2 The following questions may be used to evaluate whether the description of intended function is sufficiently specific and detailed:

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

— What assessments, decisions, or actions are the flight crew members intended to make based on the display system?

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

— What is the assumed operational environment in which the equipment will be used? For example, the pilots' tasks and operations within the flight deck, phase of flight, and flight procedures.

(b) Statement of Similarity. This is a substantiation to demonstrate compliance by a comparison to a previously approved display (system or function). The comparison details the physical, logical, and functional and operational similarities of the two systems. Substantiation data from previous installations should be provided for the comparison. This method of compliance should be used with care because the flight deck should be evaluated as a whole, rather than merely as a set of individual functions or systems. For example, display functions that have been previously approved on different programmes may be incompatible when applied to another flight deck. Also, changing one feature in a flight deck may necessitate corresponding changes in other features, in order to maintain consistency and prevent confusion (for example, use of colour).

(c) Calculation & Engineering Analyses. These include assumptions of relevant parameters and contexts, such as the operational environment, pilot population, and pilot training. Examples of calculations and engineering analyses include human performance modelling of optical detections, task times, and control forces. For analyses that are not based on advisory material or accepted industry standards, validation of calculations and engineering analyses using direct participant interaction with the display should be considered.

(d) Evaluation. This is an assessment of the design conducted by the applicant, who then provides a report of the results to the Agency. Evaluations typically use a display design model that is more representative of an actual system than drawings. Evaluations have two defining characteristics that distinguish them from tests: (1) the representation of the display design does not necessarily conform to the final documentation, and (2) the Agency may or may not be present. Evaluations may contribute to a finding of compliance, but they generally do not constitute a finding of compliance by themselves.

1 Evaluations may begin early in the certification programme. They may involve static assessments of the basic design and layout of the display, part-task evaluations and/or, full task evaluations in an operationally representative environment (environment may be simulated). A wide variety of development tools may be used for evaluations, from mock-ups to full installation representations of the actual product or flight deck.

2 In cases where human subjects (typically pilots) are used to gather data (subjective or objective), the applicant should fully document the process used to select subjects, the subjects' experience, the type of data collected, and the method(s) used to collect the data. The resulting information should be provide to the Agency as early as possible to obtain agreement between the applicant and the Agency on the extent to which the evaluations are valid and relevant for certification credit. Additionally, credit will depend on the extent to which the equipment and facilities actually represent the flight deck configuration and realism of the flight crew tasks.

(e) Test. This means of compliance is conducted in a manner very similar to evaluations (see above), but is performed on conformed systems (or conformed items relevant to the test), in accordance with an approved test plan, and may be witnessed by the Agency. A test can be conducted on a test bench, in a simulator, and/or on the actual aeroplane, and is often more formal, structured, and rigorous than an evaluation.

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

2 Flight tests should be used to validate and verify data collected from other means of compliance such as analyses, evaluations, and simulations. Per CS 25.1523, during the certification process, the flight crew workload assessments and failure classification validations should be addressed in a flight simulator or an actual aeroplane, although the assessments may be supported by appropriate analyses (see CS-25 Appendix D, for a description of the types of analyses).

47. – 50. [RESERVED]

CHAPTER 9 CONTINUED AIRWORTHINESS AND MAINTENANCE

51. Continued Airworthiness and Maintenance. The following paragraphs provide guidance for preparing instructions for the continued airworthiness of the display system and its components to show compliance with CS 25.1309 and CS 25.1529 (including Appendix H), which require preparing Instructions for Continued Airworthiness. The following guidance is not a definitive list, and other maintenance tasks may be developed as a result of the safety assessment, design reviews, manufacturer's recommendations, and Maintenance Steering Group (MSG)-3 analyses that are conducted.

a. General. Information on preparing the Instructions for Continued Airworthiness can be found in CS-25 Appendix H. In addition to those instructions, maintenance procedures should be considered for:

(1) Reversionary switches not used in normal operation. These switches should be checked during routine maintenance because, if a switch failure is not identified until the aeroplane is in flight, the switching or back up display/sensor may not be available when required. These failures may be addressed by a System Safety Assessment and should be addressed in the aeroplane's maintenance programme (for example, MSG-3).

