CS-25 AMENDMENT 17 — CHANGE INFORMATION

The Agency publishes amendments to Certification Specifications as consolidated documents. These documents are used for establishing the certification basis for applications made after the date of entry into force of the amendment.

Consequently, except for a note '[Amdt No: 25/17]' under the amended paragraph, the consolidated text of CS-25 does not allow readers to see the detailed changes introduced by the new amendment. To allow readers to also see these detailed changes, this document has been created. The same format as for the publication of Notices of Proposed Amendments (NPAs) has been used to show the changes:

(a) deleted text is marked with ~~strike through~~;

(b) new or amended text is highlighted in grey;

(c) an ellipsis (…) indicates that the remaining text is unchanged in front of or following the reflected amendment.

BOOK 1

SUBPART B –— FLIGHT

Correct a typo in CS 25.21(g)(3) as follows:

CS 25.21 Proof of compliance

(…)

(g) The requirements of this subpart

(…)

(3) If the applicant seeks certification for flight in any portion of the icing conditions of Appendix O, each requirement of this subpart, except paragraphs CS 25.121(a), 25.123(c), 25.143(b)(1) and (b)(2), 25.149, 25.201(c)(2), and 25.251(b) through (e), must be met in the Appendix O icing conditions for which certification is sought. CS 25.207(c) and (d) must be met in the landing configuration in the icing conditions specified in Appendix O for which certification is sought but need not be met for other configurations.

(…)

SUBPART C -— STRUCTURE

Amend CS 25.562 as follows:

CS 25.562 Emergency landing dynamic conditions

(See AMC 25.562)

(…)

SUBPART D –— DESIGN AND CONSTRUCTION

Amend CS 25.785 as follows:

CS 25.785 Seats, berths, safety belts and harnesses

(See AMC 25.785)

(…)

(d) Each occupant of a seat ~~(see AMC 25.785(d))~~ that makes more than an 18-degree angle with the vertical plane containing the aeroplane centre line […]

(…)

Amend CS 25.793 as follows:

CS 25.793 Floor surfaces

(See AMC to CS 25.793 and 25.810(c))

(…)

Amend CS 25.795 as follows:

CS 25.795 Security considerations

(See AMC 25.795)

(…)

(d) Each chemical oxygen generator or its installation must be designed to be secure from deliberate manipulation by one of the following:

(1) By providing effective resistance to tampering;

(2) By providing an effective combination of resistance to tampering and active tamper-evident features;

(3) By installation in a location or manner whereby any attempt to access the generator would be immediately obvious; or

(4) By a combination of approaches specified in subparagraphs (d)(1), (d)(2) and (d)(3) of this paragraph. (See AMC 25.795(d))

Amend CS 25.809 as follows:

CS 25.809 Emergency exit arrangement

(See AMC 25.809~~(a)~~)

(a)(…)

(2) (…)The viewing means may be on or adjacent to the exit provided no obstructions exist between the exit and the viewing means. (See AMC 25.809(a))

Amend CS 25.810 as follows:

CS 25.810 Emergency egress assisting means and escape routes

(See AMC 25.810~~(c)(2)~~)

(…)

(c) An escape route must (…) covered with a slip resistant surface (See AMC to CS 25.793 and CS 25.810(c)). (…)

(2) The escape route surface must have a reflectance of at least 80 %, and must be defined by markings with a surface-to-marking contrast ratio of at least 5:1. (See AMC 25.810(c)(2))

Amend CS 25.811 as follows:

CS 25.811 Emergency exit marking

(See AMC 25.811)

(…)

Amend CS 25.819 as follows:

CS 25.819 Lower deck service compartments (including galleys)

(See AMC 25.819)

(...)

SUBPART F –— EQUIPMENT

Amend CS 25.1316 as follows:

CS 25.1316 ~~System lightning protection~~ Electrical and electronic system lightning protection

(See AMC 20-136)

~~(a) For functions whose failure would contribute to or cause a condition that would prevent the continued safe flight and landing of the aeroplane, each electrical and electronic system that performs these functions must be designed and installed to ensure that the operation and operational capabilities of the systems to perform these functions are not adversely affected when the aeroplane is exposed to lightning.~~

~~(b) For functions whose failure would contribute to or cause a condition that would reduce the capability of the aeroplane or the ability of the flight crew to cope with adverse operating conditions, each electrical and electronic system that performs these functions must be designed and installed to ensure that these functions can be recovered in a timely manner after the aeroplane is exposed to lightning.~~

~~(c) Compliance with the lightning protection criteria prescribed in subparagraphs (a) and (b) of this paragraph must be shown for exposure to a severe lightning environment. The aeroplane must be designed for and it must be verified that aircraft electrical/electronic systems are protected against the effects of lightning by:~~

~~(1) Determining the lightning strike zones for the aeroplane;~~

~~(2) Establishing the external lightning environment for the zones;~~

~~(3) Establishing the internal environment;~~

~~(4) Identifying all the electrical and electronic systems that are subject to the requirements of this paragraph, and their locations on or within the aeroplane;~~

~~(5) Establishing the susceptibility of the systems to the internal and external lightning environment;~~

~~(6) Designing protection; and~~

~~(7) Verifying that the protection is~~

~~adequate.~~

(a) Each electrical and electronic system that performs a function whose failure would prevent the continued safe flight and landing of the aeroplane must be designed and installed so that:

(1) the function is not adversely affected during and after the time the aeroplane is exposed to lightning; and

(2) the system automatically recovers normal operation of that function, in a timely manner, after the aeroplane is exposed to lightning, unless the system's recovery conflicts with other operational or functional requirements of the system that would prevent continued safe flight and landing of the aeroplane.

(b) Each electrical and electronic system that performs a function whose failure would reduce the capability of the aeroplane or the ability of the flight crew to respond to an adverse operating condition must be designed and installed so that the function recovers normal operation in a timely manner after the aeroplane is exposed to lightning.

Create CS 25.1317 as follows:

CS 25.1317 High-Intensity Radiated Fields (HIRF) protection

(See AMC 20-158)

(a) Each electrical and electronic system that performs a function whose failure would prevent the continued safe flight and landing of the aeroplane must be designed and installed so that:

(1) The function is not adversely affected during and after the time the aeroplane is exposed to HIRF environment I, as described in Appendix R;

(2) The system automatically recovers normal operation of that function, in a timely manner, after the aeroplane is exposed to HIRF environment I, as described in Appendix R, unless the system's recovery conflicts with other operational or functional requirements of the system that would prevent continued safe flight and landing of the aeroplane; and

(3) The system is not adversely affected during and after the time the aeroplane is exposed to HIRF environment II, as described in Appendix R.

(b) Each electrical and electronic system that performs a function whose failure would significantly reduce the capability of the aeroplane or the ability of the flight crew to respond to an adverse operating condition must be designed and installed so that the system is not adversely affected when the equipment providing the function is exposed to equipment HIRF test level 1 or 2, as described in Appendix R.

(c) Each electrical and electronic system that performs a function whose failure would reduce the capability of the aeroplane or the ability of the flight crew to respond to an adverse operating condition must be designed and installed so that the system is not adversely affected when the equipment providing the function is exposed to equipment HIRF test level 3, as described in Appendix R.

Amend CS 25.1450(b) as follows:

CS 25.1450 Chemical oxygen generators

(…)

(b) Each chemical oxygen generator must be designed and installed in accordance with the following requirements:

(…)

(3) Comply with CS 25.795(d).

