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This advisory circular (AC) provides guidance for showing compliance with certain requirements of Title 14, Code of Federal Regulations part 25 for the design, installation, integration, and approval of electronic flight deck displays, components, and systems installed in transport category airplanes. Revision B adds appendices F and G to the original AC and updates references to related rules and documents.

If you have suggestions for improving this AC, you may use the Advisory Circular Feedback form at the end of this AC.

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CHAPTER 1. INTRODUCTION

1.1 Purpose.

This advisory circular (AC) provides guidance for showing compliance with certain requirements of Title 14, Code of Federal Regulations (CFR) part 25, as well as general guidance for the design, installation, integration, and approval of electronic flight deck displays, components, and systems installed in transport category airplanes. Appendix A of this AC provides additional guidance for displaying primary flight information (required by §§ 25.1303(b) and 25.1333(b)), and appendix B of this AC provides additional guidance for powerplant displays.

1.2 Applicability.

1.2.1 The guidance provided in this AC is directed to airplane and avionics manufacturers, modifiers, and operators of transport category airplanes.

1.2.2 This material in this AC is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for showing compliance with the applicable regulations. The Federal Aviation Administration (FAA) will consider other methods of showing compliance that an applicant may elect to present. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. If, however, we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance. Applicants for a technical standard order (TSO) should consider following the guidance in this AC when the TSO requirements do not provide sufficient guidance.

1.2.3 This material in this AC does not change or create any additional regulatory requirements, nor does it authorize changes in, or permit deviations from, regulatory requirements.

1.3 Cancellation.

This AC cancels AC 25-11A, *Electronic Flight Display Systems*, dated June 21, 2007.

1.4 General.

1.4.1 This AC applies to the design, integration, installation, and certification approval of electronic flight deck displays, components, and systems for transport category airplanes. 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,
- Flightcrew interface and interactivity, and
- Airworthiness approval (means of compliance) considerations.

1.4.2 Table 1-1 lists the topics within the guidance of this AC. Table 1-2 lists the topics not within the guidance of this AC.

Table 1-1. Topics Within the Guidance of this AC

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 (HUDs).
Enhanced and synthetic vision systems.

Table 1-2. Topics Outside the Guidance of this AC

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 flightcrew 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.

1.4.3 Other advisory material is available for use in establishing guidance for specific functionality and characteristics provided by electronic displays. For example, AC 25-23, *Airworthiness Criteria for the Installation Approval of a Terrain Awareness and Warning System (TAWS) for Part 25 Airplanes*, describes a means for airworthiness approval of TAWS, and includes guidance on the display of TAWS. This revised AC 25-11B is not intended to replace or conflict with any existing AC. Its purpose is to provide general, high-level guidance for electronic displays in the flight deck. Conflicts between this AC and other advisory material, if any, will be resolved on a case-by-case basis, in agreement with the FAA. In those cases, the more specifically applicable material should be followed.

1.4.4 The combination of the guidance material in this AC, the Aviation Rulemaking Advisory Committee (ARAC) recommendations for adding a new regulation to 14 CFR part 25 and revising two existing part 25 regulations, and the associated guidance material for the ARAC recommendations, is intended to represent the design characteristics and techniques that are—

- Widely accepted in the aviation industry,
- Relevant to the regulatory requirements, and
- Can be reasonably applied to transport airplane certification programs for electronic flight deck displays.

1.4.5 The ARAC recommendations include revising the existing § 25.1309, *Equipment, systems, and installations*; and § 25.1333(b), *Instrument systems*. It is the FAA's intent that the information in this AC does not duplicate or conflict with the information provided in the guidance material that will possibly be created as a result of the ARAC recommendations for §§ 25.1309 and 25.1333(b).

1.4.5.1 For information about the ARAC recommendation for § 25.1309, see ARAC Task 2 - System Design and Analysis Harmonization and Technology Update at the FAA website.

1.4.5.2 For information about the ARAC recommendation for § 25.1333(b), see ARAC Task 2 - Cockpit Instrument System at the FAA website. Section 25.1333(b) is one part of the recommendations for this task.

1.5 Definitions of Terms Used in this AC.

1.5.1 For the purposes of this AC, a "display system" includes not only the display hardware and software components but also the entire set of avionic devices implemented to display information to the flightcrew. Hardware and software components of other systems that affect displays, display functions, or display controls should take into account the display aspects of this AC. For example, this AC 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.

1.5.2 For the purposes of this AC, "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.

1.5.3 Definitions of technical terms used in this AC can be found in appendix C of this AC. The acronyms used throughout this document are included in appendix D of this AC. A list of applicable regulations, related guidance, and industry material is included in appendix E of this AC.

1.6 Background.

1.6.1 Electronic displays can present unique opportunities and challenges to the design and certification process. In many cases, showing compliance with regulatory requirements related to the latest flight deck display system capabilities has been subject to a great deal of interpretation by applicants and the FAA. At the time the first electronic displays were developed, they were direct replacements for the conventional

electromechanical components. The initial release of AC 25-11 established guidance for the approval of cathode ray tube (CRT) based electronic display systems used for guidance, control, or decision-making by the flightcrews of transport category airplanes. This initial guidance was appropriate for CRTs, but additional guidance was needed to update AC 25-11 to address new technologies. Additional appendices have been added as new types of displays have been developed. Appendix F includes guidance for HUDs, and appendix G includes guidance for weather displays.

1.6.2 The FAA and European Aviation Safety Agency (EASA) have established a number of regulatory requirements 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 rules that are specific to certain systems, or to rules with general applicability such as §§ 25.1301(a), 25.771(a), and 25.1523. Thus, this AC provides guidance related to these and other applicable regulations.

CHAPTER 2. ELECTRONIC DISPLAY SYSTEM OVERVIEW

2.1 General.

The following paragraphs provide guidance that applies to the overall electronic display system. This chapter, together with chapters 1 through 7 of this AC, 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 A and B of this AC constitutes an overall method of compliance for the approval of an electronic display system.

2.2 Design Philosophy.

The applicant should establish, document, and follow a design philosophy for the display system that supports the intended functions (§ 25.1301). The documented design philosophy may be included as part of a system description, certification plan, or other document that is submitted to the FAA during a certification project. The design philosophy should include a high level description of (1) information presentation, (2) color of electronic displays, (3) information management, (4) interactivity, and (5) redundancy management.

2.2.1 General Philosophy of Information Presentation.

For example, is a "quiet, dark" flight deck philosophy used or is some other approach used?

2.2.2 Color Philosophy on the Electronic Displays.

The meaning and intended interpretation of different colors. For example, does magenta always represent a constraint?

2.2.3 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?

2.2.4 Interactivity Philosophy.

For example, when and why is pilot confirmation of actions requested? When is feedback provided?

2.2.5 Redundancy Management Philosophy.

For example, how are single and multiple display failures accommodated? How are power supply and data bus failures accommodated?

2.3 Human Performance Considerations.

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

- Flightcrew workload.
- Flightcrew training time to become sufficiently familiar with using the display.
- The potential for flightcrew error.

2.3.2 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 flightcrew errors. Compliance considerations are included in chapter 8 of this AC.

2.4 Addressing Intended Function in the Certification Plan.

The certification plan should identify the appropriate part 25 rules. An important part of the certification plan will be the system description(s) and all intended functions, including attitude, altitude, airspeed, engine parameters, horizontal situation display, etc. To demonstrate compliance with § 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 FAA to be able to evaluate that the system is appropriate to its intended function. The rule § 25.1302 and AC 25.1302-1, *Installed Systems and Equipment for Use by the Flightcrew*, provide additional information on intended function requirements and guidance. 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).

2.5 Non-Interference with Flying Duties.

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

CHAPTER 3. ELECTRONIC DISPLAY HARDWARE

3.1 Display Hardware Characteristics.

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

- For electronic displays, SAE Aerospace Standards (AS) 8034B, *Minimum Performance Standard for Airborne Multipurpose Electronic Displays*.
- For HUDs, 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 ARP4256A is not considered a reliable predictor of acceptable specular reflectivity characteristics. Accordingly, this aspect of LCD performance should be specifically assessed via flightcrew evaluation to establish that there are not internal or external reflections that can result in flightcrew distraction or erroneous interpretation of displayed information.

Note 2: With regard to the criteria for malfunction indication in SAE ARP4256A, 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 ARP4256A.

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 this AC, follow the guidance in this AC.

3.2 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 AC, and the visual characteristics in SAE ARP4256A, SAE AS8034B, and SAE AS8055, described above, the display should meet the criteria for the following characteristics. These characteristics are independent of the proposed display technology.

3.2.1 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 flightcrew from the flightcrew station (see related regulation) in all foreseeable conditions, relative to the operational and lighting environment and in accordance with its intended function(s).

3.2.2 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 flightcrew station (see related regulation) in all foreseeable conditions, relative to the operational and lighting environment.

3.2.3 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 flightcrew member's eyes, and
- Night and/or dark environment.

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

3.2.3.2 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.

3.2.3.2.1 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 flightcrew's ability to perform their tasks.

3.2.3.2.2 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 color 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.

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

3.2.4 Contrast Ratio.

3.2.4.1 The display's contrast ratio should be sufficient to ensure that the information is discernible under the whole ambient illumination range from the flightcrew station (see related regulation) under all foreseeable conditions relative to the operating environment.

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

3.2.5 Chromaticity.

3.2.5.1 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 flightcrew station (see related regulation), 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 AS8034B, sections 4.3.3 and 4.3.4, for additional guidance.

3.2.5.2 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.

3.2.6 Gray Scale.

3.2.6.1 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.

3.2.6.2 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.

3.2.7 Display Response.

The dynamic response of the display should be sufficient to provide discernibility and readability of the displayed information without presenting misleading, distracting, or confusing information. The response time should be sufficient to ensure dynamic stability of colors, line widths, gray scale, and relative positioning of symbols. Undesirable display artifacts and characteristics, such as smearing of moving images and loss of luminance, should be minimized so that information is still readable and identifiable under all foreseeable conditions, not distracting, and does not lead to misinterpretation of data.

3.2.8 Display Refresh Rate.

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

3.2.9 Display Update Rate.

The display update rate should be sufficient to preclude objectionable motion artifacts that could be misleading or distracting.

3.2.10 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 ARP4256A, SAE AS8034B, and SAE AS8055.

3.2.11 Reflections.

Each pilot compartment must be free of glare and reflections that could interfere with the normal duties of a minimum flightcrew. This must be shown in day and night flight tests under non-precipitation conditions (§ 25.773(a)(2)). The criteria and the basic workload functions and factors for a minimum flightcrew are described in appendix D to part 25 and § 25.1523.

3.2.12 Flight Deck Viewing Envelope.

The size of the viewing envelope should provide visibility of the flight deck displays over the flightcrew's normal range of head motion and should 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. See paragraph 3.3.3 for installation guidance.

3.3 **Installation.**

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

3.3.2 RTCA (formerly the Radio Technical Commission for Aeronautics) DO-160G, *Environmental Conditions and Test Procedures for Airborne Equipment*, and European Organisation for Civil Aviation Electronics (EUROCAE) ED-14G, *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 airplane environment.

3.3.3 The display unit must be located in the flight deck such that flight, navigation, and powerplant information for use by any pilot is 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 (§ 25.1321(a)). The primary flight information on the primary display should not be visually obstructed and should remain prominent.

3.3.4 The installation of the display equipment must not adversely affect its readability and the external scene visibility of the flightcrew (see related regulation) under all foreseeable conditions relative to the operating and lighting environment (§ 25.773(a)(1)).

3.3.5 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 flightcrew (§ 25.773(a)(2)) under all foreseeable conditions.

3.3.6 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 flightcrew member.

3.3.7 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. Appendix F of this AC and SAE ARP5288, *Transport Category Airplane Head Up Display (HUD) Systems*, provide additional details regarding the symbol positioning accuracy for conformal symbology on a HUD.

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

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

3.3.10 The display system must not be adversely susceptible to electromagnetic interference from other airplane systems (§ 25.1431) under all foreseeable conditions.

3.3.11 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.

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

3.4 **Power Bus Transient.**

RTCA DO-160G and EUROCAE ED-14G 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 ARP4256A, *Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft*, provides additional information for power transient recovery (specifically for the display unit).

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

3.4.2 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 airplane should be affected by an engine failure. Recognizably 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 airplanes, an engine failure after takeoff 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 airplane 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 recognizes 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.

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

3.4.4 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.

3.4.5 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 airplane in attitude, altitude, airspeed, and direction.

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

CHAPTER 4. SAFETY ASPECTS OF ELECTRONIC DISPLAY SYSTEMS

4.1 General.

This chapter provides additional guidance and interpretative material for applying §§ 25.1309 and 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 airplane 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. Section 25.1309 defines the basic safety requirements for the airworthiness approval of airplane systems. The tables in this chapter use the ARAC-recommended text for revising the existing § 25.1309 hazard classifications and associated probabilities. The ARAC recommendations for revising the existing AC 25.1309-1A, *System Design and Analysis*, provide guidance that may be used to establish an acceptable means of compliance. See appendix E of this AC for references on where to find more information regarding the ARAC recommendations.

4.2 Identification of Failure Conditions.

One of the initial steps in establishing compliance with § 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 airplane and/or its occupants, any considerations related to phase of flight, and identify any flight deck indication, flightcrew action, or other relevant mitigation means.

4.2.1 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 the following:

4.2.1.1 Loss of function (system or display).

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

4.2.1.3 Malfunction (system or display) that leads to partial loss of data, or erroneous display of data that is either—

- Detected by the system (for example, flagged or comparator alert), and/or easily detectable by the flightcrew, or
- Difficult to detect by the flightcrew or not detectable and assumed to be correct (for example, "Misleading display of ….").

4.2.2 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 flightcrew may use standby instruments in two complementary roles following the failure of primary displays:

4.2.2.1 Redundant display to cope with failure of main instruments, or

4.2.2.2 Independent third source of information to resolve inconsistencies between primary instruments.

4.2.3 When the display of erroneous information is caused by failure of other systems that 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 airplane level or within the other systems' safety assessment, as appropriate, in order to assess the cumulative effect.

4.3 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.

4.3.1 Based on previous airplane certification programs, paragraph 4.6 of this AC 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 § 25.1309 safety assessment process, the FAA will need to agree with the applicant's hazard classifications for these failure conditions in order for the assessment to be considered valid.

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

4.3.2.1 Effects on the flightcrew's ability to control the airplane in terms of attitude, speed, accelerations, and flight path, potentially resulting in—

- Controlled flight into terrain,
- Loss of control of the airplane during flight and/or during critical flight phases (approach, takeoff, go-around, etc.),

- Inadequate performance capability for phase of flight, including loss of obstacle clearance capability, and exceeding takeoff or landing field length,
- Exceeding the flight envelope,
- Exceeding the structural integrity of the airplane, and
- Causing or contributing to pilot-induced oscillations.

4.3.2.2 Effects on the flightcrew's ability to control the engines, such as—

- Those effects resulting in shutting down a non-failed engine in response to the failure of a different engine, and
- Undetected, significant thrust loss.

4.3.2.3 Effects on the flightcrew's management of the airplane systems.

4.3.2.4 Effects on the flightcrew's performance, workload, and ability to cope with adverse operating conditions.

4.3.2.5 Effects on situation awareness. For example, the specific effects must be identified, such as situation awareness related to navigation or system status.

4.3.2.6 Effects on automation if the display is used as a controlling device.

4.3.3 When the display system is used as a control device for other airplane systems, consider the cumulative effect of a display system failure on all of the controlled systems.

4.4 Mitigation of Failure Conditions.

4.4.1 When determining mitigation means for a failure condition, consider the following:

4.4.1.1 Protection against common mode failures.

4.4.1.2 Fault isolation and reconfiguration.

4.4.1.3 Redundancy (for example, heading information may be provided by an independent integrated standby and/or a magnetic direction indicator).

4.4.1.4 Availability, level, timeliness, and type of alert provided to the flightcrew.

4.4.1.5 The flight phase and the airplane configuration.

4.4.1.6 The duration of the condition.

4.4.1.7 The airplane motion cues that may be used by the flightcrew for recognition.

4.4.1.8 Expected flightcrew corrective action on detection of the failure and/or operational procedures.

4.4.1.9 In some flight phases, ability of the flightcrew to control the airplane after a loss of primary attitude display on one side.

4.4.1.10 The flightcrew's ability to turn off a display (for example, full bright display at night).

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

4.4.2 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.

4.4.3 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 ARAC's recommendations for revising AC 25.1309-1A. Additionally, the safety assessment should justify and describe any functional partitioning schemes employed to reduce the effect of integrated component failures or functional failures.

4.5 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 flightcrew action is expected to cope with the effect of a failure condition, the information available to the flightcrew should be useable for detection of the failure condition and to initiate corrective action.

4.6 System Safety Guidelines.

4.6.1 Experience from previous certification programs 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.

4.6.2 Experience from previous certification programs 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.

4.6.3 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 airplane components, including power supplies, pitot static ports, and other sensors.

4.6.4 There should be a means to detect the loss or erroneous 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 flightcrew (for example, removal of the information from the display or placement of an "X" through the failed display).

4.6.5 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).

4.6.6 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.

4.6.7 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.

4.6.8 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 minimize propagation of the failure condition.

4.6.9 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 AC, 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-178C, *Software Considerations in Airborne Systems and Equipment Certification*). SAE ARP4754A, *Guidelines for Development of Civil Aircraft Systems*, provides a recommended practice for system development assurance.

4.7 System Safety Assessment Guidelines.

4.7.1 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 aviation authority. 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, and system and component independence and isolation). The system safety analysis is required by § 25.1309 and indirectly by other regulations, including §§ 25.901, 25.903, and 25.1333.

4.7.2 This AC adopts the ARAC recommendations for revising AC 25.1309-1A. This AC uses the terms "major" and "hazardous" to identify what AC 25.1309-1A refers to as a "major" failure condition. Also, for major and hazardous failure conditions identified as "improbable" in AC 25.1309-1A and in the original version of AC 25-11, this AC includes the ARAC-recommended probabilities "remote" and "extremely remote," respectively.

