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.

[Amdt 25/17]

Appendix 7 – Weather Displays

ED Decision 2015/019/R

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.

[Amdt 25/17]