

Colour should be used in a consistent manner and assure compatibility with the overall use of colour on the flight deck. Specific colours should be used such that the FGS displays are consistent with other flight deck systems, such as a Flight Management System. The use of monochrome displays is not precluded, provided that the aspects of flight crew attention and awareness are satisfied. The use of graphical or symbolic (i.e., non-textual) indications is not precluded. Implementation of such discriminators should follow accepted guidelines as described in applicable international standards (e.g., AMC 25-11) and should be evaluated for their consistency with and integration with the flight deck design. Engaged modes should be annunciated at different locations and with different colours than armed modes to assist in mode recognition. The transition from an armed mode to an engaged mode should provide an additional attention-getting feature, such as boxing and flashing on an electronic display (per AMC 25-11) for a suitable, but brief, period (e.g., ten seconds), to assist in flight crew awareness.

The failure of a mode to engage/arm when selected by the pilot should be apparent. Mode information provided to the pilot should be sufficiently detailed, so that the consequences of the interaction (e.g., ensuing mode or system configuration that has operational relevance) can be unambiguously determined. The FGS interface should provide timely and positive indication when the flight guidance system deviates from the pilot's direct commands (e.g., a target altitude, or speed setting) or from the pilot's pre-programmed set of commands (e.g., waypoint crossing). The interface should also provide clear indication when there is a difference between pilot-initiated commands (e.g., pilot engages positive vertical speed and then selects an altitude that is lower than the aircraft altitude). The default action taken by the FGS should be made apparent.

The operator should be provided with appropriate description of the FGS modes and their behaviour.

9.3 Flight Guidance Alerting (Warning, Caution, Advisory, and Status)

Alerting information should follow the provisions of [CS 25.1322](#) and associated advisory material. Alerts for FGS engagement and disengagement are described in Section 8, Flight Guidance System Engagement, Disengagement, and Override.

There should be some method for the flight crew to determine and monitor the availability or capability of the Flight Guidance System (e.g., for dispatch), where the intended operation is predicated on the use of the FGS. The method of monitoring provided should take account of the hazard resulting from the loss of the autopilot function for the intended operation.

9.3.1 Alerting for Speed Protection

To assure crew awareness, an alert should be provided when a sustained speed protection condition is detected. This is in addition to any annunciations associated with mode reversions that occur as a consequence of invoking speed protection (see Section 10.4, Speed Protection). Low speed protection alerting should include both an aural and a visual component. High-speed protection alerts need only include a visual alert component because of existing high-speed aural alert requirements, but does not preclude giving an earlier alert.

Alerting for speed protection should be consistent with the protection provided and with the other alerts in the flight deck. Care should be taken to set appropriate values for indicating speed protection that would not be considered a nuisance for the flight crew.

9.3.2 Loss of Autopilot Approach Mode

The loss of the approach mode requires immediate flight crew awareness. This may be accomplished through autopilot disengagement and related warning (as required by [CS 25.1329\(j\)](#) and specified in 8.1.2.1 of this AMC). If the autopilot remains engaged and reverts to a non-approach mode, an appropriate aural warning and/or visual alert should be provided.

9.3.3 Awareness of Potential Significant Transient Condition (“Bark before Bite”)

There have been situations where an autopilot is engaged, operating normally, and controlling up to the limit of its authority for an extended period of time, and the flight crew was unaware of the situation. This service experience has shown that, without timely flight crew awareness and action, this situation can progress to a loss of control after autopilot disengagement, particularly in rare normal or non-normal conditions. However, with adequate flight crew awareness and pilot action, loss of control may be prevented.

To help ensure crew awareness and timely action, appropriate alert(s) (generally caution or warning) should be provided to the flight crew for conditions that could require exceptional piloting skill or alertness for manual control following autopilot disengagement (e.g., significantly out of trim). The number and type of alerts required would be determined by the unique situations that are being detected and by the crew procedures required to address those situations. Any alert should be clear and unambiguous, and be consistent and compatible with other flight deck alerts. Care should be taken to set appropriate thresholds for these alerts such that they are not considered a nuisance for the flight crew.