4.7.3 This AC also includes the ARAC recommended terms "catastrophic," "failure," "failure condition," "hazardous failure condition," and "minor failure condition." ARAC recommended that these terms be included if AC 25.1309-1A is revised. Appendix C of this AC includes the definitions of these terms.

4.7.4 The following tables provide examples of failure conditions and associated hazard classifications and safety objectives common to numerous display systems that are already certified. These tables are provided to support consistency in determining hazard classifications across multiple applicants, multiple certification offices, and multiple display system designs; 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 hazard classifications, while reduced functional capability or increased operational mitigation may result in lower hazard classifications.

4.7.4.1 Attitude (Pitch and Roll). Table 4-1 lists examples of safety objectives for attitude related failure conditions.

Table 4-1. Example Safety Objectives for Attitude Failure Conditions

Failure Condition	Hazard Classification	Qualitative Probability
Loss of all attitude displays, including standby display	Catastrophic	Extremely Improbable
Loss of all primary attitude displays	Major – Hazardous[1]	Remote – Extremely Remote[1]
Display of misleading attitude information on both primary displays	Catastrophic	Extremely Improbable
Display of misleading attitude information on one primary display	Hazardous	Extremely Remote
Display of misleading attitude information on the standby display	Major	Remote
Display of misleading attitude information on one primary display combined with a standby failure (loss of attitude or incorrect attitude)	Catastrophic	Extremely Improbable[2]

[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 flightcrew may not be able to identify the correct display. Consideration will be given to the ability of the flightcrew to control the airplane after a loss of attitude primary display on one side in some flight phases (for example, during takeoff).

4.7.4.2 Airspeed. Table 4-2 lists examples of safety objectives for airspeed related failure conditions.

Table 4-2. Example Safety Objectives for Airspeed Failure Conditions

Failure Condition	Hazard Classification	Qualitative Probability
Loss of all airspeed displays, including standby display	Catastrophic	Extremely Improbable
Loss of all primary airspeed displays	Major – Hazardous[1]	Remote – Extremely Remote[1]
Display of misleading airspeed information on both primary displays, coupled with loss of stall warning or loss of over-speed warning	Catastrophic	Extremely Improbable
Display of misleading airspeed information of the standby display (primary airspeed still available)	Major	Remote
Display of misleading airspeed information on one primary display combined with a standby failure (loss of airspeed or incorrect airspeed)	Catastrophic	Extremely Improbable[2]

[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 flightcrew may not be able to separate out the correct display.

4.7.4.3 Barometric Altitude. Table 4-3 lists examples of safety objectives for barometric altitude related failure conditions.

Table 4-3. Example Safety Objectives for Barometric Altitude Failure Conditions

Failure Condition	Hazard Classification	Qualitative Probability
Loss of all barometric altitude displays, including standby display	Catastrophic	Extremely Improbable
Loss of all barometric altitude primary displays	Major – Hazardous[1]	Remote – Extremely Remote[1]
Display of misleading barometric altitude information on both primary displays	Catastrophic	Extremely Improbable
Display of misleading barometric altitude information on the standby display (primary barometric altitude still available)	Major	Remote
Display of misleading barometric altitude information on one primary display combined with a standby failure (loss of altitude or incorrect altitude)	Catastrophic	Extremely Improbable[2]

[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 flightcrew 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.

4.7.4.4 Heading. Table 4-4 lists examples of safety objectives for heading related failure conditions.

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

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

Table 4-4. Example of Safety Objectives for Heading Failure Conditions

Failure Condition	Hazard Classification	Qualitative Probability
Loss of stabilized heading in the flight deck	Major[2]	Remote[2]
Loss of all heading displays in the flight deck	Catastrophic	Extremely Improbable
Display of misleading heading information on both pilots' primary displays	Major – Hazardous[1]	Remote – Extremely Remote[1]
Display of misleading heading information on one primary display combined with a standby failure (loss of heading or incorrect heading)	Major – Hazardous[1]	Remote – Extremely Remote[1]

[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, non-stabilized heading required by § 25.1303(a)(3).

4.7.4.5 Navigation and Communication (Excluding Heading, Airspeed, and Clock Data). Table 4-5 lists examples of safety objectives for navigation and communication related failure conditions.

Table 4-5. Example Safety Objectives for Certain Navigation and Communication Failure Conditions

Failure Condition	Hazard Classification	Qualitative Probability
Loss of display of all navigation information	Major[1]	Remote[1]
Non-restorable loss of display of all navigation information coupled with a total loss of communication functions	Catastrophic	Extremely Improbable
Display of misleading navigation information simultaneously to both pilots	Major – Hazardous	Remote – Extremely Remote
Loss of all communication functions	Major	Remote

[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.

4.7.4.6 Other Parameters (Typically Shown on Electronic Display Systems). Table 4-6 lists examples of safety objectives for failure conditions related to other parameters typically shown on electronic display systems.

Table 4-6. Example Safety Objectives for Failure Conditions of Other Parameters

Failure Condition	Hazard Classification	Qualitative Probability
Display of misleading flight path vector information to one pilot	Major	Remote[1]
Loss of all vertical speed displays	Major	Remote
Display of misleading vertical speed information to both pilots	Major	Remote
Loss of all slip/skid indication displays	Major	Remote
Display of misleading slip/skid indication to both pilots	Major	Remote
Display of misleading weather radar information	Major	Remote[2]
Total loss of flightcrew alerting displays	Major	Remote
Display of misleading flightcrew alerting information	Major[3]	Remote
Display of misleading flightcrew procedures	Major – Catastrophic	Remote – Extremely Improbable[4]
Loss of the standby displays	Major	Remote

[1] The safety objective may be more stringent depending on the use and phase of flight.
[2] Applicable to the display part of the system only.
[3] Applicable to the general case, however, some cases could be more severe. Additional guidance is in AC 25.1322-1, *Flightcrew Alerting*.
[4] To be evaluated depending on the particular procedures and associated situations.

4.7.4.7 Engine. Table 4-7 lists examples of generally accepted safety objectives for engine related failure conditions. Appendix B of this AC provides additional guidance for powerplant displays.

4.7.4.7.1 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 flightcrew to maintain the engine within safe operating limits (for example, rotor speeds or exhaust gas temperature).

4.7.4.7.2 The information in table 4-7 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 flightcrew actions are not the primary means of protecting safe engine operation.

4.7.4.7.3 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."

4.7.4.7.4 Each of the general failure condition descriptions provided in table 4-7 represents a set of more specific failure conditions. The hazard classifications and probabilities provided in table 4-7 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 4-7. Example Safety Objectives for Engine Failure Conditions

Failure Condition	Hazard Classification	Qualitative Probability
Loss of one or more required engine indications for a single engine	Major	Remote
Misleading display of one or more required engine indications for a single engine	Major	Remote
Loss of one or more required engine indications for more than one engine	Hazardous	Extremely Remote[1]
Misleading display of any required engine indications for more than one engine	Catastrophic	Extremely Improbable[2]

[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 takeoff abort and loss of the backup means to assure safe engine operations. High-speed aborts have typically been classified as "hazardous" by the FAA due to the associated impacts on both flightcrew 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 back up 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 takeoff, this can lead directly to a catastrophe, either due to a high speed runway overrun or impacting an obstacle after takeoff. This classification has been debated and sustained by the FAA numerous times in the past. Hence the "Extremely Improbable" probability is listed.

4.7.4.8 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 dependent 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 AC. Table 4-8 lists the failure conditions when display systems are used as controls.

Table 4-8. Failure Conditions for Display Systems Used as Controls

Failure Condition	Qualitative Probability
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

CHAPTER 5. ELECTRONIC DISPLAY INFORMATION ELEMENTS AND FEATURES

5.1 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 AC 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.

5.2 General.

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

5.2.1.1 Each flight, navigation, and powerplant instrument for use by the flightcrew must be plainly visible from each pilot's crew station with the minimum practicable deviation from this normal position and line of vision when looking forward along the flight path (§ 25.1321(a)).

5.2.1.2 The displayed information should be easily and clearly discernible, 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. See paragraph 3.2.4 of this AC for additional guidance regarding contrast ratio.

5.2.1.3 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 (§ 25.1321(e)).

5.2.1.4 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 flightcrew station (see related regulation). If two or more pilots need to view the information, the information elements should also be discernible and interpretable over these viewing distances.

5.2.1.5 The pilots should have a clear, unobstructed, and undistorted view of the displayed information.

5.2.1.6 Information elements should be distinct and permit the pilots to immediately recognize 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 flightcrew can immediately recognize the source of the vertical guidance.

5.2.2 Factors to consider when designing and evaluating the viewability and readability of the displayed information include (1) position of displayed information, (2) vibrations, (3) visual angles, and (4) readability of displayed information.

5.2.2.1 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 flightcrew.

5.2.2.2 Vibrations.

Readability should be maintained in adverse conditions, such as vibration. One possible cause of vibration is sustained engine imbalance. AC 25-24, *Sustained Engine Imbalance*, provides readability guidance for that condition.

5.2.2.3 Visual Angles.

Account for both the position of the displayed information as well as font height. SAE ARP4102/7, *Electronic Displays*, provides additional information on this subject.

5.2.2.4 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.

5.3 **Consistency.**

Display information should be presented so it is consistent with the flight deck design philosophy in terms of symbology, location, control, behavior, size, shape, color, 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.

5.4 Display Information Elements.

5.4.1 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 recognized standard abbreviations and airport identifiers.

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

5.4.2.1 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.

5.4.2.2 The use of only upper case letters for text labels is acceptable.

5.4.2.3 Avoid contractions, such as “can’t” instead of “cannot.”

5.4.2.4 Break lines of text only at spaces or other natural delimiters.

5.4.2.5 Avoid abbreviations and acronyms where practical.

5.4.2.6 SAE ARP4102/7 provides guidelines on font sizes that are generally acceptable.

5.4.3 The choice of font also affects readability. The following guidelines apply:

5.4.3.1 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.

5.4.3.2 Sans serif fonts (for example, Futura or Helvetica) are recommended for displays viewed under extreme lighting conditions.

5.5 Labels.

Labels may be text or icons. The following paragraphs provide guidance on labeling 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. Section 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 flightcrew member with little or no

familiarity with the airplane is able to rapidly, accurately, and consistently identify their functions.

5.5.1 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 labeled "GSL."

5.5.2 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.

5.5.3 The following are guidelines and recommendations for labels:

5.5.3.1 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.

5.5.3.2 Labels should be consistent with related labels located elsewhere in the flight deck.

5.5.3.3 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.

5.5.4 Labels should be placed such that—

5.5.4.1 The spatial relationships between labels and the objects they reference are clear;

5.5.4.2 Labels for display controls are on or adjacent to the controls they identify;

5.5.4.3 Labels for display controls are not obstructed by the associated controls;

5.5.4.4 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; and

5.5.4.5 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, graying out an inactive menu button.

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

5.6 **Symbols.**

5.6.1 Electronic display symbol appearance and dynamics should be designed to enhance flightcrew comprehension and retention, and minimize flightcrew workload and errors in accordance with the intended function. The following list provides guidance for symbol appearance and dynamics:

5.6.1.1 Symbols should be positioned with sufficient accuracy to avoid interpretation errors or significantly increase interpretation time.

5.6.1.2 Each symbol used should be identifiable and distinguishable from other related symbols.

5.6.1.3 The shape, dynamics, and other symbol characteristics representing the same function on more than one display on the same flight deck should be consistent.

5.6.1.4 Symbol modifiers used to convey multiple levels of information should follow depiction rules clearly stated by the applicant. Symbol modifiers are changes to easily recognized baseline symbols such as colors, fill, and borders.

5.6.1.5 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).

5.6.2 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 flightcrew training times.

5.6.3 It is recommended that standardized symbols be used. The symbols in the following SAE documents have been found to be acceptable for compliance to the regulations:

- SAE ARP4102/7, *Electronic Displays*, appendices A through C (for primary flight, navigation, and powerplant displays).
- SAE ARP5289A, *Electronic Aeronautical Symbols* (for depiction of navigation symbology).
- SAE ARP5288, *Transport Category Airplane Head Up Display (HUD) Systems* (for HUD symbology).

5.7 **Indications.**

5.7.1 General.

Paragraphs 5.7.2 through 5.7.4 provide guidance on numeric readouts, gauges, scales, dials, tapes, and graphical depictions such as schematics. Graphics related to interactivity are discussed in paragraph 5.10 of this chapter and chapter 7 of this AC. Graphics and display indications should—

5.7.1.1 Be readily understood and compatible with other graphics and indications in the flight deck,

5.7.1.2 Be identifiable and readily distinguishable, and

5.7.1.3 Follow the guidance for viewability presented in paragraphs 5.1, 5.2, 5.3, and 5.4 of this chapter.

5.7.2 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.

5.7.2.1 Data accuracy of the numeric readout should be sufficient for the intended function and to avoid inappropriate flightcrew 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.

5.7.2.2 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 flightcrew task.

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

5.7.3 Scales, Dials, and Tapes.

Scales, dials, and tapes with fixed and/or moving pointers have been shown to effectively improve flightcrew interpretation of numeric data.

5.7.3.1 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.

5.7.3.2 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.

5.7.3.3 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.

5.7.4 Other Graphical Depictions.

Depictions include schematics, synoptics, and other graphics such as attitude indications, moving maps, and vertical situation displays.

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

5.7.4.2 To the extent it is practical and necessary, the graphic orientation and the flightcrew'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.

5.7.4.3 If there are multiple depictions, such as "thumbnail" or overlayed 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 flightcrew member.

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

5.8 **Color Coding.**

5.8.1 If color 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 color alone. However, the use of

color 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.

5.8.2 To ensure correct information transfer, the consistent use and standardization of color is highly desirable. In order to avoid confusion or an interpretation error, there should not be a change in how the color is perceived over all foreseeable conditions. Colors 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 standardization for red and amber or yellow, in accordance with § 25.1322, is required to retain the effectiveness of flightcrew 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 flightcrew awareness or response. Inconsistencies in the use of color 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.

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

5.8.4 Other graphic depictions such as terrain maps and synthetic vision presentations may use more than six colors and use color blending techniques to represent colors in the outside world or to emphasize terrain features. These displays are often presented as background imagery and the colors used in the displays should not interfere with the flightcrew interpretation of overlaid information parameters as addressed in paragraph 5.8.5 of this chapter.

5.8.5 Table 5-1 depicts previously accepted color coding and the functional meaning associated with each color. The use of these colors is recommended for electronic display systems with color displays.

Table 5-1. Recommended Colors for Certain Functions

Feature	Color
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[1]
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

[1] Use of the color green for tape elements (for example, airspeed and altitude) has also been found acceptable if the color green does not adversely affect flightcrew alerting.

5.8.6 Table 5-2 depicts display features that should be allocated a color from either Color Set 1 or Color Set 2.

Table 5-2. Specified Colors for Certain Display Features

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

[1] Use of the color yellow for functions other than flightcrew alerting should be limited and should not adversely affect flightcrew alerting.
[2] In Color Set 1, magenta is intended to be associated with those analog parameters that constitute "fly to" or "keep centered" type information.

5.8.7 The following color 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.
- Red on black.

Note: For further information on this subject, see FAA Report No. DOT/FAA/CT-03/05 HF-STD-001, *Human Factors Design Standard (HFDS): For Acquisition of Commercial Off-the-Shelf Subsystems, Non-Developmental Items, and Developmental Systems*.

5.8.8 When background color is used (for example, gray), 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 color

should conform to the overall flight deck philosophies for color 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 minimized because it may increase pilot interpretation time or errors.

5.8.9 Requiring the flightcrew to discriminate between shades of the same color 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).

5.8.10 Any foreseeable change in symbol size should ensure correct color interpretation. For example, the symbol needs to be sufficiently large so the pilot can interpret the correct color.

5.9 Dynamic (Graphic) Information Elements on a Display.

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 airplane 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 airplane control task associated with that parameter. In particular, display system lag (including the sensor) for attitude that does not exceed a first order equivalent time constant of 100 milliseconds for airplanes with conventional control system response is generally acceptable.

5.9.1 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.

5.9.2 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.

5.9.3 Dynamic information should not appreciably change shape or color 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 discernible, legible, identifiable, placed accurately, not distracting, etc.).

5.10 **Sharing Information on a Display.**

There are three primary methods of sharing information on a given display. First, the information may be overlayed or combined, such as when traffic alert and collision avoidance system (TCAS) information is overlayed 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 prioritized, but is needed, can be recovered, and that it will not be needed more quickly than it can be recovered.

5.10.1 Overlays and Combined Information Elements.

5.10.1.1 When information is graphically overlaid over other information (for example, an airplane 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 minimized.

5.10.1.2 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.

5.10.1.3 If information is integrated with other information on a display, the projection, placement accuracy, directional orientation, and 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.

5.10.1.4 Time Sharing.

5.10.1.4.1 For guidance on full-time vs. part-time displays, see paragraph 6.3.3 of this AC.

5.10.1.4.2 Any information that should or must be continuously monitored by the flightcrew should be displayed at all times (for example, attitude).

5.10.1.4.3 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 jeopardize the performance monitoring task.

5.10.1.4.4 Generally, system information, planning, and other information not necessary for the pilot tasks can be time shared.

5.10.2 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.

5.10.3 Clutter and De-Clutter.

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

5.10.3.2 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 airplane 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 flightcrew to recover the airplane.

5.11 **Annunciations and Indications.**

5.11.1 General.

Annunciations and indications include annunciator switches, messages, prompts, flags, and status or mode indications that either are on the flight deck display itself, or control a flight deck display. See § 25.1322 and AC 25.1302-1 for information regarding specific annunciations and indications such as warning, caution, and advisory level alerts.

5.11.1.1 Annunciations and indications should be operationally relevant and limited to minimize the adverse effects on flightcrew workload.

5.11.1.2 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.

