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# Minimum Operational Performance Standards for the Depiction of Navigational Information on Electronic Maps

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RTCA DO-257A

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## Foreword

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# 1.0 Purpose and Scope

## 1.1 Introduction

This document contains minimum operational performance standards (MOPS) for the graphical depiction of navigation information on electronic map displays (EMDs) used to improve the flight crew awareness of the aircraft/ownship position relative to other items depicted on the EMD. It includes requirements for electronic map displays depicting in-flight, airport surface, and vertical (profile) information.

Navigation information, as used in this document, is information intended to be used to assist the pilot to identify the aircraft's position with respect to flight plans, ground reference points, and navaid fixes (such as VORs, NDBs, etc.) as well as items on the airport surface. The requirements defined within this MOPS are not sufficient for the EMD to be used as the basis for maneuvering. Additionally, it assumes no changes to operational requirements. These standards may be applied to vector or raster based moving map displays (see definitions in section 1.8). These standards specify equipment characteristics that should be useful to designers, manufacturers, installers, and users of the equipment.

Compliance with these standards is recommended as one means of assuring that the equipment will perform its intended function(s) (see Intended Function(s) in section 1.4) satisfactorily under all conditions normally encountered in routine aeronautical operations. Any regulatory application of these standards is the sole responsibility of the appropriate governmental agencies.

Section 1.0 of this document provides information on purpose and scope needed to understand the rationale for equipment characteristics and standards stated in the remaining sections. It describes typical equipment applications and operational goals as well as establishes the basis for the standards stated in sections 2 through 3.

Section 2.0 contains general guidance and minimum performance standards for the equipment. These standards specify the required performance under standard operating and environmental conditions. Also included are recommended bench test procedures necessary to demonstrate equipment compliance with the stated minimums. Section 2.1 and 2.2 provide requirements for all EMDs addressed in this document, including in-flight, airport surface, and vertical (profile) information displays. Requirements in section 2.3 apply only to airport surface map displays. Requirements in section 2.4 apply only to vertical (profile) map displays.

Section 3.0 describes the requirements for installed equipment performance. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing, as described in section 2.

Appendix A is a list of abbreviations recommended for use with EMDs and associated documents. Appendix B contains a glossary of terms and acronyms, while Appendix C contains a bibliography and a list of all references cited in this document. Appendix D has a list of all "shall" requirements in the body of the document (summarized for the convenience of the applicant and test team). Appendix E contains color guidance. Appendix F is devoted to Raster Aeronautical Charts (RAC), while Appendix G

discusses Error Considerations for Raster Displays (e.g., Liquid Crystal Displays). Appendix H contains a table of recommended navigation aid symbology.

The word "equipment," as used in this document, includes all components and features necessary for the system to properly perform its intended function(s). Standards for the design and implementation of optional features, beyond those required for a minimum EMD, only apply if those features are implemented. This MOPS also includes characteristics of the operational environment for which these requirements are appropriate.

## 1.2 System Overview

An electronic map display system, herein referred to as EMD equipment or "the system," is a flight deck device or combination of devices which includes electronic map displays depicting in-flight, airport surface, and vertical (profile) information. The intent of this MOPS is to specify requirements for EMDs that are used as an aid to other means of navigating or taxiing the aircraft. It is recognized that the equipment that generates the electronic map defined in this document may also generate other information on the same display, such as a Course Deviation Indicator (CDI) or a flight director. However, this MOPS only addresses the aspects of the EMD specified in Figure 1-1 as items addressed in this MOPS. References to other standards are provided where available and appropriate.

As shown in Figure 1-1 the EMD will receive inputs from a navigation system or sensor (for example, flight management system, Global Navigation Satellite System (GNSS) (e.g., Global Positioning System (GPS)) navigator, etc.). The components that drive the EMD equipment, such as the navigation position source, database, etc., may be either internal or external to the physical box that houses the EMD. In either case, the requirements in this document pertain to the EMD, the associated human-machine interfaces (display, controls, etc.), and relevant internal database(s). In addition this document contains requirements related to the position sensor for Aerodrome Moving Map displays. In this MOPS, all other components are considered outside the scope of this document (see Figure 1-1).

### 1.2.1 EMD Systems Covered by this MOPS

The EMD equipment may have the physical form of a main processing unit including microprocessor, display, input/output of digital data signal and analog discrete signals, and program memory. Additionally, the processing unit will include or be complemented by a unit designed to allow for flight crew interface and interaction with the equipment, such as a control panel.

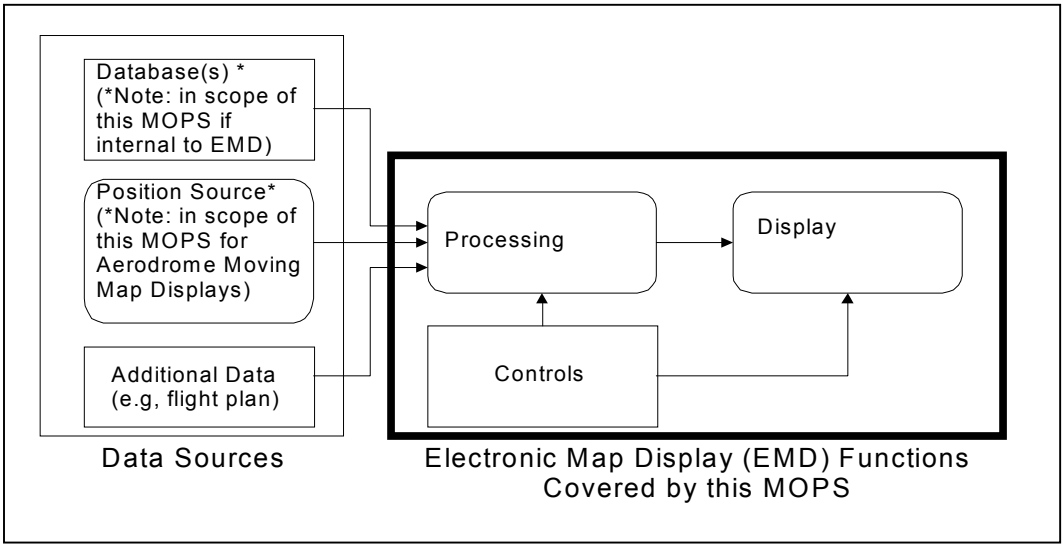


**FIGURE 1-1 ELECTRONIC MAP DISPLAY SYSTEM**

#### 1.2.1.1 Processing

The Processing unit receives inputs from Data Sources and Controls, combining the data and user inputs to present a map display on the Display device.

The system processing will have sufficient performance and capacity to carry out the full range of functionality of the EMD (including such minimum functions as required by this MOPS, and any other discretionary functions, as specified by the manufacturer) under all anticipated operating conditions.

#### 1.2.1.2 Display

The EMD includes a graphic display function for presenting pertinent navigation information to the pilot in accordance with the selections he has made regarding content, luminance, scale, and orientation.

#### 1.2.1.3 Controls

The EMD will include controls to adjust, manage or change the display and map information. Controls typically include those necessary to change luminance, map range, map orientation, and information content.

### 1.2.2 Data Sources

The requirements for those features labeled in Figure 1-1 as "data sources", including the database(s), and position source are addressed in this MOPS if they are an internal part of the EMD system. Requirements in other documents may also apply to the data source if it supports other functions not described in this document (e.g., RTCA DO-208[43], RTCA DO-229C[44], DO-236A[45], TSO-C129a[30], TSO-C115b[28], TSO C145a[31], and TSO C146a[32]).

*Note: When standards defining data interfaces between different systems do not exist, the certification package should include the definition of the interface between the EMD and other systems. Compliance with the interface requirements will be determined for each installation or certification.*

#### 1.2.2.1 Database

The database, defining locations of elements depicted on the EMD, can be either inside or outside of the EMD.

*Notes:*

1. *RTCA DO-200A/EUROCAE ED-76[41] contains minimum standards and guidance for the processing of aeronautical data that are used for navigation, flight planning, terrain awareness and for other applications. When applied, the standard will provide the user with assurance of the level of quality that can be associated with the processed data, (e.g., aeronautical database).*
2. *RTCA DO-201A/EUROCAE ED-77[42] contains standards and guidance for the development of the aeronautical information used in the navigation database.*
3. *RTCA DO-236A[45] contains minimum standards and guidance for navigation databases intended for RNP RNAV equipment. The section of RTCA DO-236A[45] entitled "navigation database requirements" provides an acceptable standard for minimum navigation database interface requirements and content.*
4. *RTCA DO-272/EUROCAE ED-99[48] provides standards and reference material applicable to the content, origination, publication, updating, exchange, and enhancement of aerodrome mapping information.*
5. *RTCA DO-276/EUROCAE ED-98[49] contains guidance applicable to terrain and obstacle data, identifies errors associated with terrain and obstacles, and suggests means by which these errors may be mitigated.*

#### 1.2.2.2 Position Source

A data interface will be necessary to receive ownship position information. For this MOPS, the position sensor is considered out of scope for in-flight and vertical situation displays, even if the position information originates from a sensor contained in the same unit. However, this MOPS does address position source requirements for Aerodrome Moving Map Display (AMMD).

