U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: **INSTALLATION OF ELECTRONIC DISPLAYS IN PART 23 AIRPLANES**

Date: Draft 4/19/04
Initiated By: ACE-100

AC No: 23.1311-1B
Change:

1. PURPOSE

This advisory circular (AC) provides an acceptable means, but not the only means, of showing compliance with Title 14 of the Code of Federal Regulations (14 CFR) applicable to the installation of electronic displays in part 23 airplanes. This material is neither mandatory nor regulatory in nature and does not constitute a regulation.

2. CANCELLATION

AC 23.1311-1A, "Installation of Electronic Display Instrument Systems in Part 23 Airplanes," dated March 12, 1999, is cancelled.

DRAFT

Dorenda D. Baker
Manager, Small Airplane Directorate
Aircraft Certification Service

DRAFT

CONTENTS

3.0 RELATED REGULATIONS AND DOCUMENTS

3.1 REGULATORY SECTIONS

These acceptable means of compliance refer to the applicable sections of 14 CFR, part 23. The corresponding paragraphs of the former Civil Air Regulations (CAR) are shown in parenthesis for airplanes certificated under CAR 3.

§ 23.771 (3.381)	Pilot compartment
§ 23.773 (3.382)	Pilot compartment view
§ 23.777 (3.384)	Cockpit controls
§ 23.1301 (3.651 and 3.652)	Equipment: Function and installation
§ 23.1303 (3.655(a))	Flight and navigation instruments
§ 23.1305 (3.655(b))	Powerplant instruments
§ 23.1309	Equipment, systems, and installations
§ 23.1311	Electronic display instrument systems
§ 23.1321 (3.661 and 3.662)	Arrangement and visibility
§ 23.1322	Warning, caution, and advisory lights
§ 23.1323 (3.663)	Airspeed indicating system
§ 23.1326	Pitot heat indication systems
§ 23.1331 (3.668)	Instruments using a power source
§ 23.1335 (3.669)	Flight director systems
§ 23.1337 (3.671, 3.672, 3.673, 3.674, and 3.675)	Powerplant instruments installation
§ 23.1351 (3.681, 3.682, 3.685, and 3.686)	Electrical Systems and Equipment: General
§ 23.1353 (3.683)	Storage battery design and installation
§ 23.1357 (3.690, 3.691, and 3.692)	Circuit protective devices
§ 23.1359	Electrical system fire protection
§ 23.1361 (3.688)	Master switch arrangement
§ 23.1365 (3.693)	Electric cables and equipment
§ 23.1367 (3.694 and 3.695)	Switches
§ 23.1381 (3.696 and 3.697)	Instrument lights
§ 23.1431 (3.721)	Electronic equipment
§ 23.1501 (3.735 and 3.737)	Operating Limitations and Information: General
§ 23.1525 (3.750)	Kinds of Operation
§ 23.1529	Instructions for Continued Airworthiness
§ 23.1541 (3.755)	Markings and Placards: General
§ 23.1543 (3.756)	Instrument markings: General
§ 23.1545 (3.757)	Airspeed indicator
§ 23.1549 (3.759)	Powerplant and auxiliary power unit instruments
§ 23.1551 (3.760)	Oil quantity indicator
§ 23.1553 (3.761)	Fuel quantity indicator
§ 23.1555 (3.762)	Control markings

DRAFT

§ 23.1559 (3.772)	Operating limitations placard
§ 23.1581 (3.777)	Airplane Flight Manual and Approved Manual Material: General
§ 23.1583 (3.761 and 3.778)	Operating limitations
§ 91.205	Powered civil aircraft with standard category U.S. airworthiness certificates: Instrument and equipment requirements
§ 121.305	Flight and navigational equipment
§ 135.149	Equipment requirements: General
§ 135.159	Equipment requirements: Carrying passengers under Visual Flight Rules (VFR) at night or under VFR over-the-top conditions
§ 135.163	Equipment requirements: Aircraft carrying passengers under Instrument Flight Rules (IFR)

3.2 ADVISORY CIRCULARS AND RELATED DOCUMENTS

NOTE: The ACs, Order, and policy memorandum can be accessed on the FAA website: www.faa.gov. Copies of current editions of the following publications may be obtained free of charge from the U.S. Department of Transportation, Subsequent Distribution Office, M-30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785.

AC 20-115B	RTCA, Inc., RTCA/DO-178B
AC 20-136	Protection of Aircraft Electrical/Electronic Systems against the Indirect Effects of Lightning
AC 20-145	Guidance For Integrated Modular Avionics (IMA) that Implement TSO-C153 Authorized Hardware Elements
AC 20-176A	Guidelines for the Certification, Airworthiness, and Operational Approval of Electronic Flight Bag Computing Devices
AC 21-16D	RTCA Document DO-160D
AC 23-15	Small Airplane Certification Compliance Program
AC 23-17A	Systems and Equipment Guide for Certification of Part 23 Airplanes
AC 23-18	Installation of Terrain Awareness and Warning System (TAWS) Approved for Part 23 Airplanes
AC 23.1309-1C	Equipment, Systems, and Installations in Part 23 Airplanes

DRAFT

AC 25-11	Transport Category Airplane Electronic Display Systems
AC 91-75	Attitude Indicator
Order 8110.49	Software Approval Guidelines, dated June 3, 2003
PS-ACE100-2001-004	Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Part 23 Small Airplanes

NOTE: The ACs can be accessed on the FAA website: www.faa.gov. Copies of current editions of the following ACs may be purchased from the Superintendent of Documents, Post Office Box 371954, Pittsburgh, PA l5250-7954. Make check or money order payable to the Superintendent of Documents.

AC 20-88A	Guidelines on the Marking of Aircraft Powerplant Instruments (Displays)
AC 23-8B	Flight Test Guide for Certification of Part 23 Airplanes
DOT/FAA/CT-03/05	Human Factors Design Standards for Acquisition of Commercial Off-The-Shelf Subsystems, Non-Developmental Items, and Developmental Systems. This document can be accessed on the FAA website: www.hf.faa.gov.
DOT/FAA/OAM-TM-03-01	Multi-Function Displays A Guide for Human Factors Evaluations
ICAO 8400/5	Procedures for Air Navigation Services, ICAO Abbreviations and Codes. Fifth Edition-1999.

3.3 TECHNICAL STANDARD ORDER (TSO)

You may obtain a copy of the current edition of the following publications from the Federal Aviation Administration; Aircraft Certification Service; Aircraft Engineering Division; Technical and Administrative Support Staff Branch, AIR-103; 800 Independence Avenue, SW; Washington, DC 20591 or at the FAA website: www.faa.gov. The following is a partial list of the FAA Technical Standard Orders (TSOs) that may relate to electronic displays. For a complete list of TSOs, see AC 20-110, “Index of Aviation Technical Standards Orders.” It should be noted applicants might apply for a TSO that does not adequately address all of the functionality in the system. Alternatively, applicants may apply for multiple TSOs, since no single TSO applies to all functions.

PARTIAL INDEX OF TSOs THAT MAY BE APPLICABLE

TSO-C2d	Airspeed Instruments
TSO-C3d	Turn and Slip Instrument
TSO-C4c	Bank and Pitch Instruments
TSO-C5e	Direction Instrument, Non-magnetic (Gyroscopically Stabilized)
TSO-C6d	Direction Instrument, Magnetic (Gyroscopically Stabilized)
TSO-C7d	Direction Instrument, Magnetic Non-Stabilized Type (Magnetic Compass)
TSO-C8d	Vertical Velocity Instruments (Rate-of-Climb)
TSO-C9c	Automatic Pilots
TSO-C10b	Altimeter, Pressure Actuated, Sensitive Type
TSO-C31d	High Frequency (HF) Radio Communications Transmitting Equipment Operating within the Radio Frequency Range of 1.5-30 Megahertz
TSO-C34e	ILS Glide Slope Receiving Equipment Operating within the Radio Frequency Range of 328.6-335.4 Megahertz (MHz)
TSO-C35d	Airborne Radio Marker Receiving Equipment
TSO-C36e	Airborne ILS Localizer Receiving Equipment Operating within the Radio Frequency Range of 108-112 Megahertz (MHz)
TSO-C37d	VHF Radio Communications Transmitting Equipment Operating within the Radio Frequency Range 117.975 to 137.000 Megahertz
TSO-C38d	VHF Radio Communications Receiving Equipment Operating within the Radio Frequency Range 117.975 to 137.000 Megahertz
TSO-C40c	VOR Receiving Equipment Operating within the Radio Frequency Range of 108-117.95 Megahertz (MHz)
TSO-C41d	Airborne Automatic Direction Finding (ADF) Equipment
TSO-C43c	Temperature Instruments
TSO-C44b	Fuel Flowmeters
TSO-C45a	Manifold Pressure Instruments
TSO-C46a	Maximum Allowable Airspeed Indicator Systems
TSO-C47	Pressure Instruments - Fuel, Oil, and Hydraulic
TSO-C49b	Electric Tachometer: Magnetic Drag (Indicator and Generator).

DRAFT

TSO-C50c	Audio Selector Panels and Amplifiers
TSO-C52b	Flight Director Equipment
TSO-C54	Stall Warning Instruments
TSO-C55	Fuel and Oil Quantity Instruments (Reciprocating Engine Aircraft)
TSO-C63c	Airborne Weather and Ground Mapping Pulsed Radars
TSO-C66c	Distance Measuring Equipment (DME) Operating within the Radio Frequency Range of 960-1215 Megahertz
TSO-C67	Airborne Radar Altimeter Equipment (For Air Carrier Aircraft)
TSO-C87	Airborne Low-Range Radio Altimeter
TSO-C92c	Airborne Ground Proximity Warning Equipment
TSO-C93	Airborne Interim Standard Microwave Landing System Converter Equipment
TSO-C94a	Omega Receiving Equipment Operating within the Radio Frequency Range of 10.2 to 13.6 Kilohertz
TSO-C95	Mach Meters
TSO-C101	Over Speed Warning Instruments
TSO-C102	Airborne Radar Approach and Beacon Systems for Helicopters
TSO-C104	Microwave Landing System (MLS) Airborne Receiving Equipment
TSO-C105	Optional Display Equipment for Weather and Ground Mapping Radar Indicators
TSO-C106	Air Data Computer
TSO-C110a	Airborne Passive Thunderstorm Detection Equipment
TSO-C113	Airborne Multipurpose Electronic Displays
TSO-C115b	Airborne Area Navigation Equipment Using Multi-Sensor Inputs
TSO-C117a	Airborne Windshear Warning and Escape Guidance Systems for Transport Airplanes
TSO-C118	Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS I
TSO-C119b	Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II
TSO-C120	Airborne Area Navigation Equipment Using Omega/VLF Inputs

DRAFT

TSO-C129a	Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)
TSO-C145a	Airborne Navigation Sensors using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS)
TSO-C146a	Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented By the Wide Area Augmentation System (WAAS)
TSO-C147	Traffic Advisory System (TAS) Airborne Equipment
TSO-C151b	Terrain Awareness and Warning System
TSO-C153	Integrated Modular Avionics Hardware Elements

3.4 INDUSTRY DOCUMENTS

Copies of current editions of the following publications may be obtained as follows and are an excellent resource material for additional information, guidance, and standards.

3.4.1 RTCA Documents

The following RTCA documents are available from RTCA, Inc., Suite 805, 1828 L Street NW, Washington, DC 20036-4001 or at their website at www.rtca.org.

RTCA/DO-160D	Environmental Conditions and Test Procedures for Airborne Equipment
RTCA/DO-178B	Software Considerations in Airborne Systems and Equipment Certification
RTCA/DO-187	Minimum Operational Performance Standards for Airborne Area Navigation Equipment using Multi-Sensor Inputs
RTCA/DO-200A	Standards for Processing Aeronautical Data
RTCA/DO-201A	Standards for Aeronautical Information
RTCA/DO-254	Design Assurance Guidance for Airborne Electronic Hardware
RTCA/DO-257A	Minimum Operational Performance Standards for the Depiction of Navigation Information on Electronic Maps

DRAFT

3.4.2 Society of Automotive Engineers (SAE), Inc.

The following Society of Automotive Engineers (SAE), Inc., documents are available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or from their website at www.sae.org.

