— 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 becausethe 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 AMC 20-115 Software Considerations for Airborne Systems and Equipment Certification). SAE ARP 4754A/EUROCAE ED-79A, Guidelines for development of civil aircraft and 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

Notes

(1) 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.

(2) 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

Notes

(1) 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.

(2) 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

Notes

(1) 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.

(2) 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 heading on the flight deck on both pilots' primary displays	Remote
Loss of all heading displays on the flight deck	Extremely Improbable
Display of misleading heading information on both pilots' primary displays	Remote - Extremely Remote2)
Display of misleading heading information on one primary display combined with a standby failure (loss of heading or incorrect heading)	Remote – Extremely Remote2)

Notes

(1) 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.

(2) This assumes the availability of an independent, 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

Note

(1) "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

Notes

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

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

(3) See also AMC 25.1322.

(4) 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

Notes

(1) 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.

(2) 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.

— 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 with the regulations:

— SAE ARP 4102/7, Electronic Displays, Appendices A through C (for primary flight, navigation, and powerplant displays);

— SAE ARP 5289A, Electronic Aeronautical Symbols, (for depiction of navigation symbology); and

— SAE ARP 5288, Transport Category Aeroplane Head Up DisplayD) Systems, (for HUD symbology).