacted format” should not be selectable unless there is a display failure. The concepts and specifications of CS 25.1321, as discussed in paragraph 36(b)(3) of this chapter, still apply.

(b) The compacted display format should maintain the same display attributes (colour, symbol location, etc.) and include the same required information, as the primary formats it is replacing. The compacted format should ensure the proper operation of all the display functions it presents, including annunciation of navigation and guidance modes, if present. However, due to size constraints and to avoid clutter, it may be necessary to reduce the amount of display functions on the compacted format. For example, in some cases, the use of numeric readouts in place of graphical scales has been found to be acceptable. Failure flags and mode annunciations should, wherever possible, be displayed in a location common with the normal format.

(2) Sensor Selection and Annunciation.

(a) Automatic switching of sensor data to the display system is recommended, especially with highly integrated display systems to address those cases where multiple failure conditions may occur at the same time and require immediate flight crew action. Manual switching may be acceptable in less complex systems or if immediate flight crew action is not required.

(b) Independent attitude, direction, and air data sources are required for the captain and first officer’s displays of primary flight information (see CS 25.1333). If sources can be switched such that the captain and first officer are provided with single sensor information, each of them should receive a clear annunciation indicating the vulnerability to misleading information.

(c) If sensor information sources cannot be switched, then no annunciation is required.

(d) There should be a means of determining the source of the displayed navigation information and the active navigation mode. For approach operations the source of the displayed navigation information and the active navigation mode should be available on the primary flight display or immediately adjacent to the primary flight display.

(e) The selected source should be annunciated if multiple or different types of navigation sources (flight management system, instrument landing system, GNSS (global navigation satellite system) landing system, etc.) can be selected (manually or automatically).

(f) An alert should be given when the information presented to the flight crew is no longer meeting the required integrity level, in particular when there is a single sensor or loss of independence.

37. – 40. [RESERVED]

CHAPTER 7.
ELECTRONIC DISPLAY SYSTEM CONTROL DEVICES

41. General. Each electronic display system control device has characteristics unique to its operation that need to be considered when designing the functions the display system controls, and the redundancy provided during failure modes. Despite the amount of redundancy that may be available to achieve a given task, the flight deck should still present a consistent user interface scheme for the primary displays and a compatible, if not consistent, user interface scheme for auxiliary displays throughout the flight deck.

a. Multi-function Control Labels. Multi-function controls should be labelled such that the pilot is able to:

- Rapidly, accurately, and consistently identify and select all functions of the control device.
- Quickly and reliably identify what item on the display is "active" as a result of cursor positioning, as well as what function will be performed if the item is selected using the selector buttons and/or changed using the multi-function control.
- Determine quickly and accurately the function of the control without extensive training or experience.

b. Multi-function Controls. The installation guidelines below apply to control input devices that are dedicated to operating a specific function (for example, control knobs and wheels), as well as new control features (for example, a cursor control device (CCD)).

(1) "Hard" Controls.

(a) Mechanical controls used to set numeric data on a display should have adequate friction or tactile detents to allow a flight crew without extensive training or experience to set values (for example, setting an out-of-view heading bug to a displayed number) to a required level of accuracy within a time appropriate to the task.

(b) The input for display response gain to control should be optimised for gross motion as well as fine positioning tasks without overshoots. In accordance with CS 25.777(b), the direction of movement of the cockpit controls must meet the specifications of CS 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 on the aeroplane or on 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.

(2) "Soft" Controls.

(a) There are two interactive types of soft control displays, one type affects aeroplane systems and the other type does not. Displays that utilize a graphical user interface (GUI) permit information within different display areas to be directly manipulated by the flight crew (for example, changing range, scrolling crew alert messages or electronic checklists, configuring windows, or layering information.) This level of display interaction affects only the presentation of display information and has a minimal effect on flight deck operations. The other level of display interaction provides a GUI to control aeroplane system operations (for example, utility controls on displays traditionally found in overhead panel functions, FMS operations, and graphical flight planning).

(b) The design of display systems that will be used as soft controls is dependent on the functions they control. Consider the following guidelines when designing these display systems:

1 The GUI and control device should be compatible with the aeroplane system they will control. The hardware and software design assurance levels and tests for the GUI and control device should be commensurate with the level of criticality of the aeroplane system they will control.

2 Redundant methods of controlling the system may lessen the criticality required of the display control. Particular attention should be paid to the interdependence of display controls (that is, vulnerability to common mode failures), and to the combined effects of the loss of control of multiple systems and functions.

3 The applicant should demonstrate that the failure of any display control does not unacceptably disrupt operation of the aeroplane (that is the allocation of flight crew member tasks) in normal, non-normal, and emergency conditions.

4 To show compliance with CS 25.777(a) and CS 25.1523, the applicant should show that the flight crew can conveniently access required and backup control functions in all expected flight scenarios, without impairing aeroplane control, flight crew task performance, and flight crew resource management.

5 Control system latency and gains can be important in the acceptability of a display control. Usability testing should therefore accurately replicate the latency and control gains that will be present in the actual aeroplane.

6 The final display response to control input should be fast enough to prevent undue concentration being required when the flight crew sets values or display parameters CS 25.771(a)). The initial indication of a response to a soft control input should take no longer than 250 milliseconds. If the initial response to a control input is not the same as the final expected response, a means of indicating the status of the pilot input should be made available to the flight crew.

7 To show compliance with CS 25.771(e) the applicant should show by test and/or demonstration in representative motion environment(s) (for example, turbulence) that the display control is acceptable for controlling all functions that the flight crew may access during these conditions.

c. Cursor Control Devices.

When the input device controls cursor activity on a display, it is called a cursor control device (CCD). The CCDs are used to position display cursors on selectable areas of the displays. These selectable areas are “soft controls” intended to perform the same functions as mechanical switches or other controls on conventional control panels. Typically, CCDs control several functions and are the means for directly selecting display elements. When designing CCDs, in addition to the guidance provided in paragraphs 41a, 41b, and 41d of this chapter, consider the guidance in the following paragraphs, which address design considerations unique to CCDs. Additional guidance on cursor control is contained in AC 20-145, *Guidance for Integrated Modular Avionics (IMA) that Implement TSO-C153 Authorized Hardware Elements.*

(1) The CCD design and installation should enable the flight crew to operate the CCD without exceptional skill during foreseeable flight conditions, both normal and adverse (for example, turbulence and vibrations). Certain selection techniques, such as double or triple clicks, should be avoided.

(2) The safety assessment of the CCD should address reversion to alternate means of control following loss of the CCD. This includes an assessment on the impact of the failure on flight crew workload.

(3) The functionality of the CCD should be demonstrated with respect to the flight crew interface considerations outlined below:

(a) The ability of the flight crew to share tasks, following CCD failure, with appropriate workload and efficiency.

(b) The ability of the flight crew to use the CCD with accuracy and speed of selection required of the related tasks, under foreseeable operating conditions (for example, turbulence, engine imbalance, and vibration).

