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**AEROSPACE
RECOMMENDED
PRACTICE**

ARP4102/8

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FLIGHT DECK, HEAD-UP DISPLAYS

1. SCOPE:

- 1.1 This document recommends criteria for the design and installation of Head-Up Display (HUD) systems. The recommendations are applicable to HUD systems which display flight information focused at infinity in the forward field of view. This annex does not address devices for peripheral vision or displays worn by the pilot (goggles, helmet sights).

2. REFERENCES:

- 2.1 Documentation: This annex should be used in conjunction with the ARP4102 Core Document. The following documents may also be applicable:

- SAE S-7 ARP4101, Flight Deck Layout and Facilities
- SAE S-7 ARP4102/4, Flight Deck Alerting System
- SAE S-7 ARP4102/7, Electronic Displays
- SAE S-7 ARP4105, Nomenclature and Abbreviations for Use on the Flight Deck

2.2 Definitions:

2.2.1 HUD System Components:

- 2.2.1.1 Pilot's Display Unit (PDU): Component which consists of the image source, the collimating optics, and the combiner. It may include signal processing, symbol generation, drive electronics, power supplies, and controls.

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2.2.1.2 Image Source: Component which provides the optical origin of the symbology, e.g., CRT screen, conventional projector, laser projector.

2.2.1.3 Collimating Optics: Optical components used to collimate (project to infinity) the display image.

2.2.1.4 Types of Collimating Optics:

Conventional (refractive/reflective): Using lenses and mirrors for collimation/superimposition.

Holographic (diffractive): Using one or several holograms for collimation/superimposition.

2.2.1.5 Combiner: Component located in the pilot's forward field of view which provides superimposition of the symbology on the external field of view.

2.2.1.6 Types of Combiner:

Dedicated: Dedicated to HUD role.

Windshield: Utilizing an area of the windshield suitably treated, to enable it to function as a combiner.

2.2.1.7 Symbology Generator Unit (SGU): Component which provides symbology information to the image source.

2.2.2 HUD Terms, Features, and Optical Parameters: See Figure 1.

2.2.2.1 Field of View (FOV):

Total FOV: Spatial angle in which the symbology can be displayed, measured vertically and laterally from within the total viewing cone/wedge.

Instantaneous FOV:

- Monocular: Spatial angle in which the symbology can be viewed from any single eye position.
- Ambinocular: Envelope of both left and right eye monocular instantaneous FOV.
- Binocular: Envelope within the ambinocular FOV which is common to both monocular FOV, and in which the symbology can be viewed by both eyes simultaneously.

2.2.2.2 Transmittance of Combiner: Percentage of white light from an external source passing through the combiner, measured at or near the DEP.

2.2.2.3 Contrast: Ratio of display symbology brightness to external visual cue brightness, as viewed through the HUD.

2.2.3 Types of Mounting:

Overhead: PDU installed as roof mounted unit.

Glareshield: PDU installed in glareshield.

Split System: Image source and combiner installed as separate units.

2.2.4 HUD Display Characteristics:

2.2.4.1 Types of Symbology:

Analog Conformal: Related to or matching an element of the external view, e.g., horizon line, runway symbol, velocity vector.

Analog Unrelated: Not directly related to the external view, e.g., speed, ILS/MLS deviation.

Discrete Symbols: Display elements such as alphanumeric symbols.

3. OPERATIONAL REQUIREMENTS:

3.1 General: HUD systems shall provide the pilot with a display that enables him to assess aircraft attitude and flight path in relation to and association with external visual cues. Conformal symbology shall be superimposed on the external visual cues in a one-to-one relationship utilizing an optical system which has adequate field of view for the intended operation and aircraft characteristics.

3.2 System Requirements:

3.2.1 Field of View: The PDU should be designed and installed to meet all operational requirements for the specific application. In particular, the PDU should be located so as to permit the pilot some head movement without loss of significant HUD symbology, and enable him to regain HUD information easily and immediately after larger head movement.

If the displayed flight information includes a runway symbol for use during approach and landing, the lateral FOV should be sufficient to permit conformal display of the runway in approach conditions normally associated with the maximum approved landing crosswind. The vertical FOV should be sufficient to permit conformal display of flight guidance information throughout the intended operational envelope.

3.2.2 Optical Quality: The optical quality of the combiner shall be such that it does not discernibly distort or shift the image of the external world, nor shall it produce multiple images, nor significantly alter perceived external colors e.g. VASI, PAPI and runway lighting. Transmittance of the combiner should be as high as possible. Suggested minimum figures for combiner transmittance are:

90 percent for windshield combiners or HUDs intended for extended time of usage,

70 percent for HUDs intended for short time of usage.

3.2.3 Integrity: Integrity of information displayed on the HUD shall be such that the probability of displaying hazardous or misleading information without a warning or blanking is extremely remote. Parameters losing their validity shall be blanked. Failure of system computation or monitors shall result in blanking of the whole display, with suitable annunciation.

3.3 Installation Criteria:

3.3.1 Mounting of the PDU or PDU components should be such that:

- display accuracy and readability is not degraded by vibration, turbulence, maneuvering, pressurization, or body contact
- replacement is easy and does not require any adjustment.

3.3.2 The operational and stowed positions of the PDU shall not hinder pilot movement nor restrict the pilot's external vision or view of his instrument panel. A dedicated combiner shall be easily stowable.