ARP 268G	Location and Actuation of Flight Deck Controls for Transport Aircraft
AS 425C	Nomenclature and Abbreviations, Flight Deck Area
ARP 450D	Flight Deck Visual, Audible, and Tactile Signals
ARP 571C	Flight Deck Controls and Displays for Communication and Navigation Equipment for Transport Aircraft
ARP 926B	Fault/Failure Analysis Procedure
ARP 1068B	Flight Deck Instrumentation, Display Criteria, and Associated Controls for Transport Aircraft
AIR 1093A	Numeral, Letter and Symbol Dimensions for Aircraft Instrument Displays
ARP 1161	Crew Station Lighting—Commercial Aircraft
ARP 1782	Photometric and Colorimetric Measurement Procedures for Airborne Direct View CRT Displays
ARP 1834A	Fault/Failure Analysis for Digital Systems and Equipment
ARP 1874	Design Objectives for CRT Displays for Part 25 (Transport) Aircraft
ARP 4032A	Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays
ARP 4033	Pilot System Integration
ARP 4067	Design Objectives for CRT Displays for Part 23 Aircraft
ARP 4101	Flight Deck Layout and Facilities
ARP 4102	Flight Deck Panels, Controls, and Displays

DRAFT

ARP 4102/7	Electronic Displays
ARP 4103	Flight Deck Lighting for Commercial Transport Aircraft
ARP 4105B	Abbreviations and Acronyms for Use on the Flight Deck
ARP 4256	Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft
ARP 4260	Photometric and Colorimetric Measurement Procedures for Airborne Flat Panel Displays
ARP 4754	Certification Considerations for Highly Integrated or Complex Aircraft Systems
ARP 4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
ARP 5287	Optical Measurement Procedures for Airborne Head-Up Display (HUD)
ARP 5288	Transport Category Airplane Head Up Display (HUD) Systems
ARP 5289	Electronic Aeronautical Symbols
ARP 5364	Human Factor Considerations in the Design of Multifunction Display Systems for Civil Aircraft
ARP 5365	Human Interface Criteria for Cockpit Display of Traffic Information
AS 8034	Minimum Performance Standard for Airborne Multipurpose Electronic Displays
AS 8055	Minimum Performance Standard for Airborne Head Up Display (HUD)
ARD 50017	Aeronautical Charting
ARD 50062	Human Factors Issues Associated With Terrain Separation Assurance Display Technology

DRAFT

3.4.3 Underwriter's Laboratory (UL), Inc.

The Underwriter's Laboratories (UL), Inc., document listed below can be obtained from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112.

UL 1418	Implosion Protected Cathode Ray Tubes for Television Type Appliances, Revised 1992

3.4.4 General Aviation Manufacturers Association (GAMA)

General Aviation Manufacturers Association (GAMA) Publication No. 10, Recommended Practices and Guidelines for Part 23 Cockpit/Flight Deck Design.

This document is available from their GAMA website at www.gama.aero/home.php.

4.0 BACKGROUND

Title 14 CFR, part 23 was amended by amendment 23-41, effective November 26, 1990. This amendment established airworthiness standards, in § 23.1311, for installing electronic display instrument systems in normal, utility, acrobatic, and commuter category airplanes. At the time the first electronic displays were developed, they were direct replacements for the conventional electromechanical components, with later designs providing more extensive information integration. Before amendment 23-41, most electronic display instrument systems were approved for installation in part 23 airplanes by special conditions. Title 14 CFR, part 23 was further amended by amendment 23-49, effective March 11, 1996, to harmonize the Federal Aviation Regulations with the Joint Aviation Requirements (JAR). The last revision of § 23.1311 removed redundant requirements and clarified which secondary instruments are required, including the visibility requirements for those instruments.

5.0 SCOPE

This AC is generally applicable only to an applicant seeking issuance of a type certificate (TC), an amended type certificate (ATC), or a supplemental type certificate (STC) for the approval of a new type design or a change in the type design. This AC does not completely address Synthetic Vision Systems (SVS) or Enhanced Vision Systems (EVS). It is not intended to cover Head-Up Displays (HUD). **If there are conflicts with other guidance or advisory circulars and this AC, the Small Airplane Directorate should be contacted to resolve the conflict.**

6.0 ACRONYMS/DEFINITIONS

6.1 ACRONYMS

AC	Advisory Circular
ACO	Aircraft Certification Office
ADC	Air Data Computer
ADI	Attitude Director Indicator
ADDS	Aviation Digital Data Service
AFM	Aircraft Flight Manual
AFMS	Aircraft Flight Manual Supplement
AHRS	Attitude Heading Reference System
ARD	Aerospace Research Document
ARP	Aerospace Recommended Practice
AS	Aerospace Standard
ASTC	Amended Supplemental Type Certificate
ATC	Amended Type Certificate
CAR	Civil Air Regulations
CFR	Code of Federal Regulations
CIP	Current Icing Potential
CRT	Cathode-Ray Tubes
EADI	Electronic Attitude Direction Indicator
EHSI	Electronic Horizontal Situation Indicator
EICAS	Engine Indication and Crew Alert System
ELOS	Equivalent Level of Safety
EVS	Enhanced Vision Systems
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FD	Flight Director
FHA	Functional Hazard Assessment
FLS	Field-Loadable Software
FMEA	Failure Modes and Effects Analysis
FOV	Field-Of-View
GPS	Global Positioning System
HIRF	High Intensity Radiated Fields
HUD	Head-Up Display
HSI	Horizontal Situation Indicators
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMA	Integrated Modular Avionics
IMC	Instrument Meteorological Conditions
JAR	Joint Aviation Requirements
LCD	Liquid Crystal Displays
LED	Light Emitting Diodes

DRAFT

METAR	ICAO Routine Aviation Weather Report
MFD	Multifunction Flight Display
ND	Navigation Display
PFD	Primary Flight Display
PFI	Primary Flight Information
POH	Pilot's Operating Handbook
RAIM	Receiver Autonomous Integrity Monitoring (used with GPS)
SAE	Society of Automotive Engineers
STC	Supplemental Type Certificate
SVS	Synthetic Vision Systems
TAS	Traffic Advisory System
TAWS	Terrain Awareness Warning System
TFR	Temporary Flight Restrictions
TC	Type Certificate
TCAS	Traffic Alert and Collision Avoidance System
TSO	Technical Standard Order
UL	Underwriter’s Laboratories
VOR	Very High Frequency Omni-Directional Range
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WAAS	Wide Area Augmentation System

6.2 DEFINITIONS

This section contains definitions for terms in this document.

Accuracy: A degree of conformance between the estimated or measured value and the true value.

Adverse Operating Condition: A set of environmental or operational circumstances applicable to the airplane, combined with a failure or other emergency situation that results in a significant increase in normal flight crew workload.

Component: Any self-contained part, combination of parts, subassemblies or units that perform a distinct function necessary to the operation of the system.

Continued Safe Flight and Landing: This phrase means that the airplane is capable of continued controlled flight and landing, possibly using emergency procedures, without requiring exceptional pilot skill or strength. On landing, some airplane damage may occur as a result of a Failure Condition.

Conventional: A system is considered “Conventional” if its function, the technological means to implement its function, and its intended usage are all the same as, or closely similar to, that of previously approved systems that are commonly used. The systems that have established an adequate service history and the means of compliance for approval are generally accepted as "Conventional."

Criticality: Indication of the hazard level associated with a function, hardware, software, etc., considering abnormal behavior (of this function, hardware, software, etc.) alone, in combination, or in combination with external events.

Critical Function: A function whose loss would prevent the continued safe flight and landing of the airplane. *Note*: The term "Critical Function" is associated with a Catastrophic Failure Condition. Newer documents may not refer specifically to the term "Critical Function."

Design-Eye Box: A three-dimensional volume of space surrounding the Design Eye Reference Point that designers and evaluators use to determine the acceptability of display and control locations.

Design-Eye Reference Point: A single reference point in space selected by the designer where the midpoint between the pilot's eyes is assumed to be located when the pilot is properly seated at the pilot's station.

Development Assurance: All those planned and systematic actions used to substantiate, to an adequate level of confidence, that errors in requirements, design, and implementation have been identified and corrected such that the system satisfies the applicable certification basis.

Field-of-View: The angular extent of the display that can be seen with either pilot's eye with the pilot seated at the pilot's station.

Enhanced Vision System: An electronic means, though the use of an infrared sensor, image-intensifier, radar, or other sensor, to provide the pilot with an image of the external scene.

Equipment Essential to Safe Operation: Equipment installed in order to comply with the applicable certification requirements of 14 CFR, part 23 or operational requirements of 14 CFR, parts 91 and 135.

Failure: An occurrence that affects the operation of a component, part, or element such that it can no longer function as intended (this includes both loss of function and malfunction). *Note:* Errors may cause failures but are not considered failures.

Failure Conditions: A condition having an effect on either the airplane or its occupants, or both, either direct or consequential, that is caused or contributed to by one or more failures or errors considering flight phase and relevant adverse operational or environmental conditions or external events. Failure Conditions may be classified according to their severity, as follows:

DRAFT

(1) ***No Safety Effect:*** Failure Conditions that would have no affect on safety (that is, Failure Conditions that would not affect the operational capability of the airplane or increase crew workload).

(2) ***Minor:*** Failure Conditions that would not significantly reduce airplane safety and involve crew actions that are well within their capabilities. Minor Failure Conditions may include a slight reduction in safety margins or functional capabilities, a slight increase in crew workload (such as routine flight plan changes), or some physical discomfort to passengers or cabin crew.

(3) ***Major:*** Failure Conditions that would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions. These conditions would be to the extent that there would be a significant reduction in safety margins or functional capabilities; a significant increase in crew workload or in conditions impairing crew efficiency; or a discomfort to the flight crew or physical distress to passengers or cabin crew, possibly including injuries.

(4) ***Hazardous:*** Failure Conditions that would reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions to the extent that there would be the following:

(i) A large reduction in safety margins or functional capabilities;

(ii) Physical distress or higher workload such that the flight crew cannot be relied upon to perform their tasks accurately or completely; or

(iii) Serious or fatal injury to an occupant other than the flight crew.

(5) ***Catastrophic:*** Failure Conditions that are expected to result in multiple fatalities of the occupants, or incapacitation or fatal injury to a flight crewmember, normally with the loss of the airplane.

Notes:

(a) The phrase "are expected to result" is not intended to require 100 percent certainty that the effects will *always* be catastrophic. Conversely, just because the effects of a given failure, or combination of failures, could conceivably be catastrophic in extreme circumstances, it is not intended to imply that the failure condition will necessarily be considered catastrophic.

(b) The term "Catastrophic" was defined in previous versions of the rule and the advisory material as a Failure Condition that would prevent continued safe flight and landing.

DRAFT

Function: The lowest defined level of a specific action of a system, equipment, and flight crew performance aboard the airplane that, by itself, provides a complete recognizable operational capability (for example, an airplane heading is a function). One or more systems may contain a specific function or one system may contain multiple functions.

Functional Hazard Assessment: A systematic, comprehensive examination of airplane and system functions to identify potential Minor, Major, Hazardous, and Catastrophic Failure Conditions that may arise as a result of a malfunction or a failure to function.

Fix: A generic name for a geographical position. A fix may be referred to as a fix, waypoint, intersection, reporting point, etc.

Flight Plan: Refers to any sequence of fixes that are interconnected by the desired path. Flight plans may range from the simplest that include only the aircraft's present position, the active waypoint, and the desired path in between, to more complicated plans that include departure and destination airports with multiple intermediate fixes.

Hardware: An object that has physical being. Generally refers to circuit cards, power supplies, etc.

Hazard: Any condition that compromises the overall safety of the airplane or that significantly reduces the ability of the flight crew to cope with adverse operating conditions.

Head-Up Display: A see-through flight display presented in the pilot's forward view of the outside world.

Independent: A component, part, element, or system that is not relying on some other component, part, element, or system for accomplishing its function. This design concept ensures that the failure of one item does not cause a failure of another item. For redundancy, each means of accomplishing the same function need not necessarily be identical.

Indicator: A means for displaying information of a parameter. More than one indicator could be depicted on one display. For example, a primary flight display may have indicators for attitude, altitude, airspeed, heading, and navigation.

Instrument: Devices that are physically contained in one unit and devices that are composed of two or more physically separate units or components connected together. (One example is a remote indicating gyroscopic direction indicator that includes a magnetic sensing element, a gyroscopic unit, an amplifier, and an indicator connected together).

Map Orientation: Refers to the rule that determines the directional relation of the map to the upper part of the display depiction. Thus, using a North-up rule, the North side of the map would be toward the top of the display and the south side of the map would be at the

DRAFT

bottom. Using a desired path-up rule, the map would be oriented so that the desired path would be vertical on the map and pointing straight up toward the top of the display.

Map Range: The geographic extent of the map region (for example, the distance covered by the map representation in either the vertical or horizontal direction).

Malfunction*:* Failure of a system, subsystem, unit, or part to operate in the normal or usual manner. The occurrence of a condition whereby the operation is outside specified limits.

Multi-Function Display: An MFD is any physical display unit, other than the PFD, used to present a variety of information, on which the layout may be reconfigured.

Navigation: The process of planning, recording, and controlling the movement of an airplane from one place to another.

Navigation Display: The display or suite of instruments by which navigation data is presented to the pilot.

Navigation Information: Information that aids the flightcrew in determining the aircraft's location in a given environment (for example, with respect to flight plans, VORs, NDBs, features on the airport surface including taxiway, signage, etc).

Primary: As used for instruments, it is defined in § 23.1311(c) as the "display of a parameter that is located in the instrument panel such that the pilot looks at it first when wanting to view that parameter."

Primary Flight Display: A PFD is a single physical unit that always provides the primary display of all of the following: altitude, airspeed, aircraft heading (direction) and attitude located directly in front of the pilot in a fixed layout in accordance with § 23.1321.

Primary Flight Information: A PFI refers to those functions or parameters that are required by the airworthiness and operational rules such as airspeed, altitude, attitude, heading (direction), required engine instruments, etc.