*Note: While the position source is external to the EMD subsystem, it may be an internal component of a single device (e.g., a Global Navigation Satellite System (GNSS) receiver with integral moving map). In this case, for in flight and vertical situation displays, the position source performance, features, and capability requirements are not specified in this MOPS.*

#### 1.2.2.3 Additional Data

Additional information such as speed, track, flight plan (e.g., flight plan data from a navigation system, such as a flight management system), and details of nearby fixes may also be received.

## 1.3 Operational Application

This MOPS establishes requirements for a moving map display component of the operating environment and infrastructure. The map display system described in this MOPS is intended to be compatible with both existing and future airspace operations. Its display capability, performance, and functionality will support the intended function(s) and operational goals described in the sections below.

## 1.4 Intended Function(s)

The EMDs addressed in this document depict navigation information in a combination of textual and graphical form, which are used as an aid to other means of navigating or taxiing the aircraft. The EMD is intended to serve as an aid for pilots to identify the aircraft's location while in-flight (either horizontal and/or vertical) or on the airport surface. The term "situation awareness" is often used as an intended function for these types of displays. To be more specific the following potential intended functions are included below.

Potential intended functions may include any or all of the following:

1. The intended function of the plan view map display is to facilitate the pilot's awareness with respect to surrounding factors that may affect the overall conduct of the flight, such as flight plan, geographical features, or ground-based facility locations.

2. The intended function of the Vertical Situation Display (VSD) is to facilitate the pilot's awareness with respect to:

   - Stabilization of the aircraft's vertical flight path (e.g., speed component to this- slow down to a certain speed by a certain waypoint);

   - Aircraft energy management awareness (e.g., knowledge of speed vs. vertical descent- slow down to a certain speed by a certain waypoint)

3. The intended function for the aerodrome moving map display (AMMD) is to 1) assist flight crews in orienting themselves on the airport surface by enhancing the pilots awareness of ownship position on the airport surface and 2) improve pilot position awareness with respect to taxi operations.

*Note: The requirements in this document are not intended to be sufficient to support more critical applications such as runway incursion alerting, land and hold short operations, or surface navigation guidance. The requirements defined are not sufficient for the EMD to be used as the basis for maneuvering. The AMMD assumes no changes to operational requirements.*

For a discussion of failure classifications see section 2.1.8. If the EMD is intended to be used for functions beyond those addressed in this document, additional requirements may apply. All intended functions must be specified by the applicant. For example, if the display that depicts the electronic map also depicts other navigation information, such as a Course Deviation Indicator (CDI), that is intended for primary course guidance, it must meet the requirements described in the applicable references (e.g., RTCA DO-236A[45]; RTCA DO-229C[44]; TSO-C129a[30]; TSO-C115b[28]; AC 20-138[16], AC 25-11[19], AC 23.1311-1A[17], AC 27-1B[21] and AC 29-2C[22], AC 120-29A[25] or AC 120-28D[24], as amended, for Category I, II, or III). Additionally, aspects of the installation, size, scale, resolution, and sensitivity would be evaluated for any system proposed for guidance and control.

## 1.5 Operational Goals

The operational goal of EMDs addressed in this document is to improve the efficiency and safety of flight operations. Some expected results of using an EMD include:

1. Increased position awareness
2. Reduction in pilot deviations
3. Increased ability to detect data entry and flight planning errors
4. Reduction of runway incursions (AMMDs only) and collisions.

## 1.6 Assumptions and Scope

The design requirements and guidelines presented in this document assume several system characteristics and applications as listed below:

1. WGS-84[2] position reference system or an equivalent earth reference model is used for all displayed data. (Reference RTCA DO-236A[45]; ICAO Annex 15[2]).
2. This MOPS provides a baseline for the display of navigation information on an EMD, but does not contain an exhaustive or comprehensive list of shared display considerations (e.g., for a display system that simultaneously depicts navigation data integrated with terrain data or any other type of data).
3. The display function may be stand-alone or part of a multi-function display.
4. The intent of this MOPS is to specify requirements for EMDs that are used as an aid to other means of navigating or taxiing the aircraft. The requirements defined within this MOPS are not sufficient for the EMD to be used as the basis for maneuvering. Additionally it assumes no changes to operational requirements (e.g., no change to existing visibility requirements for taxiing). (Reference section 1.2).
5. This MOPS is not sufficient to comprehensively address requirements for EMD systems intended to be approved for navigation (i.e., where the EMD is the basis for maneuvering).
6. This MOPS is not intended to comprehensively address requirements for EMD systems using Raster Aeronautical Charts (RAC) intended to be approved for navigation (i.e., where the EMD is the basis for maneuvering) (see Appendix F).
7. This MOPS is not intended for heads-up displays (HUDs).
8. This MOPS does not specifically address:

- 3-D or 4-D perspective displays
- Night Vision Goggle compatibility (Reference Military Specification MIL-L-85762A[60]; Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible)
- Vertical status information in plan view map displays (plan view) (e.g. Altitude errors and altitude range arcs)

9. Unique aspects and issues associated with portable EMDs were not the primary consideration in the development of this MOPS. However, this guidance may be useful in assessing EMD functions that may be applicable to EFBs, including portable Class 2 devices (EFB). The guidance in this document may be used by applicants intending to request TSO Authorization, or applicants seeking Operational Approval. Applicants seeking Operational Approval of devices may use this guidance in any applicable hazard analysis, commensurate with the intended function and operational use of the device. Further guidance is provided in advisory circulars AC 23.1309-1C[18], AC 25.1309-1A[20] and AC 120-76A[26].
10. The unique aspects and issues associated with rotorcraft (e.g., taxi hover) were not considered in the development of this MOPS.

## 1.7 Test Procedures

The test procedures specified in this document are intended to be used as one means of demonstrating compliance with the performance requirements. Although specific test procedures are cited, it is recognized that other methods may be preferred. These alternate procedures may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

The order of the tests specified suggests that the equipment be subjected to a succession of tests as it moves from design and design qualification into operational use. For example, compliance with the requirements of section 2.0 will have been demonstrated as a precondition to satisfactory completion of the installed system test of section 3.0.

### 1.7.1 Environmental Tests

Environmental tests are specified in section 2.5. The procedures and their associated limit requirements are intended to provide a laboratory means of determining the electrical and mechanical performance of the equipment under environmental conditions expected to be encountered in actual aeronautical operations. Unless otherwise specified, the environmental test procedures contained in RTCA DO-160D[38] *Environmental Conditions and Test Procedures for Airborne Equipment* will be used to demonstrate equipment compliance.

### 1.7.2 Bench Tests

Bench test procedures are specified in section 2.6. These tests provide a laboratory means to demonstrate compliance with the requirements in section 2.2. Test results may be used by equipment manufacturers as design guidance for monitoring manufacturing compliance and, in certain cases, for obtaining formal approval of equipment design.

Due to the number of possible sensor complements and position-fixing modes for this equipment, it is deemed impractical to define complete test procedures for all current and future equipment designs. Test procedures contained in section 2.6 apply to the minimum system requirements in accordance with the minimum performance parameters specified in this standard.

### 1.7.3 Installed Equipment Tests

The installed test procedures and their associated limits and requirements are specified in section 3.0. Although bench and environmental test procedures are not included in the installed equipment tests, their successful completion is normally a precondition to the completion of the installed tests. In certain instances, however, installed equipment tests may be used in lieu of bench test simulation of such factors as power supply characteristics, interference from or to other equipment installed on the aircraft, etc. Installed tests are normally performed under two conditions:

1. With the aircraft on the ground and using simulated or operational system inputs.

2. With the aircraft in flight using operational system inputs appropriate to the equipment under test.

Test results may be used to demonstrate functional performance in the intended operational environment.

### 1.7.4 Operational Tests

The operational tests are specified in section 4.0. These test procedures and their associated limits are intended to be conducted by operating personnel as one means of ensuring that the equipment is functioning properly and can be reliably used for its intended function(s).

## 1.8 Definitions of Terms

This section contains a definition of terms used that may have multiple, special, or unique meanings in this document. Additional definitions for terms that are well established and do not have a special or unique meaning in this document are in Appendix B.