5.11.2 Location.

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

5.11.3 Managing Messages and Prompts.

The following general guidance applies to all messages and prompts:

5.11.3.1 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.

5.11.3.2 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.

5.11.3.3 See § 25.1322 and AC 25.1302-1 for information on warning, caution, and advisory alerts.

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

5.11.4 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.

5.11.5 Use of Imaging.

This paragraph provides guidance on the use of images that depict a specific portion of the airplane 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.

5.11.5.1 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 airplane flight manual

(AFM), image location, adequate labeling, distinct texturing, or other means.

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

5.11.5.3 Dynamic images should meet the guidance in paragraph 5.9 of this chapter. The overall system lag time of a dynamic image relative to real time should not cause flightcrew misinterpretation or lead to a potentially hazardous condition. Image failure, freezing, coasting, or color changes should not be misleading and should be considered during the safety analysis.

5.11.5.4 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 color for all foreseeable conditions of the underlying image and range of motion.

5.11.5.5 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 flightcrew'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.

CHAPTER 6. ORGANIZING ELECTRONIC DISPLAY INFORMATION ELEMENTS

6.1 Organizing Information Elements.

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 that 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 AC provides guidance for information elements including text, labels, symbols, graphics, and other depictions (such as video) in isolation and combination.

6.2 Types and Arrangement of Display Information.

This paragraph provides guidance for the arrangement and location of categories of information. The categories of information include the following:

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

6.2.1 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:

6.2.1.1 Primary flight information. (See paragraph 6.2.3 in this chapter and appendix A of this AC.)

6.2.1.2 Powerplant information. (See paragraph 6.2.4 in this chapter and appendix B of this AC.)

6.2.1.3 Flightcrew alerts. Each flightcrew alert should be displayed in a specific location or in a central flightcrew alert area.

6.2.1.4 Autopilot and flight director modes of operation.

6.2.1.5 Lateral and vertical path deviation indicators.

6.2.1.6 Radio altitude indications.

6.2.1.7 Failure flags should be presented in the location of the information they reference or replace.

6.2.1.8 Data labels for navigation, traffic, airplane system, and other information should be placed in a consistent position relative to the information they are labeling.

6.2.1.9 Supporting data for other information, such as bugs and limit markings, should be consistently positioned relative to the information they support.

6.2.1.10 Features on electronic moving map displays (for example, very high frequency omnirange stations (VORs), waypoints, etc.) relative to the current airplane position. In addition, the features should be placed on a constant scale for each range selected.

6.2.1.11 Segment of flight information relative to similar information or other segments.

6.2.2 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.

6.2.3 Arrangement—Basic T Information.

6.2.3.1 Section 25.1321(b) includes requirements for the "Basic T" arrangement of certain information required by § 25.1303(b).

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

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

6.2.3.2.2 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 backup displays, HUDs, and moving map displays. The primary airspeed, altitude, and direction indications are the respective display indications closest to the primary attitude indication.

6.2.3.2.3 The primary attitude indication should be centered about the plane of the flightcrew's forward vision. This should be measured from the DEP at the

flightcrew station (see related regulation). If located on the main instrument panel, the primary attitude indication must be in the top center position (§ 25.1321(b)). The attitude indication should be placed so that the display is unobstructed under all flight conditions. See SAE ARP4102/7 for additional information.

6.2.3.2.4 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.

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

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

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

6.2.3.2.8 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.

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

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

6.2.3.2.11 If an applicant seeks approval of alternative instrument arrangements by equivalent safety under § 21.21(b)(1), the FAA will normally require well-founded research, or relevant service experience from military, foreign, or other sources to substantiate the applicant's proposed compensating factors.

6.2.4 Arrangement—Powerplant Information.

6.2.4.1 Required engine indications necessary to set and monitor engine thrust or power should be continuously displayed in the flightcrew's primary field of view, unless the applicant can demonstrate that this is not necessary (see the guidance in paragraph 6.3.3 of this chapter and appendix B of this AC). The automatically selected display of powerplant information should not suppress other information that requires flightcrew awareness.

6.2.4.2 Powerplant information must be closely grouped (in accordance with § 25.1321) in an easily identifiable and logical arrangement that allows the flightcrew 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.

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

6.2.5.1 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.

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

6.2.5.3 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 flightcrew when needed. For guidance on part-time displays, see paragraph 6.3.3 of this chapter.

6.2.5.4 Other information should not be located where the primary flight information or required powerplant information is normally presented. See paragraphs 6.2.1 and 6.2.3 of this chapter for primary flight information guidance. See paragraphs 4.7 and 6.2.4 of this AC for powerplant information guidance.

6.3 **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.

6.3.1 Window.

A window is a defined area that 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:

6.3.1.1 The window(s) should have fixed size(s) and location(s).

6.3.1.2 Separation between information elements within and across windows should be sufficient to allow the flightcrew to readily distinguish separate functions or functional groups (for example, powerplant indication) and avoid any distractions or unintended interaction.

6.3.1.3 Display of selectable information, such as a window on a display area, should not interfere with or affect the use of primary flight information.

6.3.1.4 For additional information regarding the display of data on a given location, data blending, and data over-writing, see Aeronautical Radio, Inc. (ARINC) Standard 661-5, *Cockpit Display System Interfaces to User Systems*.

6.3.2 Menu.

6.3.2.1 A menu is a displayed list of items from which the flightcrew 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 it may be done by pointing

(with a cursor control device or other mechanism), entering an associated option code, or activating a function key.

6.3.2.2 The hierarchical structure and organization of the menus should be designed to allow the flightcrew 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 flightcrew knows where to find them. At all times the system should indicate the current position within the menu and menu hierarchy.

6.3.2.3 The number of sub-menus should be designed to assure timely access to the desired option without over-reliance on memorization 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.

6.3.2.4 The number of steps required to choose the desired option should be consistent with the frequency, importance, and urgency of the flightcrew's task.

6.3.2.5 When a menu is displayed, it should not obscure required information.

6.3.3 Full-Time versus Part-Time Display of Information.

Some airplane parameters or status indications are required to be displayed by the regulations (for example, powerplant information required by § 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.

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

6.3.3.1.1 Continuous display of the parameter is not required for safety of flight in all normal flight phases.

6.3.3.1.2 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.

6.3.3.1.3 Display of the inhibited parameter can be manually selected by the flightcrew without interfering with the display of other required information.

6.3.3.1.4 If the parameter fails to be displayed when required, the failure effect and compounding effects must meet the requirements of all applicable regulations (for example, § 25.1309).

6.3.3.1.5 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.

6.3.3.1.6 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.

6.3.3.2 Pop-up display of information. Certain types of information, such as terrain and TCAS, are required by the operation regulations to be displayed, yet they are only necessary or required in certain phases of flight (similar to the part-time display of required airplane parameters (see paragraph 6.2.3 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. Consider the following criteria for displaying automatic pop-up information:

6.3.3.2.1 Information is automatically displayed when its value indicates a predetermined condition, or when the associated parameter reaches a predetermined value.

6.3.3.2.2 Pop-up information should appropriately attract the flightcrew's attention while minimizing task disruption.

6.3.3.2.3 If the flightcrew deselects the display of the automatic pop-up information, then another automatic pop-up should not occur until a new condition/event causes it.

6.3.3.2.4 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 color associated with the nature of the alert, prompting the flightcrew to make the necessary changes for the display of the information. This guidance differs from the part-time display of information required by part 25 because the required information should be displayed regardless of the configuration.

6.3.3.2.5 If a pop-up 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 flightcrew task. Additionally, the pop-ups should not cause a misleading presentation.

6.3.3.2.6 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

prioritize the pop-up events based on their criticality. Pop-up display orientation should be in track-up or heading-up.

6.3.3.2.7 Any information to a given system that is not continuously displayed, but the safety assessment determines it is necessary to be presented to the flightcrew, should automatically pop-up or otherwise indicate that its display is required.

6.4 **Managing Display Configuration.**

The following paragraphs address managing the information presented by an electronic display system and its response to failure conditions and flightcrew 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.

6.4.1 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 flightcrew should be designed and evaluated for arrangement, visibility, and interference.

6.4.2 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 requirements also apply in failure conditions. Alternative display locations used in non-normal conditions should be evaluated by the FAA or its designees to determine if the alternative locations meet the criteria for acceptability.

6.4.2.1 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 requirements.

6.4.2.2 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.

6.4.2.3 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).

6.4.2.4 If several possibilities exist for relocating the failed display, a recommended flightcrew procedure should be considered and documented in the AFM.

6.4.2.5 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 airplane's airspeed, altitude, heading, and attitude by one of the pilots without additional flightcrew action, after any single failure or combination of failures that is not assessed to be extremely improbable.

6.4.2.6 The following means to reconfigure the displayed information are acceptable:

6.4.2.6.1 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.

6.4.2.6.2 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 flightcrew that the displayed information is from a single graphic generator source.

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

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

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

6.5 **Methods of Reconfiguration.**

6.5.1 Compacted Format.

6.5.1.1 The term "compacted format," as used in this AC, 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 flightcrew. Except for training purposes, the "compacted format" should not be selectable unless there is a display failure. The concepts and requirements of § 25.1321, as discussed in paragraph 6.2.3 of this chapter, still apply.

6.5.1.2 The compacted display format should maintain the same display attributes (color, 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.

6.5.2 Sensor Selection and Annunciation.

6.5.2.1 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 flightcrew action. Manual switching may be acceptable in less complex systems or if immediate flightcrew action is not required.

6.5.2.2 Independent attitude, direction, and air data sources are required for the captain and first officer's displays of primary flight information (see § 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.

6.5.2.3 If sensor information sources cannot be switched, then no annunciation is required.

6.5.2.4 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.

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

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

CHAPTER 7. ELECTRONIC DISPLAY SYSTEM CONTROL DEVICES

7.1 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.

7.2 Multi-Function Control Labels.

Multi-function controls should be labeled such that the pilot is able to—

7.2.1 Rapidly, accurately, and consistently identify and select all functions of the control device;

7.2.2 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; and

7.2.3 Determine quickly and accurately the function of the control without extensive training or experience.

7.3 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)).

7.3.1 "Hard" Controls.

7.3.1.1 Mechanical controls used to set numeric data on a display should have adequate friction or tactile detents to allow a flightcrew 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.

7.3.1.2 The input for display response gain to control should be optimized for gross motion as well as fine positioning tasks without overshoots. In accordance with § 25.777(b), the direction of movement of the cockpit controls must meet the requirements of § 25.779. Wherever practicable, the sense of motion involved in the operation of other controls must correspond to the sense of the effect of the operation on the airplane 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.

7.3.2 "Soft" Controls.

7.3.2.1 There are two interactive types of soft control displays, one type affects airplane systems and the other type does not. Displays that use a graphical user interface (GUI) permit information within different display areas to be directly manipulated by the flightcrew (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 airplane system operations (for example, utility controls on displays traditionally found in overhead panel functions, flight management system (FMS) operations, and graphical flight planning).

7.3.2.2 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:

7.3.2.2.1 The GUI and control device should be compatible with the airplane 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 airplane system they will control.

7.3.2.2.2 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.

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

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

7.3.2.2.5 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 airplane.

7.3.2.2.6 The final display response to control input should be fast enough to prevent undue concentration being required when the flightcrew sets values or display parameters (§ 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 flightcrew.

7.3.2.2.7 To show compliance with § 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 flightcrew may access during these conditions.

7.4 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 7.2, 7.3, and 7.5 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 20-170, *Integrated Modular Avionics Development, Verification, and Approval Using RTCA/DO-297 and Technical Standard Order-C153*, October 28, 2010.

7.4.1 The CCD design and installation should enable the flightcrew 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.

7.4.2 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 flightcrew workload.

7.4.3 The functionality of the CCD should be demonstrated with respect to the flightcrew interface considerations outlined below:

7.4.3.1 The ability of the flightcrew to share tasks, following CCD failure, with appropriate workload and efficiency.

7.4.3.2 The ability of the flightcrew 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).

7.4.3.3 Satisfactory flightcrew task performance and CCD functionality, whether the CCD is operated with a dominant or non-dominant hand.

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

7.4.3.5 Ease of recovery from incorrect use.

7.5 **Cursor Displays.**

7.5.1 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 flightcrew. 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.

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

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

7.5.2.2 The failure mode of an uncontrollable and distracting display of the cursor should be evaluated.

7.5.2.3 Because in most applications more than one flightcrew member will be using one cursor, the applicant should establish an acceptable method for handling "dueling 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.

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

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

CHAPTER 8. SHOWING COMPLIANCE FOR APPROVAL OF ELECTRONIC DISPLAY SYSTEMS

8.1 General Compliance Considerations (Test and Compliance).

This chapter provides guidance for demonstrating compliance to the regulations 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.

8.2 Means of Compliance.

8.2.1 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.

8.2.2 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).

8.2.3 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.)

8.2.4 The following guidance describes means of compliance for electronic displays:

8.2.4.1 System Descriptions. This may include system architecture, description of the layout and general arrangement of the flight deck, description of the intended function, flightcrew interfaces, system interfaces, functionality, operational modes, mode transitions, and characteristics (for example, dynamics of the display system), and applicable requirements 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 regulations can easily be reduced to simple geometry, arrangement, or the presence of a given feature on the drawing. The following questions may be used to evaluate whether the description of intended function is sufficiently specific and detailed:

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

8.2.4.1.2 What assessments, decisions, or actions are the flightcrew members intended to make based on the display system?

8.2.4.1.3 What other information is assumed to be used in combination with the display system?

8.2.4.1.4 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.

8.2.4.2 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 programs 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 color).

8.2.4.3 Calculation and 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 modeling 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.

8.2.4.4 Evaluation. This is an assessment of the design conducted by the applicant, who then provides a report of the results to the FAA. 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 FAA 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.

8.2.4.4.1 Evaluations may begin early in the certification program. 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 mockups to full installation representations of the actual product or flight deck.

8.2.4.4.2 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 provided to the FAA as early as possible to obtain agreement between the applicant and the FAA 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 flightcrew tasks.

8.2.4.5 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 airplane, and is often more formal, structured, and rigorous than an evaluation.

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

8.2.4.5.2 Flight tests should be used to validate and verify data collected from other means of compliance such as analyses, evaluations, and simulations. According to § 25.1523, during the certification process, the flightcrew workload assessments and failure classification validations should be addressed in a flight simulator or an actual airplane, although the assessments may be supported by appropriate analyses (see AC 25.1523-1, *Minimum Flightcrew*, for a description of the types of analyses).

CHAPTER 9. CONTINUED AIRWORTHINESS AND MAINTENANCE

9.1 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 §§ 25.1309 and 25.1529 (including appendix H to part 25), 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 3 (MSG-3) analyses that are conducted.

9.2 General.

Information on preparing the Instructions for Continued Airworthiness can be found in appendix H to part 25. In addition to those instructions, maintenance procedures should be considered for the following:

9.2.1 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 airplane is in flight, the switching or backup display/sensor may not be available when required. These failures may be addressed by a system safety assessment and should be addressed in the airplane's maintenance program (for example, MSG-3).

9.2.2 Display cooling fans and filters integral with cooling ducting.

9.3 Design for Maintainability.

The display system should be designed to minimize maintenance error and maximize maintainability.

9.3.1 The display mounting, connectors, and labeling 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.

9.3.2 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.

9.3.3 If the flightcrew 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.

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

9.4 Maintenance of Display Characteristics.

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

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

9.4.3 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 that could be adopted by the airplane manufacturer.

APPENDIX A. PRIMARY FLIGHT INFORMATION

A.1 **General.**

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

A.2 **Attitude.**

A.2.1 Pitch attitude display scaling should be such that during normal maneuvers (for example, approach or climb at high thrust-to-weight ratios) the horizon remains visible in the display with at least 5° pitch margin available.

A.2.2 An accurate, easy, quick-glance interpretation of attitude should be possible for all unusual attitude situations and other "non-normal" maneuvers sufficient to permit the pilot to recognize 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.

A.2.3 Both fixed airplane 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.

A.2.4 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.

A.2.5 There should be a means to identify an excessive bank angle condition prior to stall buffet.

A.2.6 Sideslip should be clearly indicated to the flightcrew (for example, a split trapezoid on the attitude indicator) and an indication of excessive sideslip should be provided.

A.3 **Continued Function of Primary Flight Information (Including Standby) in Conditions of Unusual Attitudes or in Rapid Maneuvers.**

A.3.1 Primary flight information must continue to be displayed in conditions of unusual attitudes or in rapid maneuvers (§ 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 (§ 25.1301).

A.3.2 In showing compliance with the requirements of §§ 25.1301(d), 25.1309(a), 25.1309(b), 25.1309(c), and 25.1309(d), the analysis and test program must consider the following conditions that might occur due to pilot action, system failures, or external events—

- Abnormal attitude (including the airplane 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.

A.3.3 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 recognize and execute recovery from the unusual attitude and/or arrest the higher than normal pitch, roll, or yaw rates (§ 25.1301).

A.4 **Airspeed and Altitude.**

A.4.1 Airspeed and altitude displays should be able to convey to the flightcrew 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 airplane operational speed range, variations from this should be verified for acceptability. A displayed altitude that is geometrically derived should be easily discernible 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. See paragraph F.5.4.4 of appendix F of this AC for airspeed considerations specific to a head-up display (HUD).

A.4.2 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 $V_{stall\ warning}$, V_1, V_R, V_2, 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 flightcrew adequate information for system monitoring as required by § 25.1309(c).

A.4.3 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.

A.4.4 Airspeed scale markings such as stall warning, maximum operation speed/maximum operating Mach number, or flap limits, should be displayed to provide the flightcrew 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, stabilized approach operating between stall warning and flap limit speeds).

A.4.5 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.

A.4.6 Airspeed scale graduations in 5-knot increments with graduations labeled 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.

A.4.7 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 airplanes 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.

A.4.8 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 flightcrew'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.