(c) Satisfactory flight crew task performance and CCD functionality, whether the CCD is operated with a dominant or non-dominant hand.

(d) Hand stability support position (for example, wrist rest).

(e) Ease of recovery from incorrect use.

d. Cursor Displays.

(1) The cursor symbol should be restricted from areas of primary flight information or where occlusion of display information by a cursor could result in misinterpretation by the flight crew. If a cursor symbol is allowed to enter a critical display information field, it should be demonstrated that the cursor symbol's presence will not cause interference during any phase of flight or failure condition.

(2) Because the cursor is a directly controllable element on the display it has unique characteristics. Consider the following when designing a cursor display:

(a) Presentation of the cursor should be clear, unambiguous, and easily detectable in all foreseeable operating conditions.

(b) The failure mode of an uncontrollable and distracting display of the cursor should be evaluated.

(c) Because in most applications more than one flight crew member will be using one cursor, the applicant should establish an acceptable method for handling "duelling cursors" that is compatible with the overall flight deck philosophy (for example, "last person on display wins"). Acceptable methods should also be established for handling other possible scenarios, including the use of two cursors by two pilots.

(d) If more than one cursor is used on a display system, a means should be provided to distinguish between the cursors.

(e) If a cursor is allowed to fade from a display, some means should be employed for the flight crew to quickly locate it on the display system. Common examples of this are "blooming" or "growing" the cursor to attract the flight crew's attention.

42. – 45. [RESERVED]

CHAPTER 8
SHOWING COMPLIANCE FOR APPROVAL OF ELECTRONIC DISPLAY SYSTEMS

46. Compliance Considerations (Test and Compliance).

a. General. This chapter provides guidance for demonstrating compliance to the specifications for the approval of electronic flight deck displays. Since so much of display system compliance is dependent on subjective evaluations, this chapter focuses on providing specific guidance that facilitates these types of evaluations.

b. Means of Compliance.

(1) The acceptable means of compliance for a display system depends on many factors and is determined on a case-by-case basis. For example, when the proposed display system technology is mature and well understood, means such as analogical reasoning documented as a Statement of Similarity may be sufficient. However, more rigorous and structured methods, such as analysis and flight test, are appropriate if the proposed display system design is deemed novel, complex, or highly integrated.

(2) The acceptable means of compliance depends on other factors as well. These include the subjectivity of the acceptance criteria and the evaluation facilities of the applicant (for example, high-fidelity flight simulators) and the manner in which these facilities are used (for example, data collection).

(3) When subjective criteria are used to satisfy a means of compliance, the subjective data should be collected from multiple people (including pilots, engineers, and human factor specialists.)

(4) The following guidance describes means of compliance for electronic displays:

(a) System Descriptions.

1 System descriptions may include system architecture, description of the layout and general arrangement of the flight deck, description of the intended function, flight crew interfaces, system interfaces, functionality, operational modes, mode transitions, and characteristics (for example dynamics of the display system), and applicable specifications addressed by this description. Layout drawings and/or engineering drawings may show the geometric arrangement of hardware or display graphics. Drawings typically are used in cases where showing compliance to the specifications can easily be reduced to simple geometry, arrangement, or the presence of a given feature on the drawing.

2 The following questions may be used to evaluate whether the description of intended function is sufficiently specific and detailed:

- Does each system, feature, and function have a stated intended function?

- What assessments, decisions, or actions are the flight crew members intended to make based on the display system?
- What other information is assumed to be used in combination with the display system?
- What is the assumed operational environment in which the equipment will be used? For example, the pilots' tasks and operations within the flight deck, phase of flight, and flight procedures.

(b) Statement of Similarity. This is a substantiation to demonstrate compliance by a comparison to a previously approved display (system or function). The comparison details the physical, logical, and functional and operational similarities of the two systems. Substantiation data from previous installations should be provided for the comparison. This method of compliance should be used with care because the flight deck should be evaluated as a whole, rather than merely as a set of individual functions or systems. For example, display functions that have been previously approved on different programmes may be incompatible when applied to another flight deck. Also, changing one feature in a flight deck may necessitate corresponding changes in other features, in order to maintain consistency and prevent confusion (for example, use of colour).

(c) Calculation & Engineering Analyses. These include assumptions of relevant parameters and contexts, such as the operational environment, pilot population, and pilot training. Examples of calculations and engineering analyses include human performance modelling of optical detections, task times, and control forces. For analyses that are not based on advisory material or accepted industry standards, validation of calculations and engineering analyses using direct participant interaction with the display should be considered.

(d) Evaluation. This is an assessment of the design conducted by the applicant, who then provides a report of the results to the EASA. Evaluations typically use a display design model that is more representative of an actual system than drawings. Evaluations have two defining characteristics that distinguish them from tests: (1) the representation of the display design does not necessarily conform to the final documentation, and (2) the Agency may or may not be present. Evaluations may contribute to a finding of compliance, but they generally do not constitute a finding of compliance by themselves.

1 Evaluations may begin early in the certification programme. They may involve static assessments of the basic design and layout of the display, part-task evaluations and/or, full task evaluations in an operationally representative environment (environment may be simulated). A wide variety of development tools may be used for evaluations, from mock-ups to full installation representations of the actual product or flight deck.

2 In cases where human subjects (typically pilots) are used to gather data (subjective or objective), the applicant should fully document the process used to select subjects, the subjects' experience, the type of data collected, and the method(s) used to collect the data. The resulting information should be provide to the Agency as early as possible to obtain agreement between the applicant and the Agency on the extent to which the evaluations are valid and relevant for certification credit. Additionally, credit will depend on the extent to which the equipment and facilities actually represent the flight deck configuration and realism of the flight crew tasks.

(e) Test. This means of compliance is conducted in a manner very similar to evaluations (see above), but is performed on conformed systems (or conformed items relevant to the test), in accordance with an approved test plan, with either the FAA or its designated representative present. A test can be conducted on a test bench, in a simulator, and/or on the actual aeroplane, and is often more formal, structured, and rigorous than an evaluation.

1 Bench or simulator tests that are conducted to show compliance should be performed in an environment that adequately represents the aeroplane environment, for the purpose of those tests.

2 Flight tests should be used to validate and verify data collected from other means of compliance such as analyses, evaluations, and simulations. Per CS 25.1523, during the certification process, the flight crew workload assessments and failure classification validations should be addressed in a flight simulator or an actual aeroplane, although the assessments may be supported by appropriate analyses (see CS-25 Appendix D, for a description of the types of analyses).

47. – 50. [RESERVED]

CHAPTER 9.