*Aerodrome:* A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure, and surface movement of aircraft. In this document the term aerodrome is used synonymously with the term "airport." (Reference ICAO Annex 14[1])

*Electronic Map Display (EMD)*: An electronic map display system (as illustrated in Figure 1-1) including ownship position used to depict navigation information. This includes electronic map displays depicting in-flight, airport surface, and vertical (profile) information.

*May:* The term "may" in this document is used for items that are optional. They may be done or not.

*Must:* The term "must" in this document is used for items which are requirements, but required either by a "shall" in this document or by some other document (e.g., a regulation).

*Raster Aeronautical Chart (RAC):* A digital image created or captured as a set of samples in 2-dimensional space (e.g., by scanning a paper chart). The RAC is an array of pixels that define a digital image of that chart. See Appendix F for a further discussion of issues.

*Shall:* The term "shall" in this document is used to indicate requirements, for items which are requirements, as opposed to "should" items which are recommendations. Compliance with all "shall" statements is necessary in order to use this document as a means of compliance with a TSO or Advisory Circular which invokes this document.

*Shared Display*: A display that is used for a variety of display functions such as presenting navigation information, terrain data, and traffic information. The data may be presented in a single, integrated depiction, as layers where one data set overlays another, or the display may be switched from one function to another such that each data set is presented alone when it is selected.

*Should:* The term "should" in this document is used to denote recommendations or guidelines that do not constitute a requirement. Compliance with all "should" statements is not necessary in order to use this document as a means of compliance with a TSO or Advisory Circular which invokes this document. However, deviations from the recommendations (should statements) should be able to be justified.

*Swath:* the swath is the slice of the environment that is depicted on the VSD. That slice may include significant terrain, airports, navaids, other traffic, etc. On the plan view display the swath may or may not be depicted. See Figure 2-5 in section 2.4.1. The swath depicted may be based on a projection along the aircraft's current track (track mode), or along the desired path (flight plan mode).

*Vertical Situation Display:* A two dimensional profile display which depicts elevation or altitude along one axis versus range along the other axis.

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

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## 2.0 Equipment Performance Requirements and Test Procedures

### 2.1 General Requirements

While it must be determined that each requirement listed in this section (i.e., section 2.1 and all subsequent subsections) has been complied with, many of these requirements do not lend themselves to detailed test procedures. Thus, the requirements in this section do not have particular test procedures specified in the test procedure subsection. However, the EMD and associated controls must be exercised and assessed based upon the requirements in this section.

> *Note: In this document, the term "shall" is used to indicate requirements. An approved design must comply with every requirement. This can be assured by inspection, test, analysis, or demonstration. The term "should" is used to denote a recommendation or guideline that does not constitute a requirement.*

#### 2.1.1 Airworthiness

In the design and manufacture of the equipment, the manufacturer shall provide for installation so as not to impair the airworthiness of the aircraft.

#### 2.1.2 Intended Function(s)

The equipment shall perform its intended function(s) as defined by the manufacturer, and its proper use shall not create a hazard to the aircraft or its occupants.

#### 2.1.3 Federal Communications Commission Rules

All equipment shall comply with the applicable rules of the Federal Communications Commission.

#### 2.1.4 Fire Protection

All materials used shall be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets, and small electric parts) that would not contribute significantly to the propagation of a fire.

> *Note: The Code of Federal Regulations 14 CFR, Part23 and Part 25 - Appendix F contains the method of compliance in the United States.*

### 2.1.5 Controls

This section contains requirements and guidelines for the design of control hardware that may be used with EMDs. Guidance presented in the general section is relevant for all configurations of control hardware. Guidance for specific types of controls is also provided.

Controls should be designed to maximize usability, minimize flight crew workload, and reduce pilot errors. Operations that occur with high frequency or in the terminal area should be executable with a minimum number of control operations. The number of operations may be reduced through the use of dedicated controls, automated changes that anticipate flight crew requirements, and the use of quick access menus designed to facilitate rapid selection of display function or configuration options.

This document does not specifically address Cursor Control Devices. The following documents provide some design guidance for Cursor Control Devices:

1. Bullinger, H. J., Kern, P., Braun, M. (1997)[64]. Controls. In Salvendy, Handbook of Human Factors and Ergonomics (2nd ed., pp. 697-728). New York, NY: Wiley.

2. DOT/FAA/CT-96/1[36], *Human Factors Design Guide For Acquisition of Commercial Off-the-shelf Subsystems, Non-developmental Subsystems: Final report and Guide* (Wagner, Birt, Snyder, and Duncanson, 1996). Atlantic City, NJ: Federal Aviation Administration Technical Center. (Reference section 8.8)

3. Greenstein, J. S. and Arnout, L. Y. (1987) [70]. Human factors aspects of manual computer input devices. Chapter 11.4 in G. Salvendy (ed.), Handbook of Human Factors, New York: John Wiley & Sons, pp. 1451-1489.

4. Schneiderman, B. (1998)[72]. Designing the user interface: Strategies for effective human-computer interaction (3rd ed.). (Chapter 9) Reading, MA: Addison Wesley.

#### 2.1.5.1 General

1. The equipment shall be designed so that controls intended for use during flight cannot be operated in any position, combination or sequence that would result in a condition detrimental to the equipment or operation of the aircraft.

2. Controls shall provide feedback when operated.

   *Note: Tactile and visual cues are acceptable forms of feedback. Aural cues may also be acceptable.*

3. Controls shall be resistant to inadvertent activation.

4. The use of controls should not cause inadvertent activation of adjacent controls.

   *Notes: Common and acceptable means of reducing the likelihood of inadvertent operation through key design include the following:*

   1. *A minimum edge-to-edge spacing between buttons of 1/4 inch. (Keys should not be spaced so that sequential use is awkward or error prone.)*
   2. *Placing fences between closely spaced adjacent controls.*

3. *Concave upper surface of keys to reduce slippage.*

4. *Size of control surface sufficient to provide for accurate selection.*

5. Control operation should allow sequential use without unwanted multiple entries.

6. Manual controls used in flight shall be operable with one hand.

7. Activation or use of a control should not require simultaneous use of two or more controls in flight (e.g., pushing two buttons at once).

8. If a control can be used for multiple functions, the current function shall be indicated either on the EMD or on the control.

9. Controls should be designed for nighttime usability (e.g., illuminated).

   *Note: Control illumination may be achieved by either illuminating the control itself or providing flight deck (external) illumination. This will need to be evaluated on an installation specific basis.*

10. Labels shall be used to identify the functions of all controls used to manipulate the information content and operating characteristics of the EMD.

    *Note: This requirement applies to standard mechanical controls (e.g., buttons, knobs, etc.)*

**2.1.5.2 Layout**

1. Controls that are normally operated by the flight crew shall be readily accessible.

2. Controls should be organized in logical groups according to function and frequency of use.

3. Controls most often used together should be located together.

4. Controls used most frequently should be the most accessible.

5. Dedicated controls should be used for frequently used functions.

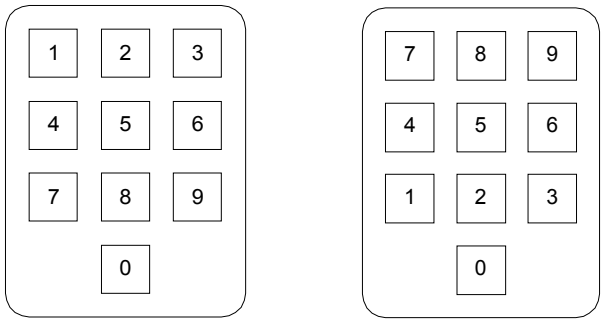
6. Line select function keys should acceptably align with adjacent text.

   *Note: Different installations result in different parallax issues. Consideration should be given to providing a skew function to account for different pilot-to-Control Display Unit viewing angles.*

**2.1.5.3 Keypads**

1. Letter keys should be arranged alphabetically or in a QWERTY format.

2. If a separate numeric keypad is used, the keys should be arranged in order in a row or in a 3X3 matrix with the zero at the bottom, as indicated in Figure 2-1.




**Telephone Style** **Calculator Style**

**FIGURE 2-1 KEYPAD LAYOUTS**

3. If non-alphanumeric special characters or functions are used, dedicated keys should be provided (e.g., space, slash (/), change sign key (+/-), "clear" and "delete," etc.).