A.5 **Low- and High-Airspeed Awareness Cues.**

A.5.1 Section 25.1541(a)(2) states the airplane must contain: "Any additional information, instrument markings, and placards required for the safe operation if there are unusual design, operating, or handling characteristics." The part 25 regulations 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" according to § 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.

A.5.2 Low-speed awareness cues should provide adequate visual cues to the pilot that the airspeed is below the reference operating speed for the airplane 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:

A.5.2.1 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 transport category airplanes have a wide range of stall speeds due to multiple flap/slat configurations and potentially large variations in gross weight.

A.5.2.2 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 (§ 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 use an amber and red bar adjacent to the airspeed tape to provide this quick-glance low/high speed awareness. The preferred colors to be used are amber or yellow to indicate that the airspeed has decreased below a reference speed that provides adequate maneuver 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 airplane 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 FAA approved systems use a pilot selectable operating speed "bug" at V_{REF} supplemented by system-computed low speed cues that vary in color as airspeed decreases below certain multiples of the appropriate stall speed (for example, white below 1.3 V_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.

A.5.2.3 Low-speed awareness displays should be sensitive to load factor (g-sensitive) to enable the pilot to maintain adequate maneuver margins above stall warning in all phases of flight. The accuracy of this g-sensitivity function should be verified by flight tests.

A.5.2.4 Flight tests should also be conducted in maneuvering 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 maneuvering flight.

A.5.2.4.1 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.

A.5.2.4.2 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.

A.6 **Vertical Speed.**

The display range of vertical speed (or rate of climb) indications should be consistent with the climb/descent performance capabilities of the airplane. 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.

A.7 **Flight Path Vector or Symbol.**

A.7.1 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.

A.7.2 The FPV symbol can be especially useful on HUD applications. See paragraph F.5.4.5 of appendix F for HUD-specific FPV considerations.

A.7.3 The FPV or FPA indication may also be displayed on the head-down display (HDD). In some HDD and most HUD applications, the FPV or FPA is the primary control and tracking cue for controlling the airplane 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.

A.7.4 If the FPV/FPA is used as the primary means to control the airplane in pitch and roll, the FPV/FPA system design should allow pilots to control and maneuver the airplane with a level of safety that is at least equal to traditional designs based on attitude (§ 25.1333(b)).

A.7.5 There may be existing airplane 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 flightcrew. 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.

A.7.6 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 center of the pilot's primary field of view, as required by § 25.1321.

A.7.7 Airplane designs that 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).

A.7.8 In existing cases where an FPV is displayed head up and an FPA head down on an airplane, 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 flightcrew. A mixture of the two types of flight path indications is not recommended due to possible misinterpretation by the flightcrew.

A.7.9 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.

A.7.10 Implementation of air mass-based FPV/FPA presentations should account for inherent limitations of air mass flight path computations.

A.7.11 Flight directors should provide some lateral movement to the lateral flight director guidance cue during bank commands.

A.7.12 To show compliance with §§ 25.1301(a), 25.1303(b)(5), and 25.143(b), the FPV/FPA FD design must—

A.7.12.1 Not have any characteristics that may lead to oscillatory control inputs;

A.7.12.2 Provide sufficiently effective and salient cues to support all expected maneuvers in longitudinal, lateral, and directional axes, including recovery from unusual attitudes; and

A.7.12.3 Not have any inconsistencies between cues provided on the HUD and HDD displays that may lead to pilot confusion or have adverse effects on pilot performance.

A.7.13 Performance and system safety requirements for flight guidance systems are found in the following ACs:

- AC 25.1329-1B, Change 1, *Approval of Flight Guidance Systems*.
- AC 120-28D, *Criteria for Approval of Category III Weather Minima for Takeoff, Landing, and Rollout*.
- AC 120-29A, *Criteria for Approval of Category I and Category II Weather Minima for Approach*.

APPENDIX B. POWERPLANT DISPLAYS

B.1 **General.**

B.1.1 At the time § 25.1305 was adopted, flight deck powerplant displays were primarily a collection of dedicated, independent, full-time analog "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 FAA has used certification issue papers and other guidance material 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 § 25.1305. This AC provides some of that guidance material.

B.1.2 To comply with one of the provisions of § 25.1305, a display should provide all the instrument functionality of a full-time, dedicated analog type instrument as intended when the rule 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 § 25.1305 and § 25.1549 were initially adopted. In addition, the capabilities of modern control systems to automate and complement flightcrew functions were not envisioned. In some cases these system capabilities obviate the need for a dedicated full-time analog type instrument.

B.1.3 When making a compliance finding, all uses of the affected displays should be taken into consideration, including—

B.1.3.1 Flight deck indications to support the approved operating procedures (§ 25.1585),

B.1.3.2 Indications as required by the powerplant system safety assessments (§ 25.1309), and

B.1.3.3 Indications required in support of the instructions for continued airworthiness (§ 25.1529).

Note: For example, compliance with § 25.1305(c)(3) for the engine N2 rotor was originally achieved by means of a dedicated, full time analog 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 § 25.903(d)(2);

- Provide the indication of normal, precautionary, and limit operating values required by § 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 §§ 25.901, 25.1309, etc.

B.1.4 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 § 25.903(d)(2). Additionally, engine condition monitoring programs 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 analog N2 rotor speed indication, in accordance with the guidance found in paragraph 6.3.3 of chapter 6 of this AC.

B.2 **Design Guidelines.**

B.2.1 Safety-related engine limit exceedances should be indicated in a clear and unambiguous manner. Flightcrew alerting is addressed in § 25.1322.

B.2.2 If an indication of significant thrust loss is provided, it should be presented in a clear and unambiguous manner.

B.2.3 In addition to the failure conditions listed in chapter 3 of this AC, the following design guidelines should be considered:

B.2.3.1 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 §§ 25.901(b)(2), 25.901(c), and 25.903(d)(2)).

B.2.3.2 No single failure could prevent the continued safe operation of more than one engine or require immediate action by any flightcrew member for continued safe operation. (See §§ 25.901(c), 25.903(b), and 25.1309(b)).

B.2.3.3 Engine indications needed during engine re-start should be readily available after an engine out event. (See §§ 25.901(b)(2), 25.901(c) 25.903(d)(2), 25.903(e), 25.1301, 25.1305, 25.1309, and paragraph 6.3.3 of chapter 6 of this AC).

APPENDIX C. DEFINITIONS

C.1 **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.

C.2 **Alert:**

A generic term used to describe a flight deck indication meant to attract the attention of, and identify to the flightcrew, a non-normal operational or airplane system condition. Warnings, cautions, and advisories are considered to be alerts.

C.3 **Annunciation:**

A visual, auditory, or tactile stimulus used to attract a flightcrew member's attention.

C.4 **Architecture:**

The manner in which the components of a display or display system are organized and integrated.

C.5 **Basic T:**

The arrangement of primary flight information as required by § 25.1321(b), including attitude, airspeed, altitude, and direction information.

C.6 **Brightness:**

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

C.7 **Bugs:**

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

C.8 **Catastrophic:**

Failure conditions that result in multiple fatalities, usually with the loss of the airplane.

Note: In previous versions of § 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.

C.9 **Chrominance:**

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

C.10 **Chromaticity:**

Color characteristic of a symbol or an image defined by its u', v' coordinates. (See *Colorimetry*, 3rd edition, Commission Internationale de L'Eclairage, CIE publication 15:2004.)

C.11 **Clutter:**

Excessive number and/or variety of symbols, colors, or other information on a display that may reduce flightcrew access or interpretation time, or decrease the probability of interpretation error.

C.12 **Coasting Data:**

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

C.13 **Coding:**

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

C.14 **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, color, motion, location, etc.

C.15 **Color Coding:**

The structured use of color to convey specific information, call attention to information, or impose an organizational scheme on displayed information.

C.16 **Command Information:**

Displayed information directing a control action.

C.17 **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.

C.18 **Conformal:**

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

C.19 **Contrast Ratio:**

- For head-up display: Ratio of the luminance over the background scene. (See SAE AS8055).
- For head-down display: Ratio of the total foreground luminance to the total background luminance.

C.20 **Criticality:**

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

C.21 **Design Eye Position (DEP):**

The position at each pilot's station from which a seated pilot achieves the required combination of outside visibility and instrument scan. The DEP is a single point selected by the applicant that meets the requirements of §§ 25.773(d), 25.777(c), and 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.

C.22 **Display Element:**

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

C.23 **Display Refresh Rate:**

The rate at which a display completely refreshes its image.

C.24 **Display Resolution:**

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

C.25 **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).

C.26 **Display Surface/Screen:**

The area of the display unit that provides an image.

C.27 **Display System:**

The entire set of avionic devices implemented to display information to the flightcrew. This is also known as an electronic display system.

C.28 **Display Unit:**

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

C.29 **Earth Referenced System:**

An inertial-based system that 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.

C.30 **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 millimeter wave radiometry, millimeter wave radar, and low light level image intensifying.

C.31 **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, millimeter wave radiometry, millimeter 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 (m), and must display the imagery with instrument flight information on a head-up display.

C.32 **Extremely Improbable:**

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

C.33 **Extremely Remote:**

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

C.34 **Eye Reference Position (ERP):**

A single spatial position located at or near the center of the head-up display (HUD) eye box. The HUD ERP is the primary geometrical reference point for the HUD.

C.35 **Failure:**

An occurrence that 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). Errors may cause failures but are not considered to be failures.

C.36 **Failure Condition:**

A condition having an effect on the airplane 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.

C.37 **Field-of-View (FOV):**

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

C.38 **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).

C.39 **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 flightcrew.

C.40 **Flight Path Angle (FPA):**

Also known as a Flight Path Symbol, Climb, Dive Angle, or “Caged” (on the Attitude Indicator Centerline) 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 airplane 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.

C.41 **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 airplane heading created by wind drift and slip/skid. For most designs, the FPV is earth referenced, though some use air mass vectors that cannot account for wind effects.

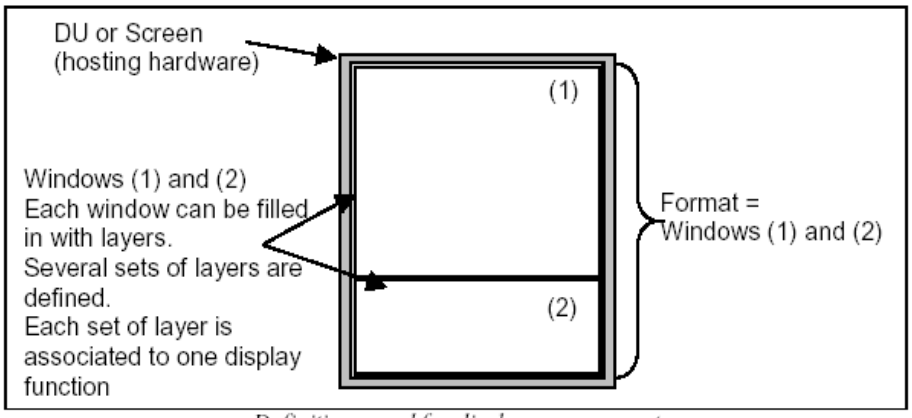
C.42 **Foreseeable Conditions:**

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.

C.43 **Format:**

An image rendered on the whole display unit surface. A format is constructed from one or more windows (see ARINC Standard 661). (See figure C-1 of this appendix.)

Figure C-1. Display Format



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

C.44 **FPV/FPA-Referenced Flight Director (FD):**

A head-up display or head-down display 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 airplane (that is, pitch, boresight) symbol to follow pitch and roll commands.

C.45 **Full-Time Display:**

A dedicated continuous information display.

C.46 **Functional Hazard Assessment:**

A systematic, comprehensive examination of airplane 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.

C.47 **Gray Scale:**

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

C.48 **Hazard:**

Any condition that compromises the overall safety of the airplane or that significantly reduces the ability of the flightcrew to cope with adverse operating conditions.

C.49 **Hazardous:**

A hazardous failure condition reduces the operation of the airplane or the ability of the flightcrew 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 flightcrew 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 flightcrew.

C.50 **Head-Down Display (HDD):**

A primary flight display located on the airplane'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 flightcrew to look below the glareshield in order to use the HDD to fly the airplane.

C.51 **Head-Mounted Display (HMD):**

A special case of head-up display mounted on the pilot's head. Currently, there are not any HMDs used in part 25 installations, but guidance will be provided in the future, as needed.

C.52 **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.

C.53 **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.

C.54 **Icon:**

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

C.55 **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).

Note: 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 AS8055.)

C.56 **Indication:**

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

C.57 **Information Update Rate:**

The rate at which new data is displayed or updated.

C.58 **Interaction:**

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

C.59 **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.

C.60 **Layer:**

A layer is the highest level entity of the display system that is known by a user application.

C.61 **Luminance:**

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

C.62 **Major:**

A major failure condition reduces the operation of the airplane or the ability of the crew to operate in adverse conditions to the extent that there would be, for example—

- A significant reduction in safety margins or functional capabilities,
- A significant increase in crew workload or in conditions impairing crew efficiency,
- Discomfort to the flightcrew, or
- Physical distress to passengers or cabin crew, possibly including injuries.

C.63 **Menu:**

A list of display options available for selection.

C.64 **Message:**

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

C.65 **Minor:**

A minor failure condition would not significantly reduce airplane 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.

C.66 **Misleading Information:**

Incorrect information that is not detected by the flightcrew because it appears as correct and credible information under the given circumstances.

Note: When incorrect information is automatically detected by a monitor resulting in an indication to the flightcrew, 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.

C.67 **Mode:**

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

C.68 **Maintenance Steering Group 3 (MSG-3):**

A steering group sponsored by the Airline Transportation Association whose membership includes representatives from the aviation industry and aviation regulatory authorities.

C.69 **Occlusion:**

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

C.70 **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.

C.71 **Pixel:**

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

C.72 **Pixel Defect:**

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

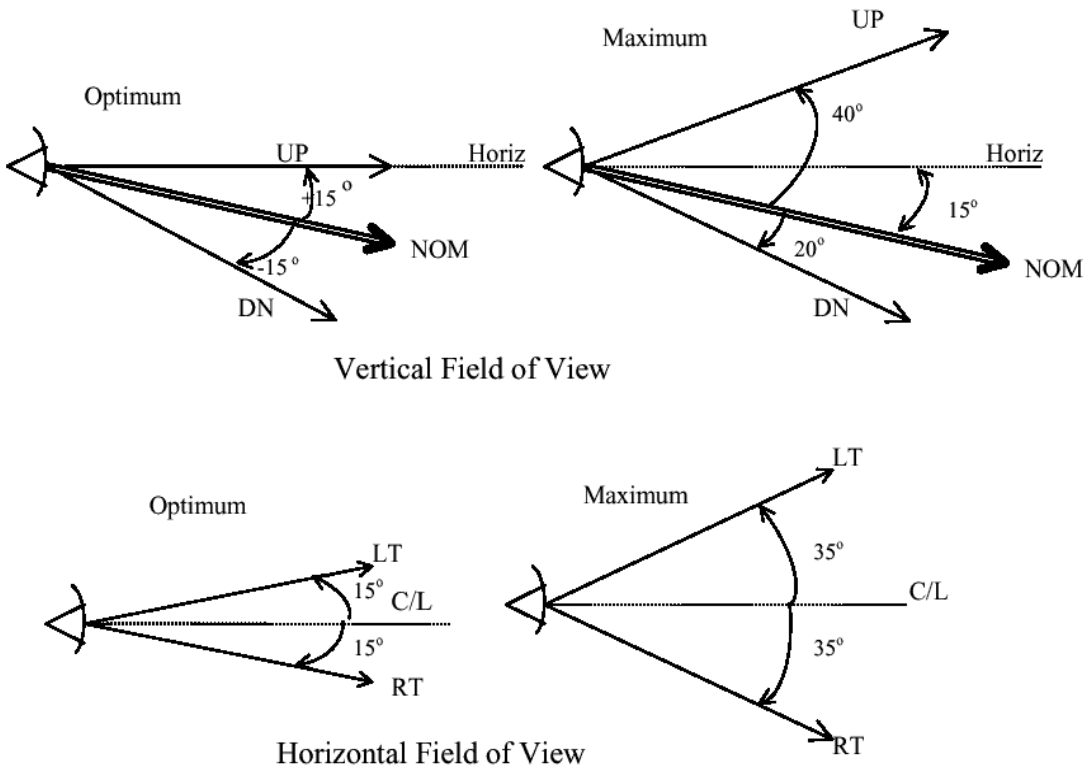
C.73 **Primary Flight Displays (PFDs):**

The displays used to present primary flight information.

C.74 **Primary Field-of-View (FOV):**

Primary FOV 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. Figure C-2 and the following description provide an example of how this may apply to head-down displays: With the normal line-of-sight established at 15° below the horizontal plane, the values for the vertical (relative to normal line-of-sight forward of the airplane) are ±15° optimum, with +40° up and -20° down maximum.

Figure C-2. Primary Field-of-View



C.75 **Primary Flight Information:**

The information whose presentation is required by §§ 25.1303(b) and 25.1333(b), and arranged by § 25.1321(b).

C.76 **Primary Flight Instrument:**

Any display or instrument that serves as the flightcrew'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 flightcrew's primary reference for pitch, bank, and command steering information.

C.77 **Prompt:**

A method of cueing the flightcrew that some input or action is required.

C.78 **Required Engine Indications:**

The information whose presentation is required by § 25.1305.

C.79 **Reversionary:**

The automatic or flightcrew initiated (manual) relocation of display formats or windows following a display failure.

C.80 **Shading:**

Shading is defined as—

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

C.81 **Soft Control:**

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

C.82 **Standby Display:**

A backup display that is used if a primary display malfunctions.

C.83 **Status Information:**

Information about the current condition of an airplane system and its surroundings.

C.84 **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.

C.85 **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.

C.86 **Synthetic Vision System:**

An electronic means to display a synthetic vision image of the external scene topography to the flightcrew.

C.87 **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); and
- To enhance similarity between a synthetic image and the real world image.