Situations that should be considered for an alert include:

Sustained Lateral Control Command: If the autopilot is holding a sustained lateral control command, it could be indicative of an unusual operating condition (e.g., asymmetric lift due to icing, fuel imbalance, asymmetric thrust) for which the autopilot is compensating. In the worst case, the autopilot may be operating at or near its full authority in one direction. If the autopilot were to disengage while holding this lateral trim, the result would be that the aeroplane would undergo a rolling moment that could possibly take the pilot by surprise. Therefore, a timely alert should be considered to permit the crew to manually disengage the autopilot and take control prior to any automatic disengagement which might result from the condition.

Sustained Longitudinal Out of Trim: If the autopilot is holding sustained longitudinal trim, it could be indicative of an unusual operating condition (e.g., an inoperative horizontal stabilizer) for which the autopilot is compensating. If the autopilot were to disengage while holding this longitudinal trim, the result would be that the aeroplane would undergo an abrupt change in pitch that could possibly take the pilot by surprise. Therefore, a timely alert should be considered to permit the crew to manually disengage the autopilot and take control prior to any automatic disengagement, which might result from the condition.

Bank and Pitch Angles Beyond Those Intended for Autopilot Operations: Most autopilots are designed with operational limits in both the pitch and roll axes, such that those predetermined limits will not be purposely exceeded. If the aeroplane exceeds those limits, it could be indicative of a situation (which may not be covered by items 1. or 2.) that requires the pilot to intervene. Therefore, a timely alert

should be considered to bring this condition to the attention of the flight crew to and permit the crew to manually disengage the autopilot and take control prior to any automatic disengagement, which might result.

It is preferable that the autopilot remains engaged during out-of-trim conditions. However, if there is an automatic disengagement feature due to excessive out-of-trim, an alert should be generated and should precede any automatic disengagement with sufficient margin to permit timely flight crew recognition and manual disengagement. See also Section 8.4, Flight Crew Override of the FGS, for related material.

NOTE:This section is not intended to require alerting for all instances of automatic autopilot disengagement. It is intended only for conditions, which, if not addressed, would lead to such disengagement, which, could result in a significant transient for which the pilot may be unprepared. The intent is to provide crew awareness that would allow the flight crew to be prepared with hands on controls and take appropriate corrective action before the condition results in a potentially hazardous aeroplane configuration or state.

NOTE:This section describes alerting requirements for conditions resulting in unintended out-of-trim operation. There are FGS functions that can intentionally produce out-of-trim operation (e.g. parallel rudder operation in align or engine failure compensation modes, pitch trim operation during the approach/landing to provide trim up/flare spring bias, or pitch trim operation for certain types of Speed/Mach trim systems). It is not the intent of this section to require alerts for functions producing intentional out-of-trim conditions. Other system indications (e.g., mode and status annunciations) should be provided to make the crew aware of the operation of these functions where appropriate.

9.3.4 Failures Affecting Flight Director Guidance

Wherever practicable a failure should cause the immediate removal from view of the guidance information. If the guidance information is retained but a warning given instead, it should be such that the pilot cannot fail to observe it whilst using the guidance information.

9.4 FGS Considerations for Head-Up Displays (HUD)

Head-up displays (HUD) have unique characteristics compared to flight displays installed on the instrument panel. Most of these HUD differences are addressed during HUD certification whether or not the HUD provides flight guidance functions. The intent of this section is to address how such HUD differences may affect FGS functions.

9.4.1 Characteristics of HUD Guidance

If the HUD is designed as a supplemental use display system, it does not replace the requirement for standard Head Down Display (HDD) of flight instrument data. The HUD is intended for use during takeoff, climb, cruise, descent, approach and landing under day, night, VMC and IMC conditions. When it can be reasonably expected that the pilot will operate primarily by reference to the HUD, it should be shown that the HUD is satisfactory for manually controlling the aeroplane and for monitoring the performance of the FGS system.