### 2.1.5.4 Rotary Knobs

1. Where knob rotation is used to control cursor movement, sequence through lists, or cause quantitative changes, the results of such rotation should be consistent with established behavior stereotypes (Reference Sanders & McCormick, 1987[71]) as follows:

   a) For X-Y cursor control (e.g., moving a pointer across the surface of the map):

      - Knob below or to the right of the display area: clockwise movement of the knob moves the cursor up or to the right.
      - Knob above the display area: clockwise rotation of knob moves cursor up or to the left.
      - Knob to left of display area: clockwise rotation of knob moves cursor down or to the right.

   b) For quantitative displays, clockwise rotation increases values.

   c) For alphabet character selection or alphabetized lists, clockwise rotation sequences forward.

      *Note: This does not preclude the use of wrap-around lists.*

2. Concentric knob assemblies should be limited to no more than two knobs per assembly.

   *Notes: General conventions of concentric knobs are:*

   *1. Outer/large knob (the one closest to the face of the panel) changes cursor position, selects information category, operating/display mode, or large value changes.*

   *2. Inner/smaller knob is used to select among the information contents, sub categories of the position selected with the outer knob, or fine value changes.*

### 2.1.6 Color

Government guidelines and industry standards describing requirements and conventions in the use of color on flight deck displays are available for reference. These include 14 CFRs 23.1322[4], 25.1322[5], 27.1322[7], and 29.1322[8], AC 23.1311-1A[17], AC 25-11[19], SAE ARP4032[52], SAE ARP4102[53] and DOT/FAA/RD-95/1[35]. These standards are the basis for the following guidelines.

1. No more than six colors should be used for color-coding on the map display. See SAE ARP4032[52] and Appendix E for color guidelines.

   *Notes:*

   1. *Use of additional colors for other purposes should not detract from the discriminability of colors used for coding.*
   2. *This restriction on the number of colors may not apply to information shared with the EMD such as terrain and weather.*

2. Color-coded information should be accompanied by another distinguishing characteristic such as shape, location, or text.

3. The use of all colors must be consistent with commonly accepted aviation practice. The accepted practice for the use of red and amber is consistent with 14 CFRs 23.1322[4], 25.1322[5], 27.1322[7], and 29.1322[8] as follows:

   a. Red shall be used only for indicating a hazard that may require immediate corrective action.

   b. Amber shall be used only for indicating the possible need for future corrective action.

   c. Any other color may be used for aspects not described in items a-b of this section, providing the color differs sufficiently from the colors prescribed in these items to avoid possible confusion.

   *Notes:*

   1. *Requirements a & b are intended to preclude the excessive use of amber & red on the AMMD. They are not meant to inhibit the use of red and amber for the coding of surface signs, lights, and markings.*
   2. *These requirements are not intended to supersede system specific requirements in other avionics documents invoked by the FAA (e.g. TSO-C151b[33] (TAWS), TSO-C119b[29] (TCAS), AC 20-131A[15] (TCAS II)).*
   3. *For Flight Information Service (FIS) overlays, the color guidelines of RTCA SC-195 apply. RTCA DO-267[47] is being updated by SC-195 including guidelines on the use of color.*

4. Colors used with RACs should closely approximate the colors depicted on the paper chart.

   *Note: Items 1-3 do not apply to the display of RAC data, but do apply to any additional information superimposed onto the RAC.*

5. The color of any required symbol shall be the same on the plan view EMD and vertical situation display if they are on the same display or part of a multi-function display.

### 2.1.7 Effects of Tests

The equipment shall be designed so that the application of specific test procedures is not detrimental to equipment performance following the application of those tests, except as specifically allowed.

### 2.1.8 Design Assurance

The equipment shall be designed to the appropriate design assurance level(s) based on the intended function(s) of the equipment and aircraft class in which it is to be installed. The appropriate design assurance level(s) are determined by an 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 purpose of this analysis, a failure is defined as either a loss of function or the output of misleading information. Additional guidance is contained in advisory circulars AC 23.1309-1C[18] and AC 25.1309-1A[20] and section 1309 of AC 27-1B[21] and AC 29-2C[22].

If the equipment implementation includes a computer software package, the guidelines contained in RTCA DO-178B[39] should be followed.

The hazard classification for misleading information of either the airborne plan view EMD or Vertical Situation Display (VSD) is left to future work.

The following hazard classifications apply for EMD equipment intended to be used only as an aid to other, approved means of navigating or taxiing the aircraft (e.g., for IFR in-flight that means that the EMD must be used in conjunction with approved navigation equipment that provides course guidance):

1. The display of misleading information on an aerodrome moving map display (AMMD) is considered a minor failure condition.

2. Loss of function is considered to be a minor failure condition. However, loss of function of an AMMD might be deemed to have no safety effect depending on the operational use of the display.

*Notes:*

1. *The hazard classifications described above are based on the intended function described in section 1.4 and the airworthiness guidance for installed equipment published in AC 25.1309-1A[20] and AC 23.1309-1C[18]. For plan view map displays and VSD, misleading information can cause a significant increase in crew workload to resolve the discrepancy between the map display and the limited information provided by analog instruments. For aerodrome map displays, only a slight increase in workload is expected since the flight crew can more readily resolve a discrepancy by stopping and looking out the window. The loss of an EMD causes a slight increase in crew workload, as the crew will have to revert to other means of ascertaining their situation awareness that are less effective than the EMD.*

2. *The hazard classification for specific equipment may vary if the intended function is different. For example, if an AMMD is intended to be used as a means to determine the projected path of the aircraft while on the ground and take action based on this information, failure of the system could result in the display of misleading information which could cause or contribute to a "major" or " hazardous" failure condition for the aircraft (e.g., taxi guidance for low visibility operations or blind taxi). If an EMD is intended to be used as part of the navigation system (e.g., if it is a required component for complex RNP procedures), the loss of that function could be a major failure condition. Similarly, the failure condition may be less severe depending on the intended function and resulting impact to the aircraft and flight crew.*

3. *The hazard classification information described above is based upon existing guidance for compliance with airworthiness regulations. Airworthiness regulations do not apply to portable equipment that is not installed. FAA AC 120-76A[26], Guidelines for the Certification, Airworthiness, and Operational Approval of Electronic Flight Bag Computing Devices, provides some guidelines for portable equipment for 14 CFR Part 121[10], 125[11], 129[12], 135[13], and certain Part 91[9] operators.*

### 2.1.9 Shared Display Considerations

The usefulness of the EMD can be increased through the addition or integration of other functional capabilities such as weather, traffic, or terrain and obstacle depictions. Much of this information may be displayed with the basic map or in some cases it may temporarily displace it. The standards below are not intended to be an exhaustive or comprehensive list of requirements and guidelines for shared or multi-function displays (MFD), but they represent the items that the committee felt were pertinent.

1. If information, such as traffic or weather, is integrated with the navigation information on the EMD, the projection, the directional orientation and the map range should be consistent among the different information sets.

2. Where information on the shared display is inconsistent, the inconsistency shall be obvious or annunciated, and should not contribute to errors in information interpretation.

3. Symbols and colors used for one purpose in one information set should not be used for another purpose within another information set.

4. Deselection of shared information (e.g., weather, terrain, etc.) should be possible to declutter the display or enhance readability.

### 2.1.10 Data from Multiple Position Sources

This section is referring to multiple position sources input to the EMD (e.g., two Global Navigation Satellite System (GNSS) receivers, two flight management systems, etc.), not multiple sensors (e.g., VOR/DME or DME/DME, LORAN) input to an FMS which in turn generates a position source. RTCA DO-187[40] and AC 20-130A[14] provide guidance for the use of data from position sources.

1. If the EMD can use multiple position sources, other than multiple Global Navigation Satellite System (GNSS) sensors, a means of identifying the active source(s) shall be provided.

## 2.2 Equipment Performance Requirements - Standard Conditions (All EMDs)

Table 2-1 indicates the minimum set of information and control functions that must be provided on an EMD. Additional information and system capabilities may be provided to increase the usefulness of the map depiction.

**TABLE 2-1 MINIMUM SET OF INFORMATION DISPLAY AND CONTROL FUNCTION REQUIREMENTS**

| | Description | Reference Section |
|---|---|---|
| Map Depiction | 1. Aircraft location | 2.2.1 Map Depiction |
| | 2. Desired Path[1] | 2.2.1.2.1 Desired Path |
| | 3. Active fix [1,2] | 2.2.1.2.2 Fixes |
| | 4. Next fix [1,2] | 2.2.1.2.2 Fixes |
| Operating Status | 5. Indication of map range | 2.2.4 Display Operating Characteristics and Status Indications |
| | 6. Indication of map orientation | 2.2.4 Display Operating Characteristics and Status Indications |
| Control Functions | 7. Select map orientation | 2.2.4 Display Operating Characteristics and Status Indications |
| | 8. Select map range | 2.2.4 Display Operating Characteristics and Status Indications |
| | 9. De-clutter | 2.2.1.3 Display of Additional Information |
| Minimum Symbol Set | 10. Waypoint[1] | 2.2.1.1 Symbols |
| | 11. Airport[1,2] | 2.2.1.1 Symbols |
| | 12. VOR[1,2] | 2.2.1.1 Symbols |
| | 13. NDB[1,2] | 2.2.1.1 Symbols |
| | 14. Intersection[1,2] | 2.2.1.1 Symbols |
| | 15. Aircraft (ownship) | 2.2.1.1 Symbols |

[1] Not a minimum required symbol for the AMMD function. See additional requirements for these items in the AMMD section (see section 2.3).