CONTINUED AIRWORTHINESS AND MAINTENANCE

51. Continued Airworthiness and Maintenance. The following paragraphs provide guidance for preparing instructions for the continued airworthiness of the display system and its components to show compliance with CS 25.1309 and CS 25.1529 (including Appendix H), which require preparing Instructions for Continued Airworthiness. The following guidance is not a definitive list, and other maintenance tasks may be developed as a result of the safety assessment, design reviews, manufacturer’s recommendations, and Maintenance Steering Group (MSG)-3 analyses that are conducted.

a. General. Information on preparing the Instructions for Continued Airworthiness can be found in CS-25 Appendix H. In addition to those instructions, maintenance procedures should be considered for:

(1) Reversionary switches not used in normal operation. These switches should be checked during routine maintenance because, if a switch failure is not identified until the aeroplane is in flight, the switching or back up display/sensor may not be available when required. These failures may be addressed by a System Safety Assessment and should be addressed in the aeroplane’s maintenance programme (for example, MSG-3).

(2) Display cooling fans and filters integral with cooling ducting.

b. Design for Maintainability. The display system should be designed to minimise maintenance error and maximise maintainability.

(1) The display mounting, connectors, and labelling, should allow quick, easy, safe, and correct access for identification, removal and replacement. Means should be provided (for example, using physically coded connectors) to prevent inappropriate connections of system elements.

(2) If the system has the capability of providing information on system faults (for example diagnostics) to maintenance personnel, it should be displayed in text instead of coded information.

(3) If the flight crew needs to provide information to the maintenance personnel (for example overheat warning), problems associated with the display system should be communicated to the maintenance personnel as appropriate, relative to the task and criticality of the information displayed.

(4) The display components should be designed so they can withstand cleaning without internal damage, scratching and/or crazing (cracking).

c. Maintenance of Display Characteristics.

(1) Maintenance procedures may be used to ensure that the display characteristics remain within the levels presented and accepted at certification.

(2) Experience has shown that display quality may degrade with time and become difficult to use. Examples include lower brightness/contrast; distortion or discolouration of the screen (blooming effects); and areas of the screen that may not display information properly.

(3) Test methods and criteria may be established to determine if the display system remains within acceptable minimum levels. Display system manufacturers may alternatively provide “end of life” specifications for the displays which could be adopted by the aeroplane manufacturer.

52. – 60. [RESERVED]

Appendix 1

Primary Flight Information

This appendix provides additional guidance for displaying primary flight information. Displaying primary flight information is required by CS 25.1303(b) and CS 25.1333(b). The specifications for arranging primary flight information are specified in CS 25.1321(b).

1.1 Attitude

Pitch attitude display scaling should be such that during normal manoeuvres (for example, approach or climb at high thrust-to-weight ratios) the horizon remains visible in the display with at least 5 degrees pitch margin available.

An accurate, easy, quick-glance interpretation of attitude should be possible for all unusual attitude situations and other "non-normal" manoeuvres sufficient to permit the pilot to recognise the unusual attitude and initiate an appropriate recovery within one second. Information to perform effective manual recovery from unusual attitudes using chevrons, pointers, and/or permanent ground-sky horizon on all attitude indications is recommended.

Both fixed aeroplane reference and fixed earth reference bank pointers ("ground and/or sky" pointers) are acceptable as a reference point for primary attitude information. A mix of these types in the same flight deck is not recommended.

There should be a means to determine the margin to stall and to display that information when necessary. For example, a pitch limit indication is acceptable.

There should be a means to identify an excessive bank angle condition prior to stall buffet.

Sideslip should be clearly indicated to the flight crew (for example, a split trapezoid on the attitude indicator) and an indication of excessive sideslip should be provided.

1.2 Continued Function of Primary Flight Information (Including Standby) in Conditions of Unusual Attitudes or in Rapid Manoeuvres

Primary flight information must continue to be displayed in conditions of unusual attitudes or in rapid manoeuvres (CS 25.1301). The pilot must also be able to rely on primary or standby instrument information for recovery in all attitudes and at the highest pitch, roll, and yaw rates that may be encountered (CS 25.1301).

In showing compliance with the specifications of CS 25.1301(d), CS 25.1309(a), CS 25.1309 (b), CS 25.1309 (c), and CS 25.1309 (d), the analysis and test programme must consider the following conditions that might occur due to pilot action, system failures, or external events:

- Abnormal attitude (including the aeroplane becoming inverted);
- Excursion of any other flight parameter outside protected flight boundaries; or
- Flight conditions that may result in higher than normal pitch, roll, or yaw rates.

For each of the conditions identified above, primary flight displays and standby indicators must continue to provide useable attitude, altitude, airspeed and heading information and any other information that the pilot may require to recognise and execute recovery from the unusual attitude and/or arrest the higher than normal pitch, roll, or yaw rates (CS 25.1301).

2.1 Airspeed and Altitude

Airspeed and altitude displays should be able to convey to the flight crew a quick-glance sense of the present speed or altitude. Conventional round-dial moving pointer displays inherently give some of this sense that may be difficult to duplicate on moving scales. Scale length is one attribute related to this quick-glance capability. The minimum visible airspeed scale length found acceptable for moving scales has been 80 knots; since this minimum is dependent on other scale attributes and aeroplane operational speed range, variations from this should be verified for acceptability. A displayed altitude that is geometrically derived should be easily discernable from the primary altitude information, which is barometrically derived altitude. To ensure the pilot can easily discern the two, the label “GSL” should be used to label geometric height above mean sea level.

Airspeed reference marks (bugs) on conventional airspeed indicators perform a useful function by providing a visual reminder of important airspeed parameters. Including bugs on electronic airspeed displays is encouraged. Computed airspeed/angle-of-attack bugs such as Vstall warning, V1, VR, V2, flap limit speeds, etc., displayed on the airspeed scale should be evaluated for accuracy. The design of an airspeed indicator should include the capability to incorporate a reference mark that will reflect the current target airspeed of the flight guidance system. This has been required in the past for some systems that have complex speed selection algorithms, in order to give the flight crew adequate information for system monitoring as required by CS 25.1309(c).

Scale units marking for air data displays incorporated into primary flight displays are not required (“knots,” “airspeed” for airspeed, “feet,” “altitude” for altimeters) as long as the content of the readout remains clear. For altimeters with the capability to display both English and Metric units, the scale and primary present value readout should remain scaled in English units with no units marking required; the Metric display should consist of a separate present value readout that does include units marking.

Airspeed scale markings such as stall warning, maximum operation speed/maximum operating mach number, or flap limits, should be displayed to provide the flight crew a quick-glance sense of speed relative to key targets or limits. The markings should be predominant enough to confer the quick-glance sense information, but not so predominant as to be distracting when operating normally near those speeds (for example, stabilised approach operating between stall warning and flap limit speeds).

If airspeed trend or acceleration cues are associated with the speed scale, vertically oriented moving scale airspeed indications should have higher numbers at the top so that increasing energy or speed results in upward motion of the cue. Speed, altitude, or vertical rate trend indicators should have appropriate hysteresis and damping to be useful and non-distracting, however, damping may result in erroneous airspeed when accelerating. In this case, it may be necessary to use acceleration data in the algorithms to compensate for the error. The evaluation should include turbulence expected in service.