Primary Flight Instruments: Those instruments or displays that provide the primary flight information.

Primary Function: A function that is installed to comply with the applicable regulations for the required function, and one that provides the most pertinent controls or information instantly and directly to the pilot.

Primary Navigation: Where the pilot looks first for a display of navigation information such as on an HSI or CDI. It has the capability of displaying vertical and lateral deviation and it may have the digital distance indication to/from the selected fix.

DRAFT

Redundancy: The presence of more than one independent means for accomplishing a given function. Each means of accomplishing the function need not necessarily be identical.

Reversionary Display: A secondary means to provide information initially presented on the PFD or MFD by the transfer of information to an alternate display.

Scale: The relative proportion of the linear dimensions of objects on a display to the dimensions of the corresponding objects and distances being represented (for example, 1 inch = 100 nautical miles).

Secondary Display: A means to provide display of information on another display.

Standby Instrument: A dedicated instrument that is always available that presents primary flight information in a fixed format.

Supplemental: An additional function that is provided that is not required or intended to meet all the airworthiness and operational requirements.

System: A combination of components, parts, and elements that is interconnected to perform one or more functions.

Synthetic Vision System: A system used to create a synthetic image representing the environment external to the airplane. An image display based entirely or partially on an internal database carried on the aircraft.

Track: The projection on the earth's surface of the path of an aircraft, the direction of which is usually expressed in degrees from North (true, magnetic, or grid). The actual flight path of an aircraft over the surface of the earth.

NOTE: For additional definitions related to safety assessments, refer to AC 23.1309-1C for the appropriate definitions.

7.0 DISPLAY DESCRIPTION

The following paragraphs give a brief description of an electronic display. They do not cover all the capabilities and details of these displays or the information presented on them.

7.1 General

Electronic displays have replaced many of the traditional electromechanical and analog instruments that provide flight and powerplant information. These displays also augment and/or combine the functionality of conventional systems, such as radios and navigational systems. The major display technologies now used are multicolor cathode-ray tubes (CRTs), liquid crystal displays (LCDs), electro luminescence, plasma, and light emitting diodes (LEDs). The initial electronic displays mimicked the traditional mechanical and

DRAFT

electromechanical flight and powerplant instruments. Colors, symbols, and formats resemble these conventional instruments.

7.2 Display Configuration

Electronic displays may be installed in several configurations. A basic electronic display may provide only one flight or powerplant parameter, while more sophisticated systems integrate many parameters on one electronic display. One of the major design goals for these systems is eliminating separate conventional gauges, instruments, and annunciators. Recent installations show a trend toward a higher degree of integration. Integration of various systems should include analysis to ensure that the complexity and workload are compatible with general aviation pilots' capabilities. For example, an integrated primary flight display provides several parameters such as attitude, heading (direction), airspeed, and altitude. For additional guidance on Integrated Modular Avionics (IMA) that implement TSO authorized hardware elements, see TSO-153 and AC 20-145.

8.0 FLIGHT DISPLAYS

8.1 Instrument Requirements

Sections 23.1303, 23.1305, 23.1311, and 23.1321, in conjunction with the applicable operating rules (14 CFR, part 91, part 121, and part 135), incorporate flight and powerplant instrument requirements for part 23 airplanes. The navigation equipment requirements are given in operational rules specified in §§ 91.205, 121.303, 121.305, and 121.307, 135.143, 135.149, 135.159, 135.161, and 135.165. Display requirements for navigation information are dependent on the navigation system installed in the aircraft. Instruments and equipment required for flights under part 91, part 121, and part 135 may be affected by the electronic display installation. These instruments and equipment include gyroscopic bank and pitch, gyroscopic direction, gyroscopic rate-of-turn, slip-skid instruments, and other required communication and navigational equipment.

8.2 Primary Flight Information (PFI)

Primary flight information (PFI) refers to those functions or parameters that are required by the airworthiness and operational rules, such as airspeed, altitude, attitude, heading (direction), and the required engine instruments. Attitude, airspeed, altitude, and heading (direction) are the PFI required in § 23.1311(a)(3) and (5) and must be arranged according to § 23.1321 in the "basic T" arrangement. Direction should be heading with track displayed as a selectable option. The horizon reference line on the PFD should not be less than 3.25 inches wide in straight and level flight. When the true horizon is no longer on the display, the artificial horizon line must provide a distinctive demarcation between sky and ground (or the background). Display of PFI on reversionary or standby displays should be arranged in the basic T-configuration, but it is not required. Additionally, PFI is considered essential for safe operation and should meet minimum standards of applicable TSOs or equivalent and follow the guidance in AC 23.1309-1C, AC 23-17A, and this AC.

DRAFT

8.3 Standby Instruments or another PFD

The purpose of standby instruments or another independent PFD is to assure that primary flight information is available to the pilot during all phases of flight and during system failures. This can be accomplished by using dedicated standby instruments, another PFD, or through reversionary displays. Individual indicators should be a minimum of 2 inches in diameter or, if combined, a minimum 3 inches displayed.

Electronic display systems with dual PFDs should incorporate dual, independently powered Attitude Heading Reference (AHRS) with comparators and dual Air Data Computer (ADC) sub-systems that provide primary flight parameters. This configuration is significantly more reliable than presently certified mechanical systems, and the skills required while flying in reversionary mode are identical to those used when flying in primary mode. A single AHRS should not be used simultaneously to drive the PFD and the autopilot.

8.4 Reversionary Flight Displays

8.4.1 Secondary Display

Reversionary flight displays provide a secondary means to provide PFI through alternate display formats on another PFD or MFD by the transfer of information to an alternate display or by some other means. Reversionary modes can be automatically or manually selected, but they may require an equivalent level of safety if the PFI is not provided by a dedicated standby instrument or by another PFD. The function of an MFD system is to provide the pilot access to a variety of data, or combinations of data, used to fly the aircraft, to navigate, to communicate, and/or to manage aircraft systems. MFDs may also display PFI as needed to ensure continuity of operations.

8.4.2 Reversionary Methods

Reversionary flight information should be presented by an independent source and display to prevent complete loss of PFI due to a single failure. 14 CFR, part 23, § 23.1311(b), states that the system "must be designed so that one display of information essential for continued safe flight and landing will remain available to the crew, without need for immediate action by any pilot for continued safe operation, after any single failure or probable combination of failures." One method is to have a full time standby display or another PFD.

A second method is to have fully automatic reversionary displays capable of determining that the displays are functioning. This second method should also include a means to access the reversionary mode manually. Automatic reversion shall provide a complete display of all intended flight, navigation, communication, and engine information on the remaining display within one second if a fault is detected.

DRAFT

Other methods may be acceptable that require a single pilot action to select reversionary displays. However, a project specific Equivalent Level of Safety (ELOS) approved by the Small Airplane Directorate would be required for these implementations.

If PFI on another display is not provided, all detectable faults involving display of essential information (attitude, altitude, airspeed, and required powerplant parameters) should result in an automatic selection of secondary information or reversion. Reversionary display modes should provide consistent display formats to the PFD.

8.5 Display of Attitude

For flights under IFR conditions in part 91 and part 135 operations, and under VFR at night for part 135 operations, attitude information is required. The loss of all attitude information or the presentation of misleading attitude information could result in a catastrophic failure condition where the pilot could not continue safe flight and landing of the airplane.

8.6 Display of Direction (Heading or Track)

8.6.1 General

The loss of direction (heading or track) information could result in reduced capability of the pilot to cope with adverse operating conditions. Direction should be heading with track displayed as a selectable option, with the data source clearly annunciated. The orientation of any secondary navigation display is optional (for example, Track-up, North-up, Heading-Up). For flights under IFR conditions, the primary display of the direction parameter must be provided by a stabilized heading indicator. The reversionary display of direction may be provided by a non-stabilized magnetic direction indicator (compass).

8.6.2 Hazardous Misleading Heading Information

The Functional Hazard Assessment (FHA) for the failure effects of hazardous misleading heading information from attitude-heading reference systems (AHRS) was clarified in policy statement PS-ACE100-2002-003. This policy is specifically about the application of AC 23.1309-1C for an airplane with the certification basis under amendments 23-41 or later. This clarification is limited to installations approved for operation in Instrument Meteorological Conditions (IMC) under IFR. For operations limited to VFR, a misleading heading indication is not considered hazardous.

An FHA, and the related safety assessments, should be made for the specific airplane type and configuration as there can be a large number of combinations of failures, various mitigating factors, and other functions available to a pilot. These numerous factors affect the criticality of the heading indication; therefore, a safety assessment process using AC 23.1309-1C should be used to classify the failure conditions for misleading heading information.

DRAFT

A hazardously misleading heading is usually when the accuracy error is greater than 10 degrees on the primary heading instrument and it is an undetected error from the AHRS. The safety assessment process should consider appropriate mitigating factors.

8.7 Display of Altitude, Airspeed, and Magnetic Compass Information

When the original requirements of CAR 3 were adopted and later recodified into part 23, § 23.1303, paragraphs (a), (b), and (c), it was envisioned that airspeed, altitude, and magnetic compass information would remain available to the pilot on the loss of the airplane's primary electrical power. Airspeed and altitude functions were provided by pneumatically driven displays. For electronic displays, § 23.1311(a)(3) requires that the primary display of attitude, airspeed, and altitude not be inhibited in any normal mode of operation. Section 23.1311(a)(5) requires an independent magnetic direction indicator, and either an independent secondary mechanical altimeter, airspeed indicator, and attitude instrument, or individual electronic display indicators for the altitude, airspeed, and attitude. Primary altitude or airspeed displays that require electrical power are acceptable if means are provided for their continued operation upon loss of the airplane's primary electrical power, or if pneumatically driven instruments are available for the pilot's use.

8.8 Accuracy of the Magnetic Heading System

8.8.1 General

The operating rules, such as 14 CFR, part 91, and 14 CFR, part 135, specify the minimum required equipment that must be installed in part 23 airplanes based on the type of operation, such as VFR or IFR. 14 CFR, part 91, § 91.205, requires for heading information, under VFR operation, a magnetic non-stabilized direction indicator (i.e., compass) and, under IFR operation, a gyroscopically stabilized heading system.

The general airworthiness requirements in 14 CFR, part 23, § 23.1301 and § 23.1525, determine the flight instrument and equipment accuracy requirements for part 23 airplanes. Part 23 does not prescribe specific accuracy requirements for magnetic gyroscopically stabilized heading systems. Specific accuracy requirements for avionics may be found in related TSO and, as acceptable means of compliance to § 23.1301, in ACs, notices, or policy statements/letters.

8.8.2 Magnetic Non-Stabilized Direction Indicator

A magnetic non-stabilized direction indicator (compass) is required (reference § 23.1327) to have an accuracy of ±10 degrees or have a correction card, placard, or a back-up gyroscopic direction indicator provided the indicator is accurate better than ±10 degrees. If the sole purpose of the gyroscopic direction indicator is for backing up the magnetic non-stabilized direction indicator, then the accuracy of displayed headings can also be to ±10 degrees. However, if a gyroscopic direction indicator is installed to meet the IFR operating rules, then the installation requirements are defined by § 23.1301.

DRAFT

8.8.3 Magnetic Stabilized Gyroscopically Stabilized Direction Indicator

As installed, final accuracy for a magnetic stabilized gyroscopic direction indicator of ±4 degrees on the ground or ±6 degrees in normal level flight on any heading would meet the requirements of 14 CFR, part 23, § 23.1301. This accuracy applies after compensation and should include cumulative errors in all combinations due to the equipment itself, the current flow in any item of electrical equipment and its associated wiring, the movement of any component (for example, controls or undercarriage), and the proximity of any item of equipment containing magnetic material to the direction indicators.

8.8.4 Comparator Monitor

For systems installations that include two magnetic gyroscopic stabilized heading systems and a comparator that monitors the differences between the headings of the two systems, the comparator trip point, set as follows, would meet the requirements of 14 CFR, part 23, § 23.1301.

- 6 degrees in stabilized level flight.
- 6 degrees plus one half of the bank angle; or
- 12 degrees with a bank angle greater than 6 degrees.
- The alert function can be disabled at a bank angle greater than 20 degrees.
- An alert is provided if the condition exceeds 60 seconds, but allows two minutes for a turn error as stated in the TSO.

Please note that the 6-degree trip point during level flight allows a heading error of as much as 12 degrees. This would be comprised of one system at the 6 degrees in-flight tolerance limit while the other system, presumably with some malfunction, could have an error of 12 degrees in the same direction before the comparator monitor alert is tripped.

8.9 Rate-of-Turn Instrument

Under §§ 91.205 and 135.159, a rate-of-turn instrument is not required if a third attitude instrument usable though flight attitudes of 360 degrees of pitch-and-roll is installed following the instrument requirements prescribed in § 121.305(j). If required, the rate-of-turn indicator should be placed near the heading indicator.

An approved attitude indicator may substitute for the rate-of-turn instrument. AC 91-75, Attitude Indicator, provides one method. This AC is applicable to part 23 certificated airplanes (or airplanes certificated under earlier equivalent regulations) that weigh less than 12,500 pounds and are operated under part 91. The second approved attitude indicator must be powered by a different power source other than the source that provides power to the primary attitude indicator.

