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SAE ARP5119

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Location of and Display Symbology Requirements for Head-Down Electronic Flight Displays for Steep IMC Approaches

RATIONALE

ARP5119 has been reaffirmed to comply with the SAE five-year review policy.

FOREWORD

Vertical flight aircraft possess the unique capability to perform approaches at angles above that of a conventional or even STOL aircraft. Such approach angles often exceed 4° and in visual meteorological conditions (VMC) may approach 45°. Instrument meteorological condition (IMC) approaches of 6 to 12° are not impossible (in a flight director driven autopilot coupled system), with 6 to 9° being the most likely for normal operations (using manually flown flight director guidance).

These numbers are derived from flight test and simulation and a function of display symbology and aircraft handling qualities coupled with automated flight control systems. To assist in the performance of steep approaches, flight displays need to be located in the most advantageous place for pilot viewability and the symbology depicted needs to be intuitive and readily useable.

Workload reduction and performance are related to (and are a function of) both display symbology and aircraft flying (handling) qualities. For a pilot to perform steeper approaches with a lower workload in an aircraft with less than desirable handling qualities, a set of correctly selected and displayed symbols is required. Conversely, given an aircraft with an excellent flight control system and fairly benign handling qualities, a pilot can accept a poorer set of symbology, since the aircraft can absorb the workload.

Excellent, intuitive displays are essential. They are required to:

1. augment poor flying qualities which are sometimes produced by flight controls system malfunction modes

2. ounter or compensate for unusually adverse combinations of wind, turbulence, icing, etc.

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http://www.sae.org/technical/standards/ARP5119

FOREWORD (Continued)

Intuitive, low workload - high performance displays are essential. Potential display degradation may be acceptable only if the environment and the aircraft handling qualities are fairly benign.

Recommended approaches to this symbology/handling qualities mix may include traditional flight director symbology, but may be better served by innovative and more intuitive symbology such as pictorial flight path displays (tunnel-in-the-sky) and flight path vector guidance.

NOTE: Requirements for helmet/head-mounted and/or head-up displays will be addressed in another, separate document.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

1. SCOPE:

The recommendations of this document apply to such aircraft as are able to perform both normal angle and steep IMC approaches, the latter being defined as those approaches having a final approach segment angle greater than 4°. Such aircraft can include both conventional and STOL fixed-wing aircraft, commercial air transport and/or utility and normal category helicopters, compound helicopters and powered lift vehicles (tiltrotors, tiltfans, tiltwings, etc.).

1.1 Purpose:

The purpose of this document is to set forth the recommendations of SAE Committee G-10 Vertical Flight Subcommittee relative to the location, control, and implementation of electronic flight information systems, primary flight displays, secondary (standby flight) displays, engine and instruments displays, crew alert displays and associated required flight deck/cockpit displays. These recommendations are intended to derive intuitive and easily interpretable displays and display locations to minimize confusion, distraction and fatigue, thereby reducing crew workload and increasing crew performance, efficiency, safety and reducing factors detrimental to flight safety. In arriving at these recommendations the committee carefully reviewed the layouts of modern commercial and military aircraft, developmental tiltrotor flight deck/cockpit layouts, the recommendations and requirements of the Federal Aviation Administration Aircraft Certification branch and the requirements of commercial operators and aircraft manufacturers. In cases where conflicting opinions existed, suitable compromises were made.

1.2 Field of Application:

This document applies to all electronic flight instrument display systems, including but not limited to Liquid Crystal Displays (LCD), Field Emitting Diodes (FED), Light Emitting Diodes (LED) or Cathode Ray Tube (CRT) technology.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AS425	Nomenclature and Abbreviations for Use on the Flight Deck
AS8034	Minimum Performance Standards for Airborne Multi-Purpose Electronic Displays
AS8035	Minimum Performance Standards for Airborne Head Up Display (HUD)
ARP268	Location and Activation of Flight Deck Controls for Transport Aircraft
ARP1068B	Flight Deck Instrumentation, Display Criteria and Associated Controls for Transport Aircraft
ARP1093	Numeral, Letter, and Symbol Dimensions for Aircraft Instrument Displays
ARP1874	Design Objectives for CRT Displays for Part 25 (Transport) Aircraft
ARP4032	Human Engineering Considerations in the Application of Color to Electronic Flight Displays
ARP4033	Flight Crew System Integration
ARP4067	Design Objectives for CRT Displays for Part 23 Aircraft
ARP4102	Core Document: Flight Deck Panels, Controls and Displays
ARP4102/2	Flight Crew Visibility From the Flight Deck
ARP4102/4	Flight Deck Alerting Systems
ARP4102/7	Appendix B: Electronic Display Symbology for EHSI/ND
ARP4102/8	Flight Deck Design EFIS Displays, Head Up Displays
ARP4104	Design Objectives for Handling Qualities of Transport Aircraft
ARP4105	Abbreviations and Acronyms for Use on the Flight Deck
ARP4107	Aerospace Glossary for Human factors Engineers
ARP4155A	Human Interface Design Methodology for Integrated Display Symbology
ARP4256	Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft
ARP5287	Optical Measurement Procedures for Airborne Head Up Displays (HUD)
ARP5288	Transport Category Airplanes Head Up Display(HUD) Systems
ARP5289	Standardized Color and Symbology for Displays
ARD50018	The Integration of Vertical Flight Aircraft Into The National Airspace System
SAE TP 942165	David Green and Ralph Kimberlin, Helicopter Unique Instrument Approaches: Trajectories, Flying Qualities, Controls and Displays, Technical Paper Series 942165, SAE Aerotech '94, Los Angeles, October, 1994
SAE TP 965600	Vincent Anderson and Robert Smerke, Pilot-Vehicle Integration: An Overview for Conceptual Design, Technical Paper Series 965600, SAE World Aviation Congress, Los Angeles, October, 1996
SAE TP 965614	Eric Bolz, Arthur Kramer, Brian Sawyer and Leon Zmroczek, Vertical Flight in an Obstacle Rich Environment, Technical Paper Series 965614, SAE World Aviation Congress, Los Angeles, October, 1996
SAE TP 951997	Robert Wilkins, Designing The Conceptual Flight Deck for a Short Haul Civil Transport/Civil Tiltrotor, Technical Paper Series 951997, SAE World Aviation Congress, Los Angeles, October, 1995