Airspeed scale graduations in 5-knot increments with graduations labelled at 20-knot intervals are acceptable. In addition, a means to rapidly identify a change in airspeed (for example, speed trend vector or acceleration cue) should be provided on moving scale tapes; if trend or acceleration cues are used, or a numeric present value readout is incorporated in the airspeed display, scale markings at 10-knot intervals are acceptable.

Minimum altimeter graduations should be in 100-foot increments with a present value readout, or 50-foot increments with a present value index only. Due to operational requirements, it is expected that aeroplanes without either 20-foot scale graduations or a readout of present value, will not be eligible for Category II low visibility operation with barometrically determined decision heights.

Altimeters present special design problems in that: (1) the ratio of total usable range to required resolution is a factor of 10 greater than for airspeed or attitude, and (2) the consequences of losing sense of context of altitude can be detrimental. The combination of altimeter scale length and markings, therefore, should be adequate to allow sufficient resolution for precise manual altitude tracking in level flight, as well as enough scale length and markings to reinforce the flight crew's sense of altitude and to allow sufficient look-ahead room to adequately predict and accomplish level-off. When providing low altitude awareness, it may be helpful to include radio altimeter information on the scale so that it is visually related to the ground position.

2.2 Airspeed and Altitude for HUD

To reduce display clutter, during the precision approach phase of flight, HUD formats have been accepted that provide an alphanumeric-only display of airspeed and altitude. Acceptance of these display formats is predicated on the unique characteristics of the precision approach operation and the availability of compensating features for the lack of visual awareness of high and low speed limits.

The compensating features for HUD formats that provide an alphanumeric-only display of airspeed and altitude is that the information display should also provide clear and distinct alerts to the flight crew when these and any other required parameters exceed well defined tolerances around the nominal approach range, and when these alerts have associated procedures that require the termination of the approach. Previously accepted display formats also included effective cues for acceleration and speed deviation so that the pilot could manually achieve tight speed control to preclude unintended proximity to low speed limits. When an alphanumeric-only indication of airspeed and altitude HUD format is displayed, there should still remain an overall awareness of the following indications:

- Airspeed/altitude,
- Airspeed/altitude trends,
- Deviations from selected airspeed/altitude targets,
- Low and high airspeed limits, and
- Selected airspeed/altitude setting changes.

2.3 Low and High Speed Awareness Cues

CS 25.1541(a)(2) states: “The aeroplane must contain – Any additional information, ***instrument markings***, and placards required for the safe operation if there are unusual design, operating, or handling characteristics.” The CS-25 certification specifications related to instrument systems and their markings were not developed with modern day electronic displays in mind; consequently, these electronic displays are considered an “unusual design characteristic” per CS 25.1541(a)(2), and may require additional marking to warrant safe operation. In particular, it is considered necessary to incorporate additional markings on electronic airspeed displays in the form of low and high speed awareness cues to provide pilots the same type of “quick glance” airspeed awareness that was an intrinsic feature of round dial instruments.

Low speed awareness cues should provide adequate visual cues to the pilot that the airspeed is below the reference operating speed for the aeroplane configuration (that is, weight, flap setting, landing gear position, etc.); similarly, high speed awareness cues should provide adequate visual cues to the pilot that the airspeed is approaching an established upper limit that may result in a hazardous operating condition. Consider the following guidance when developing airspeed awareness cues:

- Take into account all independent parameters that may affect the speed against which protection is being provided. This is most important in the low speed regime where all large aeroplanes have a wide range of stall speeds due to multiple flap/slat configurations and potentially large variations in gross weight.
- The cues should be readily distinguishable from other markings such as V-speeds and speed targets (bugs). The cues should indicate not only the boundary value of the speed limit, but must clearly distinguish between the normal speed range and the unsafe speed range beyond those limiting values (CS 25.1545). Since the moving scale display does not provide any inherent visual cue of the relationship of present airspeed to low or high airspeed limits, many electronic displays utilize an amber and red bar adjacent to the airspeed tape to provide this quick-glance low/high speed awareness. The preferred colours to be used are amber or yellow to indicate that the airspeed has decreased below a reference speed that provides adequate manoeuvre margin, changing to red at the stall warning speed. The speeds at which the low speed awareness bands start should be chosen as appropriate to the aeroplane configuration and operational flight regime. For example, low speed awareness cues for approach and landing should be shown starting at V_{REF} with a tolerance of +0 and –5 knots. Some Agency approved systems use a pilot selectable operating speed “bug” at V_{REF} supplemented by system-computed low speed cues that vary in colour as airspeed decreases below certain multiples of the appropriate stall speed (for example, white below $1.3V_S$, amber below $1.2\ V_{S,}$ and red below $1.1\ V_S$). Consider the specific operating needs of other flight regimes when developing the criteria for the associated visual cue.
- Low speed awareness displays should be sensitive to load factor (g-sensitive) to enable the pilot to maintain adequate manoeuvre margins above stall warning in all phases of flight. The accuracy of this g-sensitivity function should be verified by flight tests. Flight tests should also be conducted in manoeuvring flight and expected levels of turbulence to evaluate proper functioning of any damping routines incorporated into the low speed awareness software; the level of damping should preclude nuisance/erratic movement of the low speed cues during operation in turbulence but not be so high that it inhibits adequate response to accurately reflect changes in margins to stall warning and stall during manoeuvring flight.
- High speed awareness should be provided to prevent inadvertent excursions beyond limit speeds. Symbology should be provided to permit easy identification of flap and landing gear speed limits. A visual cue should be incorporated to provide adequate awareness of proximity to V_{MO}; this awareness has been provided by amber bands, similar to the previously discussed low speed cues, and instantaneous airspeed displays that turn amber (or flash amber digits) as the closure rate to V_{MO} increases beyond a value that sill provides adequate time for pilot corrective action to be taken without exceeding the limit speed.
- The display requirements for airspeed awareness cues are in addition to other alerts associated with exceeding high and low speed limits, such as the stick shaker and aural overspeed warning.

3. Vertical Speed

The display range of vertical speed (or rate of climb) indications should be consistent with the climb/descent performance capabilities of the aeroplane. If the resolution advisory (RA) is integrated with the primary vertical speed indication, the range of vertical speed indication should be sufficient to display the red and green bands for all TCAS RA information.

4. Flight Path Vector or Symbol

The display of flight path vector (FPV or velocity vector) or flight path angle (FPA) cues on the primary flight display is not required, but may be included in many designs.

The FPV symbol can be especially useful on HUD applications. The FPV display on the HUD should be conformal with the outside view when the FPV is within the HUD field of view. During flight situations with large bank, pitch, and/or wind drift angles; the movement of the FPV may be limited by the available display field-of-view. In some designs, the pilot can manually cage the FPV which restricts its motion to the vertical axis, thereby making it an FPA.