(…)

Appendix F

Amend Part I as follows:

Appendix F

Part I — Test Criteria and Procedures for Showing Compliance with CS 25.853, 25.855 or 25.869

(…)

(b) *Test Procedures* –

(…)

(4) *Vertical test*.

(…)

The burn length determined in accordance with subparagraph (~~7~~8) of this paragraph must be measured to the nearest 2·5 mm (tenth of an inch).

(…)

Amend Part II as follows:

Appendix F

Part II — Flammability of Seat Cushions

(a) *Criteria for Acceptance*.

(…)

(3) Each specimen tested (…) as determined by the test specified in CS 25.853(~~c~~a), does not exceed the corresponding burn length of the dress covering used on the cushion subjected to the oil burner test.

(…)

Create a new Appendix R as follows:

Appendix R

HIRF Environments and Equipment HIRF Test Levels

This Appendix specifies the HIRF environments and equipment HIRF test levels for electrical and electronic systems under CS 25.1317. The field strength values for the HIRF environments and equipment HIRF test levels are expressed in root-mean-square units measured during the peak of the modulation cycle.

(a) HIRF environment I is specified in the following table:

Table 1 — HIRF environment I

FREQUENCY	FIELD STRENGTH (V/m)	
	PEAK	AVERAGE
10 kHz – 2 MHz	50	50
2 MHz – 30 MHz	100	100
30 MHz – 100 MHz	50	50
100 MHz – 400 MHz	100	100
400 MHz – 700 MHz	700	50
700 MHz – 1 GHz	700	100
1 GHz – 2 GHz	2 000	200
2 GHz – 6 GHz	3 000	200
6 GHz – 8 GHz	1 000	200
8 GHz – 12 GHz	3 000	300
12 GHz – 18 GHz	2 000	200
18 GHz – 40 GHz	600	200

In this table, the higher field strength applies to the frequency band edges.

(b) HIRF environment II is specified in the following table:

Table 2 — HIRF environment II

FREQUENCY	FIELD STRENGTH (V/m)	
	PEAK	**AVERAGE**
10 kHz – 500 kHz	20	20
500 kHz – 2 MHz	30	30
2 MHz – 30 MHz	100	100
30 MHz – 100 MHz	10	10
100 MHz – 200 MHz	30	10
200 MHz – 400 MHz	10	10
400 MHz – 1 GHz	700	40
1 GHz – 2 GHz	1 300	160
2 GHz – 4 GHz	3 000	120
4 GHz – 6 GHz	3 000	160
6 GHz – 8 GHz	400	170
8 GHz – 12 GHz	1 230	230
12 GHz – 18 GHz	730	190
18 GHz – 40 GHz	600	150

In this table, the higher field strength applies to the frequency band edges.

(c) Equipment HIRF test level 1.

(1) From 10 kilohertz (kHz) to 400 megahertz (MHz), use conducted susceptibility tests with Continuous Wave (CW) and 1 kHz square wave modulation with 90 % depth or greater. The conducted susceptibility current must start at a minimum of 0.6 milliamperes (mA) at 10 kHz, increasing 20 decibels (dB) per frequency decade to a minimum of 30 mA at 500 kHz.

(2) From 500 kHz to 40 MHz, the conducted susceptibility current must be at least 30 mA.

(3) From 40 MHz to 400 MHz, use conducted susceptibility tests, starting at a minimum of 30 mA at 40 MHz, decreasing 20 dB per frequency decade to a minimum of 3 mA at 400 MHz.

(4) From 100 MHz to 400 MHz, use radiated susceptibility tests at a minimum of 20 volts per meter (V/m) peak with CW and 1 kHz square wave modulation with 90 % depth or greater.

(5) From 400 MHz to 8 gigahertz (GHz), use radiated susceptibility tests at a minimum of 150 V/m peak with pulse modulation of 4 % duty cycle with a 1 kHz pulse repetition frequency. This signal must be switched on and off at a rate of 1 Hz with a duty cycle of 50 %.

(d) Equipment HIRF test level 2. Equipment HIRF test level 2 is HIRF environment II in Table II of this Appendix reduced by acceptable aircraft transfer function and attenuation curves. Testing must cover the frequency band of 10 kHz to 8 GHz.

(e) Equipment HIRF test level 3.

(1) From 10 kHz to 400 MHz, use conducted susceptibility tests, starting at a minimum of 0.15 mA at 10 kHz, increasing 20 dB per frequency decade to a minimum of 7.5 mA at 500 kHz.

(2) From 500 kHz to 40 MHz, use conducted susceptibility tests at a minimum of 7.5 mA.

(3) From 40 to 400 MHz, use conducted susceptibility tests, starting at a minimum of 7.5 mA at 40 MHz, decreasing 20 dB per frequency decade to a minimum of 0.75 mA at 400 MHz.

(4) From 100 MHz to 8 GHz, use radiated susceptibility tests at a minimum of 5 V/m.

BOOK 2

AMC — SUBPART C

Create a new AMC 25.562 as follows:

AMC 25.562

Emergency landing dynamic conditions

The FAA AC 25.562-1B, *Dynamic Evaluation of Seat Restraint Systems and Occupant Protection on Transport Airplanes*, dated 10.1.2006, except paragraph 5.e.(5)(d), and the FAA AC 20-146, *Methodology for Dynamic Seat Certification by Analysis for Use in Parts 23, 25, 27, and 29 Airplanes and Rotorcraft*, dated 19.5.2003, are accepted by the Agency as providing an Acceptable Means of Compliance to CS 25.562.

AMC — SUBPART D

Create a new AMC 25.785 as follows:

AMC 25.785

Seats, berths, safety belts and harnesses

The FAA AC 25.785-1B, *Flight Attendant Seat and Torso Restraint System Installations*, dated 11.5.2010, and relevant parts of the FAA AC 25-17A, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 18.5.2009, are accepted by the Agency as providing an Acceptable Means of Compliance to CS 25.785.

Note: 'Relevant parts' means 'the parts of the AC 25-17A that address the applicable FAR/CS-25 paragraph'.

Delete AMC 25.785(d) ('Seats and Safety Belts').

Create a new AMC to CS 25.793 and CS 25.810(c) as follows:

AMC to CS 25.793 and CS 25.810(c)

Floor surfaces

Relevant parts of the FAA AC 25-17A, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 18.5.2009, are accepted by the Agency as providing an Acceptable Means of Compliance to CS 25.793 and CS 25.810(c).

Note: 'Relevant parts' means 'the parts of the AC 25-17A that address the applicable FAR/CS-25 paragraph'.

Create a new AMC 25.795(d) as follows:

AMC 25.795(d)

Security of chemical oxygen generators

1. Purpose

CS 25.795(d) requires each Chemical Oxygen Generator (COG) or its installation to be designed so that it meets one of several criteria. The means of compliance described in this AMC provides guidance to supplement the engineering and operational judgment that should form the basis of any compliance findings related to a COG installed on an aeroplane.

2. Definition of terms

For this AMC, the following definitions apply:

(a) **Access:** The ability to manipulate the COG with the intent of making alterations for a purpose for which the COG was not originally designed. This includes gaining access to the area surrounding the COG.

(b) **Activation:** Release of the firing mechanism of the COG for the purpose of initiating the chemical reaction inside.

(c) **Alteration:** A change in the configuration of the COG once 'access' has been gained for the purpose of using the COG for a function other than the one it is intended for.

(d) **Chemical Oxygen Generator (COG):** A device that releases oxygen that is created from a chemical reaction.