[2] If available and within the selected map range.

### 2.2.1 Map Depiction

The map depiction includes aircraft location, flight plan fixes, and lines indicating the desired path between flight plan fixes. It may also include off-route reference points and additional map information.

1. All displayed symbols and graphics shall be positioned (i.e., drawn or rendered) accurately relative to one another such that placement errors are less than .013 inches on the map depiction or 1% of the shortest axis (i.e., horizontal and vertical dimension) of the map depiction, and orientation errors are less than 3° with respect to the values provided by the position and database sources.

   *Notes:*

   1. *Refer to Appendix G for display resolution issues.*
   2. *The goal of this requirement is to ensure that the EMD does not contribute significantly to the total system error to assure that the intended use of the EMD as a positional awareness tool is not diminished.*
   3. *RTCA DO-236A[45] (Minimum Aviation System Performance Standards: Required for Area Navigation) addresses error sources and error terms that make up the total system error budget.*
   4. *The EMD map display error may either preclude or limit its use for RNP based operations, unless the display has a course deviation indicator (CDI) integrated or is used with an approved navigation system that meets the appropriate performance standards.*
   5. *RAC displays may not meet this requirement because the production processes for aeronautical charts allow for some leeway in the placement of aeronautical symbols for chart readability purposes. Thus, measures must be taken to advise the user of these inherent positioning errors. See Appendix F for a discussion of this and other RAC issues.*

2. The EMD should provide an indication if the map range is smaller (i.e., "zoomed in" closer) than the level supported by the accuracy and resolution of the data. See Appendix F for discussion of this as it relates to RAC displays.

3. The EMD should have a consistent prioritization scheme for layering map data.

#### 2.2.1.1 Symbols

1. The EMD shall display distinctive symbols for different fix types (waypoints, airports, VORs, NDBs, intersections) and the aircraft (ownship).

   *Notes:*

   1. *These symbols make up the minimum required symbol set, as listed in Table 2-1.*
   2. *If the input to the EMD does not distinguish between flight plan fix types (e.g., VOR vs. NDB), then the waypoint symbol is acceptable. However, if*

*off-route fixes (e.g., VORs) are displayed, they must use the distinctive symbols appropriate for the fix type.*

2. The EMD shall use symbols similar to those shown on published charts or that are consistent with established industry standards. Guidelines for electronic display symbology are provided in SAE ARP5289[57]. See Appendix H.

3. All symbols shall be depicted in an upright orientation except for those designed to reflect a particular compass orientation. See Figure 2-2.

   *Note: This requirement does not apply to RAC data because it may not be able to meet this requirement due to the fundamental nature of that data. It does apply to vector data superimposed onto a Raster Chart.*

4. Symbols indicating a particular compass orientation shall maintain that compass orientation at all times. An example of this is a depiction of a runway symbol that maintains proper compass orientation as the map rotates. See Figure 2-2.

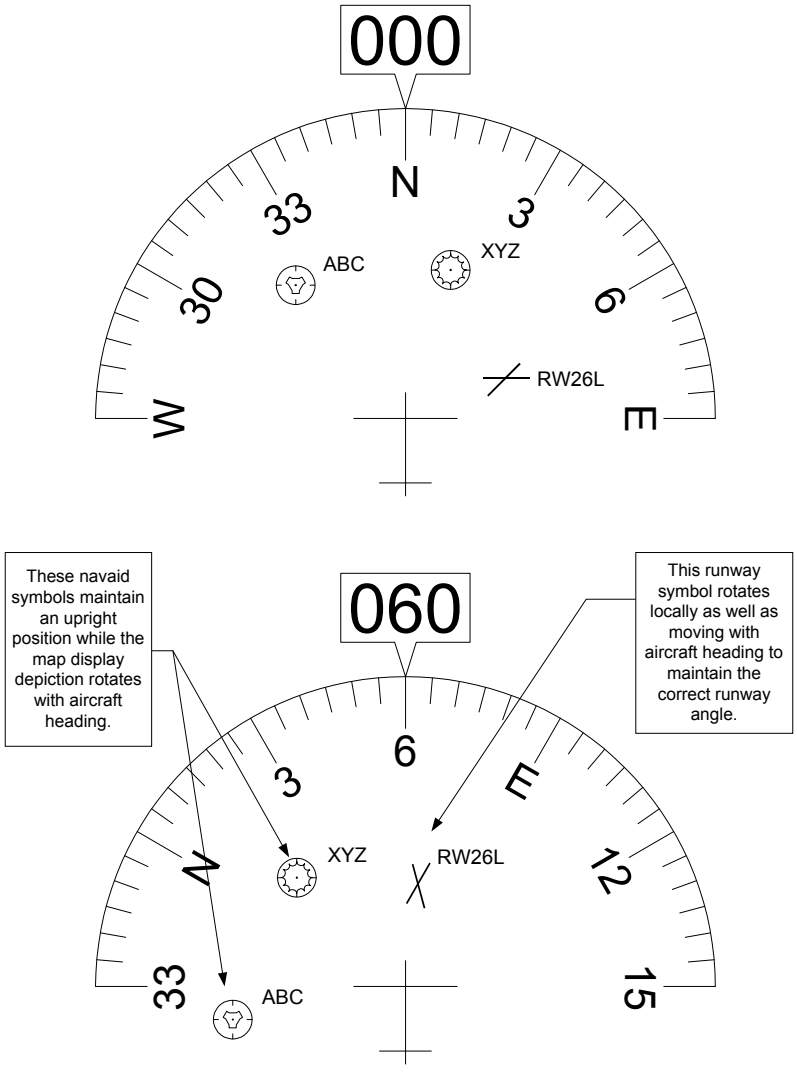


**FIGURE 2-2 ROTATING AND NON-ROTATING SYMBOLS**

5. Symbols used for one purpose on published charts should not be used for another purpose on the EMD.

6. Required symbols (per Table 2-1) shall be discriminable at a viewing distance of 30 inches under the full range of normally expected flight deck illumination conditions.

7. The ownship symbol shall be unobstructed.

   *Note: Exceptions may be allowed for multi-function displays depicting higher priority information that are required by regulation that may temporarily obstruct the ownship symbol (e.g., TCAS Traffic Advisory).*

8. If heading or track is available, the aircraft/ownship symbol shall be directional, oriented to either heading or track.

9. If the EMD supports more than one aircraft symbol directional orientation (e.g., heading and track), then the current aircraft symbol orientation shall be indicated.

### 2.2.1.2 Flight Plan

In this document the term "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 (or "TO") waypoint, and the desired path, to more complicated plans that include departure and destination airports with multiple intermediate fixes.

1. The EMD shall have the capability of displaying flight plans.

   *Notes:*

   1. *If this EMD system is intended to support RNP RNAV operations, the flight plan requirements in this document may be insufficient. See RTCA DO-283[50] (Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation) for additional requirements.*

   2. *Flight plans and/or taxi routes are not required on AMMDs.*

2. If a flight plan is being displayed and the EMD is receiving an active flight plan from an external navigation system (e.g., an external GPS Global Navigation Satellite System (GNSS) navigator or FMS), the active external flight plan shall be displayed, unaltered, on the EMD.

   *Note: This requirement is not meant to inhibit the use of other functions (such as previewing other flight plans) on the EMD while a flight plan is active. It is intended to preclude the EMD from filling in any missing portions of a procedure that is part of the active flight plan.*

3. If the EMD is used to edit the active flight plan on the EMD, it shall update the flight plan in the external navigator.

   *Notes:*

   1. *The intent of this requirement is to ensure that changes made in the EMD are reflected in the navigation system, such that the EMD remains in compliance*

*with #2 above. It is not intended to infer a particular system architecture or implementation.*

2. *An EMD operating in this manner is acting as an entry device for the navigation system. This may affect certification requirements for the EMD.*

4. The way flight plans are depicted in the preview or edit mode shall be distinctive from the normal depiction of the active flight plan.

5. The active flight plan should not be obstructed by other map data (e.g., off-route fixes or other information) except for the ownship symbol.