2.1.2 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-1472E	Human Engineering Design Criteria for Military Systems, Equipment and Facilities

2.1.3 FAR & FAA Publications from FAA: Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591.

FAA Advisory Circular AC 23-1309.1A - Equipment, Systems and Installations in Part 23 Airplanes

FAA Advisory Circular AC 23-1311-a - Installation of Electronic Display Instrument Systems in Part 23 Airplanes

FAA Advisory Circular AC 25-11, of 07-16-87 Transport Category Airplane Electronic Display Systems, Department of Transportation, FAA Advisory Circular AC 25-11, Government Printing Office, Washington, DC

FAR Part 23	Airworthiness Standards: Normal, Utility, Acrobatic and Commuter Category Airplanes
FAR Part 25	Airworthiness Standards: Transport Category Airplanes
FAR Part 27	Airworthiness Standards: Normal Category Rotorcraft
FAR Part 29	Airworthiness Standards: Transport Category Rotorcraft
JAR Part 25	Airworthiness Standards: Transport Category Airplanes
JAR Part 27	Airworthiness Standards: Normal Category Rotorcraft
JAR Part 29	Airworthiness Standards: Transport Category Rotorcraft
TSO C113	Airborne Multipurpose Electronic Displays

2.1.4 Other Publications:

ADS-33	Handling Quality Ratios

2.2 Related Publications:

The following publications are provided for information purposes only and are not a required part of this document.

Anderson, Berson, Boucek, LaLumiere-Grubbs, and Williams; Flight Status Monitor Design Guidelines, Boeing Commercial Airplane Group, unpublished, 1989

Avionics, Crew Systems Integration & Simulation Technology, AHS Technical Specialists' Meeting Proceedings, 1998

Bell*Boeing V-22 Weapons System Allocation - Volume 1, Crew Systems Design Description Document (CSDDD), Document No. 901-989-654, Revision D, 1998

Bell*Boeing V-22 Weapons System Allocation - Volume 2, Crew Systems Operation Description Document (CSODD), Document No. 901-989-654, 1996

Boeing 757 Flight Deck Design Group (January 1994), Two-crew Flight Deck Design Philosophy and Certification Process, Seattle, WA. Boeing Commercial Airplane Company.

Kelley, Brian, Greaber, and Fadden, Delmar, Applying Crew Centered Concepts to Flight Deck Technology; The Boeing 777, Flight Safety Foundation 45th International Air Safety Seminar, Long Beach, CA, November, 1992

Civil Tiltrotor Missions and Applications: A Research Study; NASA Contractor Report 177451, Boeing Commercial Airplane Company, Bell Textron, Boeing Vertol, NASA ARC, November 1987

Decker, William, CTR-4 Civil Tiltrotor Symbology Design Simulation, National Aeronautics and Space Administration, Ames Research Center, Moffett Field, 1995

Grunwald, A., Robertson, J. and Harfield, J., Evaluation of a Computer-Generated Perspective Tunnel Display for Flight Path Following, NASA Technical Paper 1736. Langley: National Aeronautics and Space Administration, December 1980

Integrated Cockpit Assessment; NASA Contract NAS2-13625 Phase 2 Task 15, Draft Report, June 1995

Managing the Modern Cockpit: Third Human Error Avoidance Techniques Conference Proceedings, SAE P-239, Society of Automotive Engineers, Inc. Warrendale, PA 1990

Newman, Richard L., Head-Up Displays: Designing the Way Ahead, Ashgate Publishing Company, Brookfield, VT, 1995

O'Hare, D, & Roscoe, S. (1990). Flightdeck Performance: the Human Factor. Iowa State University Press, Ames, IA 1990

2.2 (Continued):

Oliver, J, Improving Situational Awareness Through the Use of Intuitive Pictorial Displays. SAE Technical Paper 901829. Warrendale: Society of Automotive Engineers (SAE) 1990

Sanders, M., & McKormick E. (1987), Human Factors in Engineering and Design (6th ed.). New York: McGraw-Hill

Stokes, Kite and Wickens; Display Technology Human Factors Concepts, Society of Automotive Engineers, Warrendale, Pa., 1990

V-22 Side-Stick Controller Study, Bell*Boeing FSD V-22 Contract, Boeing Helicopters, Philadelphia, PA, 1990

Woods, David D. and Elias, Glenn, Significant Messages: An Integrated Display Concept; Ohio State University, Columbus, OH

2.3 Definitions:

DISPLAY: Any visual system used to present formatted data and/or symbology to the flight crew. Displays may be singular in purpose, such as the primary flight display, or multifunction, permitting a multitude of formats to be presented.

FLIGHT DECK: That portion of the forward aircraft fuselage containing the flight stations and all associated equipment, controls and displays necessary for the flight control of the aircraft.

2.4 Acronyms and Terminology:

AGL	Above Ground Level - Altitude measured from the ground to the aircraft wheel height/ fuselage underside, usually by radar altimeter.
AL	Altitude - Normally a notation to indicate a standby display.
AMLDC	Active Matrix Liquid Crystal Display – A device for displaying data using a series of interconnected and interactive transistors arranged in such a manner as to display a unified RGB symbol.
Area Navigation - see RNAV	
AS	Airspeed - A notation to indicate a standby display.
AT	Attitude - A notation to indicate a standby display.
BALT	Barometric Altitude
CA	Crew Alert/Crew Alerting
CAS	Crew Alert/Crew Alerting System - The system of displays and tactile/aural/visual indications, generated by the aircraft electronic flight data management systems, to alert or appraise the crew to/of any required data or condition.
CDI	Course Deviation Indicator
CDU	Control Display Unit - The keyboard and associated display used for input/display of selected/required data.
CDU/EICAS	Control Display Unit/Engine, Instruments, Crew Alerting System - The keyboard and associated display used for input/display of selected/required data associated with an integrated engine, drive and crew alerting system display.
CDS	Control Display System - Central display surface/system using the 6 in x 8 in display surface for data input/display and systems control.
CFIT	Controlled Flight Into Terrain - Inadvertent stable and controlled flight of an aircraft into underlying/adjoining terrain, with or without warning.
CMS	Cockpit Management System - The integrated computerized flight deck/cockpit systems of the V-22 used to manage/schedule/control all other systems within the V-22 aircraft.
COMM	Communications