(e) **Immediately obvious:** Where an attempt to gain 'access' to the COG would be readily recognised as suspicious (prior to gaining 'access'). This would only be in locations with 'unrestricted access' that are 'observable'.

(f) **Intervention:** The actions crew members must take to prevent damage to the aeroplane once an alert is activated indicating that the COG is being tampered with. The time it takes to intervene when the lavatory is occupied has not been determined; however, it can be assumed that it will take several minutes to resolve the issue.

(g) **Observable:** A crew member is able to see if a person attempts to gain 'access' to a COG installation during the course of the crew member's normal duties.

(h) **Tamper-evident feature:** A unique feature that provides an active and obvious contemporaneous alert to crew members that someone is trying to gain 'access' to the COG and immediate crew 'intervention' is necessary.

(i) **Tamper-resistance:** The level of deterrence for gaining 'access' to the COG.

(j) **Unrestricted access:** An area of the cabin passengers can enter without overcoming locks or other mechanical closure means.

3. Related Certification Specifications (CSs)

CS 25.795	Security considerations
CS 25.1301	Equipment — Function and installation
CS 25.1309	Equipment, systems, and installations
CS 25.1322	Flight crew alerting

CS 25.1450 Chemical oxygen generators

4. Compliance with CS 25.795(d)

(a) Acceptable means of determining if a COG or its installation is designed to be secure

Several criteria may be used for determining if a COG installation is secure or has a security vulnerability. COG installations with a security vulnerability must include design features to prevent potential misuse of the COG. Figure 1, *Criteria for Assessing an Installation*, includes assessment criteria that can be used for determining if a COG installation has a security vulnerability. Table 1 includes guidance to assist in answering the questions in Figure 1. For installations identified as having security vulnerabilities, such as those for which the answers to the assessment statements in Figure 1 result in the answer to question number 4 being yes, the design should be changed. Alternatively, the COG can be replaced with an acceptable oxygen source that is not a security threat.

Figure 1: Criteria for assessing an installation

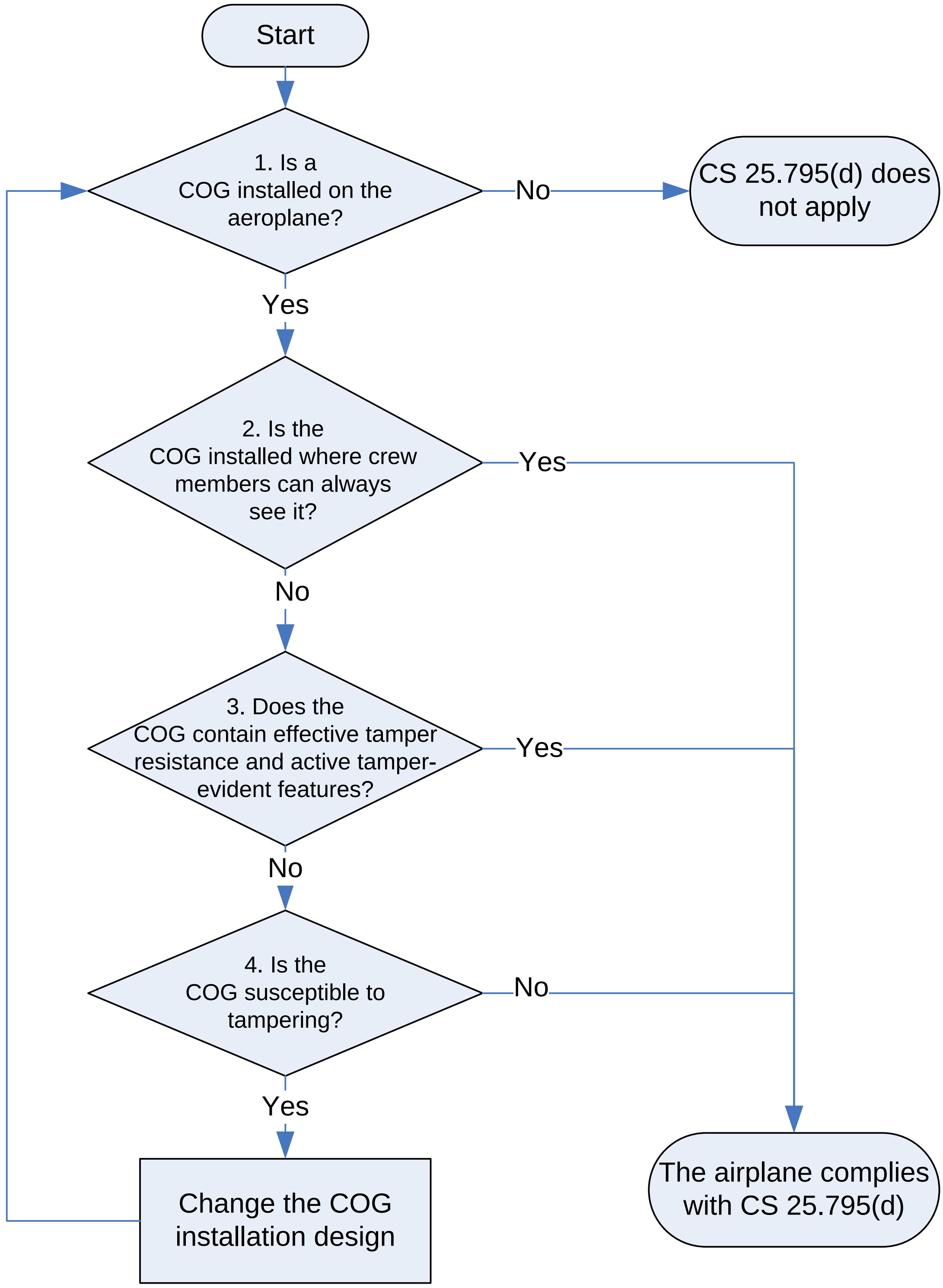

Table 1: Assessment statement analysis

Question number	Notes and questions to assist with the assessment statement analysis
1.	Review the instructions for continued airworthiness. Review the drawing system. Inspect the aeroplane's configuration.
2.	Can crew members observe the COG installation? Check the area where the COG is installed. Isolated areas such as galleys, lavatories, crew rests, enclosed occupied compartments, and lower lobe lavatory complexes are potential areas of concern and require further evaluation. Are crew members close to the COG installation during their normal duties? Are there physical barriers between the crew members and the area being evaluated? Is there significant distance between the crew members and the area being observed? How accessible is the COG? Is the COG installation surrounded by curtains? Curtained areas are also considered potential areas of concern and may require further evaluation.
3.	Are there locks on doors/access panels to prevent access? Are there tamper-resistant fasteners on panels? Are alarms or some other active alerting tamper indication method part of the installation's design?
4.	Check if the COG can be compromised in place. Assess the vulnerability of the adjacent materials to contain the compromised device. Assess the ability of the compartment to contain the event. Check if the COG can be removed.

(b) Installation of tamper-resistant features

Tamper-resistant design features can be used, in whole or in part, to make a COG installation secure. There are different types of tamper-resistant design features, and their functionality largely depends on the installation. The principal benefit of tamper-resistance is to delay exploitation of the COG as a weapon. However, it is not likely that an existing COG installation that can be accessed from within the lavatory could be modified with tamper-resistant design features sufficient to prevent a successful attack. This is because typical measures of tamper-resistance, such as special tools and fasteners, could likely be overcome given enough time. These measures are normally used as one of several layers of security. Thus, the reliance on such measures is only one element of the security system.