The FPV or FPA indication may also be displayed on the HDD. In some HDD and most HUD applications, the FPV or FPA is the primary control and tracking cue for controlling the aeroplane during most phases of flight. Even though an FPV or FPA indication may be used as a primary flight control parameter, the attitude pitch and roll symbols (that is, waterline or boresight and pitch scale) which are still required primary indications by § 25.1303 must still be prominently displayed. In dynamic situations, such as during recovery from an unusual attitude, constant availability of attitude indications is required.

If the FPV/FPA is used as the primary means to control the aeroplane in pitch and roll, the FPV/FPA system design should allow pilots to control and manoeuvre the aeroplane with a level of safety that is at least equal to traditional designs based on attitude (CS 25.1333(b)).

There may be existing aeroplane designs where the HUD provides a FPV presentation and the HDD provides a FPA presentation. However, mixture of the two different presentations is not recommended due to possible misinterpretation by the flight crew. The designs that were accepted were found to have the following characteristics: correlation between the HUD FPV display and the primary flight display FPA display; consistent vertical axis presentation of FPV/FPA; and pilots' ability to interpret and respond to the FPV and FPA similarly.

It should be easy and intuitive for the pilot to switch between FPV/FPA and attitude when necessary. The primary flight display of FPV/FPA symbology must not interfere with the display of attitude and there must always be attitude symbology at the top centre of the pilot's primary field of view, as required by CS 25.1321.

Aeroplane designs which display flight path symbology on the HUD and the HDD should use consistent symbol shapes (that is, the HUD FPV symbol looks like the HDD FPV).

In existing cases where an FPV is displayed head up and an FPA head down on an aeroplane, the symbols for each should not have the same shape. When different types of flight path indications may be displayed as head up and/or head down, the symbols should be easily distinguished to avoid any misinterpretation by the flight crew. A mixture of the two types of flight path indications is not recommended due to possible misinterpretation by the flight crew.

The normal FPV, the field-of-view limited FPV, and the caged FPV should each have a distinct appearance, so that the pilot is aware of the restricted motion or non-conformality.

Implementation of air mass-based FPV/FPA presentations should account for inherent limitations of air mass flight path computations.

Flight directors should provide some lateral movement to the lateral flight director guidance cue during bank commands.

To show compliance with CS 25.1301(a), CS 25.1303(b)(5), and CS 25.143(b), the FPV/FPA FD design must:

1. Not have any characteristics that may lead to oscillatory control inputs;
2. Provide sufficiently effective and salient cues to support all expected manoeuvres in longitudinal, lateral, and directional axes, including recovery from unusual attitudes; and
3. Not have any inconsistencies between cues provided on the HUD and HDD displays that may lead to pilot confusion or have adverse affects on pilot performance.

Performance and system safety requirements for flight guidance systems are found in the following advisory circulars:

Document Number	**Title**
AC 25.1329-1B	Approval of Flight Guidance Systems
AC 120-28D	Criteria for Approval of Category III Weather Minima for Take-off, Landing, and Rollout
AC 120-29A	Criteria for Approval of Category I and Category II Weather Minima for Approach

Appendix 2

Powerplant Displays

1. General

At the time CS 25.1305 was adopted, flight deck powerplant displays were primarily a collection of dedicated, independent, full-time analogue “round dial” type instruments. Typically, there was one display for each required indication. Today, flight deck powerplant displays are primarily electronic displays integrated with other flight deck displays on a few relatively large electronic display spaces. Throughout this technological evolution, the Agency has used certification review items (CRIs) to assure that this new technology, with its increased potential for common faults and the challenges of effectively sharing display space, did not adversely impact the timely availability and independence of the powerplant information required to meet the intent of CS25.1305. This AMC provides some of that guidance material.

To comply with one of the provisions of CS 25.1305, a display should provide all the instrument functionality of a full-time, dedicated analogue type instrument as intended when the specification was adopted (see AC 20-88A, *Guidelines on the Marking of Aircraft*). The design flexibility and conditional adaptability of modern displays were not envisioned when CS 25.1305 and CS 25.1549 were initially adopted. In addition, the capabilities of modern control systems to automate and complement flight crew functions were not envisioned. In some cases these system capabilities obviate the need for a dedicated full-time analogue type instrument.

When making a compliance finding, all uses of the affected displays should be taken into consideration, including:

(1) Flight deck indications to support the approved operating procedures (CS 25.1585),
(2) Indications as required by the powerplant system safety assessments (CS 25.1309), and
(3) Indications required in support of the instructions for continued airworthiness (CS 25.1529).

For example:

Compliance with CS 25.1305(c)(3) for the engine N2 rotor was originally achieved by means of a dedicated, full time analogue instrument. This provided the continuous monitoring capability required to:

- Support engine starting (for example, typically used to identify fuel on point);
- Support power setting (for example, sometimes used as primary or back up parameter);
- “Give reasonable assurance that those engine operating limitations that adversely affect turbine rotor structural integrity will not be exceeded in service” as required by CS 25.903(d)(2);
- Provide the indication of normal, precautionary, and limit operating values required by CS 25.1549; as well as
- Support detection of unacceptable deterioration in the margin to operating limits and other abnormal engine operating conditions as required to comply with CS 25.901, CS 25.1309, etc.

As technology evolved full authority digital engine controls (FADECs) were introduced. The FADECs were designed with the ability to monitor and control engine N2 rotor speed as required to comply with CS 25.903(d)(2). Additionally, engine condition monitoring programmes were introduced and used to detect unacceptable engine deterioration. Flight deck technology evolved such that indications could be displayed automatically to cover abnormal engine operating conditions. The combination of these developments obviated the need for a full time analogue N2 rotor speed indication, in accordance with the guidance found in Chapter 6, paragraph 36c(3) of this AMC.

2. Design Guidelines

Safety-related engine limit exceedances should be indicated in a clear and unambiguous manner. Flight crew alerting is addressed in CS 25.1322.

If an indication of significant thrust loss is provided it should be presented in a clear and unambiguous manner.

In addition to the failure conditions listed in Chapter 4 of this AMC, the following design guidelines should be considered:

1. For single failures leading to the non-recoverable loss of any indications on an engine, sufficient indications should remain to allow continued safe operation of the engine. (See CS 25.901(b)(2), CS 25.901(c), and CS 25.903(d)(2)).
2. No single failure could prevent the continued safe operation of more than one engine or require immediate action by any flight crew member for continued safe operation. (See CS 25.901(c), CS 25.903(b), and CS 25.1309(b)).
3. Engine indications needed during engine re-start should be readily available after an engine out event. (See CS 25.901(b)(2), CS 25.901(c) CS 25.903(d)(2), CS 25.903(e), CS 25.1301, CS 25.1305, CS 25.1309, and Chapter 6, paragraph 36c(3) of this AMC).