2.4 (Continued):

CRT	Cathode Ray Tube - A device for displaying data on a phosphor screen excited by a directed and focused electron beam.
Crew Alerting	The system through which flight crews are made aware of normal and non-normal system functioning.
CTR	Centered display format with the aircraft position at the center of the display. See also Civil Tiltrotor.
DCTR	De-centered display format with the aircraft position normally at the bottom center of the display.
DEU	Display Electronics Unit - An electronic module that controls formatting and logic for electronic display systems.
DGPS	Differential Global Positioning System - A system for determining exact horizontal and vertical position using satellite-based data and a locally broadcast error correction signal.
DH	Decision Height - Associated with precision approach TERPS criteria.
DMA	Defense Mapping Agency - U.S. government group tasked with developing and providing maps of the world. Usually associated with terrain maps.
DME	Distance Measuring Equipment - Ground based navigation transmitter/receiver using UHF signals that when transmitted and received will display distance in nautical miles.
DMS	Digital Map System - An onboard, computer generated navigation display system based on either DMA topographical data or a sectional/WAC-type map display used to provide enroute and terminal terrain data. Proposed to be integrated with the CFIT ground avoidance system.
EICAS	Engine, Instruments, Crew Alerting System - A centrally located display used to display both aircraft systems parameters and crew alerting data.
EFIS	Electronic Flight Information System - A system of electronic-based display surfaces enabling generated symbology to be presented on an electronic surface, typically a CRT, LCD, or other suitable device.
EGPWS	Enhanced Ground Proximity Warning System - Based on terrain data base coordinated/coupled with radar altimeter and rate of closure/rate of descent data and aircraft configuration. Generates alerts, visual tone and/or voice annunciation alerts to warn pilots of upcoming (impending) terrain along the predicted flight path. Warnings are based on terrain proximity to aircraft flight level.

2.4 (Continued):

ENAV Electronic Navigation - Navigation based on electronically transmitted ground-based navigation aids such as TACAN, VOR and VORTAC signals.

FAR Federal Aviation Regulations - That set of the Federal Code regulations governing the aviation system in the United States.

FD Flight Director - A cockpit/flight deck system that uses aircraft systems-generated data for actual attitude, performance and navigation system error data to generate a correction message. That correction message can be sent to an autopilot system, displayed to the pilot in symbology, or both.

FDP Flight Director Panel – The flight deck/cockpit control, through which all flight functions such as heading, airspeed, course and navigation system and autopilot functions are selected, actuated and annunciated.

FLIR Forward Looking Infrared - A system using infrared light energy to see heat generated data.

FMS Flight Management System - The automated computer-controlled integrated system, through which all flight dynamics including speeds, attitude, engine throttle and navigation functions are planned, controlled and monitored.

Forward Looking Infrared (see FLIR)

FOV Field of View or Field of Regard

Primary Field of View - All displays and symbology required for flight and especially for steep approaches shall be located in front of each pilot station and viewable from that station with no obstruction intervening. All required symbology (both dynamic and static) shall be inside the primary cone of vision as defined as a 30° cone originating from the operational eye point bisected by the pilot's normal line of sight. This cone shall contain required immediate warning alert system indications. This applies only to any HDD.

Secondary FOV – All displays, alerts and symbology determined to be secondary instrumentation shall be located within a 60° cone of vision.

FPLN Flight Plan - The term used in the V-22 (and other systems) to indicate the collected, associated series of waypoints and associated data that comprises the entire concept/plan of a flight.

FPV Flight Path Vector - A symbol or set of symbols that indicate the actual aircraft performance and flight path.

2.4 (Continued):

Global Positioning System (see GPS)

GPS — Global Positioning System - A U.S. system of twenty-three (or more) geosynchronous low earth orbit satellites used to broadcast navigation position signals to aircraft enabling triangulation of aircraft surface position and altitude. Russia has a similar system named GLONASS.

GPWS — Ground Proximity Warning System - Based on radar altimeter and rate of closure/rate of descent data and aircraft configuration. Emits warning tone and voice annunciation alert to perform required operation, e.g. “PULL UP....PULL UP”.

HDD — Head Down Display - Traditional display surfaces mounted into the flight deck/cockpit instrument panel, below the glare shield.

HLD — Head Level Display - Any non-seethrough display or display mounted at the head level just below a HUD in which the collimated image or symbology remains conformal.

HMD — Head Mounted Display/Helmet Mounted Display - Any optics display system mounted to the head or a helmet device used to display flight symbology through a combiner glass in front of the pilot's eyes. The display is focused to permit the pilot to look through the imagery to see the actual scene. Use of the HMD permits the symbology to be presented to the pilot regardless of the direction the pilot looks.

HUD — Head Up Display - Any optics display system mounted to the aircraft flight deck/ cockpit glare-shield used to display flight symbology through a combiner glass in front of the pilot's eyes. The display is focused to permit the pilot to look through the imagery to see the actual scene in front of the aircraft. The pilot’s eyes must be positioned in the design eye box to use the HUD.

HSD — Horizontal Situation Display - A planform view of the aircraft navigation situation with the aircraft either at the center or bottom of the display (decentered). Data displayed usually includes (but is not limited to) a compass rose with radio magnetic indicator needles (RMIs), selected course and deviation, distance data (DME), navigation reference points within range, and flight plan legs (limited number based on relevance to flight plan and display field of regard).

HVR — (1) Hover Display - V-22 display format used to provide hovering data to the flight crew. (2) V-22 Flight Director function enabling the Hover (position or ground speed) Hold mode.

IG — Image Generator - Electronic system used to generate (format and display) symbology data.