(1) A tamper-resistant installation employs multiple elements, which may include:

(i) the COG’s location;

(ii) the method of mounting;

(iii) physical protection (through shielding or mechanical isolation of key components); and

(iv) internal design.

(2) Eliminating access to the COG is the most straightforward way to make the COG tamper-resistant. Typically, this can be done by placing the COG in a location where significant disassembly of the cabin interior would be required to gain access. For example, the COG for a lavatory could be located so that the entire lavatory module would have to be removed to access the COG. However, the installer should also consider the ramifications on maintenance when this approach is used.

(c) Installation of tamper-evident features

(1) For COGs that can be accessed from isolated compartments, such as lavatories, some form of active tamper-evidence (for example, an alert) would be needed in addition to the installation of tamper-resistant features. This is necessary so that the time to intervene and stop the attack is less than the time required to carry out the attack. In this case, passive tamper-evident features, such as a tamper-evident seal, are not effective because they provide an after-the-fact notification of tampering. The effectiveness of a tamper-evident system depends on intervention; it cannot be assumed that the alarm by itself would inhibit the attack.

(2) Once an alert is activated indicating that the COG is being tampered with, actions by crew members and other available, authorised responders are necessary to prevent catastrophic damage to the aeroplane. Therefore, there is a critical relationship between the tamper-evidence system and the training and capability of the crew to respond. To be most effective, crew training should be accomplished prior to the alarm feature being deployed into the fleet. The time needed to successfully respond to the alarm may be several minutes and depends on several factors. The time available to respond to a threat and intervention times are functions of not only the design features but also of many complex and human factor-dependent variables that are difficult to define. These variables include but are not limited to the individual capabilities and numbers of flight attendants/authorised responders relative to the terrorists/accomplices, as well as the extensiveness of the training received.

(3) In order to be effective, the alerting system must itself be resistant to tampering. Otherwise, the entire concept of using the early notification to crew could be nullified and the COG accessed without impediment.

(d) System safety considerations

The applicant should consult AMC 25.1309 for guidance on compliance with CS 25.1309.

(e) Hazard classification. Failure of tamper-resistant or tamper-evident features should be considered major.

(f) System performance when installed

A tamper-evidence system installed for compliance with CS 25.795(d) is intended to notify crew members that someone is trying to gain access to a COG. The system should provide aural and visual warnings to immediately notify crew members so that they can provide direct response in a timely manner. For example, visual indication should be provided so that crew members can identify which COG location is being tampered with while performing their normal duties. Aural alerts should be distinct from other alerts and clearly audible to the crew members expected to respond to the alert. If an alert is provided to the flight crew, the alert should be presented in accordance with CS 25.1322.

5. Areas that are immediately obvious

For COG installations located where any attempt to access would be immediately obvious, additional safety measures are not required. Immediately obvious areas include the main passenger cabin and other areas where occupants are always present. While some measure of tamper-resistance is encouraged for these locations, none is required to meet CS 25.795(d). Private compartments (such as a lavatory) or visually divided sections of larger cabin areas are assessed independently. The 'immediately obvious' criterion applies to the specific location of each COG installation, not simply the general area in which it is located. In addition, the installation should be evaluated under all conditions that may exist during a flight. So, for example, if tampering would be immediately obvious except when a curtain is pulled to provide privacy, the installation should be evaluated based on the curtain being arranged in a way that most conceals the installation. As with tamper-evident designs, crews should be made aware that tampering with any COG is a safety risk, and any necessary information should be incorporated into the training programmes.

Amend AMC 25.809 as follows:

AMC 25.809

Emergency exit arrangement

Relevant parts of the FAA AC 25-17A, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 18.5.2009, are accepted by the Agency as providing an Acceptable Means of Compliance to CS 25.809.

Note: 'Relevant parts' means 'the parts of the AC 25-17A that address the applicable FAR/CS-25 paragraph'.

~~The requirement to provide a view of the outside in all ambient lighting conditions suggests the use of externally mounted lighting (although other means may be acceptable). In the landing gear collapsed cases, the rolling and pitching effects on the fuselage may redirect a fixed lamp's beam away from the area illuminated in the all landing gears extended condition. Furthermore, in the case of inflatable escape slides the toe end ground contact point will probably move in the opposite direction to that of the lamp beam.~~

~~In recognition of these effects, and in order to maintain reasonable demands on the complexity and power of external lighting equipment, the rule does not require the entire viewable area to be visible in all ambient lighting conditions. The only specific illumination requirement is for the likely areas of evacuee ground contact, with all landing gears extended, for passenger exits.~~

~~However, it is recommended that as large a field of view as is practicable should be provided, taking into account aspects such as fuselage curvature and door/window/hatch location, in order to provide the best chance to identify external evacuation hazards before exits are opened.~~

~~In the case of a flight crew emergency exit, a flight deck window as conventionally configured, used in conjunction with a suitably accessible and powerful portable illumination device (e.g. flashlight) will provide an acceptable means for viewing outside conditions.~~

~~Flight deck seats, consoles etc., as conventionally configured, are not considered to be obstructions in the meaning of this term in CS 25.809(a)(2) in the case where flight deck windows are the viewing means and the exit is an overhead hatch. Furthermore, it is considered that the distance between flight deck windows, as conventionally configured, and an overhead hatch is such that the criterion for the viewing means to be adjacent to the exit is satisfied.~~

Create a new AMC 25.809(a) as follows:

AMC 25.809(a)

Emergency exit outside viewing

The requirement to provide a view of the outside in all ambient lighting conditions suggests the use of externally mounted lighting (although other means may be acceptable). In the landing-gear-collapsed cases, the rolling and pitching effects on the fuselage may redirect a fixed lamp's beam away from the area illuminated in the all-landing-gears-extended condition. Furthermore, in the case of inflatable escape slides, the toe-end ground contact point will probably move in the opposite direction to that of the lamp beam.

In recognition of these effects, and in order to maintain reasonable demands on the complexity and power of external lighting equipment, the rule does not require the entire viewable area to be visible in all ambient lighting conditions. The only specific illumination requirement is for the likely areas of evacuee ground contact, with all landing gears extended, for passenger exits.

However, it is recommended that as large a field of view as is practicable should be provided, taking into account aspects such as fuselage curvature and door/window/hatch location, in order to provide the best chance to identify external evacuation hazards before exits are opened.

In the case of a flight crew emergency exit, a flight deck window as conventionally configured, used in conjunction with a suitably accessible and powerful portable illumination device (e.g. flashlight) will provide an acceptable means for viewing the outside conditions.

Flight deck seats, consoles, etc., as conventionally configured, are not considered to be obstructions in the meaning of this term in CS 25.809(a)(2) in the case where flight deck windows are the viewing means and the exit is an overhead hatch. Furthermore, it is considered that the distance between flight deck windows, as conventionally configured, and an overhead hatch is such that the criterion for the viewing means to be adjacent to the exit is satisfied.

Create a new AMC 25.810 as follows:

AMC 25.810

Emergency egress assisting means and escape routes

Relevant parts of the FAA AC 25-17A, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 18.5.2009, are accepted by the Agency as providing an Acceptable Means of Compliance to CS 25.810.

Note: 'Relevant parts' means 'the parts of the AC 25-17A that address the applicable FAR/CS-25 paragraph'.

Create a new AMC 25.811 as follows:

AMC 25.811

Emergency exit marking

Relevant parts of the FAA AC 25-17A, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 18.5.2009, are accepted by the Agency as providing an Acceptable Means of Compliance to CS 25.811.

Note: 'Relevant parts' means 'the parts of the AC 25-17A that address the applicable FAR/CS-25 paragraph'.