*Note: This may be accomplished by drawing the active flight plan so it is on top of other map data.*

**2.2.1.2.1 Desired Path**

The desired path may consist of straight and curved lines connecting the fixes in a flight plan thus defining the route to be flown.

1. Lines shall be displayed indicating the path to be flown between fixes in a flight plan.

*Notes:*

1. *If the EMD system is intended to support required navigation performance (RNP) area navigation (RNAV) operations, the RNP document (RTCA DO-236A[45]) specifies the types of flight path legs, segments, terminators, etc. that must be supported.*

2. *The intent of this requirement is that the desired path will be drawn correctly (e.g., when the course deviation is zero, the airplane will be shown on the desired path, despite great circle/rhumb line/projection differences). It is understood that data defining the transition paths between flight plan legs (e.g., fly-by paths) may not be available, thus the transition path would not be depicted.*

2. If the EMD receives RNP leg data (i.e., Direct to a Fix (DF), Course to a Fix (CF), Track between two Fixes (TF), course from a Fix to an Altitude (FA), constant Radius to a Fix (RF)) the EMD shall display the leg type in compliance with RTCA DO-236A[45] or not at all.

*Notes:*

1. *The intent of this requirement is to ensure that the map does not display contradictory or misleading information relative to the information displayed on the external navigator.*

2. *The leg type definitions in RTCA DO-236A[45] are the same as those in RTCA DO-229C[44].*

3. If the EMD is incapable of representing curves, due to either data or system limitations, then curved path segments shall not be depicted as a single straight line (Reference Figure 2-3).

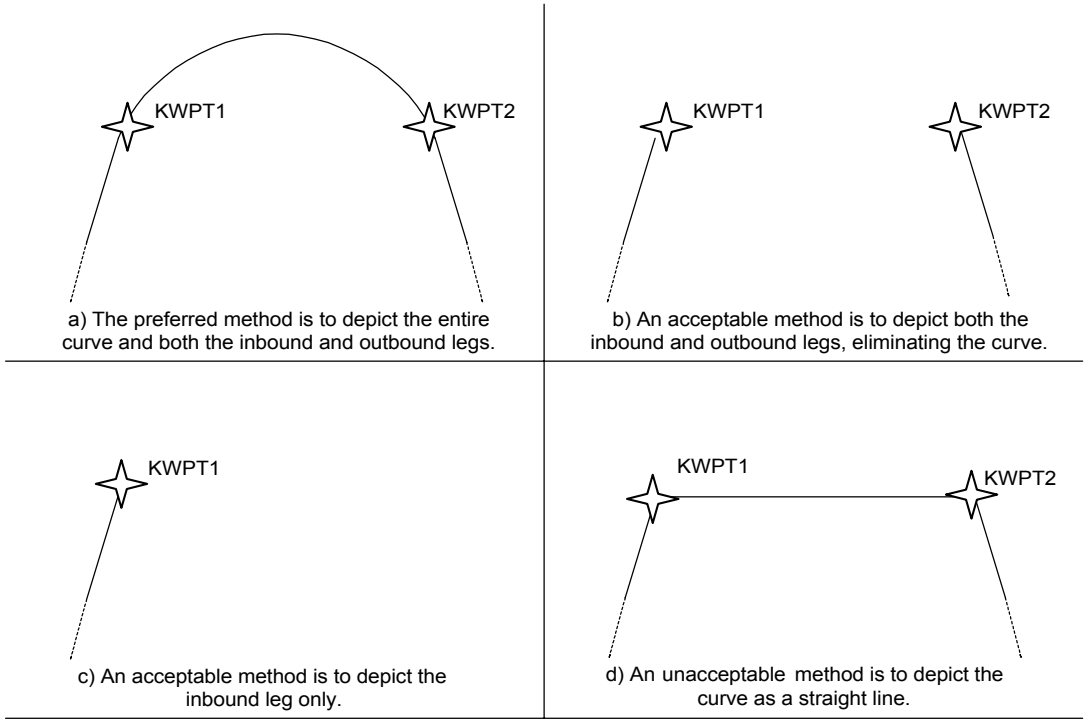



**FIGURE 2-3 CURVED PATH DEPICTION: DME ARC EXAMPLES**

*Notes: (See Figure 2-3 for clarification)*

1. *Item a is the only acceptable option for RNP RNAV operations, as defined by RTCA DO-236A[45].*
2. *A series of short straight lines may be used to depict a curved path.*
3. *Item d (a single straight line drawn along the chord of the curve) is unacceptable.*
4. *Items b and c are only acceptable when:*
    - *the external navigation source does not provide the data needed to display item a. This condition is a result of the external navigator sending a gap or discontinuity indication (item b) or a flight plan termination (item c).*
    - *the EMD is used in conjunction with a separate, approved navigation display that provides course guidance through the turn.*
    - *user documentation provides textual and graphical explanations of what the pilot can expect the EMD to display, including a directive to use the CDI for guidance through the turn. (See section 3.1.6 for documentation requirements).*

4. The active desired path shall be differentiated from any other paths displayed (e.g., alternate or inactive desired path, track history, or projected path).

5. The active leg should be differentiated from any other legs or paths.

6. Desired path lines should not interfere with the identification of flight plan fix symbols or labels.

#### 2.2.1.2.2 Fixes

1. The active fix shall be uniquely identified and distinctive from other fixes.

   *Note: This may be accomplished by using a unique color for the active fix or by uniquely identifying the desired path to the active fix.*

2. The active fix, the next fix, and their associated labels (e.g., fix identifier) shall be displayed and identifiable, if they are within the selected map range and they exist.

   *Notes:*

   1. *Color has been used as a means of facilitating ready identification*
   2. *There are times when the active fix and the next fix are the same (e.g., a direct-to a fix that is an IAF on an approach where the first leg of the approach is a holding pattern or a procedure turn where both the outbound leg and inbound leg use the same fix). In these situations, the identification of the active fix should be given priority.*

3. If the active fix is beyond the selected map range, the fix identifier shall be visible or readily accessible on the EMD.

   *Note: Possible methods of compliance include dedicated display area for the active fix identifier, changes in map range, flight plan skipping features, compressed flight plan (full flight plan on one page), fix list, etc.*

4. Flight plan fixes beyond the next fix should be displayed if available and within the selected map range.

### 2.2.1.3 Display of Additional Information on the EMD

The EMD may display, either continuously or selectively, information beyond the minimum required data set defined in Table 2-1. This information may include wind information, geographic reference data, etc. If additional information is displayed on the EMD (beyond that listed in Table 2-1), then the following become requirements for the EMD.

1. The EMD shall have the capability for manual de-cluttering during operational use.

2. If additional map information has been selected for display, it should be possible to deselect all displayed additional information as a set.

3. It should be possible for the pilot to accomplish this de-clutter function with a single action.

4. If a wind vector is displayed on the map, its orientation shall be consistent with the orientation of the map and pointing in the direction of wind flow.

*Note: This requirement is not intended to prohibit separation of the wind vector into headwind and crosswind components. In this case the separate components must still be consistent with map orientation (e.g., geo-referenced).*

5. Additional data on the display (over and above the minimum required data) should be located in a consistent location and should not interfere with the usability of the minimum data (e.g., if a graphic wind indicator is on the display it may be in a designated corner of the display).

6. All overlayed data shall be the same map orientation and scale.

### 2.2.2 Labels

1. The EMD shall have the capability to display the complete fix identifier (e.g., KBOS, not BOS) for the required minimum symbol set as defined in Table 2.1.

   *Notes:*

   1. *The source for the identifier will be either the external navigator or the internal database. Requirements for internal databases are in section 2.2.5.*
   2. *If the source for the identifier is an external navigator, the identifier is to be displayed unaltered.*

2. Labels shall be used to identify fixes, other symbols, and other information, depicted on the EMD, where appropriate.

3. The spatial relationships between labels and the objects that they reference should be clear, logical, and, where possible, consistent.

4. Alphanumeric fonts should be simple and without extraneous details (e.g., sans serif) to facilitate readability.

5. Fix labels shall be oriented to facilitate readability.

   *Notes:*

   1. *One method of compliance is to continuously maintain an upright orientation.*
   2. *This requirement does not apply to RAC data because they may not be able to meet this requirement due to the fundamental nature of the data. It does apply to vector data superimposed onto a Raster Chart.*

6. Label terminology and abbreviations used for describing control functions and identifying EMD controls should be consistent with Appendix A.

7. All labels shall be readable at a viewing distance of 30 inches under the full range of normally expected flight deck illumination conditions (Reference MIL STD 1472D[59] and SAE AIR1093[51]).