C.88 **Time Sharing:**

Showing different information in the same display area at different times.

C.89 **Transparency:**

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

C.90 **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.

C.91 **Viewing Envelope:**

Total volume of space where the minimum optical performance of the display is met (for example, luminance, contrast, or chromaticity). For a direct view display, it is the solid angle with respect to the normal of the display image and, for a head-up display, a three-dimensional volume (eyebox).

C.92 **Window:**

A rectangular physical area of the display surface. A window consists of one or more layers (see ARINC Standard 661). (See figure C-1 above.)

C.93 **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 D. ACRONYMS

Acronym	Meaning
14 CFR	Title 14, Code of Federal Regulations
AC	Advisory Circular
AFM	Airplane Flight Manual
ARAC	Aviation Rulemaking Advisory Committee
ARP	Aerospace Recommended Practices
AS	Aerospace Standard
CCD	Cursor Control Device
CFR	Code of Federal Regulations
CRT	Cathode Ray Tube
CS-AWO	EASA Certification Specifications for All Weather Operations
DEP	Design Eye Position
EASA	European Aviation Safety Agency
EFVS	Enhanced Flight Vision System
ERP	Eye Reference Position
EUROCAE	European Organization for Civil Aviation Electronics
EVS	Enhanced Vision System
FAA	Federal Aviation Administration
FADEC	Full Authority Digital Engine Controls
FD	Flight Director
FHA	Functional Hazard Assessment
FMS	Flight Management System
FOV	Field of View

Acronym	Meaning
FPA	Flight Path Angle
FPV	Flight Path Vector
GNSS	Global Navigation Satellite System
GUI	Graphical User Interface
HDD	Head-Down Display
HMD	Head-Mounted Display
HUD	Head-Up Display
ILS	Instrument Landing System
ICAO	International Civil Aviation Organization
JAA	Joint Aviation Authorities
LCD	Liquid Crystal Display
MSG-3	Maintenance Steering Group 3
PF	Pilot Flying
PNF	Pilot Not Flying
RA	Resolution Advisory
RNAV	Area Navigation
SAE	SAE International (formerly Society of Automotive Engineers)
SVS	Synthetic Vision System
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Alert and Collision Avoidance System
TSO	Technical Standard Order
VFR	Visual Flight Rules
VNAV	Vertical Navigation
VOR	Very High Frequency Omnirange Stations

APPENDIX E. RELATED REGULATIONS AND DOCUMENTS

E.1 **General.**

E.1.1 The following related documents are provided for information purposes and are not necessarily directly referenced in this AC.

E.1.2 The regulations and standards listed below are applicable to particular systems or functions that may have implications on the display system characteristics even though they do not explicitly state display requirements. It is not an exhaustive list, and the references should be reviewed to ensure currency of issue status, and to check for any others that may be applicable.

E.2 **Regulations.**

Table E-1 of this appendix lists the regulations that should be considered when certifying an electronic display system. You can download these regulations from the electronic Code of Federal Regulations (e-CFR) on the Internet. Or you can order a paper copy by writing to the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 371954, Pittsburgh, PA, 15250-7954; calling (202) 512-1800; or faxing a request to (202) 512-2250.

Table E-1. Regulations

14 CFR	Title
§ 25.143	Controllability and Maneuverability—General
§ 25.207	Stall warning
§ 25.562	Emergency landing dynamic conditions
§ 25.672	Stability augmentation and automatic and power-operated systems
§ 25.677	Trim systems
§ 25.679	Control system gust locks
§ 25.699	Lift and drag device indicator
§ 25.703	Takeoff warning system
§ 25.729	Retracting mechanism
§ 25.771	Pilot compartment

14 CFR	Title
§ 25.773	Pilot compartment view
§ 25.777	Cockpit controls
§ 25.779	Motion and effect of cockpit controls
§ 25.783	Fuselage doors
§ 25.785	Seats, berths, safety belts, and harnesses
§ 25.812	Emergency lighting
§ 25.841	Pressurized cabins
§ 25.854	Lavatory fire protection
§ 25.857	Cargo compartment classification
§ 25.858	Cargo or baggage compartment smoke or fire detection systems
§ 25.859	Combustion heater fire protection
§ 25.863	Flammable fluid fire protection
§ 25.901	Powerplant—Installation
§ 25.903	Engines
§ 25.904	Automatic takeoff thrust control system (ATTCS)
§ 25.1001	Fuel jettisoning system
§ 25.1019	Oil strainer or filter
§ 25.1141	Powerplant controls: general
§ 25.1165	Engine ignition systems
§ 25.1199	Extinguishing agent containers
§ 25.1203	Fire detector system
§ 25.1301	Equipment—Function and installation
§ 25.1302	Installed systems and equipment for use by the flightcrew
§ 25.1303	Flight and navigation instruments

14 CFR	Title
§ 25.1305	Powerplant instruments
§ 25.1309	Equipment, systems, and installations
§ 25.1316	Electrical and electronic system lightning protection
§ 25.1321	Arrangement and visibility
§ 25.1322	Flightcrew alerting
§ 25.1323	Airspeed indicating system
§ 25.1326	Pitot heat indication systems
§ 25.1327	Magnetic direction indicator
§ 25.1329	Flight guidance system
§ 25.1331	Instruments using a power supply
§ 25.1333	Instrument systems
§ 25.1337	Powerplant instruments
§ 25.1351	Electrical Systems and Equipment—General
§ 25.1353	Electrical equipment and installations
§ 25.1355	Distribution system
§ 25.1357	Circuit protective devices
§ 25.1381	Instrument lights
§ 25.1383	Landing lights
§ 25.1419	Ice protection
§ 25.1431	Electronic equipment
§ 25.1435	Hydraulic systems
§ 25.1441	Oxygen equipment and supply
§ 25.1447	Equipment standards for oxygen dispensing units
§ 25.1457	Cockpit voice recorders

14 CFR	Title
§ 25.1459	Flight data recorders
§ 25.1501	Operating Limitations and Information—General
§ 25.1523	Minimum flight crew
§ 25.1529	Instructions for Continued Airworthiness
§ 25.1541	Markings and Placards—General
§ 25.1543	Instrument markings: general
§ 25.1545	Airspeed limitation information
§ 25.1547	Magnetic direction indicator
§ 25.1549	Powerplant and auxiliary power unit instruments
§ 25.1551	Oil quantity indication
§ 25.1553	Fuel quantity indicator
§ 25.1555	Control markings
§ 25.1563	Airspeed placard
§ 25.1581	Airplane Flight Manual—General
§ 25.1583	Operating limitations
§ 25.1585	Operating procedures
§ 33.71	Lubrication system
§ 91.205	Powered civil aircraft with standard category U.S. airworthiness certificates: Instrument and equipment requirements
§ 91.219	Altitude alerting system or device: Turbojet-powered civil airplanes
§ 91.221	Traffic alert and collision avoidance system equipment and use
§ 91.223	Terrain awareness and warning system
Part 91, appendix A, section 2	Required Instruments and Equipment

14 CFR	Title
§ 121.221	Fire precautions
§ 121.305	Flight and navigational equipment
§ 121.307	Engine instruments
§ 121.308	Lavatory fire protection
§ 121.313	Miscellaneous equipment
§ 121.323	Instruments and equipment for operations at night
§ 121.325	Instruments and equipment for operations under IFR or over-the-top
§ 121.344	Digital flight data recorders for transport category airplanes[1]
§ 121.354	Terrain awareness and warning system
§ 121.356	Collision avoidance system
§ 121.357	Airborne weather radar equipment requirements
§ 121.358	Low-altitude windshear system equipment requirements
§ 135.149	Equipment requirements: General
§ 135.154	Terrain awareness and warning system
§ 135.159	Equipment requirements: Carrying passengers under VFR at night or under VFR over-the-top conditions
§ 135.163	Equipment requirements: Aircraft carrying passengers under IFR
§ 135.180	Traffic Alert and Collision Avoidance System
Part 135, appendix A	Additional Airworthiness Standards for 10 or More Passenger Airplanes

[1]Digital flight data recorders may be required to record electronic display status.

E.3 **Advisory Circulars.**

The related ACs listed in table E-2 of this appendix are provided for information purposes and might not be referenced directly in this AC. Table E-2 identifies the latest version of each AC at the time of publication. If any AC is revised after publication of this AC, you should refer to the latest version for guidance. You can find the latest version of the following ACs at the FAA website.

Table E-2. Advisory Circulars

AC Number	Title	Date
AC 20-88A	Guidelines on the Marking of Aircraft	September 30, 1985
AC 20-115C	Airborne Software Assurance	July 19, 2013
AC 20-131A	Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders	March 29, 1993
AC 20-136B	Aircraft Electrical and Electronic System Lightning Protection	September 7, 2011
AC 20-138C	Airworthiness Approval of Positioning and Navigation Systems	May 8, 2012
AC 20-140B	Guidelines for Design Approval of Aircraft Data Link Communication Systems Supporting Air Traffic Services (ATS)	September 27, 2012
AC 20-149A	Installation Guidance for Domestic Flight Information Services – Broadcast	September 23, 2013
AC 20-151A	Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II), Versions 7.0 & 7.1 and Associated Mode S Transponders	September 25, 2009
AC 20-152	RTCA, Inc., Document RTCA/DO-254, Design Assurance Guidance for Airborne Electronic Hardware	June 30, 2005
AC 20-155A	Industry Documents to Support Aircraft Lightning Protection Certification	July 16, 2013

AC Number	Title	Date
AC 20-167	Airworthiness Approval of Enhanced Vision System, Synthetic Vision System, Combined Vision System, and Enhanced Flight Vision System Equipment	June 22, 2010
AC 20-170	Integrated Modular Avionics Development, Verification and Approval Using RTCA/DO-297 and Technical Standard Order- C153	October 28, 2010
AC 21-16G	RTCA Document DO-160 versions D, E, F, and G Environmental Conditions and Test Procedures for Airborne Equipment	June 22, 2011
AC 25-7C	Flight Test Guide for Certification of Transport Category Airplanes	October 16, 2012
AC 25-12	Airworthiness Criteria for the Approval of Airborne Windshear Warning Systems in Transport Category Airplanes	November 2, 1987
AC 25-17A	Transport Airplane Cabin Interiors Crashworthiness Handbook	May 18, 2009
AC 25-23	Airworthiness Criteria for the Installation Approval of a Terrain Awareness and Warning System (TAWS) for Part 25 Airplanes	May 22, 2000
AC 25-24	Sustained Engine Imbalance	August 2, 2000
AC 25.562-1B	Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes	January 10, 2006
AC 25.703-1	Takeoff Configuration Warning Systems	March 17, 1993
AC 25.773-1	Pilot Compartment View Design Considerations	January 8, 1993
AC 25.1309-1A	System Design and Analysis	June 21, 1988
AC 25.1302-1	Installed Systems and Equipment for Use by the Flightcrew	May 3, 2013
AC 25.1322-1	Flightcrew Alerting	December 13, 2010

AC Number	Title	Date
AC 25.1329-1B, Change 1	Approval of Flight Guidance Systems	October 16, 2012
AC 25.1523-1	Minimum Flightcrew	February 2, 1993
AC 90-100A	U.S. Terminal and En Route Area Navigation (RNAV) Operations	March 1, 2007
AC 120-28D	Criteria for Approval of Category III Weather Minima for Takeoff, Landing, and Rollout	July 13, 1999
AC 120-29A	Criteria for Approval of Category I and Category II Weather Minima for Approach	August 12, 2002
AC 120-41	Criteria for Operational Approval of Airborne Wind Shear Alerting and Flight Guidance Systems	November 7, 1983
AC 120-55C, Change 1	Air Carrier Operational Approval and Use of TCAS II	March 18, 2013
AC 120-64	Operational Use and Modification of Electronic Checklists	April 24, 1996
AC 120-76B	Guidelines for the Certification, Airworthiness, and Operational Use of Electronic Flight Bags	June 1, 2012

E.4 **Technical Standard Orders.**

Table E-3 is a partial list of the FAA technical standard orders (TSOs) that may relate to electronic displays. You can find the latest version of these TSOs on the Internet at the FAA Regulatory and Guidance Library. It should be noted applicants might apply for a TSO that does not adequately address all of the functionality in the system. Applicants may also apply for multiple TSOs, since no single TSO applies to all functions. Installers of equipment manufactured using the TSO process should ensure that the equipment was tested in an environment similar to the environment where the equipment will be installed.

Table E-3. TSOs That May Be Applicable to Electronic Displays

TSO Number	Title
TSO-C2d	Airspeed Instruments
TSO-C3e	Turn and Slip Instrument
TSO-C4c	Bank and Pitch Instruments
TSO-C5f	Direction Instrument, Non-Magnetic (Gyroscopically Stabilized)
TSO-C6e	Direction Instrument, Magnetic (Gyroscopically Stabilized)
TSO-C7d	Direction Instrument, Magnetic Non-Stabilized Type (Magnetic Compass)
TSO-C8e	Vertical Velocity Instruments (Rate-of-Climb)
TSO-C10b	Altimeter, Pressure Actuated, Sensitive Type
TSO-C34e	ILS Glide Slope Receiving Equipment Operating within the Radio Frequency Range of 328.6-335.4 Megahertz (MHz)
TSO-C35d	Airborne Radio Marker Receiving Equipment
TSO-C36e	Airborne ILS Localizer Receiving Equipment Operating within the Radio Frequency Range of 108-112 Megahertz (MHz)
TSO-C40c	VOR Receiving Equipment Operating within the Radio Frequency Range of 108-117.95 Megahertz (MHz)
TSO-C41d	Airborne Automatic Direction Finding (ADF) Equipment
TSO-C43c	Temperature Instruments
TSO-C44c	Fuel Flowmeters
TSO-C46a	Maximum Allowable Airspeed Indicator Systems
TSO-C47a	Fuel, Oil, and Hydraulic Pressure Instruments
TSO-C49b	Electric Tachometer: Magnetic Drag (Indicator and Generator)
TSO-C54	Stall Warning Instruments
TSO-C55a	Fuel and Oil Quantity Instruments

TSO Number	Title
TSO-C63d	Airborne Weather Radar Equipment
TSO-C66c	Distance Measuring Equipment (DME) Operating within the Radio Frequency Range of 960-1215 Megahertz
TSO-C87a	Airborne Low-Range Radio Altimeter
TSO-C92c	Airborne Ground Proximity Warning Equipment
TSO-C93	Airborne Interim Standard Microwave Landing System Converter Equipment
TSO-C95a	Mach Meters
TSO-C101	Over Speed Warning Instruments
TSO-C104	Microwave Landing System (MLS) Airborne Receiving Equipment
TSO-C105	Optional Display Equipment for Weather and Ground Mapping Radar Indicators
TSO-C106	Air Data Computer
TSO-C110a	Airborne Passive Thunderstorm Detection Equipment
TSO-C113a	Airborne Multipurpose Electronic Displays
TSO-C115c	Flight Management System (FMS) Using Multi-Sensor Inputs
TSO-C117a	Airborne Windshear Warning and Escape Guidance Systems for Transport Airplanes
TSO-C118	Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS I
TSO-C119c	Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II with Optional Hybrid Surveillance
TSO-C145c	Airborne Navigation Sensors using the Global Positioning System Augmented by the Satellite Based Augmentation System
TSO-C146c	Stand-Alone Airborne Navigation Equipment Using the Global Positioning System Augmented By the Satellite Based Augmentation System

TSO Number	Title
TSO-C147	Traffic Advisory System (TAS) Airborne Equipment
TSO-C151c	Terrain Awareness and Warning System (TAWS)
TSO-C153	Integrated Modular Avionics Hardware Elements
TSO-C165	Electronic Map Display Equipment for Graphical Depiction of Aircraft Position
TSO-C169a	VHF Radio Communications Transceiver Equipment Operating within the Radio Frequency Range 117.975 to 137.000 Megahertz
TSO-C198	Automatic Flight Guidance and Control System (AFGCS) Equipment

E.5 **Other FAA Documents.**

E.5.1 FAA Orders.

You can find the latest version of FAA Order 8110.49, Change 1, *Software Approval Guidelines*, dated September 28, 2011, at the FAA website.

E.5.2 FAA Policy Statements.

You can find the latest version of the following policies at the FAA Regulatory and Guidance Library:

E.5.2.1 Policy No. PS-ANM-03-111-18, *Policy Statement on the Installation of Transport Category Airplane Flightdeck Liquid Crystal Displays*, dated August 9, 2006.

E.5.2.2 Policy No. PS-ANM100-01-03A, *Factors to Consider When Reviewing an Applicant's Proposed Human Factors Methods of Compliance for Flight Deck Certification*, dated February 7, 2003.

E.5.2.3 Policy No. PS-ANM100-00-113-1034, *Use of ARAC (Aviation Rulemaking Advisory Committee) Recommended Rulemaking Not Yet Formally Adopted by the FAA, as a Basis for Equivalent Level of Safety or Exemption to Part 25*, dated January 4, 2001.

E.5.3 FAA Reports.

You can find the latest version of the following FAA reports on the Internet:

E.5.3.1 FAA Report No. DOT/FAA/CT-03/05 HF-STD-001, *Human Factors Design Standard (HFDS): For Acquisition of Commercial Off-the-Shelf Subsystems, Non-Developmental Items, and Developmental Systems*, dated May 2003.

E.5.3.2 FAA Report No. DOT/FAA/AM-01/17, *Human Factors Design Guidelines for Multifunction Displays*, dated October 2001.

E.6 **ARAC Recommendations.**

You can find information about ARAC recommendations at FAA website:

E.6.1 For recommended revisions to existing § 25.1309, see ARAC Task 2 - System Design and Analysis Harmonization and Technology Update.

E.6.2 For recommended revisions to existing § 25.1333(b), see ARAC Task 2 - Cockpit Instrument System. Section 25.1333(b) is one part of the recommendations for this task.

E.7 **JAA/EASA Documents.**

You can find the EASA documents listed in table E-4 at the EASA website. You can find the JAA documents listed in table E-4 at on the Internet at the IHS Standard Store.