Amend AMC 25.813 as follows:

AMC 25.813

Emergency e~~E~~xit a~~A~~ccess

The term 'unobstructed' should be interpreted as referring to the space between the adjacent wall(s) and/or seat(s), the seatback(s) being in the most adverse position, in vertical projection from floor level to at least the prescribed minimum height of the exit.

~~For Assist Spaces,~~ R~~r~~elevant parts of the FAA Advisory Circular 25-17A, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 18.~~0~~5.~~/18/~~.2009, ~~is~~are accepted by the Agency as providing an A~~a~~cceptable M~~m~~eans of C~~c~~ompliance to~~with~~ CS 25.813~~(b)~~.

Note: 'Relevant parts' means 'the parts of the AC 25-17A that address the applicable FAR/CS-25 paragraph'.

Create a new AMC 25.819 as follows:

AMC 25.819

Lower deck service compartments (including galleys)

Relevant parts of the FAA AC 25-17A, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 18.5.2009, are accepted by the Agency as providing an Acceptable Means of Compliance to CS 25.819.

Amend AMC 25.853 as follows:

AMC 25.853

Compartment interiors

Relevant parts of the FAA Advisory Circular 25-17A, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated 18.~~0~~5~~/18/~~2009, AC 25.853-1, *Flammability Requirements for Aircraft Seat Cushions*, dated 17.~~/~~9~~/~~.1986, ~~and~~ AC 25-18, *Transport Category Airplanes Modified for Cargo Service*, dated 6.~~/~~1~~/~~.1994, and AC 20-178, *Flammability Testing of Aircraft Cabin Interior Panels After Alterations*, dated 4.6.2012, are accepted by the Agency as providing the A~~a~~cceptable M~~m~~eans of C~~c~~ompliance to~~with~~ CS 25.853.

Note: 'Relevant parts' means 'the parts of the AC 25-17A that address~~es~~ the applicable FAR/CS-25 paragraph'.

BOOK 2

AMC — SUBPART F

Correct a typo in AMC 25.1322 as follows:

AMC 25.1322

Flight Crew Alerting

(…)

Appendix 1

(…)

1. Master Visual

a. Location. Master visual alerts for Warnings (master warning) and Cautions (master caution) should be located in each pilot's primary field of view. Appendix 5 of this AMC includes a definition of pilot primary field of view.

(…)

Move AMC 25.1305(a)(2) after AMC 25.1303(b)(5) and AMC 25.1303(c)(1).

GENERAL

ACCEPTABLE MEANS OF COMPLIANCE ~~–~~(AMC)

Amend AMC 25-11 as follows:

AMC 25-11

Electronic Flight Deck Displays

Content

(…)

List of Appendices

1.1 Purpose

1.2 Definition of Head-Up Display (HUD)

1.3 Other Resources

2.0 Unique Safety Characteristics

2.1 Aircraft and Systems Safety

2.2 Crew Safety

3.0 Design

3.1 Intended Function of HUDs

3.2 HUD Controls

3.3 Visibility and Field-of-View

4.0 HUD Eyebox Criteria

4.1 Design Eye Position

4.2 Design Eyebox

4.3 Conformal Display Accuracy

4.4 Symbol Positioning Alignment

4.5 Overlapping Symbols

4.6 Alignment

4.7 Visual Display Characteristics

5.0 Guidelines for Presenting Information

5.1 HUD and Head-Down Display (HDD) Compatibility

5.2 Indications and Alerts

5.3 Display Clutter

5.4 Display of Information

6.0 Dual HUDs

6.1 Operational Concept for Dual HUDs

6.2 Flight Crew Awareness of Other Instruments and Indications

(…)

CHAPTER 1

BACKGROUND

1. What is the purpose of this AMC?

This AMC provides an A~~a~~cceptable M~~m~~eans of C~~c~~ompliance for demonstrating compliance with certain C~~c~~ertification S~~s~~pecifications of CS-25, as well as general guidance for the design, installation, integration, and approval of electronic flight deck displays, components, and systems installed in large aeroplanes.

Appendix 1 to this AMC provides additional guidance for displaying primary flight information (required by CS 25.1303(b) and CS 25.1333(b)), and Appendix 2 to this AMC provides additional guidance for powerplant displays.

(…)

Table 1: Topics Covered in this AMC

Topics
Electronic pilot displays ~~–~~— including single-function and multi-function displays.
Display features and functions that are intended for use by the pilot.
Display functions not intended for use by the pilot if they may interfere with the pilot's flying duties.
Display aspects of Class III Electronic Flight Bag (installed equipment).
Controls associated with the electronic displays covered in this AMC. These controls include hard controls (physical buttons and knobs) and soft controls (virtual or programmable buttons and knobs, generally controlled through a cursor device or line select keys).
Electronic standby displays.
Head-Up Displays (HUDs).

(…)

6. Background

a. Electronic displays can present unique opportunities and challenges to the design and certification process. In many cases, ~~showing~~ the demonstration of compliance with C~~c~~ertification S~~s~~pecifications related to the latest flight deck display system capabilities has been subject to a great deal of interpretation by applicants and the Agency. At the time the first electronic displays were developed, they were direct replacements for the conventional electromechanical components. The initial release of AMC 25-11 established an A~~a~~cceptable M~~m~~eans of C~~c~~ompliance for the approval of C~~c~~athode R~~r~~ay T~~t~~ube (CRT)-based electronic display systems used for guidance, control, or decision-making by the flight crews of large aeroplanes. This initial release was appropriate for CRTs, but additional specifications were needed to update AMC 25-11 to address new technologies. Additional appendices have been added to address Head-Up Displays (Appendix 6) and Weather Displays (Appendix 7).

(…)

CHAPTER 3

ELECTRONIC DISPLAY HARDWARE

16. Display Hardware Characteristics

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

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

(…)

a. Visual Display Characteristics

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

(1) Physical Display Size.

(…)

(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.

(…)

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

b. Installation

(…)

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

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

(…)

CHAPTER 5

ELECTRONIC DISPLAY INFORMATION ELEMENTS AND FEATURES

31. Display Information Elements and Features.

(…)

c. Display Information Elements

(…)

(3) Symbols

(…)

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

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

(…)

(5) Colour Coding

(…)

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

(…)

f. Annunciations and Indications

(…)

(3) Managing Messages and Prompts

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

- When messages are currently being displayed and there are additional messages in the queue that are not currently displayed, there should be an indication that the additional messages exist.
- Within levels of urgency, messages should be displayed in logical order. In many cases the order of occurrence of events has been found to be the most logical way to place the messages in order.
- See CS 25.1322 and AMC 25.1322 for information on warning, caution, and advisory alerts.
- ~~(b)~~ A text change by itself should not be used as an attention-getting cue (for example, to annunciate mode changes).

(…)

CHAPTER 6

ORGANISING ELECTRONIC DISPLAY INFORMATION ELEMENTS

36. Organising Information Elements

(…)

c. Managing Display Information.

(…)

(1) Window.

(…)

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

d. Managing Display Configuration.

(…)

(2) System Failure Conditions (Reconfiguration).

(…)

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

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

(…)

- ~~1~~ In certain flight phases, manual reconfiguration may not satisfy the need for the pilot controlling the aeroplane to recover primary flight information without delay. Automatic reconfiguration might be necessary to ensure the timely availability of information that requires immediate flight crew member action.
- ~~2~~ When automatic reconfiguration occurs (for example, display transfer), it should not adversely affect the performance of the flight crew and should not result in any trajectory deviation.
- ~~3~~ When the display reconfiguration results in the switching of sources or display paths that is not annunciated and is not obvious to the flight crew, care should be taken that the flight crew is aware of the actual status of the systems when necessary, depending on flight deck philosophy.