(2) Display cooling fans and filters integral with cooling ducting.

b. Design for Maintainability. The display system should be designed to minimise maintenance error and maximise maintainability.

(1) The display mounting, connectors, and labelling, should allow quick, easy, safe, and correct access for identification, removal and replacement. Means should be provided (for example, using physically coded connectors) to prevent inappropriate connections of system elements.

(2) If the system has the capability of providing information on system faults (for example diagnostics) to maintenance personnel, it should be displayed in text instead of coded information.

(3) If the flight crew needs to provide information to the maintenance personnel (for example overheat warning), problems associated with the display system should be communicated to the maintenance personnel as appropriate, relative to the task and criticality of the information displayed.

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

c. Maintenance of Display Characteristics.

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

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

(3) Test methods and criteria may be established to determine if the display system remains within acceptable minimum levels. Display system manufacturers may alternatively provide “end of life” specifications for the displays which could be adopted by the aeroplane manufacturer.

52. – 60. [RESERVED]

[Amdt 25/11]
[Amdt 25/12]
[Amdt 25/17]
[Amdt 25/21]
[Amdt 25/26]

Appendix 1 – Primary Flight Information

ED Decision 2015/019/R

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

1.1 Attitude

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

An accurate, easy, quick-glance interpretation of attitude should be possible for all unusual attitude situations and other "non-normal" manoeuvres sufficient to permit the pilot to recognise the unusual attitude and initiate an appropriate recovery within one second. Information to perform effective manual recovery from unusual attitudes using chevrons, pointers, and/or permanent ground-sky horizon on all attitude indications is recommended.

Both fixed aeroplane reference and fixed earth reference bank pointers ("ground and/or sky" pointers) are acceptable as a reference point for primary attitude information. A mix of these types in the same flight deck is not recommended.

There should be a means to determine the margin to stall and to display that information when necessary. For example, a pitch limit indication is acceptable.

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

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

1.2 Continued Function of Primary Flight Information (Including Standby) in Conditions of Unusual Attitudes or in Rapid Manoeuvres

Primary flight information must continue to be displayed in conditions of unusual attitudes or in rapid manoeuvres (CS 25.1301). The pilot must also be able to rely on primary or standby instrument information for recovery in all attitudes and at the highest pitch, roll, and yaw rates that may be encountered (CS 25.1301).

In showing compliance with the specifications of CS 25.1301(a), CS 25.1309(a), CS 25.1309(b), and CS 25.1309(c), the analysis and test programme must consider the following conditions that might occur due to pilot action, system failures, or external events:

— Abnormal attitude (including the aeroplane becoming inverted);

— Excursion of any other flight parameter outside protected flight boundaries; or

— Flight conditions that may result in higher than normal pitch, roll, or yaw rates.

For each of the conditions identified above, primary flight displays and standby indicators must continue to provide useable attitude, altitude, airspeed and heading information and any other information that the pilot may require to recognise and execute recovery from the unusual attitude and/or arrest the higher than normal pitch, roll, or yaw rates (CS 25.1301).

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 discernible from the primary altitude information, which is barometrically derived altitude. To ensure the pilot can easily discern the two, the label '''GSL''' should be used to label geometric height above mean sea level. See Section 5.4.4 of Appendix 6 for HUD-specific airspeed considerations.

Airspeed reference marks (bugs) on conventional airspeed indicators perform a useful function by providing a visual reminder of important airspeed parameters. Including bugs on electronic airspeed displays is encouraged. Computed airspeed/angle-of-attack bugs such as Vstall warning, V1, VR, V2, flap limit speeds, etc., displayed on the airspeed scale should be evaluated for accuracy. The design of an airspeed indicator should include the capability to incorporate a reference mark that will reflect the current target airspeed of the flight guidance system. This has been required in the past for some systems that have complex speed selection algorithms, in order to give the flight crew adequate information for system monitoring as required by CS 25.1309(c).