During take off and landing in certain light and visibility conditions, HUD symbology can be extremely dominant in comparison to external visual references. When

visual references are relatively dim, extremely active symbology dynamics and guidance cue gains can lead the pilot to make excessively strong corrections. It should be shown that if HUD guidance cues are followed, regardless of the appearance of external visual references, they do not cause the pilot to take unsafe actions.

Generally the criteria for the mechanization of guidance displayed on the HUD would be no different than guidance displayed on the head-down display. See Section 10, Performance of Function, for flight director performance criteria.

However, unlike head-down displays, HUD's are capable of displaying certain symbology conformal to the outside scene, including guidance cues. Consequently, the range of motion of this conformal symbology, including the guidance, 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 field of view. 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. In take off, approach, and landing FGS modes, the flight guidance symbology should have priority.

Additionally, HUD guidance is often used in cases, like the low visibility approach, where the pilot will need to reference both the information displayed on the HUD and outside references. Consequently, it should be shown that the location and presentation of the HUD information does not distract the pilot or obscure the pilot's outside view. For example, it would be necessary for the pilot to track the guidance to the runway without having the view of runway references or hazards along the flight path obscured by the HUD symbology.

9.4.2 HUD Flight Guidance System Display

The HUD display should present flight guidance information in a clear and unambiguous manner. Display clutter should be minimized. The HUD guidance symbology should not excessively interfere with pilots' forward view, ability to visually manoeuvre the aeroplane, acquire opposing traffic, and see the runway environment. Some flight guidance data elements are essential or critical and should not be removed by any de-clutter function.

9.4.3 Head-Up/Head-Down Display Compatibility

The HUD FGS symbology should be compatible and consistent with symbology on other FGS displays such as head-down EFIS instruments. The FGS-related display parameters should be consistent to avoid misinterpretation of similar information, but the display presentations need not be identical. The HUD and head-down primary flight display formats and data sources need to be compatible to ensure that the same FGS-related information presented on both displays have the same intended meaning.

While not all information displayed on the HUD is directly related to the FGS, the pilot is likely to use most of the displayed information while using the HUD-displayed guidance and FGS annunciations. Therefore, when applicable, the guidelines below for the presentation of FGS-related display information should be followed as much as possible. Certain deviations from these guidelines may be appropriate due to conflict with other information display characteristics or

requirements unique to head-up displays. These may include minimization of display clutter, minimization of excessive symbol flashing, and the presentation of certain information conformal to the outside scene.

- (a) Symbols should be the same format (e.g., a triangle-shaped pointer head-down appears as a triangle pointer head-up; however, some differences in HUD symbology such as the flight director “circle” versus head-down flight director “bars” or “wedge” have been found acceptable);
- (b) Information (symbols) should appear in the same general location relative to other information;
- (c) Alphanumeric readouts should have the same resolution, units, and labelling (e.g., the command reference indication for “vertical speed” should be displayed in the same foot-per-minute increments and labelled with the same characters as the head-down displays);
- (d) Analogue scales or dials should have the same range and dynamic operation (e.g., a Glideslope Deviation Scale displayed head-up should have the same displayed range as the Glideslope Deviation Scale displayed head-down, and the direction of movement should be consistent);
- (e) FGS modes (e.g. autopilot, flight director, autothrust) and status state transitions should be displayed on the HUD, and except for the use of colour, 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); and
- (f) Information sources should be consistent between the HUD and the head-down displays used by the same pilot.
- (g) When FGS command information (i.e., flight director commands) are displayed on the HUD in addition to the head-down displays, the HUD depiction and guidance cue deviation “scaling” needs to be consistent with that used on the head-down displays. This is intended to provide comparable pilot performance and workload when using either head-up or head-down displays.
- (h) The same information concerning current HUD system mode, reference data, status state transitions, and alert information that is displayed to the pilot flying on the HUD, should also be displayed to the pilot not flying using consistent nomenclature to ensure unambiguous awareness of the HUD operation.