2.4 (Continued):

INAV	Inertial Navigation - Navigation based on internally mounted sensor packages such as inertial reference navigation systems (INS), i.e. V-22 LightWeight Inertial Navigation Systems (LWINS).
INS	Inertial Navigation System - A computerized, self-contained onboard navigation system allowing an aircraft (or any moveable object) to update and report position based on an initial position fix and the inertia (directional velocity) of the vehicle. System provides best accuracy when periodically updated.
JAR	Joint Aviation Regulations - Aviation regulations sponsored and generated, monitored and enforced by the European community.
LCD	Liquid Crystal Display - A flat-panel display format using individually addressable GRB (Green/Red/Blue) pixels.
LLTV	Low Light Television - Used to enhance the visual scene.
MDA	Minimum Descent Altitude - The lowest altitude measured in mean sea level and above ground level to which an aircraft on a non-precision instrument approach may descend.
MDL	Minimum Display List - The minimum set of symbols that must be displayed on any display.
MFD	Multifunction Display - Any display that is reconfigurable in either federated or integrated format.
MMWR	Millimeter Wave Radar - Used to enhance the visual scene.
MSN	Mission Management - The VCDU dedicated function key on the V-22 keyboard access data and displays associated with mission management functions (flight planning, updating, waypoint lists/building, performance data, etc).
NAC	Nacelle - Normally associated with Angle (e.g., NAC Angle) representing the nacelle angle or proprotor mast angle in tiltrotor operation. Measures in degrees ZERO being full horizontal in airplane mode, and 90-97.5 being in full vertical in helicopter mode.
NAV	Navigation (mode) or display formats. See ND below.
ND	Navigation Display - Any display, either centered or de-centered, based on ENAV, INAV or the digital maps system (DMS), presented in a planform view used for lateral surface navigation.

2.4 (Continued):

NVG	Night Vision Goggle - A night vision system/unit of two optical pieces using light amplification to display a combined binocular image of outside scenes to a pilot.
PFD	Primary Flight Display - A display providing to the pilot a combination of aircraft attitude/performance information and limited planform navigation information. Used for primary flight information only without secondary function keys and/or crew alerting information.
PF	Pilot Flying - The pilot actively manipulating the flight controls occupied with primary aircraft control duties.
PNF	Pilot Not Flying - The pilot not actively manipulating the flight controls, but occupied with flight support duties.
RALT	Radar Altitude - Absolute altitude (AGL) based on data provided by radar signals reflected from the surface underneath the aircraft.
RMI	Radio Magnetic Indicator - Bearing needles added to the compass rose to indicate either relative heading or magnetic bearing.
RNAV	Area Navigation System - Any system of navigation using internal, great circle, or waypoint data for non-prescribed routing (direct, off-airway) navigation.
SAI	Standby Attitude Indicator - Instrument panel mounted stand-alone, self-contained, electro-mechanical gyroscopic or electronic (EFIS) standby attitude.
SFD	Standby Flight Display - Display to provide data/information required by the flight crew to safely fly the aircraft to a landing in the event of a total EFIS or electrical failure. SFD should be power by a separate buss and available on emergence (flight critical) power.
STAT	Visual Systems STATus - Control pages/displays are system status control-type graphic systems displays of equipment status/WRA status information designed to provide the flight crew rapid interpretation and assimilation of systems status. These pages/display may contain systems control bezel keys.
SYNOPTIC	An integrated display format used to indicate in graphic/pictorial form the layout/ design of an aircraft system (e.g., Hydraulics, Fuel, etc.) and control the operational status of the system (e.g., FUEL BOOST PUMPS ON/OFF).
TACAN	Tactical Air Navigation System - The ultra-high frequency-based Rho-theta-type navigational aid transceiver providing both azimuth (bearing) and distance data from the interrogated ground station.

2.4 (Continued):

TCL	Thrust Control Lever - A throttle-type device used in the V-22 tiltrotor to control thrust vector and amplitude (increase/decrease) of the thrust/power components. The TCL also houses the thumb-controlled nacelle control knurled knob that controls thrust direction (vector) of the proprotor component via adjustment of the nacelle angle.
TERPS	Terminal Instrument Procedures - The obstruction clearance criteria against which the FAA (or regulatory governing body) determines instrument lateral path and vertical glide slope obstruction-free safety data for instrument approaches.
VDP	Visual Decision Point - The point on an instrument approach at which the landing surface must be visually acquired to successfully and safely complete the transition to visual flight enabling deceleration to a hover and/or landing.
VNAV	Vertical Navigation - The capability to select and engage vertical flight profile guidance. With VNAV selected, the VNAV switch/light and the BALT HOLD switch/ light will illuminate ON to indicate the system is armed. When the top of descent slope is intercepted, e.g. the lower altitude required by the Flight Plan or a WYPT glide slope is intercepted, the VNAV remains ON but the BALT HOLD light will be extinguished. When the selected altitude is reached/captured, the BALT HOLD light will illuminate and the VNAV light will extinguish.
VOR	Very High Frequency Omnidirectional Range - A fixed, circular very high frequency omnidirectional range navigational aid providing azimuth (bearing in degrees) data only. If co-located with a distance measuring equipment (DME) transmitter, can provide both bearing and range in nautical miles. Co-located facility called a VORTAC.
VORTAC	Very High Frequency Omnidirectional Range/Tactical Air Navigation system combination of VOR and TACAN - A fixed, circular very high frequency omnidirectional range navigational aid providing azimuth (bearing on degrees) data only co-located with a distance measuring equipment (DME) transmitter providing range data in nautical miles. (Also VOR/TAC)
VSD	Vertical Situation Display - A generated electronic display of aircraft attitude information depicting pitch, roll and yaw information, including (but not limited to) selected aircraft parameters such as aircraft heading, altitude (barometric and absolute), engine power, torque, vertical velocity, nacelle angle, proprotor RPM, sensor position and selected crew alerting data. In the V-22, the VSD also displays the systems control soft bezel key legends.
WAC	World Aeronautical Chart - Large area colored aeronautical chart depicting significant structural, ground and limited terrain features, usually measured in 1:1,000,000.
WCA	Warning/Caution/Advisory system - WCAs see CAS or Crew Alerting System.

2.4 (Continued):

WRA Weapons Replaceable Assembly - Single unit item of hardware replaceable at the unit or intermediate maintenance level.

WYPT Waypoint - (1) A predetermined and accurately known geographical point or position formed by UTM or LAT/LONG geo-referenced data or TACAN/VORTAC range and bearing data. (2) A point or position fix along a flight plan, usually forming a start or end point on the flight plan leg. Also known as WPT.