DRAFT

8.10 Slip-Skid Instrument

The slip-skid information is required by §§ 91.205(d)(4) and 135.159(b), as applicable. It is suggested that the slip-skid display be located directly below or near the rate-of-turn instrument and under or within the primary attitude display.

8.11 Vertical Speed Indicator

If provided, the vertical speed indicator should be presented to the right or directly below the altitude indicator with a scale appropriate to the performance of the aircraft.

9.0 POWERPLANT DISPLAYS

9.1 General

This section defines a means of presenting powerplant performance and condition information pertaining to the airplane's operation, and it provides guidelines as to when these functions should be displayed to the pilot. In general, there have been two methods used to accomplish this. These methods include the following: (1) display raw engine parameters to the pilot for interpretation, or (2) collect powerplant data and have an automatic monitoring system interpret and report the powerplant condition to the pilot. The following evaluation criteria should be used when considering the installation of electronic powerplant displays.

Each airframe, engine, and airframe/engine interface with the operational characteristics of these systems needs to be evaluated by the FAA to determine the primary powerplant parameter requirements. For this evaluation, and as used in this section, a primary powerplant parameter is one needed to start the engine and set and monitor engine power within powerplant limitations.

For multiengine airplanes, a failure or malfunction affecting the display or accuracy of any propulsion system parameter for one engine should not cause the loss of display or accuracy of any parameter for the remaining engine(s). If multiple propulsion parameters are integrated on one display, and the display fails, it is acceptable to provide a secondary propulsion parameter display.

9.2 Loss Of Critical Powerplant Information

No single failure, malfunction, or probable combination of failures should result in the loss of critical powerplant information, or an erroneous display of powerplant parameters that would jeopardize continued safe flight and landing of the airplane. In most cases, for engines with limited protections, loss of powerplant displays with no additional failures will not cause immediate jeopardy to continued safe flight and landing.

DRAFT

A secondary display providing powerplant parameters may be used for cases of loss of a primary powerplant display provided the secondary display is located so the pilot can adequately view the powerplant parameters.

Throttle or power lever position may be used in place of lost powerplant display parameters. This would apply if throttle position or power lever position provides a positive indication of powerplant power level required to maintain safe flight to a landing, and it has a means to preclude exceeding powerplant operating limits.

Each proposed airframe, engine, and airframe/engine interface, including appropriate human factors considerations, needs to be evaluated by the FAA to determine its adequacy. Appropriate procedures for operation of an integrated electronic powerplant display system should be in the Airplane Flight Manual (AFM).

9.3 Powerplant Information

Display primary powerplant parameters continuously in the pilot's normal field-of-view (FOV) when they are required. For example, a parameter defined as primary for engine start, but not for other normal engine operation, may only have to be displayed continuously during engine start. All parameters that are determined to be primary for other engine operations should be displayed continuously during these engine operations. When a required display parameter is not displayed full time, adequate monitoring of the function should be provided. In addition, provide a manual select option for the pilot to display the information.

Before reaching or exceeding any operating limit, the required powerplant parameters should be indicated without pilot action. When any operating limit is reached or exceeded for the required powerplant parameter, the alerts for each phase of flight should be provided in a timely manner, and they should be provided in a form that enables the flight crew to identify and carry out the necessary remedial actions. The required powerplant information should be displayed continuously during a critical takeoff and landing phase of flight to minimize pilot distraction until an established rate of climb or minimum altitude is achieved.

Displays that provide multiple powerplant parameters should be such that any parameter, display, or alert will not suppress another display or alert that also requires immediate crew awareness necessary to conduct safe operation of the aircraft and engine(s). Alerts that could cause subsequent activation of other displays or alerts should be presented in a manner and form to ensure appropriate identification and prioritization of all significant hazards and required crew actions.

9.4 Direct-Reading Alphanumeric-Only Displays

Direct-reading alphanumeric-only displays are most valuable when integrated with an analog display by adding a precise, quantitative indication to compliment an analog display's qualitative indication. Direct-reading alphanumeric powerplant displays should not be used

DRAFT

in place of analog instruments to indicate values of engine parameters where trend or rate-of-change information is important. Direct-reading alphanumeric displays limit the flight crew's ability to assess trend information and result in reduced crew awareness. Direct-reading alphanumeric displays are also limited in their ability to provide a comparison of parameters from multiple engines or to check the general proximity of differing parameters against their individual limits. While these shortcomings can be compensated for with additional design provisions, the use of direct-reading alphanumeric displays should be made with care and evaluated for each airframe, engine, and airframe/engine integration. The required § 23.1305 powerplant instruments referred to as "indicators" should have the ability to provide trend or rate-of-change information, unless a finding of equivalence is made for direct-reading alphanumeric displays. The finding of equivalence should consider the following factors.

- The visibility and relative location of the indicated parameter should be reviewed, including appropriate conditions of lighting and instrument panel vibration.

- The ability to assess necessary trend or rate-of-change information quickly, including if and when this information may be needed during in-flight engine restarts.

- The ability to assess how close the indicated parameter is relative to a limit.

- For multiengine aircraft, the value to the crew of quickly and accurately comparing engine-to-engine data.

- Compensating engine design features or characteristics that would forewarn the crew before the parameter reaching the operating limit (for example, redline).

9.5 Marking Of Powerplant Parameters

Marking of powerplant parameters on electronic displays should be performed following § 23.1549. AC 20-88A provides alternate methods of marking electronic powerplant displays. A finding of equivalence for other methods of marking the displays may be performed. However, this should be evaluated on a case-by-case basis that depends on each airframe, engine, integration, and appropriate human factors considerations.

10.0 ELECTRONIC DISPLAYS FOR NAVIGATION INFORMATION

10.1 Guidance Information

Navigation information used by the pilot for steering commands and to monitor deviation from a navigation path should be in the pilot's primary field-of-view (FOV). Other data, such as warnings and cautions, should also be in the primary field-of-view. For more guidance on field-of-view, see paragraph 15 and Table 1 of this AC.

DRAFT

10.2 Display Integration

Navigation guidance information may be integrated with the PFDs. Common examples include horizontal situation indicators (HSIs) that combine inputs from a directional gyro along with a course deviation indicator, or a flight director (FD) integrated with the attitude direction indicator (ADI). Additionally, information from more than one navigation source may be displayed separately or simultaneously.

If information from more than one navigation source can be displayed, the selected source should be continuously indicated to the pilot. If multiple sources can be displayed simultaneously, the display should indicate unambiguously what information is provided by each source and which is for guidance. Distinctive scales or points should differentiate between angular deviations (for example, Instrument Landing System (ILS), and Very High Frequency Omni-Directional Range (VOR). If the airplane is equipped with an autopilot that is coupled to the lateral and vertical guidance system, the input to the autopilot should coincide with the navigation source selected on the PFD or primary navigational display.

10.3 Reversionary Navigation Displays

Reversionary requirements for navigation display information depends on the rules under which the aircraft is operated and the hazards associated with the loss of or misleading information from the display. The integration of non-navigation information (for example, traffic, weather or flight parameters) may affect the hazards associated with the loss of, or misleading information from, the display. In these cases, the applicant should perform a System Safety Assessment in accordance with AC 23.1309-1C. For more guidance on safety assessment, see AC 23.1309-1C and paragraph 25 of this AC for additional guidance.

11.0 AIRPLANE FLIGHT MANUAL (AFM)

For equipment required for IFR approval, the AFM or supplemental AFM should contain the limitations and the operating and emergency procedures applicable to the equipment installed. Installations limited to VFR use only may require an AFM or supplemental AFM depending on the complexity of the installation and the need to identify necessary limitation and operating procedures. Additional policy and guidance on AFMs is contained in AC 23-8B.

12.0 ELECTRONIC CHECKLIST

Policy and guidance on electronic checklist displays is contained in AC 23-8B. If installed, an electronic checklist certification should include an FAA approved AFM or a POH that fulfills the requirements of an AFM.

13.0 HUMAN FACTORS CONSIDERATIONS FOR DESIGN OF ELECTRONIC DISPLAYS

13.1 General

Electronic displays can be programmed to provide many innovative display flexibilities and features. If these innovations are designed using sound processes and appropriate design criteria that account for human performance, technology improvements in display design and integration can enhance pilot performance and improve situation awareness. Efforts should be made by the applicant to ensure that human performance considerations are adequately addressed throughout the design process. Early FAA involvement and an effective working relationship between the FAA and the applicant will greatly aid in the timely identification and resolution of human factors related issues. The applicant is encouraged to develop human performance considerations, including evaluation plans, and present them to the FAA early in the certification process.

13.2 Human Factors for Certification of Part 23 Small Airplanes

Policy statement number PS-ACE100-2001-004 provides guidance to FAA certification teams for review of an applicant's Human Factor Certification Plan or the human factor components of a general certification plan when one is submitted as part of a TC, STC, or ATC project. FAA certification teams are encouraged to use this policy in reviewing certification plans. The application of this guidance will ensure that human factors issues are adequately considered and addressed throughout the certification program.

13.3 Cockpit/Flight Deck Design, GAMA Publication No. 10

The purpose of this document is to provide manufacturers of small aircraft and systems with human factors recommendations for the design of cockpits/flight decks and their associated equipment. This publication was developed as a cooperative effort between the FAA and industry.

13.4 SAEs and RTCAs Recommended Practices and Standards

Evaluation of the electronic display system should consider airworthiness regulations, recommended practices, and standards from industry documents as listed in paragraph 3.4 of this AC.

13.5 Human Factors Compliance Considerations

The applicant should identify all human factors related regulations that apply to the installation and operation of the display system or component being certified, and the applicant should document how the system or component complies with each of these regulations. A partial list of relevant regulations is contained in policy statement PS-ACE100-2001-004. A plan to describe how the applicant intends to show compliance with

DRAFT

the relevant regulations should be developed and agreed upon by the FAA and the applicant. It should contain sufficient detail to assure that human factors compliance considerations have been adequately addressed. The test plan should also allow for adequate time to accomplish all necessary testing agreed to by the applicant and the FAA.

The areas listed below should be addressed in this plan to assure the following.

- The intended use of the system does not require any exceptional skill or generate any unreasonable workload for the pilot.
- The use of the display does not require unreasonable training requirements to adequately demonstrate that the pilot can understand and properly operate the system in all operational environments.
- Demonstration of the design characteristics of the display system support error avoidance and management (detection, recovery, etc.) that are equivalent to or less than a previously certified comparable system.
- The display system is integrated so that it is consistent or compatible with other cockpit controls and displays and creates no additional burden on the pilot with respect to the new display system or operation of other systems.
- If a failure occurs, it should be demonstrated that it does not prevent the pilot from safely operating the airplane and assure that no misleading information is presented in the event of a malfunction.
- The manufacturers should provide design rationale for their decisions regarding new or unique features in a display. Evaluation pilots should verify that the data support a conclusion that any new or unique features have no unsafe or misleading design characteristics.
- Several pilots and human factors representatives should conduct display evaluations. Include those pilots who are most representative of the intended user of the system. For systems that contain new or unique features, a greater number of evaluators should be considered. A reasonable amount of training time should be allowed to learn all required features of the display system. The evaluators should be familiar with the guidance contained in this advisory circular before the evaluation. Evaluators should be familiar with display guidance contained in the human factors policy statement referenced above, GAMA Publication No. 10, and the Multi-Function Displays, A Guide for Human Factors Evaluations.

13.6 Intended Function

One of the regulations applicable to displays is 14 CFR, part 23, § 23.1301. As part of showing compliance with 14 CFR, part 23, § 23.1301, the display system must be of a type and design appropriate to their intended function when used by representative general aviation pilots.

DRAFT

13.6.1 Demonstrate Compliance

To demonstrate compliance with § 23.1301, an applicant must show that the design is appropriate for its intended function. The applicant's statement of intended function must be specific and detailed enough for the certification authority to be able to evaluate the intended function(s) and to evaluate whether the associated pilot tasks (if any) can be adequately achieved. This is particularly important for systems with a pilot interface component, as the certification authority must evaluate the intended function from the pilot's perspective as well as from a systems perspective. There are several safety concerns, including the concern that the pilot could become reliant on a display that does not meet minimum safety standards. For example, a statement that a new display system is intended to "enhance situation awareness" must be further elaborated on, as a wide variety of different displays from terrain awareness, vertical profile, and even the primary flight displays, all enhance situation awareness in different ways. Thus, it is necessary to provide a greater level of detail to identify the specific aspect(s) of situation awareness that are to be enhanced and show how the design supports those aspects. Similarly, the terms "supplemental," "non-essential," "secondary," etc., in isolation would not be acceptable as statements of intended function. While the statement of intended function must be submitted by the applicant, the final determination of compliance to the rule, specifically on the acceptability of the proposed intended function, will be made by the certification authority.

13.6.2 Intended Function(s) and Associated Task(s)

The intended function(s) and associated task(s) should be listed for the system, as well as for individual features or functions of that system. It is acceptable for a system to have multiple intended functions, provided each function is documented and all information depicted or indicated to the flight crew supports one or more of the documented intended functions.