9.4.4 Alerting Issues

Although HUD's are typically not classified as integrated caution and warning systems, they may display warnings, cautions, and advisories as part of their FGS function. In this regard, HUD's should provide the equivalent alerting functionality as the head-down primary flight display(s). Warnings that require continued flight crew attention on the PFD also should be presented on the HUD (e.g., ACAS/TCAS, Windshear, and Ground Proximity Warning annunciations). If master alerting indications are not provided within the peripheral field of view of the pilot while using the HUD, the HUD should provide annunciations that inform the pilot of Caution and/or Warning conditions (ARP-5288, V12).

For monochrome HUD's, appropriate use of attention-getting properties such as flashing, outline boxes, brightness, size, and/or location are necessary to adequately compensate for the lack of colour normally assigned to distinguish and call attention to Cautions and warnings.

For multi-colour HUD's, the use of red, amber, or yellow for symbols not related to Caution and warning functions should be avoided, so that the effectiveness of distinguishing characteristics of true warnings and cautions is not reduced.

Single HUD installations rely on the fact that the non-flying pilot will monitor the head-down instruments and alerting systems, for failures of systems, modes, and functions not associated with primary flight displays.

Dual HUD installations require special consideration for alerting systems. It must be assumed that both pilots will be head-up simultaneously, full, or part-time, especially when the HUD is being used as the primary flight reference, or when the HUD is required equipment for the operation being conducted. If master alerting indications are not provided within the peripheral field of view of each pilot while using the HUD, then each HUD should provide annunciations that direct the pilot's attention to head-down alerting displays. The types of information that must trigger the HUD master alerting display are any Cautions or warnings not already duplicated on the HUD from head-down primary displays, as well as any Caution level or warning level engine indications or system alerts.

NOTE: The objective is to not redirect attention of the pilot flying to other display when an immediate manoeuvre is required (resolution advisory, windshear).

If a Ground Proximity Warning System (GPWS), wind shear detection system, a wind shear escape guidance system, or a Airborne Collision Avoidance System (ACAS) / Traffic alert and Collision Avoidance System (TCAS) is installed, then the guidance, warnings and annunciations required to be a part of these systems, and normally required to be in the pilot's primary field of view, should be displayed on the HUD.

9.4.5 Upset/Unusual Attitude Recovery Guidance

Upsets due to wake turbulence or other environmental conditions may result in near instantaneous excursions in pitch and bank angles and a subsequent unusual attitude.

If the HUD is designed to provide guidance 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." For example, a cue for left stick input should not be confused with a cue indicating direction to the nearest horizon. Guidance should be removed if cues become invalid at extreme attitudes, such as zenith, nadir, or inverted. For extreme attitudes it is acceptable to transition to the HDD, provided that the cues to transition from the HUD are clear and unambiguous.

If the HUD is designed to provide orientation only during upsets or unusual attitudes, cues should be designed to prevent them from being mistaken as flight control input commands.

10 PERFORMANCE OF FUNCTION

The FGS is expected to perform its intended function throughout the aeroplane's normal flight envelope. There are considerations for the FGS when operating at the limits of its performance capabilities and when operating under significant environmental conditions. The following sections provide acceptable means of compliance criteria and interpretive material for these considerations.

Where system tolerances have a significant effect on autopilot authority limits, consideration should be given to the effect on autopilot performance. Factors to be considered include but are not limited to tolerances of: servo authority, servo clutch setting, "cam-out" settings, control friction, and sensor tolerances.

10.1 Normal Performance

The FGS should provide guidance or control, as appropriate, for the intended function of the active mode(s), in a safe and predictable manner within the aeroplane's normal flight envelope.

The FGS should be designed to operate in all aeroplane configurations for its intended use within the aeroplane's normal flight envelope to provide acceptable performance for the following types of environmental conditions:

- Winds (light and moderate)
- Wind gradients (light and moderate)

NOTE: In the context of this AMC, 'wind gradient' is considered a variation in wind velocity as a function of altitude, position, or time.