Scale units marking for air data displays incorporated into primary flight displays are not required (“knots,” “airspeed” for airspeed, “feet,” “altitude” for altimeters) as long as the content of the readout remains clear. For altimeters with the capability to display both English and Metric units, the scale and primary present value readout should remain scaled in English units with no units marking required; the Metric display should consist of a separate present value readout that does include units marking.

Airspeed scale markings such as stall warning, maximum operation speed/maximum operating mach number, or flap limits, should be displayed to provide the flight crew a quick-glance sense of speed relative to key targets or limits. The markings should be predominant enough to confer the quick-glance sense information, but not so predominant as to be distracting when operating normally near those speeds (for example, stabilised approach operating between stall warning and flap limit speeds).

If airspeed trend or acceleration cues are associated with the speed scale, vertically oriented moving scale airspeed indications should have higher numbers at the top so that increasing energy or speed results in upward motion of the cue. Speed, altitude, or vertical rate trend indicators should have appropriate hysteresis and damping to be useful and non-distracting, however, damping may result in erroneous airspeed when accelerating. In this case, it may be necessary to use acceleration data in the algorithms to compensate for the error. The evaluation should include turbulence expected in service.

For acceptable means of compliance and guidance material on instrument graduations and markings, refer to the latest ETSOs and list of approved deviations on the Agency’s webse (www.easa.europa.eu).

Altimeters present special design problems in that: (1) the ratio of total usable range to required resolution is a factor of 10 greater than for airspeed or attitude, and (2) the consequences of losing sense of context of altitude can be detrimental. The combination of altimeter scale length and markings, therefore, should be adequate to allow sufficient resolution for precise manual altitude tracking in level flight, as well as enough scale length and markings to reinforce the flight crew's sense of altitude and to allow sufficient look-ahead room to adequately predict and accomplish level-off. When providing low altitude awareness, it may be helpful to include radio altimeter information on the scale so that it is visually related to the ground position.

2.2 Low and High Speed Awareness Cues

CS 25.1541(a)(2) states: "'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.'" The CS-25 certification specifications related to instrument systems and their markings were not developed with modern day electronic displays in mind; consequently, these electronic displays are considered an "unusual design characteristic" per CS 25.1541(a)(2), and may require additional marking to warrant safe operation. In particular, it is considered necessary to incorporate additional markings on electronic airspeed displays in the form of low and high speed awareness cues to provide pilots the same type of "quick glance" airspeed awareness that was an intrinsic feature of round dial instruments.

Low speed awareness cues should provide adequate visual cues to the pilot that the airspeed is below the reference operating speed for the aeroplane configuration (that is, weight, flap setting, landing gear position, etc.); similarly, high speed awareness cues should provide adequate visual cues to the pilot that the airspeed is approaching an established upper limit that may result in a hazardous operating condition. Consider the following guidance when developing airspeed awareness cues:

— Take into account all independent parameters that may affect the speed against which protection is being provided. This is most important in the low speed regime where all large aeroplanes have a wide range of stall speeds due to multiple flap/slat configurations and potentially large variations in gross weight.

— The cues should be readily distinguishable from other markings such as V-speeds and speed targets (bugs). The cues should indicate not only the boundary value of the speed limit, but must clearly distinguish between the normal speed range and the unsafe speed range beyond those limiting values (CS 25.1545). Since the moving scale display does not provide any inherent visual cue of the relationship of present airspeed to low or high airspeed limits, many electronic displays utilize an amber and red bar adjacent to the airspeed tape to provide this quick-glance low/high speed awareness. The preferred colours to be used are amber or yellow to indicate that the airspeed has decreased below a reference speed that provides adequate manoeuvre margin, changing to red at the stall warning speed. The speeds at which the low speed awareness bands start should be chosen as appropriate to the aeroplane configuration and operational flight regime. For example, low speed awareness cues for approach and landing should be shown starting at VREF with a tolerance of +0 and –5 knots. Some Agency approved systems use a pilot selectable operating speed "bug" at VREF supplemented by system-computed low speed cues that vary in colour as airspeed decreases below certain multiples of the appropriate stall speed (for example, white below 1.3VS, amber below 1.2 VS, and red below 1.1 VS). Consider the specific operating needs of other flight regimes when developing the criteria for the associated visual cue.