The following information may be used to evaluate whether the statement of intended function and associated task is sufficiently specific and detailed.

(1) Does each feature and function include a statement of the intended function? Is there a description of the task associated with this feature/function?

(2) What assessments, decisions, or actions are required by the pilot for these intended functions?

(3) What other information is required to be used in conjunction with these intended functions (for example, other cockpit systems), assumed to be used in combination with the system?

(4) Is the operational environment in which these intended functions are to be used adequately described (for example, VFR, IFR, phase of flight, etc.)?

DRAFT

13.6.3 Method(s) of Compliance

The method(s) of compliance should be adequate to enable the certification authority to determine the following.

(1) Is the system providing sufficient and appropriate information to support the intended functions and the achievement of the associated tasks?

(2) Is the level of detail, accuracy, integrity, reliability, timeliness, and update rate of the information matched appropriately to the task associated with the intended function?

(3) Does the use of the system impair the pilot's ability to use other systems or do other tasks?

(4) Does the system or the use of the system impair the safe operation or the intended function of other systems or equipment?

13.6.4 Labeling

Each piece of installed equipment must be labeled as to its identification, function or operating limitations or any combination. The assumptions and/or limitations should be adequately documented in the AFM, AFM Supplement, and/or Pilot Operating Manual (as negotiated with the ACO). This applies to the manufacturer of the equipment and not to the installer. The installer is required to verify the intended function and to make any placards or flight manual limitations, per subpart G of 14 CFR, part 23, that the installed equipment makes necessary.

14.0 LOCATION AND CONFIGURATION OF DISPLAYS

14.1 Display Usability

The location of the displays should be in a position so the pilot(s) can monitor them with minimal head and eye movement between displays. Flight information should be legible, accurate, easily interpreted, sufficiently free of visual cutoff (viewing angle), parallax and distortion, for the pilot to correctly interpret it.

14.2 Basic T Configuration

Use the basic T-configuration for airplanes certificated under § 23.1321, amendment 23-14 or later amendment. The basic T-configuration is defined as an arrangement where the airspeed and altitude data are centered, respectively, directly to the left and right of the attitude data, with the direction data located directly below the attitude data.

DRAFT

14.3 Deviations from the Basic T Configuration

Deviations from the basic T-configuration have been approved for individual instrument arrangements if the droop angle (angle below the § 23.1321(d) position) is 15 degrees or less, or if the elevated angle is 10 degrees or less. These angles are measured from a horizontal reference line that passes through the center of the attitude reference data with lines passing through the center of the airspeed and altitude data.

Use of unique displays or arrangements for attitude, altitude, airspeed, and navigation data, integration of combinations of these functions, or rearrangement of them from the basic T-configuration, may be approved when an equivalent safety finding, and a human factors evaluation is provided. This evaluation should consider the different types of airplane operations as defined by § 23.1559(b). Coordination with the Small Airplane Directorate is required. Deviations beyond these limits may be approved for individual flight instruments through a human factors evaluation and display installation evaluation, considering the following items.

- The display arrangement and its alignment to the normal line of the pilot's vision
- Cockpit view
- The integration of other functions within the displays
- The data presented, format, symbology, etc. within the display
- The ease of manipulating controls associated with the displays

15.0 PILOT FIELD-OF-VIEW CONSIDERATIONS

15.1 General

This guidance is specifically intended to address the visibility and placement of information used by the pilot. Past practice has typically involved FAA flight test pilots working with applicants to conduct qualitative assessments of the proposed equipment locations. This is intended primarily for new aircraft development programs, but it could also be used for extensive modifications to existing cockpits. Part 23 rules do not require that the applicant establish a cockpit design eye reference point from which to measure viewing distances and angular displacement to various cockpit equipments; however, it is recommended for new instrument panel designs to facilitate quantitative assessments of equipment locations. These evaluations typically involve the pilot’s subjective assessment of the applicant’s cockpit to ensure it meets the intent of 14 CFR, part 23, § 23.1321(a), which states that the pilot should be able to use all of the required instruments with “minimum head and eye movement.” These assessments have worked for previous certification efforts; however, additional information is available that may be of help in conducting more quantitative assessments and in providing a more standardized evaluation for the benefit of the applicant and the FAA certification team.

In addition, many other factors need to be considered when determining the acceptability of displayed information in the cockpit. These factors can include the following:

DRAFT

Readability
Clutter
Pilot scan pattern
Pilot workload
Parallax
Frequency of use and criticality

15.2 Primary Field-of-View

Primary field-of-view is based on the vertical and horizontal visual fields from the design eye reference point that can be accommodated with eye rotation only. With the normal line-of-sight established at 15 degrees below the horizontal plane, the values for the vertical and horizontal (relative to normal line-of-sight forward of the aircraft) are +/-15 degrees, as shown in Figure 1. This area is normally reserved for primary flight information and high priority alerts. Table 1 also provides examples of information recommended for inclusion in this visual field. In most applications, critical information that is considered to be essential for safe flight, along with warning or cautionary information that requires immediate pilot action or awareness, should be placed in the primary field-of-view.

15.3 Normal Field-of-View

Normal field-of-view is based on the vertical and horizontal visual fields from the design eye reference point that can be accommodated with minimal head rotation. These values are +/-35 degrees horizontal, and +40 degrees up and -20 degrees down vertical, as shown in Figure 1. These areas are normally used for important and frequently used information. Pilot’s visual scan and head rotation is minimized when information is placed in this area. In addition, placement of information in this area reduces the potential for spatial disorientation. Table 1 also provides examples of information recommended for inclusion in this visual field.

DRAFT

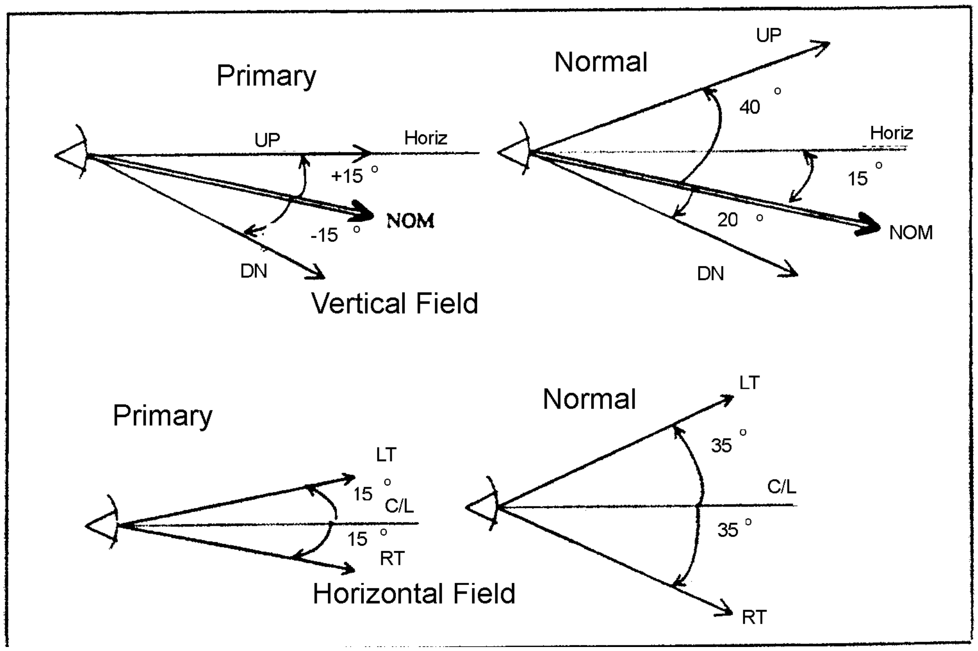

Figure 1. Field-of-View

15.4 Recommended Location for Displaying Information

Table 1 contains the recommended location for displaying information that is intended for new panel layout with integrated electronic displays; however, these guidelines should be followed for other installations as practicable. Deviations beyond these limits may be approved for individual flight instruments depending on the combination of factors listed in section 15.1, and they would need a display installation evaluation. For airplanes being retrofitted with new electronic displays, it may not be practicable to comply with the values in the table due to limitations in the systems and incompatible technologies between the aircraft and the system being added. In such cases, for any given item, the angular deviations should not increase from what was originally found to be acceptable, and the display characteristics should be at least as good as the original display. For retrofit installations, it may be acceptable for installations to fall outside the recommended data in Table 1, but such deviations may need an evaluation by the certification authority. Factors considered during this evaluation would include the distinguish ability, attention-getting quality, readability, etc. The field-of-view angles should be applied for installation approvals where a design eye reference point exists. For installation approvals where no design eye reference point is defined, the linear panel distances from center in Table 1 should be used.

DRAFT

Table 1 – Field-of-View

Data	Recommended Field-of-View	
	FOV, Deg from Pilot View Centerline (Note 1)	Approx. Distance (inches) From Reference Center Line (Note 1)
PFI – Basic T – Electronic or Mechanical	4 (Note 2)	2 (Note 2)
Navigation Course Error Data (HSI, CDI, FD)	15	8
Autopilot and /Flight Director Modes	15	8
Navigation Source Annunciation)	15 (Note 3)	8 (Note 3)
System Warnings-Including failure annunciation	15 (Note 4)	8 (Note 4)
Required Powerplant	35	21
Caution and Advisories Annunciations	35 (Note 4)	21 (Note 4)
Standby Instruments	20 (Note 5)	11 (Note 5)
Reversionary Display for PFI	35	21
Electronic Map Display that is used to monitor intended track in lieu of CDI/HSI/FD	35 (Note 6)	21 (Note 6)
Electronic Map Display– Used for position awareness	60	52

Note 1. The FOV angles and Approximate Distance from Center Reference Line, based on a viewing distance of 30 inches from the panel, are defined as acceptable angles and distance to each data source from the center of basic T, or pilot view centerline. Distances are measured center to center of the display in question, measured horizontally. Vertical placement in the panel can be from just below the basic T to the glare shield.

Note 2. PFI should be displayed as close to the center of reference as possible.

Note 3. The navigation source annunciation should be on or near the affected display and should appear on the same side of the basic T as the affected display. The guidelines for the proximity to the affected display depend on the size, color, and distinguishing characteristics of the source annunciation.

Note 4. Warnings can be presented within 35 degrees if they are associated with an aural tone or a master warning/caution light that is within 15 degrees. The warnings should be in a consistent location, such as on an annunciator panel. If an aural tone is used, it must be readily distinguishable from all other cockpit sounds and provide unambiguous information to direct the pilot's attention to a visual indication of the condition. Consideration must be given to the number of aural alerts.

Note 5. The standby instruments should be installed as close as practicable to the PFI.

Note 6: If a map display is used for navigation (instead of a CDI, HSI, or flight director), then it should meet the 15-degree FOV requirement identified for the steering command.

DRAFT

16.0 LEGIBILITY

16.1 Visual Performance

All displayed symbols and graphics should be clearly differentiated from one another and legible under all ambient illumination conditions. SAE documents Aerospace Standard (AS) 8034, and ARPs 4067 and 1068B, may be used as guidelines for evaluating the visual performance parameters of the electronic displays relative to viewing, photo colorimetric, luminance characteristics, etc. These conditions range from the night environment to direct sunlight through any window with the operational brightness at the luminance expected at the display's useful end-of-life state. The end-of-life luminance level represents the expected value of the display brightness or minimum acceptable output that is established by the manufacturer. The display luminance should sufficiently provide a comfortable level of viewing with rapid adaptation when transitioning from looking outside the cockpit.

16.2 Luminance Level

The luminance level of some displays will gradually diminish over the life of the unit. As part of the continued airworthiness requirements of § 23.1529, consider establishing an operational in-flight evaluation or maintenance evaluation to determine the minimum luminance level appropriate for the type of display, flight deck location, method of format, symbology, color used, etc. Although automatic luminance control compensation is not required, incorporating such a system may decrease pilot workload. Regardless of whether an automatic luminance control is incorporated, provide a manual luminance control that is not adversely affected by failure of any automatic luminance control. Luminance control should not result in some information disappearing while other information remains visible.

17.0 SYMBOLOGY AND FORMAT

17.1 Related Symbology

Electronic displays in the cockpit should have related symbology and format consistent with their intended use. Symbols should be readable. Instrument scaling and dynamics should be appropriate for the performance level of the airplane and (acceptable for TSO). Symbols should not have shapes that are ambiguous or could be confused with the meaning of some similar symbol. The symbology should avoid distraction, such as excessive flashing, or use other attributes that conflict with standardized meanings of alerts and warnings. Symbols should be similar to those shown with established industry standards. Appendix A to SAE ARP 4102/7 provides recommended symbols for Electronic Attitude Direction Indicator (EADI) and PFD used in the flight deck of transport aircraft. ARP 5289 provides recommendations for symbols on electronic map displays.