- Gusts (light and moderate)
- Turbulence (light and moderate)
- Icing - all icing conditions covered by [Appendix C](#) to CS-25 and applicable icing conditions covered by [Appendix O](#) to CS-25, with the exception of 'asymmetric icing' discussed under 'Rare Normal Conditions' in Section 10.2 below. For showing compliance with the CS-25 certification specifications relative to SLD icing conditions represented by Appendix O, the applicant may use a comparative analysis. AMC 25.1420(f) provides guidance for comparative analysis.

NOTE: Representative levels of the environmental effects should be established consistent with the aeroplane's intended operation.

Any performance characteristics that are operationally significant or operationally limiting should be identified with an appropriate statement or limitation in the Aeroplane Flight Manual (AFM) (Ref. [CS 25.1581](#)).

The FGS should perform its intended function during routine aeroplane configuration or power changes, including the operation of secondary flight controls.

Evaluation of FGS performance for compliance should be based on the minimum level of performance needed for its intended functions. Subjective judgment may be applied to account for experience acquired from similar equipment and levels that have been established as operationally acceptable by the end-user.

There are certain operations that dictate a prescribed level of performance. When the FGS is intended for operations that require specific levels of performance, the use of FGS should be shown to meet those specific levels of performance (e.g., Low Visibility

Operations – Category II and III operations, Reduced Vertical Separation Minimums (RVSM), Required Navigation Performance (RNP)).

The FGS performance of intended functions should at least be equivalent to that expected of a pilot for a similar task. The AMC No.2 to [CS 25.1329](#) provides for establishing the general behaviour of the FGS. When integrated with navigation sensors or flight management systems, the FGS should satisfy the flight technical error tolerances expected for the use of those systems in performing their intended functions.

The autopilot should provide smooth and accurate control without perceptible sustained nuisance oscillation.

The flight director, in each available display presentation (e.g., single cue, cross-pointer, flight path director) should provide smooth and accurate guidance and be appropriately damped, so as to achieve satisfactory control task performance without pilot compensation or excessive workload.

The autothrust function should provide smooth and accurate control of thrust without significant or sustained oscillatory power changes or excessive overshoot of the required power setting.

The automatic pitch trim function should operate at a rate sufficient to mitigate excessive control surface deflections or limitations of control authority without introducing adverse interactions with automatic control of the aircraft. Automatic roll and yaw trim functions, if installed, should operate without introducing adverse interactions with automatic control of the aircraft.

10.2 Performance in Rare Normal Conditions

The FGS will encounter a wide range of conditions in normal operations, some of which may be infrequent, but levy a greater than average demand on the FGS capabilities. Certain environmental conditions, as listed below, are prime examples. FGS performance during such rare normal conditions should be assessed. Such conditions may degrade FGS performance, but must be safe for FGS operation. The relative infrequency of such conditions may also be a factor in the flight crew's ability to detect and mitigate, in a timely manner, any limited capability of the FGS to cope with them. The FGS should be limited from operating in environmental conditions in which it cannot be safely operated.

This does not mean that the FGS must be disengaged when rare normal conditions, which may degrade its performance or capability, are encountered. Actually, the FGS may significantly help the flight crew during such conditions. However, the design should address the potential for the FGS to mask a condition from the flight crew or to otherwise delay appropriate flight crew action. See Section 9.3, Flight Guidance Alerting for discussion of alerting under such conditions.

Operations in rare normal environmental conditions may result in automatic or pilot-initiated autopilot disengagement close to the limit of autopilot authority. Autopilot disengagement in rare normal conditions should meet the safety criteria for autopilot disengagement found in Section 8.1 and the criteria for flight guidance alerting in Section 9.3.

For rare normal conditions, the FGS should provide guidance or control, as appropriate for the intended function of the active mode(s), in a safe and predictable manner, both within the normal flight envelope and for momentary excursions outside the normal flight envelope.

The following rare normal environmental conditions should be considered in the design of the FGS:

- Significant winds
- Significant wind gradients
- Windshear (e.g., microburst)

NOTE: For the purpose of this AMC, “windshear” is considered a wind gradient of such a magnitude that it may cause damage to the aircraft. The FGS may also provide suitable autopilot control during windshear. Refer to FAA Advisory Circulars AC 25-12 and AC 120-41 for windshear guidance system requirements.