Table E-4. EASA/JAA Documents

Number	Title
EASA AMC 20-4A	Airworthiness Approval and Operational Criteria for the Use of Navigation Systems in European Airspace Designated for Basic RNAV Operations
EASA AMC 20-5	Airworthiness Approval and Operational Criteria for the Use of the Navstar Global Positioning System (GPS)
EASA AMC 20-15	Certification Considerations for the Airborne Collision Avoidance System: ACAS II
EASA CS AWO	All Weather Operations
JAA TGL 10 Rev 1	Airworthiness and Operational Approval for Precision RNAV Operations in Designated European Airspace
JAA TGL 12	Certification Considerations for the Terrain Awareness Warning System: TAWS

E.8 **Industry Documents.**

The following industry publications provide additional information, guidance, and standards for electronic flight deck display systems.

E.8.1 Aeronautical Radio, Inc. (ARINC) Documents.

You can purchase the following documents from the ARINC website:

E.8.1.1 ARINC Standard 661-5, *Cockpit Display System Interfaces to User Systems*, dated July 2013.

E.8.1.2 ARINC Standard 708A-3, *Airborne Weather Radar with Forward Looking Windshield Detection Capability*, dated November 1999.

E.8.2 European Organisation for Civil Aviation Equipment (EUROCAE) Documents.

You can purchase the EUROCAE documents listed in table E-5 by mail from EUROCAE, 102 rue Etienne Dolet, 92240 Malakoff, France; or the EUROCAE website.

Table E-5. EUROCAE Documents

Document	Title	Issued
ED-12C	Software Considerations in Airborne Systems and Equipment Certification	January 2012
ED-14G	Environmental Conditions and Test Procedures for Airborne Equipment	March 2011
ED-75C	MASPS: Required Navigation Performance for Area Navigation	November 2013
ED-79A	Guidelines for Development of Civil Aircraft and Systems	December 2010
ED-80	Design Assurance Guidance for Airborne Electronic Hardware	April 2000
ED-81	Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning	May 1996 and amended August 1999
ED-84A	Aircraft Lightning Environment and Related Test Waveforms	July 2013
ED-90B	Radio Frequency Susceptibility Test Procedures	May 2010
ED-91	Aircraft Lightning Zoning	July 1998
ED-96	Requirements Specification for an Avionics Computer Resource	July 2000

Document	Title	Issued
ED-98B	User Requirements for Terrain and Obstacle Data	September 2012
ED-107A	Guide to Certification of Aircraft in a High-Intensity Radiated Field (HIRF) Environment	July 2010
ED-112A	MOPS for Crash Protected Airborne Recorder Systems	September 2013

E.8.3 International Civil Aviation Organization (ICAO) Document.

You can purchase ICAO Doc 8400, *Procedures for Air Navigation Services – ICAO Abbreviations and Codes*, 8th Edition, 2010, from the ICAO website.

E.8.4 RTCA Documents.

You can purchase the following RTCA, Inc. (formerly the Radio Technical Commission for Aeronautics) documents listed in table E-6 by mail from RTCA Inc., 1150 18th Street NW., Suite 910, Washington, DC 20036; by faxing the Document Order Form to (202) 833-9434; or from the RTCA website.

Table E-6. RTCA Documents

Document	Title	Issued
DO-160A through DO-160G	Environmental Conditions and Test Procedures for Airborne Equipment[1]	Rev G on December 8, 2010
DO-178B and DO-178C	Software Considerations in Airborne Systems and Equipment Certification	Rev B on December 1, 1992; Rev C on December 12, 2011
DO-220 and Change 1	Minimum Operational Performance Standards (MOPS) for Airborne Weather Radar with Forward-Looking Windshear Detection Capability	September 21, 1993; Change 1 on June 23, 1995
DO-236B and DO-236C	Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation	Rev B on October 28, 2003; Rev C on June 9, 2013
DO-239	Minimum Operational Performance Standards for Traffic Information Service (TIS) Data Link Communications	April 2, 1997

[1]See AC 21-16G, which outlines guidance on environmental qualification. Typically, any revision of DO-160 after DO-160D Change 3 is satisfactory.

Document	Title	Issued
DO-243	Guidance for Initial Implementation of Cockpit Display of Traffic Information	February 19, 1998
DO-253C	Minimum Operational Performance Standards for GPS Local Area Augmentation System Airborne Equipment	December 16, 2008
DO-254	Design Assurance Guidance for Airborne Electronic Hardware	April 19, 2000
DO-255	Requirements Specification for Avionics Computer Resource (ACR)	June 20, 2000
DO-257A	Minimum Operational Performance Standards for the Depiction of Navigational Information on Electronic Maps	June 25, 2003
DO-259	Applications Descriptions for Initial Cockpit Display of Traffic Information (CDTI) Applications	September 13, 2000
DO-267A	Minimum Aviation System Performance Standards (MASPS) for Flight Information Services–Broadcast (FIS-B) Data Link	April 29, 2004
DO-268	Concept of Operations, Night Vision Imaging System for Civil Operators	March 27, 2001
DO-275	Minimum Operational Performance Standards for Integrated Night Vision Imaging System Equipment	October 12, 2001
DO-282B	Minimum Operational Performance Standards for Universal Access Transceiver (UAT) Automatic Dependent Surveillance – Broadcast	December 2, 2009
DO-283A	Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation	October 28, 2003
DO-286B	Minimum Aviation System Performance Standards (MASPS) for Traffic Information Service–Broadcast (TIS-B)	October 11, 2007

Document	Title	Issued
DO-289 and Change 1	Minimum Aviation System Performance Standards (MASPS) for Aircraft Surveillance Applications (ASA)	December 9, 2003; Change 1 on December 13, 2006
DO-296	Safety Requirements Standard for Aeronautical Operational Control (AOC) Datalink Messages	October 19, 2004
DO-325	Minimum Operational Performance Standards (MOPS) for Automatic Flight Guidance and Control Systems and Equipment	December 8, 2010

E.8.5 SAE International Documents.

You can purchase the following SAE International (formerly Society of Automotive Engineers) documents listed in table E-7 by mail from SAE Customer Service, 400 Commonwealth Drive, Warrendale, PA, 15096; by faxing your order information to (724) 776-0790; or from the SAE website. Please note that the time of publication of this AC, the SAE documents have not been updated to reflect supercooled large drop analyses and testing but provide good reference material.

Note: In the event of conflicting information, this AC takes precedence as guidance for certification of transport category airplane installations.

Table E-7. SAE International Documents.

Document	Title
AIR818D	Aircraft Instrument and Instrument System Standards: Wording, Terminology, Phraseology, and Environmental and Design Standards for
AIR1093A	Numeral, Letter and Symbol Dimensions for Aircraft Instrument Displays
ARD50017	Aeronautical Charting
ARD50062	Human Factors Issues Associated with Terrain Separation Assurance Display Technology
ARP426A	Compass System Installations
ARP571C	Flight Deck Controls and Displays for Communication and Navigation Equipment for Transport Aircraft

ARP926B	Fault/Failure Analysis Procedure

Document	Title
ARP5288	Transport Category Airplane Head Up Display (HUD) Systems
ARP5289A	Electronic Aeronautical Symbols
ARP5364	Human Factor Considerations in the Design of Multifunction Display Systems for Civil Aircraft
ARP5365	Human Interface Criteria for Cockpit Display of Traffic Information
ARP5412A	Aircraft Lightning Environment and Related Test Waveforms
ARP5413A	Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning
ARP5414A	Aircraft Lightning Zoning
ARP5415A	User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lighting
AS425C	Nomenclature and Abbreviations for Use on the Flight Deck
AS439A	Stall Warning Instrument (Turbine Powered Subsonic Aircraft)
AS8034B	Minimum Performance Standard for Airborne Multipurpose Electronic Displays
AS8055	Minimum Performance Standard for Airborne Head Up Display (HUD)

E.9 **Other Documents.**

You may purchase *Colorimetry*, 3rd edition, Commission Internationale de L'Eclairage, CIE publication 15:2004, from the CIE website.

APPENDIX F. HEAD-UP DISPLAYS (HUDS)

F.1 Introduction.

F.1.1 Purpose.

This appendix provides additional guidance related to the unique aspects, characteristics, and functions of head-up displays (HUDs) for transport category airplanes. This appendix also addresses issues related to the design, analysis, and testing of HUDs. It addresses HUDs that are designed for a variety of different operational concepts and functions. This guidance applies to HUDs that are intended to be used as a supplemental display in which the HUD contains the minimum information immediately required for the operational task associated with the intended function. It also applies to HUDs that are intended to be used effectively as primary flight displays. This appendix addresses both the installation of a single HUD, typically used by the left-side pilot, as well as special considerations related to dual HUDs, one for each pilot. This appendix does not provide the guidance for display of vision system (e.g., enhanced flight vision systems (EFVS) and synthetic vision systems (SVS)) video on the HUD. The airworthiness requirements and means of compliance criteria for display of video on the HUD may be found in special conditions issued by the FAA and the current version of AC 20-167, *Airworthiness Approval of Enhanced Vision System, Synthetic Vision System, Combined Vision System, and Enhanced Flight Vision System Equipment*.

F.1.2 Definition of Head-Up Display.

A HUD is a display system that projects primary flight information (for example, attitude, air data, and guidance) on a transparent screen (combiner) in the pilot's forward field-of-view (FOV), 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 (HDDs). 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.

F.1.3 Other Resources.

For guidance associated with specific operations using HUDs, such as low visibility approach and landing operations, see the relevant requirements and guidance material (e.g., European Aviation Safety Agency (EASA) Certifications Specifications for All Weather Operations (CS-AWO), and AC 120-28D, *Criteria for Approval of Category III Weather Minima for Takeoff, Landing, and Rollout*). In addition, Society of Automotive Engineers (SAE) Aerospace Recommended Practice (ARP) 5288, *Transport Category Airplane Head Up Display (HUD) Systems*; SAE Aerospace Standard (AS) 8055, *Minimum Performance Standard for Airborne Head Up Display (HUD)*; and SAE ARP5287, *Optical Measurement Procedures for Airborne Head Up Display*; provide guidance for designing and evaluating HUDs.

F.2 **Unique Safety Considerations.**

F.2.1 Airplane and Systems Safety.

F.2.1.1 Systems. Installing HUD systems in flight decks may introduce complex functional interrelationships among the flightcrew members and other display and control systems. Consequently, a functional hazard assessment that requires a top-down approach from an airplane-level perspective should be developed in accordance with Title 14, Code of Federal Regulations (14 CFR) 25.1309. Developing a functional hazard assessment for a particular installation requires careful consideration of the role that the HUD plays within the flight deck in terms of integrity of function and availability of function, as well the operational concept of the installation to be certified (e.g., dual- versus single-HUD installation and the type and amount of information displayed). Chapter 4 of this AC provides material that may be useful in preparing the functional hazard assessment.

F.2.1.2 Airplane Flight Manual (AFM) Procedures. All alleviating flightcrew actions that are considered in the HUD safety analysis need to be validated for incorporation into the AFM procedures section or for inclusion in type-specific training.

F.2.1.3 Availability of Primary Flight Information. There might be failure conditions that result in a loss of all but one display of primary flight information. For such a condition, one HUD as the only remaining display could not comply with § 25.1333(b), since the HUD is visible only to one pilot. The rule requires that, after the loss of other flight information displays, the "one display of the information essential to the safety of flight" remain available to both pilots, not just one pilot.

F.2.2 Crew Safety.

F.2.2.1 Prevention of Head Injury. HUD equipment introduces potential hazards that are not traditionally associated with head-down electronic flight deck displays. The HUD system must be designed and installed to prevent the possibility of pilot injury in the event of an accident or any other foreseeable circumstance such as turbulence, hard landing, or bird strike. For airplanes with § 25.562 in the certification basis, the HUD installation, including the overhead unit and combiner, must comply with the head injury criteria defined in § 25.562(c)(5). A HUD combiner with a swing-arm deployment mechanism should be designed to avoid false detents and flash latch indications between the fully stowed and deployed positions. A mis-stowed combiner could swing inadvertently into the path of the pilot's head and cause injury. Additionally, the HUD installation must comply with the occupant injury requirements of § 25.785(d) and (k) and the retention requirements of § 25.789(a).

F.2.2.2 Special Considerations for Dual-HUD Installations. For dual-HUD installations, the applicant must address single events that could simultaneously incapacitate both pilots and, therefore, become safety-of-flight issues. Examples of such single events are flight or gust loads, a hard landing, or emergency landing. The FAA may need to provide an issue paper providing project-specific means of compliance if the installation geometry indicates that such events may produce occupant contact with the HUD installation.

F.2.2.3 Noninterference with Emergency Equipment. Sections 25.803, 25.1411, and 25.1447 require that the HUD installation must not interfere with, or restrict the use of, other installed equipment such as emergency oxygen masks, headsets, or microphones. The installation of the HUD must not adversely affect the emergency egress provisions for the flightcrew, or significantly interfere with flightcrew access. The system must not hinder the flightcrew's movement while conducting any flight procedures.

F.3 **Design.**

F.3.1 Intended Function of HUDs.

The applicant is responsible for identifying the intended function of the HUD. The description of the intended function should include the operational phases of flight and concept of operation, including how, when, and for what purpose(s) the HUD is to be used. For example, the HUD may display situational information and/or guidance information, be a supplemental display of primary flight information in all phases of flight, display command guidance for Category II, manual, and/or monitoring autopilot-coupled instrument approaches, display guidance for visibility takeoff, and/or display enhanced vision imagery and synthetic vision video. See paragraph 2.4 of the AC for additional guidance.

F.3.1.1 General. In most applications, HUDs provide an indication of primary flight references that allow the pilot to rapidly evaluate the airplane attitude, energy status, and position during the phases of flight for which the HUD is designed. HUDs are usually designed to present information to enhance pilot performance in such phases of flight as during the transition between instrument and visual flight conditions with variable outside visibility conditions. While HUDs may be designed to display enhanced and synthetic visual imagery, particular means of compliance guidance for this purpose is not found in this appendix. See AC 20-167 for guidance.

F.3.1.2 Display of Primary Flight Information.

F.3.1.2.1 HUD as de facto Primary Flight Display. If a HUD displays primary flight information, it is considered a de facto primary flight display while the pilot is using it, even if it is not the pilot's sole display of this information. The pilot should be able to easily recognize the primary flight information;

it should not be ambiguous or confusing when taking into account information on other flight deck displays.

F.3.1.2.2 Applicable Instrument Requirements for HUD. Primary flight information displayed on the HUD should comply with all the requirements associated with such information in part 25 (e.g., § 25.1303(b) for flight and navigation instruments that must be visible from each pilot station and § 25.1333(b) for the operational requirements of those systems). Section 25.1321(b) specifies the requirements for arranging primary flight information. For specific guidance regarding the display of primary flight information, see the main body and appendix A of this AC.

F.3.1.3 Display of Other Flight Information. Additional information may be related to the display of command guidance or specific flight parameter information needed for operating the airplane by reference to the HUD.

F.3.1.3.1 Command Guidance. When the HUD is used to display flight guidance, either for manual control or for monitoring the autopilot, it should display the following information:

- Path deviation indications based on sources of raw data that are independent from those used by the autopilot.
- Autopilot operating mode.
- Autopilot engage status.
- Autopilot disconnect warning (visual).

F.3.1.3.2 Flight Parameter Information. The HUD should also display additional flight parameter information if required to enable the pilot to operate the airplane during phases of flight for which the HUD is approved. This additional information may include:

- Flight path indication.
- Target airspeed references and speed limit indications.
- Target altitude references and altitude awareness (e.g., decision height and minimum descent altitude) indications.
- Heading or course references.

F.3.2 HUD Controls.

F.3.2.1 Control Placement. For compliance with § 25.777, the flightcrew must be able to see, identify, and reach the means of controlling the HUD, including its configuration and display modes, from the normal seated position. To comply with §§ 25.777 and 25.1301, the position and movement of the HUD controls must not lead to inadvertent operation.

F.3.2.2 Control Illumination. To comply with § 25.1381, the HUD controls must be adequately illuminated for all normal ambient lighting conditions and

must not create any objectionable reflections on the HUD or other flight instruments. Unless a fixed level of illumination is satisfactory under all lighting conditions, there should be a means to control its intensity.

F.3.2.3 Control Integration. To the greatest extent practicable, HUD controls should be integrated with other associated flight deck controls to minimize the flightcrew workload and error associated with HUD operation and to enhance flightcrew awareness of HUD modes.

F.3.2.4 Ease of Use. HUD controls, including the controls to change or select HUD modes, should be implemented to minimize flightcrew workload for data selection or data entry and allow the pilot to easily view and perform all mode control selections from the seated position.

F.3.3 Visibility and Field-of-View (FOV).

F.3.3.1 Field-of-View. The design of the HUD installation should provide adequate display FOV in order for the HUD to function as intended in all anticipated flight attitudes, airplane configurations, and environmental conditions, such as crosswinds, for which it is approved. The AFM should specify all airworthiness and operational limitations related to these factors.

F.3.3.2 Impact on Pilot Compartment View.

F.3.3.2.1 Interior View. Whether or not the combiner is deployed and the HUD is in use, it must not create additional significant obstructions to either pilot's compartment view as required by § 25.773. The HUD must also not restrict the view of any flight deck controls, indicators, or other flight instruments as required by §§ 25.777 and 25.1321.

F.3.3.2.2 External View. The HUD should not significantly obscure the necessary pilot compartment view of the outside world for normal, non-normal, or emergency flight maneuvers during any phase of flight for a pilot seated at the design eye position (DEP). The HUD should not significantly affect the ability of any flightcrew member to spot traffic or distinctly see approach lights, runways, signs, markings, or other aspects of the external visual scene. The combination of the windshield and the HUD must meet the requirements of § 25.773(a)(1).