3. SYMBOLOGY/DATA FOR HDD EFIS DISPLAYS USED IN STEEP IMC APPROACHES:

3.1 General Characteristics:

The symbology design and location affect the interpretability, utility and efficiency of the symbology used as well as the reduction of workload and the crew's performance. Any symbology used or displayed shall be based on task-dependent functionality. The location shall be such that all symbology is easily readable, are intuitive, understandable and non-confusing or conflicting. The symbology shall not be misleading. Data/symbology should be designed to be anticipatory, providing the flight crew an immediate indication of correct control application/action. Symbology used shall provide immediate and easily interpretable indication of symbol and data validity. Additionally, command (flight director) symbology sets should have the capability to de-couple normally associated symbols (e.g., vertical and lateral commands) to permit operations with one axis failed (e.g., as a pitch axis failure when heading hold remains operational.)

3.1.1 Pilot Station Field of View: The pilot field of view shall be large enough to permit accurate viewing of all instrument, situational awareness and crew alerting displays without unusual position change. All required flight instruments and/or displays required for flight and navigation should be in the pilot's primary field of view. All immediate action crew alert displays should be in the primary field of view, or 30° cone of vision.

3.1.2 Master Alerts: Master Alerts are those visual indicating devices/displays used to alert the flight crew to critical or potentially critical anomalies requiring immediate or near-immediate action. Master Alerts shall be at head level and/or within the pilot's primary field of view (FOV). Co-located MASTER alerts, such as Flight Control System alerts and the MASTER WARNING/MASTER CAUTION alerts, should be both shape and color coded to provide near-immediate recognition of the alert and the importance of the alert.

3.1.3 Crew Alerting Data: Crew Alerting Data should be displayed in a centrally located position. It shall be readily accessible and readable to all pilot crew positions. It should be coded by size, shape, color, or a combination thereof, to indicate the type and severity/importance of the alert. In an EFIS display system, the alerting data shall be differentiated to permit intelligibility in the event of a color failure within the display symbol generation system.

Crew Alerting data shall be displayed using the "Notification By Exception" principle, or only anomalies are displayed.

3.1.4 Data Relevance: Data displayed shall be relevant to the task to be performed. A set of default data should be used for all normal or non-specified situations. An example of task-related data is the potential use of heading information as a yaw rate display. Other applications may permit inclusion of roll angle indices at the edge of the primary display to indicate roll angles in lieu of the traditional roll angle (bank angle) display at the top or bottom of the PFD. Heading and bank angle data may be BOLD when important to the task (rolling and heading change).

3.1.5 Data Display Precedence: Data to be displayed should be prioritized for display to the flight crew. Only symbology and/or data required for specific, selected task performance shall be displayed. Exceedances shall require acknowledgment and shall remain displayed in a form that continues to indicate an exceedance has occurred, but in such a manner that will not distract the flight crew from concurrent task performance.

3.1.6 Flight Phase Dependent Crew Alert Inhibiting: Display of system alerting data should be flight phase dependent. Additional data, including crew alerting data not relevant or requiring immediate attention, shall be inhibited, permitting crew to focus on that symbology required for task performance. Inhibited data/alerts shall be returned for display, or the inhibits removed, at appropriate times/flight conditions as determined by crew workload assessment and/or flight profile.

An example is only immediate action items (flight safety/flight critical, e.g. ENGINE FAILURE/FIRE) shall be displayed during critical (takeoff/landing) flight profiles, while additional alerts such as Cautions/Advisories (e.g., Pressurization Fluctuations, DME failures) are displayed during non-critical flight evolutions.

3.1.7 Primary Flight Display Information: The Primary Flight Displays (PFDs), or any display used for primary flight path/attitude information, should be centered within each pilot's primary field of view (FOV), or within the forward 30° central foveal vision cone. The PFD shall contain a required set of symbology that will permit the pilot flying (PF) to control the aircraft throughout any flight phase. They may be declutterable; permitting limited tailoring of the display. If declutterable, they shall contain, in accordance with an established Minimum Display List (MDL), a non-tailorable, reduced set of symbology providing the pilot flying (PF) the symbology/information required to safely fly the aircraft in an extremis condition.

3.1.8 Standby Flight Displays: Data deemed essential to continued safe flight or required by Federal Aviation Regulations (FARs) shall be displayed on a set of standby flight displays permitting the flight crew to operate the aircraft in the event of a full electronic flight display system failure/ malfunction.

Flight test and simulation experience indicates that the minimum data displayed in any standby instruments group for vertical flight aircraft should include a horizon, aircraft attitude, airspeed, rate of descent, and both radar and barometric altitude. Minimum navigation and flight director data should also be presented.

Tiltrotors (and/or tilt engines) will require a standby display of nacelle angle (nacelle angle of incidence). Tiltwing will require a standby display on wing angle of incidence.

3.1.8 (Continued):

Additional data such as engine/drivetrain performance, engine/transmission torque or power available, flight control/hydraulic system performance, and fuel quantities, or such systemic data as appropriate, should also be displayed. Standby flight displays may be mechanical or electronic displays. Data may be displayed in analog or digital format or a combination thereof. Display formats should conform to appropriate FAR/JAR Advisory Circulars.

3.1.9 Head-Mounted/Head-Up/Head Level Display Systems: Any head-mounted, head-up or head-level display system should adhere to the characteristics of the head-down display system, with the exception of a reduced set of symbology. The symbology used for the HMD/HUD, shall be a reduced set of those symbols used with the head-down displays (HDD). Such a symbology set must be goal adapted, or task specific.

3.2 Display Resolution:

Resolution of all displays should be such that all textual or graphic symbology shall be without aliasing where necessary. It should be adequate to the task to be performed. Symbology shall be legible (of appropriate size and crispness) and interpretable at the viewing angles and distances from operational eye point to the display surface for all pilot anthropometries.

3.2.1 Graphics: Graphics and symbology shall be large enough and color coded/shaped to provide immediate recognition of parameters to be displayed. Display symbology shall be anti-aliased where necessary to provide the maximum clarity and resolution for dynamic symbology formats. Graphic symbology and formats shall be used that are easily recognized and eliminate or reduce confusion. In any case requiring redundant coding for abnormal or non-normal situations, change of color should be used prior to changing symbology shape, or “boxing,” or reverse-video of symbology to indicate an abnormal or non-normal condition.