DRAFT

17.2 Distinctive Symbols

Symbols should be distinctive to minimize misinterpretation or confusion with other symbols utilized in the displays. The type and function of symbology should be clearly defined and appropriately classified for pilot understanding. Symbols representing the same functions on more than one display should utilize the same shape and/or color-coding. Also, use of flashing letters such as an "X" should be consistent: flashing, when used, should not be a caution for one parameter and a warning for another. Although the use of different types of symbols and formats among displays is discouraged, it may be acceptable if the pilot can quickly and consistently recognize, interpret, and respond correctly to the symbol or format without incurring excessive pilot workload. For example, to indicate bank angle on the attitude displays in the cockpit, the type of pointer, ground (fix) or sky (moveable), should be similar for ease of interpretation and to minimize confusion.

17.3 Clutter

Powerful formats are possible with an electronic display system, but too much information could result in clutter and reduce the efficiency of the pilot cues. Density of the information on the display should be compatible with the pilot's ability to recognize essential information and to minimize misinterpretation. Symbols and markings that are displayed during specific phases of flight may be removed at other times to reduce clutter. Consider the minimum display size for suitable readability. In the reversionary or compacted modes, when combining essential information on a display after another display or unit fails, the display format should not be confusing and the information should still be usable, including unusual attitude. Attitude, altitude, and airspeed information on the primary electronic display should not be inhibited during these modes. The approved configuration (whether basic-T configuration or a new configuration) should be preserved.

17.4 Automatic De-clutter

The PFD should have an automatic de-clutter function on the attitude function during unusual attitudes. Without any pilot actions, only altitude, attitude, direction, airspeed indication, and airspeed trend should be display on the PFD during attitudes exceeding 70 degrees of bank or +/-30 degrees of pitch. (Note: Not applicable to aerobatic category airplanes). In this situation, display on the PFD should be limited to altitude, attitude, direction, and airspeed indication. Basic navigation information on the primary navigation display does not need to de-cluttered.

17.5 Direct-Reading

Direct-Reading presentation of airspeed, altitude, attitude, or certain propulsion parameters (as applicable) should convey to the pilot a quick-glance sense of rate and trend information. For airspeed and altitude, direct-reading alphanumeric displays may not be adequate on the primary display or on the standby instruments, but it is acceptable on a display used as supplementary information. If the applicant proposes a direct-reading

DRAFT

alphanumeric display, they should demonstrate that the pilot response is equal to or better than the response with analog data (symbology) using a human factors evaluation. The application of direct-reading alphanumeric displays to propulsion parameters should be made with care, and it is subject to evaluation on a case-by-case basis. See paragraph 9.4 of this AC for additional guidance.

17.6 Round Dial

The display of a round dial-moving pointer with a digital readout is acceptable. To accommodate a larger operating range on a linear tape, adopt a moving scale display with the present value on a digital readout. Since the moving scale display typically does not provide any inherent visual cue of the relationship of present value to low or high airspeed limits, quick-glance awareness cues may be needed.

17.7 Low-Speed And High-Speed Awareness Cues

Airspeed displays with fixed pointers and moving scales should provide appropriate low-speed and high-speed awareness cues. Conventional mechanical airspeed indicators for part 23 airplanes include simple green and white speed arcs that, when combined with a moving pointer, provides pilots with adequate low-speed awareness. Airspeed displays incorporating fixed pointers and moving scales require more cues than conventional indicators to compensate for their deficiencies. For part 23 airplanes, prominent green and white arcs provide the pilot with speed cues but not enough to be considered equivalent. Therefore, low-speed awareness cues are necessary for part 23 airplanes. The low-speed awareness cues should include a red arc starting at V_{SO} and extending down toward zero airspeed. The applicant may choose a single conservative stall speed value to account for various weight and flap configurations (reference § 23.1545(a)(4)). For most part 23 airplanes, a fixed value at gross weight and full flaps is acceptable since this has been an adequate safety standard for mechanical gauges. A red arc extending from V_{NE} or V_{MO} upward to the end of the airspeed tape should also be incorporated.

Note: The red arc below the stall speed is intended for low speed awareness only and is not intended to limit flight operation.

17.7.1 V_{NE} Airplanes

The applicant must demonstrate compliance to 14 CFR, part 23, §§ 23.1311(a)(6) and 23.1545 (paragraphs (a) through (d)), and incorporate the following speed awareness cues for V_{NE} airplanes as shown in Figure 2.

- Red band should be incorporated from V_{SO} to 0 (or minimum number).
- Red band should be incorporated from V_{NE} to the top of the airspeed tape.
- An optional yellow band in the low speed range from V_{SO} to V_{S1}. The yellow band is discouraged (due to clutter) for twin-engine airplanes that incorporate a red and blue line, per § 23.1545, for one-engine-inoperative speeds.

DRAFT

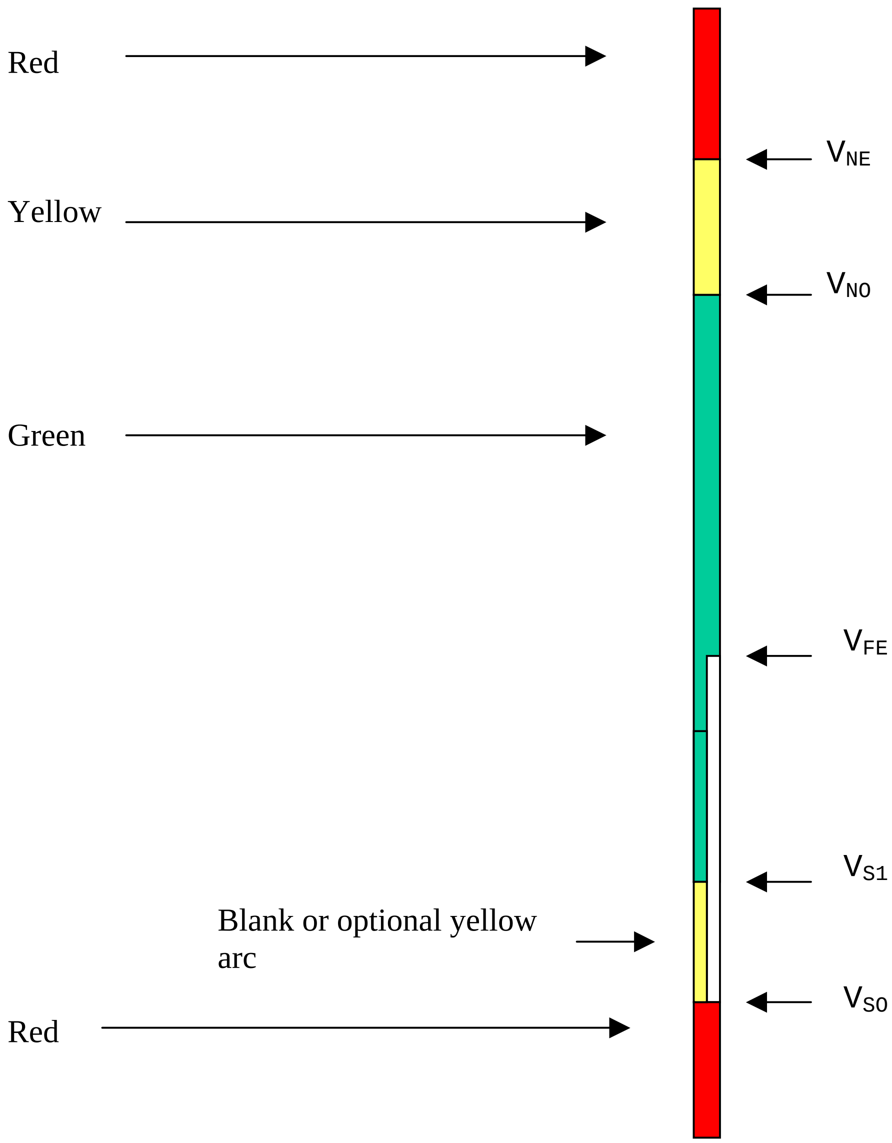

Figure 2. Low-Speed and High Speed Awareness for V_{NE} Airplanes

17.7.2 V_{MO} Airplanes

The applicant must demonstrate compliance to 14 CFR, part 23, §§ 23.1311(a)(6) and 23.1545 (paragraphs (a) through (d)), and incorporate the following speed awareness cues for V_{NE} airplanes as shown in Figure 3.

DRAFT

- Red band should be incorporated from V_{SO} to 0 (or minimum number).
- Red band should be incorporated from V_{MO} to the top of the airspeed tape.
- The green arc for normal operations is not required, but it may be used if previously approved.
- An optional yellow band in the low speed range from V_{SO} to V_{S1}.

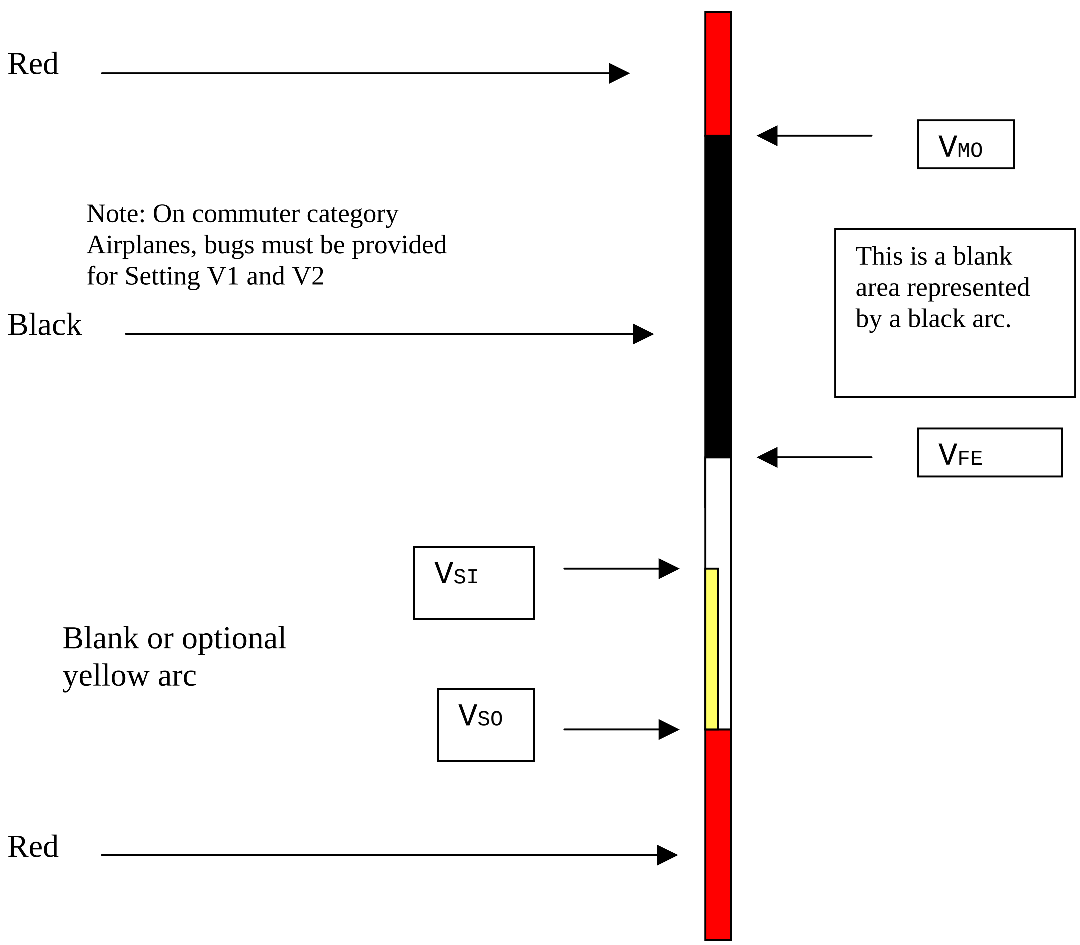

Figure 3. Low-Speed and High Speed Awareness for V_{MO} Airplanes

17.7.3 Primary Flight Display

Low-speed awareness is an important PFD display function. Stalls remain in the top five causes of fatal accidents for all types of part 23 airplanes, so it makes sense to use the unlimited display capability of new part 23 electronic PFDs to address low-speed awareness more effectively.

DRAFT

Historically, with traditional round dial instruments there was no ability to put color arcs on the airspeed indicator. Newer part 23 airplanes are required to also have a stall warning that sounds at 5-10 percent above stall. This was the best that could be afforded with existing technology. Unfortunately, the vast majority of stalls occur in V_{MC} and the pilot probably is not looking at the airspeed indicator when the airplane is slowing to a stall.

With electronic displays, designers are not constrained to simply reproducing the old round-dial type displays. The displays can have features that were not possible on conventional instruments. Applicants should consider using the display capabilities to catch the pilot's attention away from looking out the window or fixating on flight or navigation displays such as the flight director or HSI. One example that the applicants might consider is flashing a large red "STALL" in the center of the PFD and MFD. These should be large enough to catch the pilot's attention using peripheral vision. Another example is to display an angle-of-attack (AOA), or AOA-like display, above the airplane symbol (or equivalent) essentially showing the stall margin. An AOA scheme is preferred because pilots can see their stall margin diminishing and take corrective action based on a trend.

17.8 Linear Tape Altimeter Displays

Linear tape altimeter displays should include enhancements denoting standard 500- and 1,000-foot increments, and they should convey unambiguously, at a glance, the present altitude. 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 pilot's sense of altitude. The scale length should also allow sufficient look-ahead room to adequately predict and accomplish level off. Pilot evaluations have shown that, in addition to the appropriate altitude markings commensurate with aircraft performance, the use of an altitude reference bug is recommended to provide acceptable cues.