F.3.3.2.3 HUD Optical Performance. As far as practicable, the optical performance of the HUD must not cause distortions that degrade or detract from the flightcrew's view of external references or of other aircraft. The optical performance should not degrade or detract from the flightcrew's ability to safely perform any maneuvers within the operating limits of the airplane, as required by § 25.773. Where the windshield optically modifies the pilot's view of the outside world, the motions and positions of conformal HUD symbols must be optically consistent (i.e., aligned and scaled) with the perceived outside view. To avoid distortions, the optical qualities of

the HUD should be uniform across the entire FOV. When the pilot views the HUD with both eyes from any off-center position within the design eyebox, optical non-uniformities shall not produce perceivable differences in the binocular view. SAE ARP5288, *Transport Category Airplane Head Up Display (HUD) Systems*, provides additional guidance.

F.3.3.3 Conformal Symbols with Limited HUD FOV. The range of motion of conformal symbology can present certain challenges in rapidly changing and high-crosswind conditions. In certain cases, the motion of the guidance and the primary reference cue may be limited by the FOV. It should be shown that, in such cases, the guidance remains usable and that there is a positive indication that it is no longer conformal with the outside scene. It should also be shown that there is no interference between the indications of primary flight information and the flight guidance cues.

F.4 **HUD Design Eyebox Criteria.**

F.4.1 Design Eye Position.

AC 25.773-1, *Pilot Compartment View Design Considerations*, January 8, 1993, defines the design eye position as a single point that meets the requirements of §§ 25.773 and 25.777. For certification purposes, the DEP is the pilot's normal seated position. Fixed markers or some other means should be provided at each pilot station to enable the pilots to position themselves in their seats at the DEP for an optimum combination of outside visibility and instrument scan. The HUD installation must comply with §§ 25.773 and 25.1321. The HUD must be able to accommodate pilots, from 5′2″ to 6′3″ tall, while they are seated at the DEP with their shoulder harnesses and seat belts fastened, to comply with § 25.777. The DEP must be centered within the minimum design eyebox dimensions found in paragraph F.4.2.3 of this appendix. Actual HUD eyeboxes are larger than these minimum dimensions and, if not centered around the DEP, they need only be large enough that this minimum sub-volume is centered around the DEP.

F.4.2 Design Eyebox.

F.4.2.1 Display Visibility Requirements. The fundamental requirements for instrument arrangement and visibility in §§ 25.773, 25.777, 25.1301, and 25.1321 apply to HUDs. Each flight instrument, including the flight information displayed in the HUD, must be plainly visible to the pilot at that pilot's station with minimum practicable deviation from the normal position and forward line of vision. While seated at the design eye position, the pilot must be able to see the flight information displayed in the HUD. The optical characteristics of the HUD—particularly the limits of its design eyebox—cause the pilot's ability to fully view essential flight information to be more sensitive to the pilot's eye position, as compared to HDDs. The HUD design eyebox is a three-dimensional volume, specified by the manufacturer, within which display visibility requirements are met.

Thus, whenever the pilot's eyes are within the design eyebox, the required flight information must be visible in the HUD. The size of the design eyebox and the layout of flight information in the HUD should be designed so that visibility of the displayed symbols is not unduly sensitive to pilot head movements in all expected flight conditions. In the event that the pilot's view of displayed information is totally lost as a result of a head movement, the pilot must be able to regain the view of the display rapidly and without difficulty. The minimum monocular FOV required to display this required flight information should include the center of the FOV and must be specified by the manufacturer. The HUD FOV should be designed by considering the intended operational environment and potential airplane configurations.

F.4.2.2 Design Eyebox Position. The HUD design eyebox should be laterally and vertically positioned around the respective pilot's DEP. It should be large enough that the required flight information is visible to the pilot at the minimum displacements from the DEP specified by paragraph F.4.2.3 of this appendix. The symbols must be laid out and positioned such that excessive eye movements are not required to scan elements of the display. The displayed symbols that are necessary to perform the required tasks must be visible to the pilot from the DEP. The DEP used for evaluation of the eyebox location must be the same as that used for the basic flight deck in accordance with AC 25.773-1.

F.4.2.3 Design Eyebox Dimensions. The lateral and vertical dimensions of the design eyebox represent the total movement of a monocular viewing instrument with a 0.25 inches (6.35 mm) entrance aperture (pupil). The longitudinal dimension of the design eyebox represents the total fore-aft movement over which the requirement of this specification is met (see SAE AS8055). When the HUD is a primary flight display, when airworthiness approval is predicated on the use of the HUD, or when the pilot can be reasonably expected to operate primarily by reference to the HUD, dimensions larger than the minimums shown below may be necessary.

F.4.2.3.1 Lateral: 1.5 inches left and right from the DEP (3.0 inches wide).

F.4.2.3.2 Vertical: 1.0 inches up and down from the DEP (2.0 inches high).

F.4.2.3.2 Longitudinal: 2.0 inches fore and aft from the DEP (4.0 inches deep).

F.4.3 Conformal Display Accuracy.

F.4.3.1 Symbol Positioning. The accuracy of symbol positioning relative to the external references, or display accuracy, is a measure of the relative conformality of the HUD display with respect to the pilot's view of the real world through the combiner and windshield from any eye position within the HUD design eyebox. The display accuracy is a monocular measurement. For a fixed field point, the display accuracy is numerically

equal to the angular difference between the position of a real-world feature (as seen through the combiner and windshield) and the HUD projected symbology.

F.4.3.2 Error Budget. The total error budget for the display accuracy of the HUD system (excluding sensor and windshield errors) includes installation errors, digitization errors, electronic gain and offset errors, optical errors, combiner positioning errors, errors associated with the cathode ray tube (CRT) and yoke (if applicable), misalignment errors, environmental conditions (e.g., temperature and vibration), and component variations.

F.4.3.2.1 Error Sources. Optical errors are dependent upon both the head position and the field angle. Optical errors are comprised of three sources: uncompensated pupil and field errors originating in the optical system aberrations, image distortion errors, and manufacturing variations. The optical errors are statistically determined by sampling the HUD FOV and the design eyebox. (See 4.2.10 of SAE AS8055 for a discussion of FOV and design eyebox sampling).

F.4.3.2.2 Total Accuracy. The optical errors shall represent at least 95.4% (2 sigma) of all sampled points. The display accuracy errors are characterized in both the horizontal and vertical planes. The total display accuracy shall be characterized as the root-sum square errors of these two component errors.

F.4.3.2.3 Allowable Margin for Display Errors. All display errors shall be minimized across the display FOV consistent with the intended function of the HUD. Table F-1 shows the allowable display accuracy errors for a conformal HUD as measured from the HUD eye reference point.

Table F-1. Display Error Tolerances

Location on the HUD Combiner	Error Tolerance in milliradians (mrad)
At HUD boresight	≤ 5.0 mrad
≤ 10° diameter	≤ 7.5 mrad (2 sigma)
≤ 30° diameter	≤ 10.0 mrad (2 sigma)
> 30° diameter	< 10 mrad + kr[(FOV)(in degrees) - 30)] (2 sigma) where, kr = 0.2 mrad of error per degree of FOV

F.4.3.2.4 Maximum Error. The HUD manufacturer shall specify the maximum allowable installation error. In no case shall the display accuracy error tolerances cause hazardously misleading data to be presented to the pilot viewing the HUD.

F.4.4 Symbol Positioning Alignment.

The symbols intended for use in combination with other symbols and scales to convey meaning must be aligned and positioned precisely enough not to be misleading to the pilot.

F.4.5 Overlapping Symbols.

Symbols that share space with other symbols must not partially obscure or interfere with the appearance of other symbols in a way that misleads the pilot.

F.4.6 Alignment.

F.4.6.1 Outside View. The HUD combiner must be properly aligned so that display elements such as attitude scales and flight path vector symbology are conformal (i.e., the position and motion are aligned and scaled). Proper combiner alignment is needed to match conformal display parameters as close as possible to the outside real world, depending on the intended function of those parameters.

F.4.6.2 Combiner. If the HUD combiner is stowable, means should be provided to ensure that it is in its fully deployed and aligned position before using the symbology for airplane control. The HUD shall alert the pilot if the position of the combiner causes normally conformal data to become misaligned in a manner that may result in the display of misleading information.

F.4.7 Visual Display Characteristics.

The following paragraphs highlight some areas related to performance aspects that are specific to the HUD. SAE ARP5288, *Transport Category Airplane Head Up Display (HUD) Systems*, and SAE AS8055, *Minimum Performance Standard for Airborne Head Up Display (HUD)*, provide performance guidelines for a HUD. As stated in chapter 3 of this AC, the applicant should notify the airworthiness authority if any visual display characteristics do not meet the guidelines in SAE ARP5288 and SAE AS8055.

F.4.7.1 Luminance.

F.4.7.1.1 Background Light Conditions. The display luminance (brightness) should be satisfactory in the presence of dynamically changing background (ambient) lighting conditions (5 to 10,000 foot Lamberts (fL) as specified in SAE AS8055), so that the HUD data are visible.

F.4.7.1.2 Luminance Control. The HUD must have adequate means to control luminance so that displayed data is always visible to the pilot. The HUD may have both manual and automatic luminance control capabilities. It is recommended that automatic control be provided in addition to the manual control. Manual control of the HUD brightness level should be available to the flightcrew to set a reference level for automatic brightness control. If the HUD does not provide automatic control, a single manual setting should be satisfactory for the range of lighting conditions encountered

during all foreseeable operational conditions and against expected external scenes. Readability of the displays should be satisfactory in all foreseeable operating and ambient lighting conditions. SAE ARP5288 and SAE AS8055 provide guidelines for contrast and luminance control.

F.4.7.2 Reflections. The HUD must be free of glare and reflections that could interfere with the normal duties of the minimum flightcrew, as required by §§ 25.773 and 25.1523.

F.4.7.3 Ghost Images. A ghost image is an undesired image appearing at the image plane of an optical system. Reflected light may form an image near the plane of the primary image. This reflection may result in a false image of the object or an out-of-focus image of a bright source of light in the field of the optical system. The visibility of ghost images within the HUD of external surfaces must be minimized so as not to impair the pilot's ability to use the display.

F.4.7.4 Accuracy and Stability.

F.4.7.4.1 Sensitivity to Airplane Maneuvering. The system operation should not be adversely affected by airplane maneuvering or changes in attitude encountered in normal service.

F.4.7.4.2 Motion of Symbols. The accuracy of positioning of symbols must be commensurate with their intended use. Motion of non-conformal symbols must be smooth, not sluggish or jerky, and consistent with airplane control response. Symbols must be stable with no discernible flicker or jitter.

F.5 **Guidelines for Presenting Information.**

F.5.1 HUD and HDD Display Compatibility.

F.5.1.1 General. If the content, arrangement, or format of the HUD is dissimilar to the HDD, it can lead to flightcrew confusion, misinterpretation, and excessive cognitive workload. During transitions between the HUD and HDDs (whether required by navigation duties, failure conditions, unusual airplane attitudes, or other reasons), dissimilarities could make it more difficult for the flightcrew to manually control the airplane or to monitor the automatic flight control system. Dissimilarities could also delay the accomplishment of time-critical tasks. Some differences may be unavoidable, such as the use of color on the HDD and a single color (i.e., monochrome) on the HUD. The guidelines listed below are intended to minimize the potential for confusion, undue workload, and delays in flightcrew task performance.

F.5.1.2 Exceptions. Deviation from the guidelines below may be unavoidable due to conflict with other information display characteristics or requirements unique to HUDs. These deviations may relate to the minimization of

display clutter, minimization of excessive symbol flashing, and the presentation of certain information conformal to the outside scene. Deviations from these guidelines require additional pilot evaluation.

F.5.1.3 Guidelines for HUD-HDD Display Compatibility.

F.5.1.3.1 Consistent Displays and Format. The content, arrangement, symbology, and format of the information on the HUD should be sufficiently compatible with the HDDs to preclude pilot confusion, misinterpretation, increased cognitive workload, or flightcrew error. (See paragraphs 5.3 and 5.6 of this AC.) The layout and arrangement HUD and HDD formats of the same information need to convey the same intended meanings. (See paragraph 6.2 of this AC.) For example, the relative locations of barometric altitude, airspeed, and attitude should be similar. Likewise, the acronyms and relative locations of flight guidance mode annunciations for thrust and lateral and vertical flight path should be similar.

F.5.1.3.2 Symbols. Table F-2 provides the guidelines for symbols.

Table F-2. Symbol Guidelines for HUD-HDD Compatibility

Symbol	Guidelines
Shape and Appearance	HUD symbols that have similar shape and appearance as HDD symbols should have the same meaning. It is not acceptable to use similar symbols for different meanings. Symbols that have the same meaning should have the same shape and appearance on the HUD and HDDs.
Special Symbolic Features	Special display features or changes may be used to convey particular conditions, such as an overlaid “X” to mean failure of a parameter, a box around a parameter to convey that its value changed, a solid line/shape changing to a dashed line/shape to convey that its motion is limited, and so on. To the extent that it is practical and meaningful, the same display features should be used on the HUD as on the HDD.
Relative Location	Information that relates to the symbols should appear in the same general location relative to other information.

F.5.1.3.3 Alphanumeric Information. Alphanumeric (i.e., textual) information should have the same resolution, units, and labeling. For example, the command reference indication for vertical speed should be displayed in the same foot-per-minute increments and labeled with the same characters as on the HDDs. Likewise, the same terminology should be used for labels, modes, and alert messages on the HUD as on the HDDs. If the

design has exceptions to this principle, then they should be justified by necessity or impracticality, and shown not to increase workload or the potential for confusion or flightcrew error.

F.5.1.3.4 Analog Scales or Dials. Analog scales or dials should have the same range and dynamic operation. For example, a glideslope deviation scale displayed head-up should have the same displayed range as when it is displayed head-down, and the direction of movement should be consistent.

F.5.1.3.5 Flight Guidance Systems. Modes of flight guidance systems (e.g., autopilot, flight director, and autothrust) and state transitions (e.g., land 2 to land 3) should be displayed on the HUD. Except for the use of color, the modes should be displayed using consistent methods (e.g., the method used head-down to indicate a flight director mode transitioning from armed to captured should also be used head-up).

F.5.1.3.6 Command Information. When command information (e.g., flight director commands) is displayed on the HUD in addition to the HDDs, the HUD guidance cue and path deviation scaling (i.e., dots of lateral and vertical deviation) need to be consistent with that used on the HDDs. There may be cases when the other pilot is using the HDD of guidance and path deviations to monitor the flying pilot's performance. Therefore, the HDD must have path deviation scaling that is sufficiently consistent with the HUD so as not to mislead the monitoring pilot.

F.5.1.3.7 Sensor Sources. Sensor system sources for instrument flight information (e.g., attitude, direction, altitude, and airspeed) should be consistent between the HUD and the HDDs used by the same pilot.

F.5.1.4 Head-Up to Head-Down Transition.

F.5.1.4.1 Transition Scenarios. The applicant should identify conditions for which the pilot transitions between the HUD and the HDD and develop scenarios for evaluation (e.g., simulation or flight test). These scenarios should include systems failures and events leading to unusual attitudes. Transition capability should be shown for all foreseeable modes of upset.

F.5.1.4.2 Unambiguous Information. While the HUD and HDD may display information (e.g., flight path, path deviation, or airplane performance information) in a different manner, the meaning must be the same and any differences should not create confusion, misinterpretation, unacceptable delay, or otherwise hinder the pilot's transition between the two displays. The pilot should be able to easily recognize and interpret information on the HUD. The information should not be ambiguous with similar information on other airplane flight deck displays.

F.5.2 Indications and Alerts.

F.5.2.1 Monochrome Attention-Getting Properties. To comply with § 25.1322, and considering that most HUDs are predominantly monochrome devices,

the HUD should emphasize the display of caution and warning information with the appropriate use of attention-getting properties such as flashing, outline boxes, brightness, size, and/or location to compensate for the lack of color coding. For additional alerting guidance, see AC 25.1322-1, *Flightcrew Alerting*. The applicant should develop and apply a consistent documented philosophy for each alert level. These attention-getting properties should be consistent with those used on the HDDs. For example, flashing icons on the HUD should indicate situations with the same level of urgency as flashing icons on the HDDs.

F.5.2.2 Time-Critical Alerts on the HUD. For some phases of flight, airworthiness approval may be predicated on the use of the HUD. In these phases of flight, it can be reasonably expected that the pilot operates primarily by using the HUD, so the objective is to not redirect attention of the pilot flying (PF) to another display when an immediate maneuver is required (e.g., resolution advisory or windshear). The applicant should provide in the HUD the guidance, warnings, and annunciations of certain systems, if installed, such as a Terrain Awareness and Warning System (TAWS), or a traffic alert and collision avoidance system (TCAS) and a windshear detection system. If the provision of TCAS or windshear guidance is not practical on the HUD, the applicant should provide compensating design features and pilot procedures (e.g., a combination of means such as control system protections and an unambiguous reversion message in the HUD) to ensure that the pilot has equivalent and effective visual information for immediate awareness and response to the respective alerts.

F.5.2.3 Additional Resources. Additional guidance on indications and alerts is in AC 25.1329-1B, *Approval of Flight Guidance Systems*, and AC 25.1322-1 *Flightcrew Alerting*, and the associated regulations.

F.5.3 Display Clutter.

This AC addresses display clutter for traditional displays on the instrument panel. However, because the pilot must see through the HUD, special attention is needed to avoid display clutter that would otherwise unduly obscure the outside view.

F.5.4 Display of Information.

F.5.4.1 General. The HUD information display requirements depend on the intended function of the HUD. Specific guidance for displayed information is in the main body and appendix A of this AC. In addition, the following sections provide guidance related to unique characteristics of the HUD. As in the case of other flight deck displays, new and novel display formats may be subject to human factors evaluation of the pilot interface by an airworthiness authority.

F.5.4.2 Alternate Formats for Primary Flight Information.