Appendix 3
Definitions

Air Mass System - An air mass-based system that provides a heading/airspeed/vertical velocity derived flight path presentation. It depicts the flight path through an air mass, will not account for air mass disturbances such as wind drift and windshear and, therefore, cannot be relied on to show the flight path relative to the earth's surface.

Alert – A generic term used to describe a flight deck indication meant to attract the attention of and identify to the flight crew a non-normal operational or aeroplane system condition. Warnings, Cautions, and Advisories are considered to be alerts.

Annunciation - A visual, auditory, or tactile stimulus used to attract a flight crew member's attention.

Architecture - The manner in which the components of a display or display system are organised and integrated.

Basic T - The arrangement of primary flight information as required by CS 25.1321(b); including attitude, airspeed, altitude, and direction information.

Brightness - The perceived or subjective luminance. This should not be confused with luminance.

Bugs - A symbol used to mark or reference other information such as heading, altitude, etc.

Catastrophic - Failure conditions that result in multiple fatalities, usually with the loss of the aeroplane. (Note: In previous versions of CS 25.1309 and the associated advisory material a "catastrophic failure condition" was defined as a failure condition that would prevent continued safe flight and landing.)

Chrominance - The quality of a display image that includes both luminance and chromaticity and is a perceptual construct subjectively assessed by the human observer.

Chromaticity - Colour characteristic of a symbol or an image defined by its u', v' coordinates (See Commissions Internationale de L'Eclairage publication number 15.3, Colorimetry, 2004).

Clutter - Excessive number and/or variety of symbols, colours, or other information on a display that may reduce flight crew access or interpretation time, or decrease the probability of interpretation error.

Coasting Data - Data that is not updated for a defined period of time.

Coding - The use of assigning special meanings to some design element or characteristic (such as numbers, letters, symbols, auditory signals, colours, brightness, or variations in size) to represent information in a shorter or more convenient form.

Coding Characteristics - Readily identifiable attributes commonly associated with a design element that provide special meaning and differentiate the design elements from each other; for example size, shape, colour, motion, location, etc.

Colour Coding - The structured use of colour to convey specific information, call attention to information, or impose an organisational scheme on displayed information.

Command Information - Displayed information directing a control action.

Compact Mode - In display use, this most frequently refers to a single, condensed display presented in numeric format that is used during reversionary or failure conditions.

Conformal - Refers to displayed graphic information that is aligned and scaled with the outside view.

Contrast Ratio -

For HUD - Ratio of the luminance over the background scene (see SAE AS 8055).

For HDD - Ratio of the total foreground luminance to the total background luminance.

Criticality - Indication of the hazard level associated with a function, hardware, software, etc., considering abnormal behaviour (of this function, hardware, software) alone, in combination, or in combination with external events.

Design Eye Position - The position at each pilot's station from which a seated pilot achieves the required combination of outside visibility and instrument scan. The design eye position (DEP) is a single point selected by the applicant that meets the specifications of CS 25.773(d), CS 25.777(c), and CS 25.1321 for each pilot station. It is normally a point fixed in relation to the aircraft structure (neutral seat reference point) at which the midpoint of the pilot’s eyes should be located when seated at the normal position. The DEP is the principal dimensional reference point for the location of flight deck panels, controls, displays, and external vision.

Display Element – A basic component of a display, such as a circle, line, or dot.

Display Refresh Rate - The rate at which a display completely refreshes its image.

Display Resolution - Size of the minimum element that can be displayed, expressed by the total number of pixels or dots per inch (or millimetre) of the display surface.

Display Response Time - The time needed to change the information from one level of luminance to a different level of luminance. Display response time related to the **intrinsic response** (time linked to the electro-optic effect used for the display and the way to address it).

Display Surface/Screen - The area of the display unit that provides an image.

Display System - The entire set of avionic devices implemented to display information to the flight crew. This is also known as an electronic display system.

Display Unit - Equipment that is located in the flight deck, in view of the flight crew, that is used to provide visual information. Examples include a colour head down display and a head up display projector and combiner.

Earth Referenced System - An inertial-based system which provides a display of flight path through space. In a descent, an earth-referenced system indicates the relationship between the flight path and the terrain and/or the artificial horizon.

Enhanced Flight Vision System (EFVS) - An electronic means to provide a display of the forward external scene topography (the natural or manmade features of a place or region, especially in a way to show their relative positions and elevation) through the use of imaging sensors such as millimetre wave radiometry, millimetre wave radar, and low light level image intensifying.

Enhanced Vision System (EVS) - An electronic means to provide a display of the forward external scene topography through the use of imaging sensors, such as forward looking infrared, millimetre wave radiometry, millimetre wave radar, and low light level image intensifying.

NOTE: An EFVS is an EVS that is intended to be used for instrument approaches under the provisions of 14 CFR 91.175 (l) and 91.175 (m), and must display the imagery with instrument flight information on a HUD.

Extremely Improbable - An extremely improbable failure condition is so unlikely that it is not anticipated to occur during the entire operational life of all aeroplanes of one type.

Extremely Remote - An extremely remote failure condition is not anticipated to occur to each aeroplane during its total life, but may occur a few times when considering the total operational life of all aeroplanes of that type.

Eye Reference Position (ERP) - A single spatial position located at or near the centre of the HUD Eye Box. The HUD ERP is the primary geometrical reference point for the HUD.

Failure - An occurrence which affects the operation of a component, part, or element, such that it can no longer function as intended (this includes both loss of function and malfunction).

NOTE: Errors may cause failures but are not considered to be failures.

Failure Condition - A condition having an effect on the aeroplane and/or its occupants, either direct or consequential, which is caused or contributed to by one or more failures or errors, considering flight phase and relevant adverse operational or environmental conditions, or external events.

Field of View - The angular extent of the display that can be seen by either pilot with the pilot seated at either pilots station.

Flicker - An undesired, rapid temporal variation in the display luminance of a symbol, group of symbols, or a luminous field. It can cause discomfort for the viewer (such as headaches and irritation).

Flight Deck Design Philosophy - A high level description of the design principles that guide the designer and ensure a consistent and coherent interface is presented to the flight crew.

Flight Path Angle (FPA) (also known as a Flight Path Symbol, Climb, Dive Angle, or “caged” (on the attitude indicator centreline) Flight Path Vector) - A dynamic symbol displayed on an attitude display that depicts the vertical angle relative to the artificial horizon, in the pitch axis, that the aeroplane is moving. A flight path angle is the vector resultant of the forward velocity and the vertical velocity. For most designs, the FPA is earth referenced, though some use air mass vectors. Motion of the FPA on the attitude display is in the vertical (pitch) axis only with no lateral motion.