— Low speed awareness displays should be sensitive to load factor (g-sensitive) to enable the pilot to maintain adequate manoeuvre margins above stall warning in all phases of flight. The accuracy of this g-sensitivity function should be verified by flight tests. Flight tests should also be conducted in manoeuvring flight and expected levels of turbulence to evaluate proper functioning of any damping routines incorporated into the low speed awareness software; the level of damping should preclude nuisance/erratic movement of the low speed cues during operation in turbulence but not be so high that it inhibits adequate response to accurately reflect changes in margins to stall warning and stall during manoeuvring flight.

— High speed awareness should be provided to prevent inadvertent excursions beyond limit speeds. Symbology should be provided to permit easy identification of flap and landing gear speed limits. A visual cue should be incorporated to provide adequate awareness of proximity to VMO; this awareness has been provided by amber bands, similar to the previously discussed low speed cues, and instantaneous airspeed displays that turn amber (or flash amber digits) as the closure rate to VMO increases beyond a value that sill provides adequate time for pilot corrective action to be taken without exceeding the limit speed.

— The display requirements for airspeed awareness cues are in addition to other alerts associated with exceeding high and low speed limits, such as the stick shaker and aural overspeed warning.

3. Vertical Speed

The display range of vertical speed (or rate of climb) indications should be consistent with the climb/descent performance capabilities of the aeroplane. If the resolution advisory (RA) is integrated with the primary vertical speed indication, the range of vertical speed indication should be sufficient to display the red and green bands for all TCAS RA information.

4. Flight Path Vector or Symbol

The display of Flight Path Vector (FPV or velocity vector) or Flight Path Angle (FPA) cues on the primary flight display is not required, but may be included in many designs.

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 or FPA indication may also be displayed on the HDD. In some HDD and most HUD applications, the FPV or FPA is the primary control and tracking cue for controlling the aeroplane during most phases of flight. Even though an FPV or FPA indication may be used as a primary flight control parameter, the attitude pitch and roll symbols (that is, waterline or boresight and pitch scale) which are still required primary indications by § 25.1303 must still be prominently displayed. In dynamic situations, such as during recovery from an unusual attitude, constant availability of attitude indications is required.

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

There may be existing aeroplane designs where the HUD provides a FPV presentation and the HDD provides a FPA presentation. However, mixture of the two different presentations is not recommended due to possible misinterpretation by the flight crew. The designs that were accepted were found to have the following characteristics: correlation between the HUD FPV display and the primary flight display FPA display; consistent vertical axis presentation of FPV/FPA; and pilots’ ability to interpret and respond to the FPV and FPA similarly.

It should be easy and intuitive for the pilot to switch between FPV/FPA and attitude when necessary. The primary flight display of FPV/FPA symbology must not interfere with the display of attitude and there must always be attitude symbology at the top centre of the pilot's primary field of view, as required by CS 25.1321.

Aeroplane designs which display flight path symbology on the HUD and the HDD should use consistent symbol shapes (that is, the HUD FPV symbol looks like the HDD FPV).

In existing cases where an FPV is displayed head up and an FPA head down on an aeroplane, the symbols for each should not have the same shape. When different types of flight path indications may be displayed as head up and/or head down, the symbols should be easily distinguished to avoid any misinterpretation by the flight crew. A mixture of the two types of flight path indications is not recommended due to possible misinterpretation by the flight crew.

The normal FPV, the field-of-view limited FPV, and the caged FPV should each have a distinct appearance, so that the pilot is aware of the restricted motion or non-conformality.

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

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

To show compliance with CS 25.1301(a), CS 25.1303(b)(5), and CS 25.143(b), the FPV/FPA FD design must:

1. Not have any characteristics that may lead to oscillatory control inputs;
2. Provide sufficiently effective and salient cues to support all expected manoeuvres in longitudinal, lateral, and directional axes, including recovery from unusual attitudes; and
3. Not have any inconsistencies between cues provided on the HUD and HDD displays that may lead to pilot confusion or have adverse affects on pilot performance.