3.2.2 Text: Text fonts shall be used that are easily read to eliminate or reduce confusion and increase interpretability. Text that flows across disparate backgrounds should automatically change color as a function of background, i.e., white text written on a dark background will change to black text written on a light background. Text fonts shall provide the optimum readability on both day luminance and night luminance conditions. Text sizing for optimum night readability in extremely low light values should be within the range 8:1 (stroke height to width) to 10:1.

Fonts and figures should subtend not less than the following vertical angles at the design eyebox position of the pilot who normally uses the display:

Primary data - 6 milliradians
Non-essential and secondary data - 4 milliradians
Minor descriptive legends - 3 milliradians

3.2.3 Lighting: Lighting and illumination of both displays and control light plates should be capable of illumination providing full sunlight readability as well as night illumination levels essential to accommodation of night vision devices.

3.3 Display Readability:

3.3.1 Visual Interpretability: Visually displayed information and flight crew signals shall be clearly readable, discriminable, interpretable and meaningful under all ambient light conditions when viewed by the aircrew wearing all required communications headsets, life support devices and protective devices such as sunglasses.

3.3.2 Sunlight Readability: The displays shall be installed to permit clear graphic and textual readability in all sunlight conditions, from deep shade to direct and reflected sunlight. Color hue uniformity for any symbol located within the display area shall not vary to the point of causing ambiguity or incorrect identification of assigned color.

3.3.3 Cross Cockpit Viewing: Any displays used should be viewable across the flight deck or across the cockpit in all ambient light conditions. The following requirements shall apply to all primary and standby flight displays, engine instrument crew alerting and systems management displays, and associated or mission and flight-supporting displays. Considering that contrast and color coding may change as a function of viewing angle, all primary displays should be suitable to be used (viewable) by a pilot on the opposite side.

3.3.3.1 CRT Viewing: When using cathode ray tube installations, the display system, should be viewable (for cross-cockpit viewing) from a distance of 30 in (measured from the operational eye position to display surface). The measured viewing angle shall be at least 85° left and right, 25° from the top and 0° from the bottom of the display. The angle is measured from planes drawn through the sides, top and bottom of the viewable area and normal to the display surface.

3.3.3.2 LCD or EL/Plasma Display Viewing: With liquid crystal (LCD), electro-luminescent (EL) and/or gas plasma (PDP) displays installed or implemented, the display system should be viewable (for cross cockpit viewing) from a distance of 30 in (measured from the operational eye position to display surface). The measured viewing angles shall be no less than 85° left and right, 25° from the top and 0° from the bottom of the display. The angle is measured from planes drawn through the sides, top and bottom of the viewable area and normal to the display surface. Viewing shall be without significant degradation in contrast and color of the image.

4. PLACEMENT OF HDD EFIS DISPLAYS:

4.1 Display Location/Placement:

Flight Displays may be designed and installed in many orientations, and should be placed based on the task analysis/functional requirements. Typical arrangements used in current vertical flight aircraft closely mimic those found in larger fixed-wing aircraft, namely: Side-By-Side (commercial and military design) or Tandem (One Above The Other - usually military design). The number of flight crew positions, type of information to be displayed and the number of surfaces required for display will determine the number and placement of displays.

4.1 (Continued):

Single-set standby flight displays should be placed in such a position as to be readily usable by either flight station crewmember but shall be located primarily for use by the aircraft commander/ captain. Multifunction displays shall be placed in any location so as to provide accessibility to either pilot station flight crewmember.

4.1.1 Tandem Placement: Displays used as primary flight displays may be installed in tandem, one above the other. When so installed, they should be installed in such a manner that the primary flight display containing primary attitude and actual aircraft performance information shall be located directly in front of the pilot flight station (along the pilot seat butt line). All required (essential) flight information should be within the pilot's primary cone of vision. The display should be installed in such a manner that a line drawn from the pilot's operational eye point to the display is normal to the surface of the primary flight display.

The lower of the displays, typically the navigation display, shall not obstruct the pilot's FOV in a steep approach when the lower chin/knee window is required for completion of a visual transition in a steep approach and landing. The lower display shall not be installed in such a manner as to cause the pilot to be required to lower the head more than 15° from normal viewing angles required for viewing the upper flight display.

4.1.2 Side By Side Placement: Displays used as primary flight displays may be installed side by side. When so installed, they shall be installed in such a manner so that the display containing primary flight/attitude/performance information shall be located directly (as closely as possible) in front of the pilot flying (along the pilot seat butt line). All required flight information should be within the primary (30°) cone of vision. The display should be installed in such a manner that a line drawn from the pilot's operational eye point to the display is normal to the surface of the primary flight display. Any single set of standby flight displays shall be located to accommodate the primary command pilot station.

The secondary display or navigation display, and all multifunction displays shall lie within the 60° cone of vision, on the inboard side.

4.1.3 Standby Flight Display Placement: Required standby flight information, e.g., standby nacelle/wing angle data, power (engine torque), standby attitude, altimetry and airspeed, shall be located in such a manner as to lie within the secondary (60°) FOV but as close to the command primary flight information as possible. Power and lighting for standby displays shall be independent of the primary surfaces, and capable of full functionality for as long as required. Task evaluation and experimentation shall determine the time-to-function requirement.

4.1.4 Multifunction Display (MFD) Placement: The multifunction displays (MFDs) should be used as backup for the primary flight displays. They may be formatted to display aircraft systems data, synoptic graphics, systems abnormality information (crew alerts), appropriate textual or graphical messages (digital data link messages or COMM data) or such data as should be deemed appropriate.

5. EFIS DISPLAYS FOR STEEP APPROACHES:

5.1 Panel Mounted Display:

Panel mounted (Head Down) displays shall be the standard and primary display set used for all flight regimes. These displays shall conform to all restrictions and standards set forth in this document and applicable regulations, circulars, specifications and other applicable documents. The data and symbology displayed on the panel mounted displays shall be consistent with (not disparate in format or use) symbology used on any head-up (HUD/HMD) or additional ancillary display used.

5.1.1 Display Size: Display size shall be appropriate to the aircraft structure available, and of sufficient size to ensure readability of the data and symbology to be displayed.

5.2 HDD/HLD Symbology Requirements:

Symbology used for depiction of flight data used for, steep instrument or visual approaches shall be both color coded and shape coded to permit data to be readily understood. Displays should be of a size and shape that allows immediate interpretation, and that generates appropriate action. Symbology shall be of disparate color and shape to preclude confusion, e.g. Flight Director symbol/ Flight Path Vector symbol shall be different from the aircraft symbol so that one can not overlay and mask the other.