- Large gusts (lateral, longitudinal, and vertical dimensions)
- Severe and greater turbulence
- Asymmetric icing

10.3 Performance in Non-Normal Conditions

The FGS will occasionally be operating when the aeroplane transitions outside of the normal flight envelope of the aeroplane, when other aeroplane systems experience failure conditions (e.g., inoperative engine, loss of hydraulics) or when the aeroplane experiences certain extraordinary conditions such as significant fuel imbalance, non-standard flap/slat or ferry configurations. Under such circumstances, the FGS characteristics and flight crew interaction with the FGS should be shown to be safe.

10.4 Speed Protection (see [25.1329\(h\)](#))

The requirement for speed protection is based on the premise that reliance on flight crew attentiveness to airspeed indications, alone, during FGS operation is not adequate to avoid unacceptable speed excursions outside the speed range of the normal flight envelope. Many existing FGS systems have no provisions to avoid speed excursions outside the normal flight envelope. Some FGS systems will remain engaged until the aircraft slows to stall conditions and also to speeds well above V_{MO}/M_{MO} .

The intent of the rule is for the FGS to provide a speed protection function for all operating modes, such that the airspeed can be safely maintained within an acceptable margin of the speed range of the normal flight envelope.

For compliance with the intent of the rule, other systems, such as the primary Flight Control System or the FMS when in a VNAV mode, may be used to provide equivalent speed protection functionality.

If the FGS is providing speed protection function, the following are acceptable means to comply with this rule:

- The FGS may detect the speed protection condition, alert the flight crew and provide speed protection control or guidance.
- The FGS may detect the speed protection condition, alert the flight crew and then disengage the FGS.
- The FGS may detect the speed protection condition, alert the flight crew, and remain engaged in the active mode without providing speed protection control or guidance.

NOTE:If compliance with this requirement is based on use of alerting alone, the alerts should be shown to be appropriate and timely to ensure flight crew awareness and enable the pilot to keep the aeroplane within an acceptable margin from the speed range of the normal flight envelope. See Section 9.3.1 for additional discussion of speed protection alerting.

The design should consider how and when the speed protection is provided for combinations of autopilot, flight directors, and autothrust operation.

Care should be taken to set appropriate values for transitioning into and out of speed protection that the flight crew does not consider a nuisance.

The speed protection function should integrate pitch and thrust control. Consideration should be given to automatically activating the autothrust function when speed protection is invoked. If an autothrust function is either not provided or is unavailable, speed protection should be provided through pitch control alone.

The role and interaction of autothrust with elements of the FMS, the primary flight control system, and the propulsion system, as applicable, should be accounted for in the design for speed protection.

Consideration should be given to the effects of an engine inoperative condition on the performance of speed protection.

10.4.1 Low Speed Protection

When the FGS is engaged in any modes (with the possible exception of approach as discussed in Section 10.4.1.1) for which the available thrust is insufficient to maintain a safe operating speed, the low speed protection function should be invoked to avoid unsafe speed excursions.

Activation of speed protection should take into account the phase of flight, factors such as turbulence and gusty wind conditions, and be compatible with the speed schedules. The low speed protection function should activate at a suitable margin to stall warning consistent with values that will not result in nuisance alerts. Consider the operational speeds, as specified in the Aeroplane Flight Manual (AFM), for all-engine and engine-inoperative cases during the following phases of flight:

- Takeoff.
- During departure, climb, cruise, descent and terminal area operations aeroplanes are normally operated at or above the minimum manoeuvring speed for the given flap configuration.

NOTE:For high altitude operations, it may be desirable to incorporate low speed protection at the appropriate engine out drift-down speed schedule if the FGS (or other integrated sensors/systems) can determine that the cause of the thrust deficiency is due to an engine failure.

- Approach.

NOTE:A low speed alert and a transition to the speed protection mode at approximately 1.2VS, or an equivalent speed defined in terms of VSR, for the landing flap configuration has been found to be acceptable.

- The transition from approach to go-around and go-around climb.