F.5.4.2.1 Phase of Flight. There may be certain operations and phases of flight during which certain primary flight reference indications in the HUD do not need to have the analog cues for trend, deviation, and quick glance awareness that would normally be necessary. For example, during the precision approach phase, HUD formats have been accepted that provide a digital-only display of airspeed and altitude. Acceptance of these displays has been predicated on the availability of compensating features that provide clear and distinct warning to the flightcrew when these and certain other parameters exceed well-defined tolerances around the nominal approach state (e.g., approach warning). These warnings have associated procedures that require a missed approach.

F.5.4.2.2 Digital Displays. Formats with digital-only display of primary flight information (e.g., airspeed, altitude, attitude, and heading) should be demonstrated to provide at least one of the following:

F.5.4.2.2.1 A satisfactory level of task performance.

F.5.4.2.2.2 A satisfactory awareness of proximity to limit values, like V_S, V_{MO}, and V_{FE}.

F.5.4.2.2.3 A satisfactory means to avoid violating such limits.

F.5.4.2.3 Go-Around and Missed Approach. If a different display format is used for go-around than that used for the approach, the format transition should occur automatically as a result of the normal go-around or missed approach procedure.

F.5.4.2.4 Minimize Format Changes. Changes in the display format and primary flight data arrangement should be minimized to prevent confusion and to enhance the flightcrew's ability to interpret vital data.

F.5.4.3 Airplane Control Considerations. For those phases of flight where airworthiness approval is predicated on the use of the HUD, or when it can be reasonably expected that the flightcrew will operate primarily by reference to the HUD, the HUD should adequately provide the following information and cues:

F.5.4.3.1 Flight State and Position. The HUD should provide information to permit the pilot to instantly evaluate the airplane's flight state and position. This information should be adequate for manually controlling the airplane and for monitoring the performance of the automatic flight control system. Using the HUD for manual control of the airplane and monitoring of the automatic flight control system should not require exceptional pilot skill, excessive workload, or excessive reference to other flight displays.

F.5.4.3.2 Attitude Cues. Attitude cues must enable the pilot to instantly recognize unusual attitudes. Attitude cues must not hinder unusual attitude recovery. If the HUD is designed to provide guidance or information for recovery from upsets or unusual attitudes, recovery steering guidance commands should be distinct from, and not confused with, orientation symbology

such as horizon pointers. This capability should be shown for all foreseeable modes of upset, including crew mishandling, autopilot failure (including "slowovers"), and turbulence/gust encounters.

F.5.4.4 Airspeed Considerations.

F.5.4.4.1 Airspeed Scale Range. As with other electronic flight displays, the HUD airspeed indications may not typically show the entire range of airspeed. Section 25.1541(a)(2) states the airplane must contain "Any additional information, instrument markings, and placards required for the safe operation if there are unusual design, operating, or handling characteristics."

F.5.4.4.2 Low- and High-Speed Awareness Cues. Low-speed awareness cues on the HUD should provide adequate visual cues to the pilot that the airspeed is below the reference operating speed for the airplane configuration (e.g., weight, flap setting, and landing gear position). 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.

F.5.4.4.3 Format of Low- and High-Speed Awareness Cues. The low- and high-speed awareness cues should be readily distinguishable from other markings such as V-speeds and speed targets (e.g., bugs). The cues should indicate the boundary value of speed limit, and they should also clearly distinguish between the normal speed range and the unsafe speed range beyond those limiting values. Cross-hatching or other similar coding techniques may be acceptable to delineate zones of different meaning.

F.5.4.5 Flight Path Considerations.

F.5.4.5.1 General. The type of flight path information displayed (e.g., earth-referenced or air mass) may be dependent on the operational characteristics of a particular airplane and the phase of flight during which the flight path is to be displayed.

F.5.4.5.2 Velocity/Flight Path Vector. An indication of the airplane's velocity vector, or flight path vector, is considered essential to most HUD applications. Earth-referenced flight path display information provides an instantaneous indication of where the airplane is actually going. During an approach, this information can be used to indicate the airplane's impact or touchdown point on the runway. The earth-referenced flight path shows the effects of wind on the motion of the airplane. The flight path vector can be used by the pilot to set a precise climb or dive angle relative to the conformal outside scene or relative to the HUD's flight path (pitch) reference scale and horizon displays. In the lateral axis, the flight path symbols should indicate the airplane track relative to the boresight.

F.5.4.5.3 Air-Mass-Derived Flight Path. Air-mass-derived flight path may be displayed as an alternative, but it does not show the effects of wind on the

motion of the airplane. In this case, the lateral orientation of the flight path display represents the airplane's sideslip, while the vertical position relative to the reference symbol represents the airplane's angle of attack.

F.5.4.6 Attitude Considerations.

F.5.4.6.1 General. For all unusual attitude situations and command guidance display configurations, the displayed attitude information should enable the pilot to make accurate, easy, quick glance interpretation of the attitude situation.

F.5.4.6.2 Pitch. The pitch attitude display should be such that, during all maneuvers, a horizon reference remains visible with enough margin to allow the pilot to recognize pitch and roll orientation. For HUDs that are capable of displaying the horizon conformally, the display of a non-conformal horizon reference should appear distinctly different than the display of a conformal horizon reference.

F.5.4.6.3 Display of Unusual Attitude Conditions. Extreme attitude symbology and automatically decluttering the HUD at extreme attitudes has been found acceptable (i.e., extreme attitude symbology should not be visible during normal maneuvering).

F.5.4.6.4 Unusual Attitude Recovery. When the HUD is not designed to be used for recovery from unusual attitude, the applicant should provide a satisfactory demonstration of the following:

- Compensating features (e.g., characteristics of the airplane and the HUD system).
- Immediate annunciation on the HUD to direct the pilot to use the head-down primary flight display for recovery.
- Satisfactory demonstration of timely recognition and correct recovery maneuvers.

F.5.4.6.5 Flightcrew Awareness of HUD Modes. The same information concerning current HUD system mode, reference data, status state transitions, and alert information that is displayed to the pilot using the HUD should also be displayed head-down to the other pilot. The display of this information for the other pilot should use consistent nomenclature to ensure unmistakable awareness of the HUD operation.

F.6 **Dual HUDs.**

F.6.1 Operational Concept for Dual HUDs.

The applicant should define the operational concept using dual HUDs. The operational concept should detail the tasks and responsibilities of both PF and pilot-not-flying (PNF) in regards to using and monitoring HDDs and HUDs during all phases of flight.

It should specifically address the simultaneous use of the HUD by both pilots during each phase of flight, as well as cross-flight-deck transfer of control.

F.6.2 Flightcrew Awareness of Other Instruments and Indications.

With single HUD installations, the PF likely uses the HUD as a primary flight reference and the PNF monitors the head-down instruments and alerting systems for failures of systems, modes, and functions that are not displayed on the primary flight displays or HUD. However, in the case where both flightcrew members simultaneously use HUDs, the flightcrew should be able to maintain an equivalent level of awareness of key information that is not displayed on the HUD (e.g., powerplant indications, alerting messages, and airplane configuration indications).

F.6.3 Roles and Responsibilities.

The applicant should define the operational concept to account for the expected roles and responsibilities of the PF and PNF. The concept should also take into account the following considerations:

F.6.3.1 Impact on Head-Down Vigilance. When both pilots of the flightcrew use a HUD as the primary flight display, the visual head-down indications may not receive the same level of vigilance (as compared to a pilot using the head-down primary flight display).

F.6.3.2 Assurance of Head-Down Scan. The applicant should explain how the scan of the head-down instruments is ensured during all phases of flight, and, if not, what compensating design features help the flightcrew maintain awareness of key information that is only displayed on HDDs (e.g., powerplant indications, alerting messages, and airplane configuration indication). The applicant should describe which pilot scans the head-down instrument indications and how often. For any case in which at least one pilot is not scanning the head-down instruments full-time, the design should have compensating design features that ensure an equivalent level of timeliness and awareness of the information provided by the head-down visual indications.

F.6.3.3 Alerts. The design should effectively compensate for any cautions and warnings that do not have visual indications in the HUD that are equivalent to the head-down primary flight display. The purpose of the compensating design features is to make the pilot using the HUD aware of the alerts so there are no additional delays in awareness and response time. The flightcrew should be able to respond to alerts without any reduction in task performance or degraded safety.

F.6.3.4 Reassessment. The applicant should globally reassess the alerting functions to ensure that the flightcrew is aware of alerts and responds to them in a timely manner. The reassessment should review the design and techniques, the alerting attention-getting properties (e.g., visual master warning, master caution, and aural alerts), and other alerts in the flight

deck. The flightcrew's awareness of alerts might differ between single- and dual-HUD installations. With a dual-HUD installation, there may be periods when neither pilot is scanning the instrument panel. With a single-HUD configuration, the PNF refers only to the head-down instrument panel and may have responsibility for monitoring indications on that panel. With dual-HUD configurations, both pilots' attention may be turned to their HUDs, and they might miss an alert that would otherwise be plainly visible to a pilot not using a HUD.

F.7 **Flight Data Recording.**

Flight data recorders must record the minimum data parameters required by §§ 25.1459(e) and 121.344. Optionally, the flight data recorders may also record other information regarding unique operating characteristics of the HUDs. For example, they may include information such as the mode in which the HUD was operating, the status (e.g., in use or inoperative), and if the display declutter mode was operating.

F.8 **Continued Airworthiness.**

Sections 25.1309 and 25.1529 and appendix H to part 25 require instructions for the continued airworthiness of a display system and its components. The content of the instructions depends on the type of operation and intended function of the HUD.

APPENDIX G. WEATHER DISPLAYS.

G.1 Introduction.

G.1.1 Purpose.

This appendix provides additional guidance for displaying weather information in the flight deck. Weather displays provide the flightcrew with additional tools to help make decisions based on weather information.

G.1.2 Examples.

Sources of weather information may include, but are not limited to, onboard weather sensors, data-linked weather information, and pilot/air traffic reports. The information from these sources can be displayed in a variety of graphical or text formats. Because many sources of weather information exist, it is important that the applicant identify the source of the information, assess its intended function, and apply the guidance contained within this AC.

G.2 Key Characteristics.

In addition to the general guidelines provided in the body of this AC, the following guidelines should be considered when establishing the intended functions of weather displays.

G.2.1 Unambiguous Meanings.

The meaning of the presentations (e.g., display format, colors, labels, data formats, and interaction with other display parameters) should be clear and unambiguous. The flightcrew should not misunderstand or misinterpret the weather information.

G.2.2 Color.

G.2.2.1 The use of color should be appropriate to its task and use.

G.2.2.2 The use of color must not adversely affect or degrade the attention-getting qualities of the information as required by Title 14, Code of Federal Regulations (14 CFR) 25.1322(f).

G.2.2.3 Color conventions should be followed (such as the conventions established in ARINC 708A-3, *Airborne Weather Radar with Forward Looking Windshield Detection Capability*; and AC 20-149A, *Installation Guidance for Domestic Flight Information Services – Broadcast*).

G.2.2.4 The use of red and yellow must be in compliance with § 25.1322(e). Compliance can be shown using the guidance in AC 25.1322-1, *Flightcrew Alerting*, and this AC.

Note 1: AC 20-149A indicates an exclusion to the acceptability of RTCA DO-267A, *Minimum Aviation System Performance Standards (MASPS) for Flight Information Services-Broadcast (FIS-B) Data Link*, Sections 2.0 and 3.0, for part 25 airplanes.

Note 2: See paragraph 5.8 of this AC for information on guidelines on color progression.

G.2.3 Multiple Sources of Weather Information.

G.2.3.1 The weather display should enable the flightcrew to quickly, accurately, and consistently differentiate among sources of the displayed weather information. Time-critical information should be immediately distinguishable from dated, non-time-critical information.

G.2.3.2 If more than one source of weather information is available, the source of the weather information should be indicated on the selector and the resulting display.

G.2.3.3 When simultaneously displaying information from multiple weather sources (e.g., weather radar and data link weather), the display should clearly and unambiguously indicate the source of that information. In other words, the flightcrew should know the source of the symbol and whether it is coming from data-linked weather or real-time weather sources. These guidelines also apply to symbols (e.g., winds aloft and lightning) that have the same meaning but originate from different weather information sources.

G.2.3.4 If weather information is overlaid on an existing display, it should be easily distinguished from the existing display. It also should be consistent with the information it overlays in terms of position, orientation, range, and altitude.

G.2.3.5 When fusing or overlaying multiple weather sources, the resulting combined image should convey its intended meaning and meet its intended function, regardless of any differences in the sources in terms of image quality, projection, data update rates, data latency, or sensor alignment algorithms, for example.

G.2.3.6 If weather information is displayed on a head-up display, the guidance of this AC including appendix F of this AC should be followed.

G.2.3.7 When the source of the weather information source is not the onboard sensors, some means to identify its relevance (e.g., a time stamp or the age of the product) should be provided. Presenting the product age is particularly important when combining information from multiple weather products. In addition, the effective time of forecast weather should also be provided.

G.2.3.8 If a weather-looping (animation) display feature is provided, the system should provide the means to readily identify the total elapsed time of the image compilation so the flightcrew does not misinterpret the movement of the weather cells.

G.2.3.9 For products that have the ability to present weather for varying altitudes (e.g., potential or reported icing, radar, and lightning strikes), information should be presented that allows the flightcrew to distinguish or identify which altitude range applies to each feature.

G.2.3.10 Weather information may include a number of graphical and text information features or sets of information (e.g., text and graphical Aviation Routine Weather Reports and winds aloft). The display should provide a means to identify the meaning of each feature to ensure that the information is correctly used.

G.2.3.11 If the flightcrew or system has the ability to turn a weather information source on or off, the flightcrew should be able to easily determine if the source is on or off.

G.2.3.12 When weather information is presented in a vertical situation display, the lateral width of the weather swath (like that of the terrain swath) should be carefully considered to ensure that weather information that is relevant to the current phase of flight or flight path is displayed. An unsuitable lateral swath width could either mislead the flightcrew to abort an operation for weather that poses no hazard, or fail to abort an operation when the weather does pose a hazard. If swath dimensions are automatically controlled, then careful consideration should be given to include only the area that would be relevant to the operation. Means may be provided for the flightcrew to select the swath widths that they consider suitable for the phase of flight and prevailing weather conditions. The lateral width of the weather swath (like that of the terrain swath) should be made readily apparent to the flightcrew (e.g., use the same swath as is used for the terrain, or display its boundaries on the plan view weather display). Generally, if the vertical situation displays terrain and weather at the same time, the choice of flight path-centered or track/heading-centered swath should be consistent. If the weather overlay is designed to show a smaller vertical swath than is represented by the altitude scale, then the boundaries of this swath should be clearly depicted on the display.

G.2.3.12.1 Weather information displayed on a vertical situation display should be accurately depicted with respect to the scale factors of the display (i.e., vertical and horizontal).

G.2.3.12.2 Consideration should be given to making the width of the information on the weather display consistent with the width used by other systems, including the Terrain Awareness and Warning System, if displayed. This

should not be interpreted as a restriction precluding other means of presentation that can be demonstrated to be superior.

G.3 On-Board Weather Radar Information.

G.3.1 Background.

On-board weather radar provides forward-looking weather detection, including in some cases windshear and turbulence detection.

G.3.2 Minimum Performance Standards.

The display of on-board weather radar information should be in accordance with the applicable portions of RTCA DO-220, *Minimum Operational Performance Standards (MOPS) for Airborne Weather Radar with Forward-Looking Windshear Detection Capability*. TSO-C63d, *Airborne Weather Radar Equipment*, allows exceptions to the minimum performance standards of RTCA DO-220 for Radar Equipment Class A and B.

G.3.3 Hazard Detection.

The weather display echoes from precipitation and ground returns should be clear, automatic, timely, concise, and distinct so the flightcrew can easily interpret, analyze, and avoid hazards. The radar range, elevation, and azimuth indications should provide sufficient information for flightcrews to safely avoid the hazard.

G.4 Predictive Windshear Information.

G.4.1 General.

If provided, windshear information should be clear, automatic, timely, concise, and distinct so the flightcrew can easily interpret, detect, and minimize the threat of windshear activity.

G.4.2 Presentation Methods.

When a windshear threat is detected, the corresponding display may be automatically presented or selected by the flightcrew at an appropriate range to identify the windshear activity and minimize the windshear threat to the airplane.

G.4.3 Pilot Workload.

Pilot workload necessary for the presentation of windshear information should be minimized. When the flight deck is configured for normal operating procedures, it should not take more than one action to display the windshear information.

G.4.4 Windshear Threat Symbol.

The size and location of the windshear threat symbol should allow the flightcrew to recognize the dimension of the windshear and its position. The symbol should be presented in accordance with RTCA DO-220.

G.4.5 Relative Position to the Airplane.

The relative position and azimuth of the windshear threat with respect to the nose of the airplane should be displayed in an unambiguous manner.

G.4.6 Range.

The range selected by the flightcrew for the windshear display should allow the flightcrew to distinguish the windshear event from other information. Amber radial lines may be used to extend from the left and right radial boundaries of the icon extending to the upper edge of the display.

G.5 **Safety Aspects.**

G.5.1 Functional Hazard Assessment.

Both the loss of weather information and the display of misleading weather information should be addressed in the functional hazard assessment (FHA). In particular, the FHA should address failures of the display system that could result in the loss of the display and failures that could result in the presentation of misleading weather information.

G.5.2 Misleading Information.

The functional hazard assessment should address the effects of displaying misleading information. In accordance with chapter 4 of this AC, the display of misleading weather radar includes information that would lead the flightcrew to make a bad decision or introduce a potential hazard. Examples include—but are not limited to—storm cells displayed in the incorrect position, at the wrong intensity, or mis-registered in the case of a combined (e.g., fused) image.

Advisory Circular Feedback

If you find an error in this advisory circular (AC), have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by (1) emailing this form to 9-AWA-AVS-AIR500-Coord@faa.gov or (2) faxing it to the attention of the Aircraft Certification Service Directives Management Officer at (202) 267-3983.

Subject: _____ Date: _____

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph _____ on page _____.

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