Appendix 1

Primary Flight Information

(…)

2.1 Airspeed and Altitude

Airspeed and altitude displays should be able to convey to the flight crew a quick-glance sense of the present speed or altitude. Conventional round-dial moving pointer displays inherently give some of this sense that may be difficult to duplicate on moving scales. Scale length is one attribute related to this quick-glance capability.

The minimum visible airspeed scale length found acceptable for moving scales has been 80 knots; since this minimum is dependent on other scale attributes and aeroplane operational speed range, variations from this should be verified for acceptability. A displayed altitude that is geometrically derived should be easily discernaible 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 Section 5.4.4 of Appendix 6 for HUD-specific airspeed considerations.

(…)

~~2.2 Airspeed and Altitude for HUD~~

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

~~The compensating features for HUD formats that provide an alphanumericonly display of airspeed and altitude is that the information display should also provide clear and distinct alerts to the flight crew when these and any other required parameters exceed well defined tolerances around the nominal approach range, and when these alerts have associated procedures that require the termination of the approach.~~

~~Previously accepted display formats also included effective cues for acceleration and speed deviation so that the pilot could manually achieve tight speed control to preclude unintended proximity to low speed limits. When an alphanumericonly~~

~~indication of airspeed and altitude HUD format is displayed, there should still remain an overall awareness of the following indications:~~

~~• Airspeed/altitude,~~

~~• Airspeed/altitude trends,~~

~~• Deviations from selected airspeed/altitude targets,~~

~~• Low and high airspeed limits, and~~

~~• Selected airspeed/altitude setting changes.~~

2.~~3~~2 Low and High Speed Awareness Cues

CS 25.1541(a)(2) states: '"The aeroplane must contain – Any additional information, ***~~instrument markings~~*** instrument markings, (…)'

(…)

4. Flight Path Vector or Symbol

The display of F~~f~~light P~~p~~ath V~~v~~ector (FPV or velocity vector) or F~~f~~light P~~p~~ath A~~a~~ngle (FPA) cues on the primary flight display is not required, but may be included in many designs.

The FPV symbol can be especially useful on HUD applications. See Section 5.4.5 of Appendix 6 for HUD-specific FPV considerations. ~~The FPV display on the HUD should be conformal with the outside view when the FPV is within the HUD field of view. During flight situations with large bank, pitch, and/or wind drift angles;nglesV display on the HUD should be conformal with the outside vifieldofview.~~

~~In some designs, the pilot can manually cage the FPV which restricts its motion to the vertical axis, thereby making it an FPA.~~

(…)

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

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

(…)

Appendix 4

Acronyms used in this AMC

AC	(FAA) Advisory Circular
AMC	Acceptable Means of Compliance
ARAC	Aviation Rulemaking Advisory Committee
ARP	Aerospace Recommended Practices
AS	Aerospace Standard
CCD	Curs~~e~~or 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
ETSO	European Technical Standard Order
EUROCAE	European Organisation for Civil Aviation ~~Electronics~~ Equipment
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
FPA	Flight Path Angle
FPV	Flight Path Vector
GNSS	Global Navigation Satellite System
GUI	Graphical User Interface
HDD	Head-D~~d~~own Display

HMD	Head-Mounted Display
HUD	Head-U~~u~~p Display
ILS	Instrument Landing System
ICAO	International Civil Aviation Organization
JAA	Joint ~~Airworthiness~~ 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
VFR	Visual Flight Rules
VNAV	Vertical Navigation
VOR	Very High Frequency Omnirange Stations

Appendix 6

Head-Up Display

Contents

6.4 Reassessment

7.0 Flight data recording

8.0 Continued airworthiness

1.0 Introduction

1.1 Purpose

This Appendix provides additional guidance related to the unique aspects, characteristics, and functions of Head-Up Displays (HUDs) for transport category aeroplanes. 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 the Certification Review Items (CRIs) issued by the Agency until new CSs and AMCs are issued.

1.2 Definition of Head-Up Display (HUD)

An 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 of the windshield, without scanning the Head-Down Displays (HDDs). The flight information symbols should be presented as a virtual image focussed at optical infinity. Attitude and flight path symbology needs to be conformal (that is, aligned and scaled) with the outside view.

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. EASA Certifications Specifications for All Weather Operations (CS-AWO), and FAA Advisory Circular (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 Aeroplane 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.

2.0 Unique safety considerations

2.1 Aeroplane and systems safety

2.1.1 Systems

Installing HUD systems in flight decks may introduce complex functional interrelationships among the flight crew members and other display and control systems. Consequently, a functional hazard assessment which requires a top-down approach from an aeroplane-level perspective should be developed in accordance with CS 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 and availability of function, as well as the operational concept of the installation to be certified (e.g. dual-HUD versus single-HUD installation, and the type and amount of information displayed). Chapter 4 of this AMC provides material that may be useful in preparing the functional hazard assessment.

2.1.2 Aeroplane Flight Manual (AFM) procedures

All alleviating flight crew 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.

2.1.3 Availability of primary flight information

Requirements for the availability of primary flight information are provided in CS 25.1333.

2.2 Crew safety

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. An HUD combiner with a swing-arm deployment mechanism should be designed to avoid false detents and false latch indications between the fully stowed and deployed positions. A misstowed combiner could swing inadvertently into the path of the pilot's head and cause injury. Additionally, the HUD installation, including the overhead unit and combiner, must comply with the occupant injury requirements of CS 25.785(d) and (k) and the retention requirements of CS 25.789(a).

2.2.2 Special considerations for dual-HUD installations

For dual-HUD installations, the applicant should 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 an emergency landing. The Agency may need to issue a Certification Review Item providing project-specific means of compliance if the installation geometry indicates that such events may produce occupant contact with the HUD installation.

2.2.3 Non-interference with emergency equipment

CS 25.803, CS 25.1411, and CS 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 should not adversely affect the emergency egress provisions for the flight crew, or significantly interfere with flight crew access. The system should not hinder the flight crew's movement while conducting any flight procedures.

3.0 Design

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 the 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 manually flown approaches and/or for monitoring autopilot-coupled instrument approaches, display guidance for low-visibility take-off, and/or display enhanced vision imagery and synthetic vision video. See paragraph 11.c of this AMC for additional guidance.

3.1.1 General

In most applications, HUDs provide an indication of primary flight references, which allow the pilot to rapidly evaluate the aircraft 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 but will be addressed by associated CRIs until new CSs and AMCs are issued.

3.1.2 Display of primary flight information

3.1.2.1 HUD as de facto primary flight display

If an 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 recognise the primary flight information — it should not be ambiguous or confusing when taking into account information displayed on other flight deck displays.

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 CS-25 (e.g. CS 25.1303(b) for flight and navigation instruments that must be visible from each pilot station, and CS 25.1333(b) for the operational requirements of those systems). CS 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 1 of this AMC.

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 aeroplane by reference to the HUD.

3.1.3.1 Command guidance

When the HUD is used to monitor the autopilot, it should display the following information:

— situation information based on independent raw data;

— autopilot operating mode;

— autopilot engage status; and

— autopilot disconnect warning (visual).

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 aeroplane 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; or

— heading or course references.