Flight Path Vector (FPV) (also known as Velocity Vector or Flight Path Marker) - A dynamic symbol displayed on an attitude display that depicts the vector resultant of real-time flight path angle (vertical axis) and lateral angle relative to aeroplane heading created by wind drift and slip/skid. For most designs, the FPV is earth referenced, though some use air mass vectors which cannot account for wind effects

Foreseeable Conditions - The full environment that the display or the display system is assumed to operate within, given its intended function. This includes operating in normal, non-normal, and emergency conditions.

Format (See Figure A3-2) - An image rendered on the whole display unit surface. A format is constructed from one or more windows (see ARINC Specification 661).

FPV/FPA-referenced Flight Director (FD) - A HUD or HDD flight director cue in which the pilot "flies" the FPV/FPA cue to the FD command in order to comply with flight guidance commands. This is different from attitude FD guidance where the pilot "flies" the aeroplane (that is, pitch, boresight) symbol to follow pitch and roll commands.

Full-time Display - A dedicated continuous information display.

Functional Hazard Assessment - A systematic, comprehensive examination of aeroplane and system function to identify potential Minor, Major, Hazardous, and Catastrophic failure conditions that may arise as a result of malfunctions or failures to function.

Grey Scale - The number of incremental luminance levels between full dark and full bright.

Hazard - Any condition that compromises the overall safety of the aeroplane or that significantly reduces the ability of the flight crew to cope with adverse operating conditions.

Hazardous – A hazardous failure condition reduces the operation of the aeroplane or the ability of the flight crew to operate in adverse conditions to the extent that there would be:

- A large reduction in safety margins or functional capabilities;
- Physical distress or excessive workload such that the flight crew cannot be relied upon to perform their tasks accurately or completely; or
- Serious or fatal injury to a relatively small number of the occupants other than the flight crew.

Head Down Display (HDD) - A primary flight display located on the aeroplane's main instrument panel directly in front of the pilot in the pilot's primary field of view. The HDD is located below the windscreen and requires the flight crew to look below the glareshield in order to use the HDD to fly the aeroplane.

Head Mounted Display (HMD) – A special case of HUD mounted on the pilot's head. Currently, there are not any HMDs used in CS-25 installations, but guidance will be provided in the future, as needed.

Head Up Display (HUD) - A display system that projects primary flight information (for example, attitude, air data, guidance, etc.) on a transparent screen (combiner) in the pilot's forward field of view, between the pilot and the windshield. This allows the pilot to simultaneously use the flight information while looking along the forward path out the windshield, without scanning the head down displays. The flight information symbols should be presented as a virtual image focused at optical infinity. Attitude and flight path symbology needs to be conformal (that is, aligned and scaled) with the outside view.

HUD Design Eye Box - The three-dimensional area surrounding the design eye position, which defines the area, from which the HUD symbology and/or imagery are viewable.

Icon - A single, graphical symbol that represents a function or event.

Image Size - The viewing area (field) of the display surface.

- Direct View Display: The useful (or active) area of the display (for example, units cm x cm).
- Head Up Display: The total field of view (units usually in degrees x degrees).

(Total field of view defines the maximum angular extent of the display that can be seen by either eye allowing head motion within the eyebox (see SAE AS 8055).

Indication - Any visual information representing the status of graphical gauges, other graphical representations, numeric data messages, lights, symbols, synoptics, etc. to the flight crew.

Information Update Rate - The rate at which new data is displayed or updated**.**

Interaction - The ability to directly affect a display by utilizing a graphical user interface (GUI) that consists of a control device (for example, a trackball), cursor, and “soft” display control that is the cursor target.

Latency - The time taken by the display system to react to a triggered event coming from an input/output device, the symbol generator, the graphic processor, or the information source.

Layer - A layer is the highest level entity of the Display System that is known by a User Application.

Luminance - Visible light that is emitted from the display. Commonly-used units: foot-lamberts, cd/m^{2}.

Major - A major failure condition reduces the operation of the aeroplane or the ability of the flight crew to operate in adverse conditions to the extent that there would be, for example:

- A significant reduction in safety margins or functional capabilities;
- Physical discomfort or a significant increase in flight crew workload
- Physical distress to passengers or cabin crew, possibly including injuries.

Menu - A list of display options available for selection.

Message - A communication that conveys an intended meaning such as an alerting or data link message.

Minor - A minor failure condition would not significantly reduce aeroplane safety and would involve crew actions well within their capabilities. Minor failure conditions may include:

- A slight reduction in safety margins or functional capabilities;

- A slight increase in crew workload (such as routine flight plan changes); or
- Some physical discomfort to passengers or cabin crew.

Misleading Information - Incorrect information that is not detected by the flight crew because it appears as correct and credible information under the given circumstances.

When incorrect information is automatically detected by a monitor resulting in an indication to the flight crew, or when the information is obviously incorrect, it is no longer considered misleading. The consequence of misleading information will depend on the nature of the information, and the given circumstances.

Mode - The functional state of a display and/or control system(s). A mode can be manually or automatically selected.

MSG-3 - Maintenance Steering Group 3. A steering group sponsored by the Airline Transportation Association whose membership includes representatives from the aviation industry and aviation regulatory authorities.

Occlusion - Visual blocking of one symbol by another, sometimes called occulting.

Partitioning - A technique for providing isolation between functionally independent software components to contain and/or isolate faults and potentially reduce the effort of the software verification process.

Pixel - A display picture element which usually consists of three (red, green, blue) sub-pixels (also called dots on a cathode ray tube).

Pixel Defect - A pixel that appears to be in a permanently on or off-state.

Primary Flight Displays - The displays used to present primary flight information.

Primary Field of View (FOV) (See Figure A3-1) - Primary Field-of-View is based on the optimum vertical and horizontal visual fields from the design eye reference point that can be viewed with eye rotation only using foveal or central vision. The description below provides an example of how this may apply to head-down displays.

With the normal line-of-sight established at 15 degrees below the horizontal plane, the values for the vertical (relative to normal line-of-sight forward of the aircraft) are
+/-15 degrees optimum, with +40 degrees up and -20 degrees down maximum.