17.9 Heading Display

The heading display should provide a clear and unmistakable display of aircraft symbol and heading. HSI should provide a clear and unmistakable display of aircraft position, heading, and track relative to the desired course/track. Pilot computation or interpretation should be minimized. On the primary display, the heading scale should have a mode that presents at least 120 degrees of arc. Other display formats may be acceptable and have been previously approved, but they need to be evaluated for human factors effectiveness.

17.10 Alternative Formats

Alternative formats or arrangements to those described above should have an adequate human factors evaluation completed to show that pilot response is timely and accurate to at least the level of the existing conventional displays. Human factors criteria should be defined as part of the design process. Because displays are a function of the specific cockpit

DRAFT

layout and configuration, human factors evidence needs to be provided during certification. Specific human factors evaluations and studies that have been performed may support the configuration of displays and their location in the cockpit. An alternative is validating these evaluations/studies on each airplane during the installation process of the certification.

17.11 Integration of Display Parameters

Integration of a number of display parameters into one common display provides distinct benefits, but it raises some certification issues. New approaches presenting data and commands to the pilot are encouraged. To overcome the issues that may occur as a result of this integration, present the data and commands in a simple format to alleviate any increase in pilot workload. Specific areas to address include more intuitive guidance commands, combination of various navigation sensors, and similar functions. One example would be where the pilot selects a destination point (that is, a runway, an altitude, a fix, etc.). The system commands would provide guidance to that point, which could integrate the attitude sensor information, navigation data, air data information, etc., in a common display command element without the raw data being provided to the flight crew. The overall goal of this effort is to meet or exceed the existing cockpit performance levels currently in operational use while maintaining pilot workload at acceptable levels.

17.12 Overlays

If overlays are provided, the display format should allow the pilot to overlay weather or other graphics relevant to the flight path on one display without ambiguity. Each new graphic should be evaluated both individually and with allowed combinations of other weather, terrain, and navigation symbology to guard against confusing the pilot or cluttering the screen. When layering two or more functions, the use of the same or similar color to convey different information is not recommended. If the usage of the same or similar colors is required, then the meaning of the different information must be retained. This may be done by the use of patterning, bordering, or blanking to clearly depict the different sets of data.

If overlays are presented, the data must be presented in an airplane heading orientation. All overlay data shall be the same map orientation and scale as the display it is placed on. For additional information, see RTCA/DO-257A. Orientation of the presentation on any navigation display should not change when an overlay is added, unless required by TSO guidance. A thumbnail display is not considered an overlay.

17.13 Layering

The ability to perform layering is one of the greatest strengths of an electronic display, but it also creates the potential to produce cluttered or misleading information. Therefore, the number of layers shall not cause the information displayed to become unusable through cluttering or obscuration. Combinations of multiple data presentations shall not cause conflicting interpretation of the symbology or icons. Conflicting range scaling shall not

DRAFT

occur. Map range should be provided. Range scale for the primary navigation display should always be displayed to the pilot in the same location on that manufacturer's product.

18.0 ANNUNCIATION

18.1 General

The electronic display system should provide the pilot with visibly discernible annunciators that will indicate the system operating modes. The visual annunciators should be distinctive under all normal lighting conditions and consistent with cockpit warnings. Under night lighting with the display average brightness at the lowest usable level for prolonged flight, visual annunciators should be usable. Annunciations should be consistently located in a specific area of the electronic display to ensure proper interpretation by the pilot. Except for a flight director display, use of the display selection control position as annunciation is acceptable only when the control position is in direct view of the pilot, without head movement, and when the control position is obvious under all lighting conditions. When a failure occurs or when reversionary modes are used, an annunciation of abnormal system status shall be provided, per § 23.1311(a)(7). The display should not provide hazardously misleading information. Annunciations that require flight crew action should be evaluated to determine if the required actions could be accomplished in a timely manner without exceptional pilot skill. A failure of any PFI sensor input to the PFD must be appropriately annunciated on the PFD.

18.2 Multiple System Configurations

Where multiple system configurations and more than one sensor input are available for source selection, the switching configuration by annunciation or by selector switch position should be readily visible, readable, and should not be hazardously misleading to the pilot using the system. Labels for mode and source selection annunciators should be compatible throughout the cockpit. To ensure that the flight crew can properly interpret the system status, cautionary annunciation methods should be consistent when numerous interface-switching configurations are possible.

18.3 Alerting Messages

Alerting messages should differentiate between normal and abnormal indications. Abnormal indications should be clear and unmistakable, using techniques such as different shapes, sizes, colors, flashing, boxing, outlining, etc. Individual alerts should be provided for each function essential for safe operation.

18.4 Visual Crew Alerting and Display Prioritization

Due to the ability to display information from a number of various sources on an integrated display, a prioritization scheme ensures the continuous availability of essential information to the flight crew. Prioritization of time critical alerts such as TAWS, Predictive Windshear

System (PWS), Traffic Alert and Collision Avoidance (TCAS), and Reactive Windshear System (RWS) have been established for small airplane category airplane applications and are shown in AC 23-18. Crew alerting information systems require the prioritization of warning, caution, or advisory information to be appropriately established. This prioritization includes both visual and aural alerts. The use of layering the new information over an existing moving map display or an existing weather display as a result of an automatic pop-up capability is a common technique. Annunciation of any system level warning, caution, and advisory alert should be compatible with the time critical alert schema. Systems information displayed on the MFD should be prioritized in such a manner that it will allow ready access to critical information. Less critical information may be less accessible. A means should be provided for the flight crew to select higher priority information as needed with a single entry on the MFD control panel or keypad.

18.5 Visual Alerts for Time Critical Warnings

Visual alerts for time critical warnings that require immediate pilot action should be annunciated with an aural. Terrain, traffic, and weather are typically displayed in a layered format on the Navigational Display (ND), although weather and terrain cannot be displayed at the same time in many current designs. Existence of a time critical threat should trigger an automatic pop-up and the appropriate display on the ND, as well as the appropriate aural alert. Subsequent time critical alerts of a higher priority may override the visual display, but must override the previous aural alert. Other MFD functions, such as checklists, synoptic and expanded systems information, should only be shown when selected by the crew or displayed by phase of flight.

18.6 Supplementary Monitoring of System Status through Independent Sensors

Electronic displays can present system parameters, such as engine instruments, that can serve as supplementary information to the certified aircraft systems. This information can use sensors that are completely independent from the originally approved sensors. When supplementary information is presented using independent sensors, the presentation cannot interfere or conflict with the primary information. Any exceedance should be clearly annunciated and/or displayed to the pilot in the appropriate color, per 14 CFR, part 23, §§ 23.1322 and 23.1549. The Airplane Flight Manual Supplement (AFMS) and/or the Pilot Operating Handbook must clearly identify the relationship and procedures associated with those annunciations.

19.0 LAG TIME AND DATA UPDATE

The display of information essential to the safety of flight should be thoroughly responsive and accurate to the operational requirements. Electronic display system delay effects of essential information, including attitude, airspeed, altitude, heading, and specific propulsion parameters, should not degrade the pilot's ability to control the airplane. Any lag introduced by the display system should be consistent with the airplane control task associated with that

DRAFT

parameter. Update rates of data on displays must be fast enough so that required symbol motion is free from objectionable lag or stepping.

SAE ARPs provide recommended lag times for display of the format and primary flight data, and minimum rates for data updates, to meet symbol motion. A 50-60 Hz refresh rate is typically adequate to remove traces of visible flicker on the display. Frequencies above 55 Hz for stroke symbology or non-interlaced raster and 30/60 Hz for interlace raster are generally satisfactory. Some map information may be judged as adequate for enroute navigation displays with update rates of at least 1 Hz, depending on the specific aircraft. Other critical data, such as attitude, heading, or air data symbology, should be updated at a rate of at least 15 Hz, depending on the airplane.

20.0 CONTROLS

Display controls should be clearly visible and usable by the pilot, with the least practicable deviation from the normal position and from the line of vision when the pilot is looking forward along the flight path. Controls should have an appropriate amount of tactile feel (for example, detents, friction, stops, or damping, etc.) so that they can be changed without undue concentration, which minimizes the potential for inadvertent changes. Controls need to be designed for the pilot to use intuitively. The controls should be easily identified and located in all lighting conditions, allow differentiation of one control from another, and have feedback through the system appropriate for the function being controlled.

21.0 TEST FUNCTIONS

The electronic display should incorporate a pilot selectable or automatic test mode that exercises the system to a depth appropriate to the system design. This function should be included even if the system failure analysis is not dependent on such a mode, or if display test is also a maintenance function. The test mode (or a sub mode) should display warning flags in their proper locations. Alerting and annunciation functions that are necessary to alert the pilot of unsafe conditions should be exercised. It has been found acceptable to incorporate the display test with a centralized cockpit light test switch to have the display test function disabled when airborne. The test mode may provide a convenient means to display the software configuration.

22.0 COLOR STANDARDIZATION

22.1 General

Color is considered an enhancement for understanding the display information that leads to performance improvement. Select color to minimize display interpretation errors. A proliferation of color sets can ultimately reduce safety rather than increase it. Using contrast between basic colors provides a better differentiation of display elements than arbitrarily using colors near to each other in the color table. Prior to defining the color standard to be used in a specific display, establish a consistent color philosophy throughout the display.

DRAFT

The FAA does not intend to limit electronic displays to the below listed colors, although these have been shown to work well. The following section depicts colors found acceptable for compliance with § 23.1322, and other recommended colors as related to their functional meaning for electronic display systems. Deviations may be approved with acceptable justification. The use of the colors red and yellow for other than warnings and cautions is discouraged.

22.2 Color for Display Features

Display features should be color coded as follows:

Warnings	Red
Flight envelope and system limits	Red
Cautions, abnormal sources	Amber/Yellow
Earth	Tan/Brown
Scales and associated figures	White
Engaged modes, flight guidance	Green
Sky	Cyan/Blue
ILS deviation pointer	Magenta
Flight director bar	Magenta/Green
Pilot selectable references (bugs)	Magenta

22.3 Color Sets

One of the following color sets should be used:

	Color Set 1	Color Set 2
Fixed reference symbols, i.e., lubber lines	White	Yellow*****
Current data, values	White	Green
Armed modes	White	Cyan
Selected data, values	Green	Cyan
Selected heading	Magenta******	Cyan
Active route/flight plan	Magenta	White

*****The extensive use of the color yellow for other than caution/abnormal information is discouraged.

******In color set 1, magenta is associated with those analog parameters that constitute "fly to" or "keep centered" type information.

22.4 Color for Depiction of Weather Precipitation and Turbulence

The depiction of weather precipitation and turbulence should be coded as follows:

DRAFT

Precipitation	0-1 mm/hr		Black
	1-4	"	Green
	4-12	"	Amber/Yellow
	12-50	"	Red
Above 50		"	Magenta (other colors may be acceptable)
Turbulence		"	White or Magenta
Icing		"	Light Blue

A background color (neutral color) may be used to enhance displaypresentation.

22.5 Color Deviation

When the color assignments deviate from the above color set, the applicant should ensure that the chosen color assignments are not susceptible to confusion of symbol meaning and increased workload. Where appropriate, color assignment should be consistent with other color displays in the panel. Luminance and color differences should not be confusing or ambiguous under any operating ambient illumination conditions. The specific colors should be consistent with change in brightness on the displays over the full range of ambient light conditions. Under high and low levels of lighting, color degradation should not prevent the pilot from properly interpreting display information. Where precipitation is integrated with other information, the precipitation colors can be presented at half intensity. Service experience has shown that this provides enhanced presentation and reduced ambiguity. Warnings should be at full intensity.

22.6 Enhancement

Color is an enhancement for understanding the display information that leads to performance improvement, but it should not be the sole means of discrimination of critical information. Use symbols or letters, in addition to color, to further enhance the effectiveness of the display. Use of color alone has been shown to be less effective than when used in conjunction with distinct symbol (object, graphic, or letter). Color degradation should be obvious and should not preclude the pilot from interpreting the remaining display information. Displays should remain legible, stable, and unambiguous when operating in a degraded mode.

22.7 Color for Warnings and Cautions

For warnings and cautions, § 23.1322 provides specific requirements for the assignment of red and amber for visual annunciations. Red should be used as the warning annunciation for emergency operating conditions when immediate flight crew recognition is required, and immediate correction or compensatory action may be required. Amber should be used for the cautionary annunciation for abnormal operating conditions when immediate flight crew awareness is required, and subsequent flight crew action may be required. White or another unique color should be used for advisory annunciations of operating conditions that require

DRAFT

flight crew awareness, and action may be required. Green should be used for indication of safe operating conditions.