3.2 HUD controls

3.2.1 Control placement

For compliance with CS 25.777, the flight crew 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 CS 25.777 and CS 25.1301, the position and movement of the HUD controls must not lead to inadvertent operation.

3.2.2 Control illumination

To comply with CS 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.

3.2.3 Control integration

To the greatest extent practicable, HUD controls should be integrated with other associated flight deck controls to minimise the flight crew workload and error associated with HUD operation and to enhance flight crew awareness of HUD modes.

3.2.4 Ease of use

HUD controls, including the controls to change or select HUD modes, should be implemented to minimise flight crew workload for data selection or data entry, and allow the pilot to easily view and perform all mode control selections from the seated position.

3.3 Visibility and Field-of-View (FOV)

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, aircraft 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.

3.3.2 Impact on pilot compartment view

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 CS 25.773. The HUD must also not restrict the view of any flight deck controls, indicators, or other flight instruments as required by CS 25.777 and CS 25.1321.

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 manoeuvres 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 flight crew member to spot traffic, 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 CS 25.773(a)(1).

3.3.2.3 HUD optical performance

As far as practicable, the optical performance of the HUD should not cause distortions that degrade or detract from the flight crew's view of external references or of other aircraft. The optical performance should not degrade or detract from the flight crew's ability to safely perform any manoeuvres within the operating limits of the aeroplane, as required by CS 25.773. Where the windshield optically modifies the pilot's view of the outside world, the motions and positions of conformal HUD symbols should 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-centre position within the design eyebox, optical non-uniformities should not produce perceivable differences in the binocular view. SAE ARP 5288, *Transport Category Aeroplane Head Up Display (HUD) Systems*, provides additional guidance.

3.3.3 Conformal symbols with limited HUD Field-of-View

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.

4.0 HUD design eyebox criteria

4.1 Design eye position

The FAA AC 25.773-1, *Pilot Compartment View Design Considerations*, defines DEP as a single point that meets the requirements of CS 25.773 and CS 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 CS 25.773 and CS 25.1321. The HUD should be able to accommodate pilots, from 1 575 to 1 905 mm (5 ft 2 in to 6 ft 3 in) tall, while they are seated at the DEP with their shoulder harnesses and seat belts fastened, to comply with CS 25.777. The DEP should be centred within the minimum design eyebox dimensions found in paragraph 4.2.3 of this Appendix. Actual HUD eyeboxes are larger than these minimum dimensions and, if not centred around the DEP, they need only be large enough so that this minimum sub-volume is centred around the DEP.

4.2 Design eyebox

4.2.1 Display visibility requirements

The fundamental requirements for instrument arrangement and visibility in CS 25.773, CS 25.777, CS 25.1301, and CS 25.1321 apply to HUDs. Each flight instrument, including the flight information displayed on 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 DEP, the pilot must be able to see the flight information displayed on 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 on the HUD. The size of the design eyebox and the layout of flight information on 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 should 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 centre of the FOV and should be specified by the manufacturer. The HUD FOV should be designed by considering the intended operational environment and potential aeroplane configurations.

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 so that the required flight information is visible to the pilot at the minimum displacements from the DEP specified in paragraph 4.2.3 of this Appendix. The symbols should be laid out and positioned such that excessive eye movements are not required to scan elements of the display. The displayed symbols which are necessary to perform the required tasks should be visible to the pilot from the DEP. The DEP used for the evaluation of the eyebox location should be the same as that used for the basic flight deck in accordance with the FAA AC 25.773-1.

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 6.35 mm (0.25 in) 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 (refer to SAE AS 8055). 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.

4.2.3.1 Lateral: 38.1 mm (1.5 in) left and right from the DEP (76.2 mm (3.0 in) wide).

4.2.3.2 Vertical: 25.4 mm (1.0 in) up and down from the DEP (50.8 mm (2.0 in) high).

4.2.3.3 Longitudinal: 50.8 mm (2.0 in) fore and aft from the DEP (101.6 mm (4.0 in) deep).

4.3 Conformal display accuracy

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.

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, digitisation errors, electronic gain and offset errors, optical errors, combiner positioning errors, errors associated with the CRT and yoke (if applicable), misalignment errors, environmental conditions (e.g. temperature and vibration), and component variations.

4.3.2.1 Error sources

Optical errors are dependent upon both the head position and the field angle. Optical errors comprise three sources: uncompensated pupil and field errors originating in the optical system aberrations, image distortion errors, and manufacturing variations. 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).

4.3.2.2 Total accuracy

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

4.3.2.3 Allowable margin for display errors

All display errors should be minimised across the display FOV consistent with the intended function of the HUD. Table A6-1 shows the allowable display accuracy errors for a conformal HUD as measured from the HUD eye reference point:

Table A6-1 — Allowable display accuracy errors

Location on the HUD combiner	Error tolerance in milliradians (mrad)
At HUD bore sight	≤ 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

4.3.2.4 Maximum error

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

4.4 Symbol positioning alignment

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

4.5 Overlapping symbols

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

4.6 Alignment

4.6.1 Outside view

The HUD combiner should 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.

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 aircraft control. The HUD should 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.

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 Aeroplane Head Up Display (HUD) Systems* and SAE AS8055, *Minimum Performance Standard for Airborne Head Up Display (HUD)*, provide performance guidelines for an HUD. As stated in Chapter 3 of this AMC, the applicant should notify the Agency if any visual display characteristics do not meet the guidelines in SAE ARP5288 and AS8055.

4.7.1 Luminance

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-Lambert (fL), as specified in SAE AS8055), so that the HUD data are visible.

4.7.1.2 Luminance control

The HUD should 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 is provided in addition to the manual control. Manual control of the HUD brightness level should be available to the flight crew 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.

4.7.2 Reflections

The HUD must be free of glare and reflections that could interfere with the normal duties of the minimum flight crew, as required by CS 25.773 and CS 25.1523.

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 should be minimised so as not to impair the flight crews ability to use the display.

4.7.4 Accuracy and stability

4.7.4.1 Sensitivity to aircraft manoeuvring

The system operation should not be adversely affected by aircraft manoeuvring or changes in attitude encountered in normal service.

4.7.4.2 Motion of symbols

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

5.0 Guidelines for presenting information

5.1 HUD and HDD compatibility

5.1.1 General

If the content, arrangement, or format of the HUD is dissimilar to the HDD, it can lead to flight crew confusion, misinterpretation, and excessive cognitive workload. During transitions between the HUD and HDDs (whether required by navigation duties, failure conditions, unusual aeroplane attitudes, or other reasons), dissimilarities could make it more difficult for the flight crew to manually control the aeroplane 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 colour on the HDD and a single colour (i.e. monochrome) on the HUD. The guidelines listed below are intended to minimise the potential for confusion, undue workload, and delays in flight crew task performance.

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

5.1.3 Guidelines for HUD–HDD compatibility

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 flight crew error (see paragraphs 31.b and 31.c(3) of this AMC). The layout and arrangement of HUD and HDD formats of the same information need to convey the same intended meanings (see paragraph 36.b of this AMC). 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.

5.1.3.2 Symbols

Table A6-2 provides the guidelines for symbols.

Table A6-2 — Symbol guidelines for HUD–HDD compatibility

Symbol characteristics	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 HDDs.
Relative location	Information that relates to the symbols should appear in the same general location relative to other information.

5.1.3.3 Alphanumeric information

Alphanumeric (i.e. textual) information should have the same resolution, units, and labelling. For example, the command reference indication for vertical speed should be displayed in the same foot-per-minute increments and labelled 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 flight crew confusion or flight crew error.

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.