Approach symbology depict actual aircraft performance, lateral and vertical boundary planes, and current aircraft spatial orientation relative to required boundary planes. Intuitiveness should be measured using the NASA TLX or other appropriate workload measurement system, where the mental demand for cognitive processing is measured. The resultant measurements for mental demand for cognitive processing should be medium to low and the performance index should be medium to high.

The type of symbology, and the requirement to display should be a function of the information requirements and the availability of that information. Symbology may synthesize several separate but related bits of data.

5.2.1 Functionality: Aircraft attitude and performance data should be displayed wherever possible by using frequency separated symbology, with aircraft attitude and performance data displayed concurrently. Displayed data such as navigation cross track error data or flight path deviation from altitude and/or heading shall be optimized for performance and shall indicate near-immediate (less than 150 ms delay) deviation from planned track/performance. Display symbology shall be provided for all conditions within the aircraft flight envelope and shall display all applicable limits to the flight crew.

Airspeed and ground speeds as well as rate of closure and vertical flight path shall display immediate deviations from planned/commanded performance.

The flight path vector (FPV) data should be displayed to complement/supplement the flight director command data to display actual aircraft performance and flight path prediction. The FPV data should be stable and not subject to rapid changes in perturbation (upsets) caused by external influences (gusts).

Altitudes shall be displayed in both barometric and absolute (radar altitude), especially within the final approach fix or within 1000 ft vertically of the landing surface.

In the event of a near full-scale deviation from nominal, the path/course to recapture the optimum track shall be displayed to the flight crew.

5.2.1.1 Predictive Versus Actual: Approach symbology should be predictive or anticipatory. Application of a control motion/movement should display to the flight crew the immediate aircraft position/control input as a quantitative value of that motion/movement. A command to reduce airspeed followed by a power reduction should display the immediate and trend value of the airspeed correlated to the amount of power reduction.

5.2.1.2 Flight Path Display (FPV): Display of Flight Path Vector (FPV) or instantaneous aircraft performance is preferred over flight director cueing. The FPV shows actual aircraft attitude and predicted performance and may be displayed in either a conventional display (attitude director indicator, or with a lateral and vertically bounded path such as a tunnel in the sky display. Flight director cueing displays only the commands to guide the aircraft to a new position/attitude. FPV shows actual performance. Even with traditional flight director guidance cues, a two bar director (lateral command cue/vertical command cue), a Delta/Vee bar cue, or appropriate command symbology, the FPV symbol should be incorporated and used. Given the tunnel or pathway display, placing the FPV on the pathway or in the tunnel, within the guidance boundaries, guarantees obstacle clearance and guidance precision.

5.2.1.3 Flight Director Guidance: The traditional Flight director should be either a two bar director command (lateral command cue/vertical command cue), or a Delta/Vee-Bar command. New symbology may be used so as to provide the pilot flying (PF) the necessary cues to maneuver the aircraft to and within the minimum lateral and vertical boundaries forming the minimum operational standards of the task to be performed. Flight director cues shall provide command direction and command satisfaction indications. Flight director cues shall be easily interpretable and shall be anticipatory. Vertical path selection/tracking and rate-of-closure data shall be displayed. Flight Director cues shall include lateral, longitudinal and vertical steering/commands as well as power-required commands and such additional cues as are appropriate to the category and type air vehicle to be flown. Flight director cues, including power required cue, shall be located within the pilot's primary field of view. All cues should be designed so as to cause the pilot to maneuver the inceptor/control/aircraft symbol to the command symbol, "fly to" commands, as opposed to "fly from" or "zero out" commands. (This is contrary to the NASA/ Army derived 4-cue flight director where the "power" cue indicates too much or too little power and therefore is "fly-from".)

5.2.2 Shape: The shape of the symbology used shall conform as much as possible to the conventions in applicable FARs/JARs for the task or control to be performed or manipulated, i.e. a symbol representing the aircraft shall approximate the shape of the aircraft or be an internationally accepted symbol. The symbol shapes shall be easily distinguishable in the event of a display color failure.

5.2.3 Size: Size and font of all text and symbology shall be appropriate to the display size and distance from the operational eye point. They shall be of appropriate size and font to be readily readable/ distinguishable from the planned cross-cockpit viewing angle.

5.2.4 Coloration: Colors of symbols and backgrounds (e.g., visual scenarios, map data, etc) should be such that readability is maximized through color contrast. Colors used in the EFIS displays shall conform to appropriate FAR/JAR Advisory Circulars and accepted standards. Colors shall be used to make symbology readily distinguishable and to differentiate important data. Colorization shall permit viewing in dark/dusk/shaded cockpit conditions as well as in direct sunlight.

5.2.5 Conventional: Conventional analog displays/symbology shall include all functions and symbology as necessary to accomplish the required tasks for a steep approach. This shall include but not be limited to approach, descent, rate-of-descent arrestment and hover/landing. All displays shall include a backup redundancy management schema to preclude loss of all guidance symbology from commencement of the approach through completion of the landing phase. Symbology shall be arranged in the basic "T" pattern in accordance with applicable FAR/JAR Advisory Circulars.

5.2.6 Advanced (Integrated): Advanced integrated displays/symbology shall include all functions and symbology as necessary to accomplish the required tasks for a steep approach. This shall include but not be limited to approach, descent, rate-of-descent arrestment and hover/landing. Such advanced displays shall include a redundancy management schema to preclude loss of all guidance symbology from commencement of the approach through completion of the landing phase. Flight data used in integrated symbol sets shall be arranged in a manner that all primary flight data shall be within the pilot flying's primary foveal field of view. Secondary/complementary data shall be within the pilot's secondary/peripheral field of view.

5.3 Flight Deck/Cockpit Layout:

The cockpit and/or flight deck shall be designed and specified so as to provide full functionality and an acceptable crew vehicle interface between the flight crew and all controls and displays required for all tasks to be performed by the flight crew within/on that flight deck.

5.3.1 Vertical Situation Displays: Vertical situation displays are defined as those flight displays used or provided to maintain situational awareness of the actual aircraft performance and attitude. They shall be located directly in front of the pilot flight stations and will contain all symbology and data necessary for safe piloting operation of the aircraft throughout all required flight regimes/phases to include but not be limited to performance, altitude, related traffic, terrain, obstacles and weather.