3.3.3 The PDU shall not induce hazards of high voltage, radiation, or visual impairment. Protruding parts of the PDU shall incorporate impact protection (fold away, break away, or padding).

3.3.4 Master warning and master caution lights of the basic flight deck warning system shall be located so as to be visible to a pilot using the HUD or suitable alert indication shall be repeated within the HUD display.

4. Number not used.

5. CONTROLS:

5.1 HUD Specific Controls:

- ON/OFF, unless coupled with stowing action
- MODE, unless automatic
- Contrast or brightness
- Others as required

HUD specific controls should be either on the PDU or on a dedicated control panel located within easy reach of the pilot, so that they can be operated without him leaving the DEP.

5.2 Other Controls: Controls related to display parameters should, whenever possible, be combined with those of head-down instruments.

6. DISPLAY CRITERIA:

6.1 General:

6.1.1 The HUD system may repeat, augment, or replace head-down displays/information for any or all phases of flight. HUD systems designed to replace head-down displays must contain the information required by the pilot for manual control during the selected flight phase.

- 6.1.2 Although HUD symbology may differ considerably from head-down symbology, the HUD format and usage should permit transition from head-up to head-down, or vice versa, to be accomplished by the pilot rapidly, easily, and without confusion.
- 6.1.3 Symbology for each guidance mode or flight phase should be the minimum required to fulfill the intended function.
- 6.1.4 The symbology chosen should promote instinctive use by the pilot without the need for extensive learning or experience.

6.2 Basic HUD Information:

6.2.1 The following shall be provided:

- (i) attitude
- (ii) selected heading
- (iii) flight path angle (gamma) or equivalent
- (iv) airspeed or angle of attack
- (v) altitude

6.2.2 The HUD shall provide a clear, self-explanatory, and unmistakable display of aircraft attitude, flight path, and altitude. Attitude shall be displayed by the horizon line, airspeed in a suitable format, e.g., as moving scale or deviation from selected IAS. The general arrangement of the "basic T" shall be retained within the HUD format. Scaling of attitude, heading, and flight path angle shall be 1:1.

6.3 Visual Approach Information:

6.3.1 In addition to the basic information, the following shall be provided:

- (i) selected flight path angle
- (ii) flare guidance

6.3.2 Optional information for visual approach:

- (i) selected course/desired track
- (ii) drift angle
- (iii) airspeed/angle of attack with limits
- (iv) potential flight path

6.4 See-to-Land Instrument Approach/Go-Around Information:

6.4.1 In addition to the information per paragraph 6.3.1 the following shall be provided:

- (i) ILS/MLS situation (deviation or window) and/or
- (ii) runway symbol (edges and/or centerline)
- (iii) precision altitude indication (PA and/or RA)
- (iv) DH indication and visual alert

6.4.2 Optional Information:

- (i) pitch/roll/yaw guidance
- (ii) bank angle limits
- (iii) ILS deviation warning
- (iv) flight guidance mode(s)
- (v) AP/AT disconnect warning
- (vi) VOR situation display

6.5 Non-Visual Takeoff and Landing Information: The following additional information should be provided:

- (i) directional guidance for takeoff and rollout
- (ii) acceleration/deceleration information

6.6 Other Information: As required.

6.7 Warnings: Appropriate and unambiguous means shall be provided to warn the pilot of any partial or total failure of the system and of a failure of any input data, whether the source of the signal is on the ground or within the aircraft.

6.8 Symbology Criteria:

6.8.1 General: Symbols shall appear clean-shaped, clear, and explicit. Lines shall appear narrow, sharp-edges, and without halo or smear. When two or more strokes are used to produce wider lines, the strokes should start and end so as to provide uniform ends. Symbology shall be designed with full regard to operational experience and research findings. Analog presentation of information should be utilized in preference to alphanumeric data. Where applicable, scale orientation and sense shall be consistent with the conventional motion of the parameter and the head-down presentation of that same parameter.

6.8.2 Size of Characters: Figures and letters should subtend not less than the following vertical angles:

Primary data	10 milliradians (34.4 arcmin)
Secondary data, legends	6 milliradians (20.6 arcmin)

6.8.3 Accuracy, Stability: The accuracy of symbol positioning shall be commensurate with the intended use of the respective parameter. Conformal symbols shall be positioned and moved so that no mismatch with their visual equivalents is readily discernible. Motion of non-conformal symbols shall be smooth, not sluggish or jerky, and consistent with aircraft control response. Symbols shall be stable with no discernible flicker or jitter.

6.8.4 Brightness: All symbols should be equally bright, unless special enhancement intended. Brightness control shall provide a suitable contrast between symbols and external visual cues over the whole range of likely ambient lighting conditions. Brightness control should be automatic with initial manual selection of the individually desired contrast.

7. COLORS: Colors should be used only where an improvement over monochrome can be demonstrated, and should be consistent with those used for the respective head-down symbols. A degradation in accuracy or sharpness due to color shall not occur. Each color shall be assessed for acceptable contrast against all likely background/ambient conditions. For critical data, color must not be the only discriminant. In a degraded or monochromatic mode a color display must remain legible and unambiguous. Color degradation under extreme lighting conditions must not affect interpretation of the display.

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