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 colour, 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).

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.

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.

5.1.4 Head-up to head-down transition

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.

5.1.4.2 Unambiguous information

While the HUD and HDD may display information (e.g. flight path, path deviation, or aircraft performance information) in a different manner, the meaning should 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 recognise and interpret information on the HUD. The information should not be ambiguous with similar information on other aircraft flight deck displays.

5.2 Indications and alerts

5.2.1 Monochrome attention-getting properties

To comply with CS 25.1322, and considering that most HUDs are predominantly monochrome devices, the HUD should emphasise 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 colour coding. For additional alerting guidance, see AMC 25.1322 'Flight Crew 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.

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 manoeuvre 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 on the HUD) to ensure that the pilot has equivalent and effective visual information for immediate awareness and response to the respective alerts.

5.2.3 Additional resources

Additional guidance on indications and alerts is contained in AMC No 1 to CS 25.1329, *Flight Guidance System*, in AMC No 2 to CS 25.1329, *Flight Testing of Flight Guidance Systems*, in AMC 25.1322, *Flight Crew Alerting*, and in the associated rules.

5.3 Display clutter

This AMC 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.

5.4 Display of information

5.4.1 General

The HUD information display requirements depend on the intended function of the HUD. Specific guidance for displayed information is contained within the main body and Appendix 1 of this AMC. 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.

5.4.2 Alternate formats for primary flight information

5.4.2.1 Phase of flight

There may be certain operations and phases of flight during which certain primary flight reference indications on 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 flight crew 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.

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:

— a satisfactory level of task performance;

— a satisfactory awareness of proximity to limit values like V_S, V_{MO}, and V_{FE}; and

— a satisfactory means to avoid violating such limits.

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.

5.4.2.4 Minimise format changes

Changes in the display format and primary flight data arrangement should be minimised to prevent confusion and to enhance the flight crew's ability to interpret vital data.

5.4.3 Aircraft 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 flight crew will operate primarily by reference to the HUD, the HUD should adequately provide the following information and cues.

5.4.3.1 Flight state and position

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

5.4.3.2 Attitude cues

Attitude cues should enable the pilot to instantly recognise unusual attitudes. Attitude cues should 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 'slow-overs'), and turbulence/gust encounters.

5.4.4 Airspeed considerations

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. CS 25.1541(a)(2) states that 'The aeroplane must contain- Any additional information, instrument markings, and placards required for the safe operation if there are unusual design, operating, or handling characteristics.'.

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 aeroplane 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.

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.

5.4.5 Flight path considerations

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 aeroplane and the phase of flight during which the flight path is to be displayed.

5.4.5.2 Velocity/flight path vector

An indication of the aeroplane'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 aeroplane is actually going. During an approach, this information can be used to indicate the aeroplane's impact or touchdown point on the runway. The earth-referenced flight path shows the effects of wind on the motion of the aeroplane. 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 aeroplane's track relative to the bore sight.

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

5.4.6 Attitude considerations

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.

5.4.6.2 Pitch

The pitch attitude display should be such that, during all manoeuvres, a horizon reference remains visible with enough margin to allow the pilot to recognise 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.

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 manoeuvring).

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.

5.4.6.4.1 Compensating features (e.g. characteristics of the aeroplane and the HUD system).

5.4.6.4.2 Immediate annunciation on the HUD to direct the pilot to use the head-down primary flight display for recovery.

5.4.6.4.3 Satisfactory demonstration of timely recognition and correct recovery manoeuvres.

5.4.6.5 Flight crew 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 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.

6.0 Dual HUDs

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) with regard 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.

6.2 Flight crew 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 on the HUD. However, in the case where both flight crew members simultaneously use HUDs, they 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 aircraft configuration indications).

6.3 Roles and responsibilities

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

6.3.1 Impact on head-down vigilance

When both pilots of the flight crew use an 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).

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 flight crew maintain awareness of key information that is only displayed on the HDDs (e.g. powerplant indications, alerting messages, and aircraft 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.

6.3.3 Alerts

The design should effectively compensate for any cautions and warnings that do not have visual indications on 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 flight crew should be able to respond to alerts without any reduction in task performance or degraded safety.

6.4 Reassessment

The applicant should globally reassess the alerting functions to ensure that the flight crew 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 flight crew’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 an HUD.

7.0 Flight data recording

Flight data recorders must record the minimum data parameters required by the applicable operational regulations. In addition, flight data recorders should also record other parameters regarding unique operating characteristics of HUDs in compliance with CS 25.1459(e). 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.

8.0 Continued airworthiness

CS 25.1309, CS 25.1529 and Appendix H to CS-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 the intended function of the HUD.

Appendix 7

Weather Displays

1. Introduction

1.1 Purpose

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

1.2 Examples

Sources of weather information may include but are not limited to on-board 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 AMC.

2.0 Key characteristics

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

2.1 Unambiguous meanings

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

2.2 Colour

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

2.2.2 The use of colour must not adversely affect or degrade the attention-getting qualities of the information as required by CS 25.1322(f).

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

2.2.4 The use of red and yellow must be in compliance with CS 25.1322(e) for flight crew alerts, or with CS 25.1322(f) for information other than flight crew alerts. Compliance can be demonstrated by using the guidance in AMC 25.1322, *Flight Crew Alerting*, and this AMC.

Note 1: The FAA 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/CS-25 aeroplanes.

Note 2: Refer to paragraph 31.c(5) in Chapter 5 of this AMC for information on guidelines on colour progression.

2.3 Multiple sources of weather information

2.3.1 The weather display should enable the flight crew 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.

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.

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 flight crew 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.

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.

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.

2.3.6 If weather information is displayed on an HUD, the guidance of this AMC including its Appendix 6 should be followed.

2.3.7 When the source of the weather information source is not the on-board 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.

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 that the flight crew does not misinterpret the movement of the weather cells.

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 flight crew to distinguish or identify which altitude range applies to each feature.

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 (METARs) and winds aloft). The display should provide a means to identify the meaning of each feature to ensure that the information is correctly used.

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

2.3.12 When weather information is presented on 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 flight crew 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 flight crew 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 flight crew (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-centred or track/heading-centred 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.

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).

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 (TAWS), if displayed. This should not be interpreted as a restriction precluding other means of presentation that can be demonstrated to be superior.

3.0 On-board weather radar information

3.1 Background

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

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 for Airborne Weather Radar with Forward-Looking Windshear Capability*. TSO-C63d allows exceptions to the minimum performance standards of RTCA/DO-220 for Class A and B radar equipment.

3.3 Hazard detection

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

4.0 Predictive windshear information

4.1 General

If provided, windshear information should be clear, automatic, timely, concise, and distinct so that the flight crew can easily interpret, detect, and minimise the threat of windshear activity.

4.2 Presentation methods

When a windshear threat is detected, the corresponding display may be automatically presented or selected by the flight crew at an appropriate range to identify the windshear activity and minimise the windshear threat to the aeroplane.

4.3 Pilot workload

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

4.4 Windshear threat symbol

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

4.5 Relative position to the aeroplane

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

4.6 Range

The range selected by the flight crew for the windshear display should allow the flight crew 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.

5.0 Safety aspects

5.1 Functional Hazard Assessment (FHA)

Both the loss of weather information and the display of misleading weather information should be addressed in the 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.

5.2 Misleading information

The FHA should address the effects of displaying misleading information. In accordance with Chapter 4 of this AMC, the display of misleading weather radar includes information that would lead the flight crew 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 misregistered in the case of a combined (e.g. fused) image.