5.3.1.1 Primary Flight Display PFD: The Primary Flight Display (PFD) is a vertical situation display designed as an integrated flight display to support pilot situational awareness and aircraft control. As such, it should be placed directly in front of the pilot in the outboard display position. It is a combination of the attitude director indicator (flight dynamics and flight director data) with a portion of the compass rose/horizontal situation indicator with an appropriate radio magnetic indicator (RMI) and course deviation indication (CDI) information. The PFD provides full attitude and flight director information for flight. In addition, the display shall provide horizontal navigation situation information including commanded and actual heading. The PFD is intended for use in all modes of flight.

Minimum display symbology for vertical flight aircraft should include, but not be limited to:

5.3.1.1 (Continued):

Primary Flight Display

1. Flight Path Vector
2. Reference Airplane Symbol
3. Airspeed Data (Analog and Digital)
4. Attitude Source Indicator
5. Average Mast Torque/Drive Sys
6. TQ Box
7. Bank Angle Scale
8. Bank Angle Pointer
9. Barometric Altitude Tape
10. Barometric Altitude Box
11. Commanded Airspeed Pointer
12. Commanded Altitude Indicator
13. Commanded Heading Indicator
14. Partial Compass Rose,
15. Declutter Level Indicator
16. Vertical and Lateral Command Symbology
17. Fuel Dump Annunciator
18. DH/MDA Annunciator
19. Heading Box
20. Heading Pointer
21. Heading MAG/TRUE Indicator
22. Selected RMI Needles
23. Course Deviation Indicator
24. Course Selector Needle
25. Lateral Deviation Scale
26. Lateral Deviation Pointer
27. Nacelle Angle Indicator
28. Nacelle Angle Pointer
29. Nacelle Trim Direction Indicator
30. Nacelle Angle Box (Required For Powered Lift Vehicles)
31. Attitude Director Indicator Ball
32. Horizon Line
33. Pitch Ladder/Scale
34. Bank Angle Radial Lines
35. Power Command/Cue
36. Radar Altitude Tape/Scale
37. Radar Altitude Digital Readout
38. Radar Altitude LOW Set Indexer
39. Decision Height Set Indexer
40. VDP (Visual Decision/Deceleration Point) Indicator
41. Bank Angle Scale.
42. Vertical Deviation Scale

5.3.1.1 (Continued):

43. Vertical Deviation Pointer
44. Vertical Velocity Scale
45. Vertical Velocity Pointer
46. Power Available versus Power Required

5.3.1.2 Approach to-Hover/Hover Display: The Approach to-Hover/Hover Display (HVR) is a vertical situation display designed to assist in the transition of the aircraft from the cruise flight/approach condition to the hover flight condition. It is an integrated combination of the attitude director indicator (flight dynamics) and a centered full compass rose and is used as a hover lateral and longitudinal maneuvering symbol set for precision hovering flight.

The symbology used shall support both the approach and hover requirements. As an approach-to-hover/approach display, the display should provide precision lateral and vertical flight path deviation indices as well as flight dynamics (aircraft attitude) such as airspeed, ground speed (rate of closure), barometric and absolute (radar) altitude and flight path vector. As a hover display it shall provide lateral and longitudinal information as well as acceleration and velocity vector data required for precision hovering maneuvering. The display needs to match the methodology that the pilot uses in maneuvering the aircraft. If flying using hovering techniques, then command/error symbology should support hovering techniques. If the maneuver is forward flight, command/error data should support that flight regime's techniques.

Minimum display symbology should include, but not be limited to:

Approach to Hover/Hover Display

1. Flight Path Vector Symbology
2. Reference Airplane Symbol
3. Airspeed Data (Analog/Digital)
4. Digital Ground Speed (closure rate)
5. Airspeed Indicator Box
6. Airspeed Digital Readout
7. Attitude Source Indicator
8. Average Mast Torque/Drive Sys TQ Box
9. Bank Angle Scale
10. Bank Angle Pointer
11. Barometric Altitude Tape
12. Barometric Altitude Box
13. Commanded Airspeed Pointer
14. Commanded Altitude Indicator
15. Commanded Heading Indicator
16. Acceleration Cue
17. (same as 8)
18. Compass Rose
19. Heading Pointer and Box
20. Heading MAG/TRUE Indicator

5.3.1.2 (Continued):

21. Nacelle Angle Indicator
22. Nacelle Angle Pointer
23. Nacelle Trim Direction Indicator,
24. Nacelle Angle Box (Required For Powered Lift Vehicles)
25. Horizon Line
26. Pitch Ladder/Scale
27. Bank Angle Radial Lines
28. Power Command/Cue
29. Radar Altitude Tape/Scale
30. Radar Altitude Digital Readout
31. Radar Altitude LOW Set Indexer
32. Decision Height Set Indexer
33. Bank Angle Scale.
34. Vertical Deviation Scale
35. Vertical Deviation Pointer
36. Vertical Velocity Scale
37. Vertical Velocity Pointer
38. Positional Hover Reference
39. Vertical and Lateral Command Symbology
40. Fuel Dump Annunciator
41. DH/MDA Annunciator
42. VDP (Visual Decision/Deceleration Point) Indicator
43. (same as 20)
44. Selected RMI Needles
45. Course Deviation Indicator
46. Selected Course Needle
47. Lateral Deviation Scale
48. Lateral Deviation Pointer
49. Power Available versus Power Required

5.3.2 Horizontal Situation Display (HSD): The Horizontal Situation Display (HSD) is the primary Navigation Display (ND). It should have all features and symbols required for navigation, either inertial or electronic. The display should be selectable for either a centered situation display (CTR) or NAV display with display capability for a CDI or a de-centered (DCTR) map-type wedge display with the aircraft at the bottom center of the display. Flight plan and mission/flight navigation data shall be capable of being displayed on either format.

CTR/ND/CDI. The centered navigation display shall be a circular display, with selectable range rings. The aircraft should be located at the center of the display. Compass data and radio magnetic information (RMI) data shall be displayed in this format. The centered display is normally used within the CDI as an approach display with lateral and vertical deviation symbology displayed.