   *Note: The size of numbers and letters required to achieve acceptable readability may depend on the display technology used.*

### 2.2.3 Display

These parameters do not ensure that the equipment will be suitable for installation in all aircraft. It is recommended that the viewing angle be maximized to increase the flexibility of the equipment for installation.

1. The operating range of display luminance and contrast shall be sufficient to ensure display readability through the full range of normally expected flight deck illumination conditions (Reference SAE ARP4256[55]).

   *Note: The full range of normally expected flight deck illumination span from complete darkness to direct and unfiltered sunlight.*

2. Reflectance of the display should be minimal to ensure display readability.

3. The display shall be readable through a horizontal viewing angle 30 degrees either side of a line normal to the display surface, and through a vertical angle 20 degrees above and 5 degrees below a line normal to the display surface (Reference SAE ARP4256[55] and also SAE ARP4102[53]).

   *Note: This requirement applies to viewing angle of the EMD and can be validated on the bench. In addition, the specific installation in the aircraft will be evaluated during the installation approval process.*

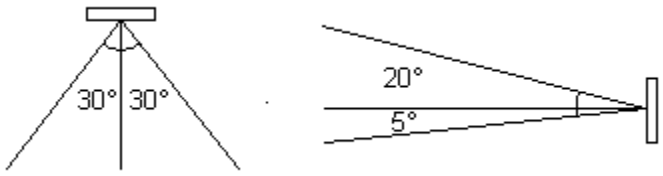



**FIGURE 2-4 VIEWING ANGLES**

4. If color is used for information coding, the selected color set shall be discriminable under the full range of normally expected flight deck illumination conditions and the design viewing angle (Reference SAE ARP4256[55]).

### 2.2.4 Display Operating Characteristics and Status Indications

1. The EMD shall have the capability of manually changing the map range.

2. Current map range shall be indicated continuously.

3. If the EMD is controlling the map range automatically, the mode (e.g., auto map range) should be indicated.

4. If the EMD is controlling the map range automatically, then the capability shall exist to activate or deactivate the automatic map range.

   *Note: An acceptable method of compliance is to have a discrete control action (e.g., button push) to activate the automatic range function.*

5. If the automatic map range function is deactivated, the display should maintain the last range scale prior to deactivation until the flight crew manually selects another map range.

6. When the display is switched to a previously viewed page then the display should maintain the settings (e.g., range, pan) associated with that previously viewed page.

7. If a panning and/or range selection function is available, the equipment should provide the capability to return to an ownship-oriented display with a maximum of two discrete control actions (e.g., two button pushes).

   *Note: The panning function is defined as moving the center reference of the display independent of ownship.*

8. When using the panning and/or range selection function, an indicator of ownship current position within the overall displayed image should be provided.

   *Note: While panning across a map, moving from one area to another, the operator may lose track of what is being displayed, and be uncertain how to move in order to see some other area of interest. An indicator of current position may help operators to maintain overall orientation (Foley Van Dam 1982[68]).*

9. The EMD shall have the capability to present map information in at least one of the following orientations: actual track-up or heading-up.

   *Notes:*

   1. *In addition to the above, desired track-up and North-up orientations (to facilitate cross checking with the paper charts and flight planning) are also acceptable.*
   2. *Default of track-up or heading-up in-flight is encouraged.*
   3. *This requirement does not apply to systems while displaying RAC data.*

10. If desired track-up orientation is used, the aircraft symbol shall be oriented to actual track or heading.

    *Note: In desired track-up orientation, it is recommended that a track extension line that projects the actual track out from the aircraft be displayed.*

11. If the flight crew has selected a display orientation (e.g., track-up), that display orientation should be maintained until an action that requires an orientation change occurs.

    *Note: Actions can include crew selection of a different orientation or a mode change (e.g., TCAS auto popup).*

12. If the system is in North-up, the orientation of the map shall be referenced to true North.

13. The default reference for all direction information on the EMD (e.g., heading, track, etc.) shall be magnetic and "MAG" mode need not be annunciated.

14. If direction information is referenced to true North, this shall be indicated.

15. Data fields should include the units of measurement or labels for the displayed data (Smith & Mosier, 1986[73]).

*Notes:*

1. *RTCA DO-229C[44] specifies that bearings be labeled with "º" to the right of the bearing value.*
2. *The label/ unit guideline need not apply if the numeric bearing number is anchored on a compass rose, and thus is not likely to be misunderstood.*

16. True bearings should be labeled with "ºT" to the right of the bearing value.

    *Note: This recommendation applies to all courses, tracks, and bearings. Reference RTCA DO-229C[44].*

17. Current map orientation shall be clearly, continuously, and unambiguously indicated (e.g., track-up vs. North-up).

    *Notes:*

    1. *Issue: systems exist that have four orientation modes available without any explicit indication of mode: actual track-up, North-up, heading-up, desired track-up. The orientation mode selected must be continuously indicated. Alternatively, the indication could be done using external annunciators or an external switch that indicates the orientation currently selected.*
    2. *An acceptable means of compliance would be to have a "desired track-up" (or DTK↑), "North-up" (or N ↑), "heading-up" (or HDG ↑) or "actual track-up" (or TRK ↑) on the display.*
    3. *A compass arc/rose or North indicator is an acceptable means of compliance for a system that provides only two options (North-up and one other option).*

18. The EMD shall respond to operator control inputs within 500 msec.

    *Note: It is desirable to provide a temporary visual cue to indicate that the control operation has been accepted by the system (e.g., hour glass or message). It is recommended that the system respond within 250 msec.*

19. The EMD shall update the displayed minimum required information set, as defined in Table 2-1, at least once per second.

    *Notes: The following exceptions apply:*

    1. *While the EMD must be capable of operating at an update rate of once per second, it is acceptable to adjust the update rate either dynamically or at installation to match the update rate of the position source. While acceptable it is not necessary to update the display more often than once per second even if the data source is being updated at a higher rate.*
    2. *It is acceptable for a longer delay, not exceeding five seconds, to occur at state transitions (e.g., orientation mode, range, and leg changes).*
    3. *At larger map ranges this requirement may not be necessary since the movement of the minimum required information set may not be noticeable.*

20. Maximum latency of aircraft position data at the time of display update shall be one second, measured from the time the data is received by the EMD system.

21. Movement of map information should be smooth throughout the range of aircraft maneuvers.

22. When the EMD receives a "data not valid" or "reduced performance" (e.g., dead reckoning mode) indication from the source, this condition shall be indicated on the EMD within one second.

    *Notes:*

    1. *For vertical profile displays, if the altitude source fails or is degraded, the altitude data must be flagged or removed from the display.*
    2. *Caution- some Global Navigation Satellite System (GNSS) receivers compliant with TSO-C129a[30] do not provide this indication via the data bus. These position sources may continue to output last known position after a sensor failure. This is not acceptable.*

23. If aircraft positioning data are not received by the EMD for five seconds (i.e., data timeout), this condition shall be indicated to the flight crew.

24. If there is an active flight plan and the flight plan data are not received by the EMD for 30 seconds, this condition shall be indicated to the flight crew.

    *Notes:*

    1. *This minimum is based on the use of the EMD for position awareness only. It is recommended that the time-out for the active flight plan data be less than 30 seconds if the interface characteristics support this.*
    2. *AMMD's are not required to have flight plan information while on the airport surface. This requirement does apply to AMMD's that have flight plan information and also to AMMD's that depict a taxi route. Otherwise, this requirement does not apply to AMMDs.*

### 2.2.5 Database

As an alternative to (or in addition to) an external data source, the EMD may use an internal database to store information such as flight plans, nearby fixes, airspace boundaries, raster aeronautical charts, or airport mapping information. If an internal database is being used, the following requirements apply:

1. The EMD shall provide a means to identify the database(s) version and valid operating period.

   *Notes:*

   1. *An acceptable means of compliance is to require the pilot to acknowledge an out-of-date (or "expired") database upon EMD start-up. Alternatively, a flight crew procedural check of data base validity would also be acceptable.*
   2. *This requirement does not apply to an AMMD database that is separate from the EMD navigation information database. Database requirements for AMMDs are in section 2.3.5.*

2. The EMD shall indicate if any data is not yet effective or is out of date.

*Notes: Acceptable means of compliance include:*

1. *disabling the display of out-of-date data;*
2. *using a distinct means of identifying out-of-date data on the display (e.g., unique color, shape, special label, etc.); or*
3. *indicating to the pilot during start-up which specific data is out-of-date (e.g., a. message that says "off-route data not current" or "only on-route fixes and off-route airports are current, all other data is out of date"), and indicate in the operating manual that any out-of-date data displayed on the EMD must either a) be verified to be correct by the flight crew before use or b) not be used. Complex start-up messages with long lists of what is out of date are not acceptable.*

3. There should be a required pilot action acknowledging an expired database.

4. The aeronautical information used in the development of a navigation database should meet the standards specified in RTCA DO-201A/EUROCAE ED-77[42] and RTCA DO-276/EUROCAE ED-98[49].