22.8 Airplane Flight Manual

A complete list of warnings, cautions, and annunciation messages should be included in the AFM, supplemental AFM, and placards. If the manufacturer's Pilot Operating Guide is found adequate and acceptable, it may be referenced in the AFM or supplemental AFM as a means to satisfy this requirement

23.0 COLOR FOR AVIATION ROUTINE WEATHER

23.1 General

Electronic color graphic display of aviation routine weather to surface meteorological data often refers to METARS. Additional policy is being developed to provide guidance for standardized use of the colors magenta, red, yellow, and or amber for cockpit display of weather information related to graphical METARS. This guidance is also being discussed in the RTCA special committee 195, which is developing a revision to RTCA/DO-267. The following management strategy was issued for future revisions of RTCA/DO-257 and RTCA/DO-267. **Note:** This section will be updated as more guidance is developed.

23.2 Color Issues Framework Agreement

23.2.1 Flight Information Services

For flight information services (FIS) products, such as weather graphics and potentially hazardous airspace, the philosophy governing the use of green-yellow-red-magenta is the "situation awareness" philosophy of "increasing potential hazard," the traditional color usage for on-board weather radar. The crew alerting philosophy for systems status annunciators, which is expressed in § 23.1322, does not govern FIS products. Additional guidance will be in section 3.8.2.1 of RTCA/DO 267, which is drafted.

23.2.2 Graphics METARS

Red may be used on graphical METARS to depict airports with "low IFR" conditions, i.e., ceiling and visibility below non-precision approach minima. Magenta may be used to depict below Category I weather minima. Additional guidance will be in Table II of RTCA/DO 267, which is being drafted. Graphics showing various levels of icing and turbulence (such as Current Icing Potential (CIP), on the Aviation Digital Data Service (ADDS) server) may use red to depict the highest levels of potential or intensity.

Red may be used to depict temporary flight restrictions (TFRs), and similarly for prohibited and restricted areas.

DRAFT

23.2.3 Weather Phenomena

Maps simultaneously showing multiple weather phenomena (such as the upcoming National Weather Service (NWS) Graphical Area Forecasts), may use colors in a way that deviate from the potential hazard philosophy, but use as little color as possible. The following is permissible, but whatever color scheme is used should be used consistently.

Magenta:	Mountain Obscuration
Red:	Convective Significant Meteorological Advisories (SIGMETs)
Yellow:	IFR
Green:	Turbulence
Blue:	Icing

23.2.4 Overlays

Overlays should be governed by the principles specified in proposed Appendix I to RTCA/DO-267. The text of section 3.8.3 of RTCA/DO-267 should include additional points from the summary. These include methods of de-cluttering the display, having maps with "yellow" items pop up on the screen, and not allowing the red from situation awareness products (such as weather) to obscure the red from a pilot alert function (such as TCAS). Additional guidance will be available in section 3.8.3 of RTCA/DO 267, which is being drafted.

RTCA/DO 257A provides guidance on color for Depiction of Navigational Information on Electronic Maps. This RTCA document should also be modified to be consistent with the above principles. Examples of depictions that meet and do not meet the above principles should be added to RTCA/DO 267.

24.0 AIRCRAFT ELECTRICAL POWER SOURCE

24.1 Electrical Power

Each electronic display instrument system should be installed so that it receives electrical power from a bus that provides the necessary reliability, per the § 23.1309 safety assessment, without jeopardizing other essential or critical electrical loads connected to that bus. The applicant should provide a means to indicate when adequate power is available for proper operation of the instrument.

24.2 Power Interruptions

Use techniques that reduce the momentary power interruptions or design the equipment so momentary power interruptions will not adversely affect the availability or integrity of essential information required for continued safe flight and landing. The category selected from RTCA/DO-160( ) for momentary power interruptions should be appropriate for the intended use. The PFD being used by the pilot during the takeoff phase of flight should be

DRAFT

usable within one second after a momentary power interruption up to 200-millisecond duration. Large electrical loads required to restart an engine (for example, turboprops and small jets) should not affect the availability or integrity of essential information required for continued safe flight and landing.

24.3 Independent Power Source

Each reversionary or standby display providing primary flight information should be powered from a power source that is independent of the source for the primary display and should function independently from the primary display, such as a second alternator or battery. The power source for each reversionary display should provide for uninterrupted operation for at least 30 minutes after failure of the power source for the primary display. The independent power source may be provided by manual or automatic means. Section 23.1353(h) requires a minimum supply of 30 minutes of electrical power to the essential loads for continued safe flight and landing of the airplane should a complete loss of the primary electrical power generating system occur, including the reversionary displays. The airplane's primary electrical power includes the airplane's electrical generating system and the airplane's starter battery when only one battery is installed. The starter battery is not considered an acceptable standby power source unless proper state of charge is monitored and displayed to the pilot. In this case, an ELOS may be required. See AC 23-17A for more guidance.

25.0 SAFETY ASSESSMENTS

25.1 Regulations Prior to and After Amendment 23-41

Part 23 regulations, promulgated before amendment 23-41, were based on single-fault or fail-safe concepts. A single failure would cause the loss of only one primary instrument function. Only mechanical or electromechanical instruments that function independently for the primary parameter display were envisioned; that is, flight and powerplant instruments were isolated and independent. In some cases, several other instrument functions (indication of the function, display, or indicator) are housed in a common case. Since electronic displays permit presentation of several parameters on one display, a failure in the electronic display may affect more than one required parameter. Section 23.1309, amendment 23-41, allowed approval of more advanced and complex systems. Amendment 23-41 also incorporated § 23.1311 into 14 CFR, part 23, which provides the standards for electronic displays. Section 23.1311, amendment 23-49, revised and clarified the secondary instruments and the visibility requirements.

25.2 Common-Mode Failures

Section 23.1311(b) states that “the electronic display indicators, including their systems and installations, and considering other airplane systems, must be designed so that one display of information essential for continued safe flight and landing will remain available to the crew, without need for immediate action by any pilot for continued safe operation, after any single

DRAFT

failure or probable combination of failures." In general, without considering specific characteristics of an airplane design, information essential to continued safe flight and landing are attitude, airspeed, altitude, warnings, and any applicable propulsion parameter(s). Major common-mode failures should be addressed. These include such failures induced by software errors, lightning effects, electromagnetic interference, power transients, etc., that could simultaneously affect the display of more than one parameter. The criticality of these failure conditions is explained in AC 23.1309-1C.

25.3 Safety Analysis

Safety assessment methods for identifying and classifying each failure condition and choosing the method(s) of safety assessment are described in AC 23.1309-1C. Certification of electronic display systems may involve new and complex technology that may not utilize traditional service-proven design concepts. In this case, technically qualified judgment can be enhanced when a quantitative analysis is included in the safety assessment, whether or not a quantitative analysis is required by § 23.1309.

The use of electronic displays allows a higher degree of integration than was practical with previous electromechanical instruments. The evaluation of failure states and the determination of display function criticality in highly integrated systems may be complex. Safety assessment determination should refer to the display function and include all causes that could affect the displays of that function, not only the display equipment.

The installation of electronic systems in cockpits creates complex functional interrelationships between the pilots and other display and control systems. The FHA identifies the failure conditions for all display functions, analyzes the effects on the aircraft and flight crew, and assigns the corresponding criticality classification (no safety effect, minor, major, hazardous, catastrophic) while considering both loss of functions, malfunctions, and situations that provide misleading information.

A pilot initiated preflight test may be used to reduce failure exposure times associated with the safety analysis required under § 23.1309. If the flight crew is required to test a system before each flight, it should be assumed, for the safety analysis, that the flight crew will actually accomplish this test at least once per day, providing the preflight test is conveniently and acceptably implemented.

26.0 SOFTWARE AND HARDWARE DEVELOPMENT ASSURANCE

26.1 General

Applicants must show compliance to AC 23.1309-1C, regardless of the intended function of the display system. The equipment shall be designed to the appropriate software and hardware development assurance level(s) based on the intended function and application of the equipment, including and the aircraft class in which it is to be installed (see AC 23.1309-1C, Figure 2). The appropriate development assurance level(s) are determined by an

DRAFT

analysis of the failure modes of the equipment and a categorization of the effects of the failure on the operation of the aircraft. For the analysis for displays, a failure is defined as either a loss of function or the output of misleading information. Flight guidance information must meet the appropriate design assurance levels required for that function.

26.2 Software Guidance

26.2.1 General

AC 20-115B discusses how RTCA/DO-178B provides an acceptable means for showing that software complies with pertinent airworthiness requirements. All software used in electronic displays systems should be developed to the guidance of RTCA/DO-178B, Software Considerations in Airborne Systems and Equipment Certification, dated December 1, 1992, or another acceptable means of compliance, as agreed to between the applicant and the cognizant FAA Aircraft Certification Office (ACO).

26.2.2 Software Levels

The software levels for all software should be determined by the appropriate safety assessments (see AC 23.1309-1C, Figure 2) and any additional requirements, such as those specified by functional TSOs.

26.2.3 Field-Loadable Software (FLS)

Many electronic displays systems utilize Field-Loadable Software (FLS) as part of the TC/STC/ASC/ASTC installation. FLS is software that can be loaded without removal of the equipment from the aircraft installation. FLS might also include software loaded into a line replaceable unit (LRU) or hardware element at a repair station or shop. FLS can refer to either executable code or data. When obtaining certification approval for utilization of the FLS capability, refer to the guidance in Order 8110.49 and AC 20-145.

26.3 Electronic Hardware Guidance

If the electronic display system contains electronic devices whose functions cannot feasibly be evaluated by test and/or analysis, the electronic devices should comply with RTCA/DO-254, or other acceptable means of compliance, as agreed to by the cognizant ACO. The hardware levels for all hardware should be determined by the appropriate safety assessments (see AC 23.1309-1C, Figure 2) and any additional requirements, such as those specified by functional TSOs.

DRAFT

27.0 ENVIRONMENTAL CONDITIONS

27.1 General

The equipment environmental limits established by the manufacturer should be compatible with the operating environment of the airplane. Evaluation of the equipment installation should consider factors such as the maximum operating altitude of the airplane and whether the equipment is located within a temperature and pressure-controlled area. Applicable methods for testing the performance characteristics of equipment for specified environmental conditions are provided in RTCA/DO-160( ). Either test or analysis, or both, ensures the compatibility between the operational environment and the environmental equipment category of the laboratory tests.

27.2 Temperature

Electronic systems reliability is strongly related to the temperature of the solid-state components in the system. Component temperatures are dependent on internal thermal design and external cooling. In evaluating the temperature environment, consider the additional heat generated by the equipment, especially in a location where airflow is restricted. To determine if adequate cooling is provided, the evaluation should make maximum use of previous data from comparable installations thus limiting ground or flight tests to those installations that cannot be verified conveniently by other means. When the equipment-operating environment cannot be verified from previous experience or from an evaluation of temperature values in that equipment location, a cooling test should be conducted.

27.3 Attitude Information

Attitude information should continue to be presented for a minimum of 30 minutes after the in-flight loss of cooling for the primary instrument when operating in the normal operating environment (temperature/altitude). If proper performance of the flight instrument function(s) is adversely affected due to in-flight loss of cooling, such failure conditions should be annunciated. Automatic over-temperature shutdown of the system should be considered a failure condition. Subsequent pilot actions should be documented in the AFM or on placards. These actions may include procedures to allow possible recovery of a system that has an over-temperature shutdown condition.

27.4 Annunciation

Annunciation of in-flight loss of cooling or fan monitors may not be required if it is shown by a safety analysis or test demonstration that a hazardous or catastrophic failure condition does not occur. The safety analysis should consider the reliability of the fans, redundancies of the functions, reversionary features (such as the ability to transfer critical functions), the annunciation of over-temperature and its response time, and the availability of other flight instrumentation. In some systems, cooling fans may only be installed to extend the life of the components and not to prevent a failure condition or shutdown of the equipment. These types of installations do not require fan monitors or temperature sensors. If the cooling fans are needed to prevent a hazardous or catastrophic failure condition, install fan monitors or another method to determine the status of the cooling fan during preflight checks.

28.0 ELECTROMAGNETIC PROTECTION

Current trends indicate increasing reliance on electrical and electronic systems for safe operations. For systems that perform flight, propulsion, navigation, and instrumentation functions, electromagnetic effects should be considered. AC 23.1309-1C and AC 23-17A provides additional guidance for lightning and High Intensity Radiated Fields (HIRF) protection.

29.0 ELECTROMAGNETIC INTERFERENCE

The electronic display instrument system should not be the source of objectionable conducted or radiated interference; nor should it be adversely affected by conducted or radiated interference from other equipment or systems installed in the airplane.

30.0 IMPLOSION PROTECTION

The display unit should be designed and constructed to prevent implosion when the unit is operating over the range of normal and abnormal operating environment in the airplane. When a display unit contains a component containing lower pressure than the ambient atmospheric pressure and it is susceptible to implosion, no incapacitation of the flight crew or adjacent equipment should result if an implosion occurs. Test the display unit for the most severe environmental conditions of pressure and temperature levels, and test for variations in both normal and abnormal operating conditions (including overpressure and decompression) specified by RTCA/DO-160( ). To verify that the display unit is acceptable in the event of an implosion, the unit should meet the requirements in UL 1418 listed in paragraph 3.4 of this AC. Similarity of a particular display to a unit already tested may be used to comply with this requirement.

DRAFT