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

Document Number	Title
AMC N°1 to CS 25.1329	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

[Amdt No: 25/11]
[Amdt No: 25/12]
[Amdt No: 25/17]

Appendix 2 – Powerplant Displays

ED Decision 2011/004/R

1. General

At the time CS 25.1305 was adopted, flight deck powerplant displays were primarily a collection of dedicated, independent, full-time analogue “round dial” type instruments. Typically, there was one display for each required indication. Today, flight deck powerplant displays are primarily electronic displays integrated with other flight deck displays on a few relatively large electronic display spaces. Throughout this technological evolution, the Agency has used certification review items (CRIs) to assure that this new technology, with its increased potential for common faults and the challenges of effectively sharing display space, did not adversely impact the timely availability and independence of the powerplant information required to meet the intent of CS 25.1305. This AMC provides some of that guidance material.

To comply with one of the provisions of CS 25.1305, a display should provide all the instrument functionality of a full-time, dedicated analogue type instrument as intended when the specification was adopted (see AC 20-88A, Guidelines on the Marking of Aircraft). The design flexibility and conditional adaptability of modern displays were not envisioned when CS 25.1305 and CS 25.1549 were initially adopted. In addition, the capabilities of modern control systems to automate and complement flight crew functions were not envisioned. In some cases these system capabilities obviate the need for a dedicated full-time analogue type instrument.

When making a compliance finding, all uses of the affected displays should be taken into consideration, including:

(1) Flight deck indications to support the approved operating procedures (CS 25.1585),

(2) Indications as required by the powerplant system safety assessments (CS 25.1309), and

(3) Indications required in support of the instructions for continued airworthiness 25.1529).

For example:

Compliance with CS 25.1305(c)(3) for the engine N2 rotor was originally achieved by means of a dedicated, full time analogue instrument. This provided the continuous monitoring capability required to:

— Support engine starting (for example, typically used to identify fuel on point);

— Support power setting (for example, sometimes used as primary or back up parameter);

— “Give reasonable assurance that those engine operating limitations that adversely affect turbine rotor structural integrity will not be exceeded in service” as required by CS 25.903(d)(2);

— Provide the indication of normal, precautionary, and limit operating values required by CS 25.1549; as well as

— Support detection of unacceptable deterioration in the margin to operating limits and other abnormal engine operating conditions as required to comply with CS 25.901, CS 25.1309, etc.

As technology evolved full authority digital engine controls (FADECs) were introduced. The FADECs were designed with the ability to monitor and control engine N2 rotor speed as required to comply with CS 25.903(d)(2). Additionally, engine condition monitoring programmes were introduced and used to detect unacceptable engine deterioration. Flight deck technology evolved such that indications could be displayed automatically to cover abnormal engine operating conditions. The combination of these developments obviated the need for a full time analogue N2 rotor speed indication, in accordance with the guidance found in Chapter 6, paragraph 36c(3) of this AMC.

2. Design Guidelines

Safety-related engine limit exceedances should be indicated in a clear and unambiguous manner. Flight crew alerting is addressed in CS 25.1322.

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

In addition to the failure conditions listed in Chapter 4 of this AMC, the following design guidelines should be considered:

1. For single failures leading to the non-recoverable loss of any indications on an engine, sufficient indications should remain to allow continued safe operation of the engine. (See CS 25.901(b)(2), CS 25.901(c), and CS 25.903(d)(2)).
2. No single failure could prevent the continued safe operation of more than one engine or require immediate action by any flight crew member for continued safe operation. (See CS 25.901(c), CS 25.903(b), and CS 25.1309(b)).
3. Engine indications needed during engine re-start should be readily available after an engine out event. (See CS 25.901(b)(2), CS 25.901(c), CS 25.903(d)(2), CS 25.903(e), CS 25.1301, CS 25.1305, CS 25.1309, and Chapter 6, paragraph 36c(3) of this AMC).

[Amdt 25/11]