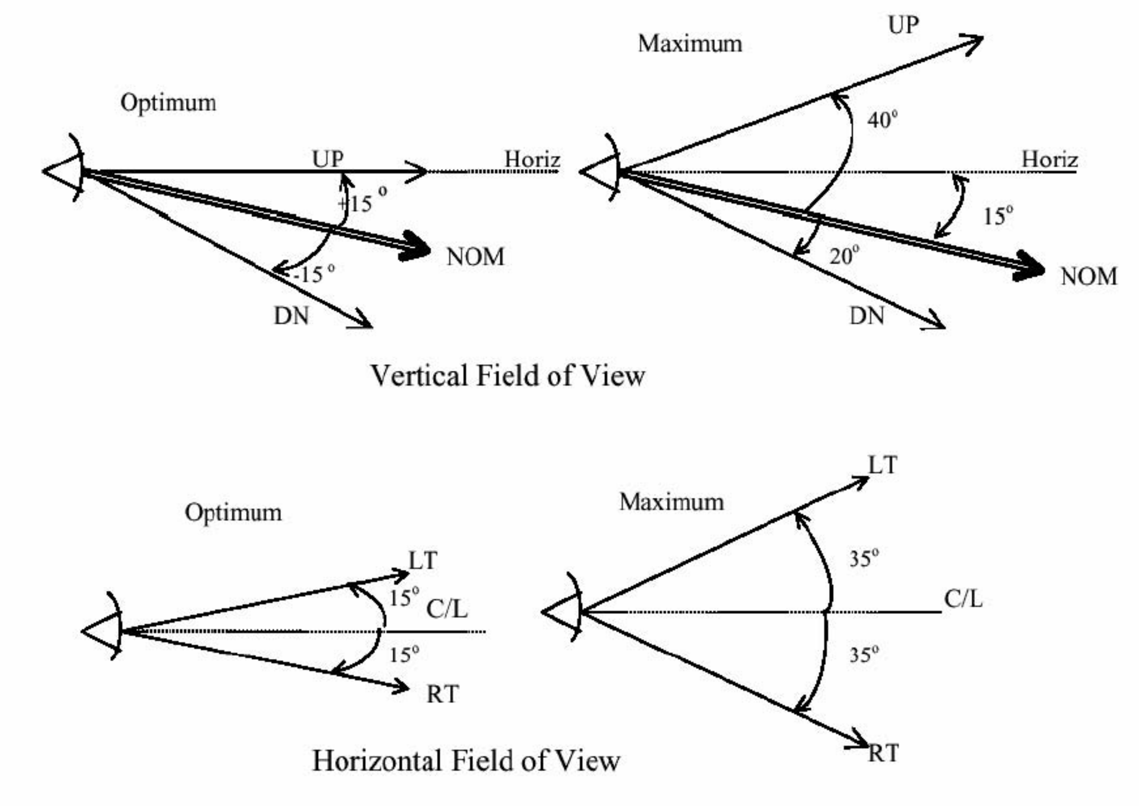


Figure A3-1 Primary Field of View

Primary Flight Information - The information whose presentation is required by CS 25.1303(b) and CS 25.1333(b), and arranged by CS 25.1321(b).

Primary Flight Instrument - Any display or instrument that serves as the flight crew's primary reference of a specific parameter of primary flight information. For example, a centrally located attitude director indicator is a primary flight instrument because it is the flight crew's primary reference for pitch, bank, and command steering information.

Prompt - A method of cueing the flight crew that some input or action is required.

Required Engine Indications - The information whose presentation is required by CS 25.1305.

Reversionary - The automatic or flight crew initiated (manual) relocation of display formats or windows following a display failure.

Shading - Shading is used as:

- A coding method for separating information, change in state, give emphasis, and depth information.
- A blending method between graphic elements (map displays, synthetic vision system).

Soft Control - Display element used to manipulate, select, or de-select information (for example, menus and soft keys).

Standby Display - A backup display that is used if a primary display malfunctions.

Status information - Information about the current condition of an aeroplane system and its surroundings.

Symbol - A symbol is a geometric form or alpha-numeric information used to represent the state of a parameter on a display. The symbol may be further defined by its location and motion on a display.

Synthetic Vision – A computer generated image of the external topography from the perspective of the flight deck. The image is derived from aircraft attitude, high-precision navigation solution, and terrain database terrain, obstacles, and relevant cultural features.

Synthetic Vision System – An electronic means to display a synthetic vision image of the external scene topography to the flight crew.

Texturing - A graphic, pictorial effect used to give a displayed object or graphic a specific "look" (metallic, grassy, cloudy, etc.). Texture is used:

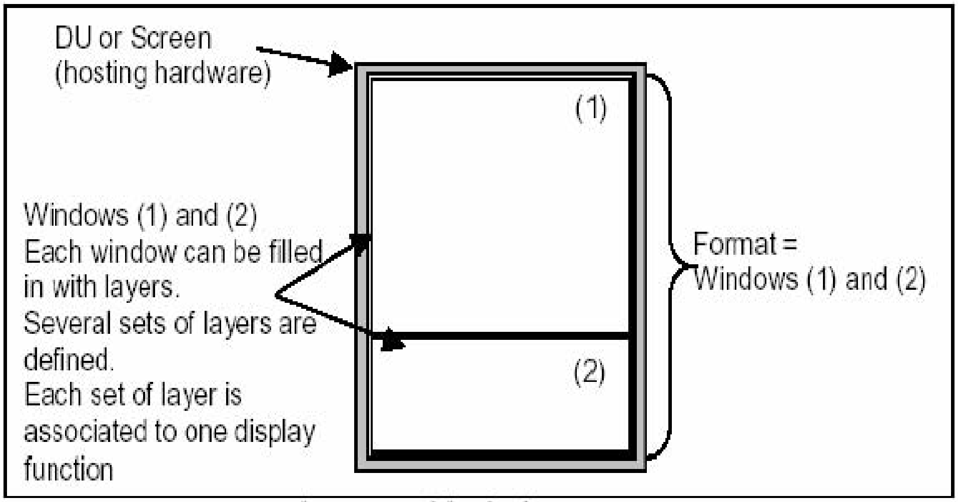
- As a coding method for separating information, change in state, give emphasis, and depth information.
- As a blending method between graphic elements (map displays, synthetic vision system).
- To enhance similarity between a synthetic image and the real world image.

Time Sharing – Showing different information in the same display area at different times.

Transparency - A means of seeing a background information element through a foreground information element. Transparency can alter the colour perception of both the "front" element and the "back" element.

Viewing Angle – The angle between the normal line of sight (looking straight ahead) and the line from the eye to the object being viewed. The angle can be horizontal, vertical, or a composite of those two angles.

Window (See Figure A3-2) - A rectangular physical area of the display surface. A window consists of one or more layers (see ARINC Specification 661).



Definitions used for display management
Example : format composed of 2 windows

Figure A3-2 – Display Format

Windowing - The technique to create windows. Segmenting a single display area into two or more independent display areas or inserting a new display area onto an existing display.

Appendix 4

Acronyms Used in this AMC

AC	(FAA) Advisory Circular
AMC	Acceptable Means of Compliance
ARAC	Aviation Rulemaking Advisory Committee
ARP	Aerospace Recommended Practices
AS	Aerospace Standard
CCD	Curser Control Device
CFR	Code of Federal Regulations
CRT	Cathode Ray Tube
DEP	Design Eye Position
EASA	European Aviation Safety Agency
EUROCAE	European Organisation for Civil Aviation Electronics
FAA	Federal Aviation Administration
GUI	Graphical User Interface
HDD	Head down Display
HUD	Head up Display
JAA	Joint Airworthiness Authorities
LCD	Liquid Crystal Display
SAE	SAE International (formerly Society of Automotive Engineers)
TCAS	Traffic Alert and Collision Avoidance System