   *Note: RTCA DO-272/EUROCAE-99[48] also provides guidance in this area. It is not listed here because data which is compliant with RTCA DO-272/EUROCAE-99[48] are not yet widely available in the United States or world-wide. This RTCA DO-272/EUROCAE-99[48] document may be applicable in the future when more data is available.*

5. The process of updating navigation databases shall meet the standards specified in RTCA DO-200A/EUROCAE ED-76[38].

6. WGS-84 position reference system or an equivalent earth reference model shall be used for all displayed data. (Reference RTCA DO-236A[45] and ICAO Annex 15[2]).

   *Note: It is recognized that many datums exist other than ICAO Annex 15 WGS-84[15] and that conversions exist between various datums. However, datums and conversions other than WGS-84 cannot be approved without determining acceptable datum equivalency to WGS-84. It is the responsibility of the approving authority to determine if an alternate datum is equivalent.*

## 2.3 Equipment Performance Requirements – Standard Conditions (Aerodrome Moving Map Display)

This section contains requirements and guidelines specific to the depiction of aerodrome moving map displays (AMMD). These requirements apply in addition to those in sections 2.1 and 2.2. If the EMD does not have the AMMD function then the requirements described in this section are not applicable. The intended function for the AMMD is described in section 1.4.

### 2.3.1 Map Depiction

This section provides a summary of requirements associated with the depiction of aerodrome map attributes and ownship position.

1. The AMMD shall provide an indication if the accuracy implied by the display is better than the level supported by the total system accuracy.

   *Notes:*

   1. *The total system accuracy includes consideration of all error sources, including the positioning accuracy, the data accuracy and resolution, display resolution and addressability, latency, etc.*
   2. *The accuracy implied by the display depends upon the system implementation. For example, the scale of the ownship symbol relative to the map range may imply a level of accuracy. If a system provides the ability to display a circle around the ownship symbol that indicates the system accuracy, then the circle would define the implied accuracy. The system may account for the fact that the inaccuracy is not constant: for example, the accuracy of survey data may vary. The objective is to ensure the user is aware of the performance limitations of the system. See also section 3.2.3.*
   3. *Although new airport surveys are expected to provide more accurate airport data, currently the most significant error source is expected to be the data describing the airport environment. As described in section 2.3.5, rather than trying to validate the accuracy of data before it is used, acceptable system performance is achieved through reporting of errors, and having a process to take corrective action or notify operators when there is an unresolved error. It is expected that pilots will report errors if they observe that the indicated position is inconsistent with the accuracy implied by the display. One intent of the indication required by this paragraph to reduce the number of false data error reports, caused because the implied accuracy is better than the actual, expected accuracy.*

#### 2.3.1.1 Map Attributes

The minimum required aerodrome map attribute is the depiction of runways. Additional map attributes may, however, be provided and guidance on a selected set of features is provided below.

##### 2.3.1.1.1 Runways

1. The capability shall exist to depict runways.

2. The depiction of runways shall be distinctive from all other symbology.

*Note: The use of color as the sole means of distinguishing runways may not be sufficient to meet this requirement.*

3. With the exception of instances where two or more runways intersect, each runway should be depicted as a contiguous area (i.e., an unbroken rectangle).

4. Runways should be depicted as filled areas, rather than outlined areas.

5. The aircraft position sensor horizontal positional accuracy for runways shall be less than 36m.

   *Notes:*

   1. *Horizontal positional accuracy is defined as the difference between a sensor's measured horizontal position and it's true horizontal position.*
   2. *The sensor horizontal positional accuracy requirement of 36 m was derived from the 95 percent horizontal performance of GPS (Reference DOD, GPS Standard Positioning Service Performance Standard, October 2001[61]). The horizontal positional accuracy supports the total accuracy requirement provided in section 3.2.3.*
   3. *There are no horizontal protection limit (HPL) requirements for the position information used for the AMMD.*
   4. *An acceptable method of compliance with this requirement is to demonstrate that the system is connected to any Global Navigation Satellite System (GNSS) sensor.*

6. The aerodrome total database accuracy for runways shall be 43m or less.

   *Notes:*
   1. *Aerodrome total database accuracy was derived as follows: (Aerodrome total database accuracy)$^2$ = (database accuracy)$^2$ + (survey accuracy)$^2$ where database accuracy and survey accuracy both equal 30m.*
   2. *The aerodrome total database accuracy supports the total accuracy requirement provided in section 3.2.3.*
   3. *An acceptable method of compliance with this requirement is to utilize data from a vendor that states the aerodrome database meets the 43m requirement (see section 2.3.5).*

**2.3.1.1.2 Taxiways**

1. The capability should exist to depict taxiways.

2. Taxiways should be depicted as filled areas, rather than outlined areas.

3. The aircraft position sensor horizontal positional accuracy for taxiways shall be less than 36m.

4. The aerodrome total database accuracy for taxiways shall be 65m or less.

   *Notes: Acceptable means of compliance for requirement #4 include:*

   1. *Utilize data from a vendor that state the aerodrome database meets the 65m requirement.*

2. *Compare the taxiway data for the AMMD in question with data surveyed to a known accuracy (e.g., RTCA DO-272/ED-99[48]). This should be done for a sampling of airports.*
3. *For airports where no known taxiway data is published and errors are noted, operators using the moving map will report database errors to the database supplier as described in section 2.3.5.*

#### 2.3.1.1.3 Taxi Routes

In this document the term "taxi route" refers to any sequence of taxiway and/or runway fixes (e.g., turn left at Echo) that are interconnected and depict the desired taxi path. If taxi route information is depicted, the following requirements apply:

1. Taxi route information shall be distinguishable from all other AMMD map attributes.
2. The way taxi routes are depicted in the preview or edit mode shall be distinctive from the depiction of the active taxi route.

   *Note: An active taxi route is defined as the intended path that will be used during taxi.*

3. The depiction of taxi routes should not obscure runway or taxiway identifiers.

   *Note: The intent of this recommendation is to ensure that taxi routes do not completely cover the identifiers.*

### 2.3.1.2 Depiction of Ownship Position

1. The AMMD shall contain a symbol representing the location of ownship.
2. If direction/track is not available, the ownship symbol shall not imply directionality.

   *Note: When using GNSS track for deriving ownship directionality, if directionality becomes unusable due to low taxi speeds or when stopped, the ownship would revert to a non-directional symbol (e.g., circle).*

3. If directional data is available, the ownship symbol should indicate directionality..

   *Note: This MOPS does not define a total system accuracy requirement for displaying direction. The accuracy of the AMMD is addressed in section 2.2.1, which requires less than 3 degrees of error from the display. The total system accuracy will be evaluated as part of an installation or operational evaluation. For equipment that uses Global Navigation Satellite System source as the position source to derive track, the total system accuracy is expected to be less than 5 degrees when taxiing in a straight line.*

4. If ownship directionality information becomes unusable then this condition should be indicated on the AMMD.

*Notes:*

1. *One method for indicating the loss of directionality information may consist of changing the ownship depiction from a directional symbol to a non-directional symbol (e.g., circle).*
2. *Equipment that does not have access to heading information may derive track based on changes in position over time (e.g., a Global Navigation Satellite System (GNSS) sensor used to derive track). However, this information will become unreliable when the taxi speed is low relative to turning velocity. Directionality information is generally considered unusable if it is not within 15 degrees of actual track.*

5. If the ownship symbol is directional, the front of the symbol that conveys directionality (e.g., apex of a chevron or nose of the aircraft if using an aircraft icon) should correspond to the aircraft location.

6. If the ownship symbol is non-directional, the aircraft location should correspond to the center of the non-directional symbol.

### 2.3.2 Labels

1. The runway identifiers shall be available for depiction on the display, if available.

2. If taxiways are depicted then the taxiway identifiers should be available for depiction on the display, if available.

*Note: For requirement 1 and 2, the equipment is not required to continuously display all taxiway and runway identifiers. For example, some implementations may include a de-cluttering function to remove the identifiers.*

3. If runway markings (e.g., runway centerline) are provided they should be depicted in their correct relative position.

4. Runway identifier should be distinguishable from the depiction of runway markings.

5. At reduced map ranges, at least one identifier should be displayed for any taxiway or runway depicted within the selected map range.

6. When surface map features are being depicted, the aerodrome designator (e.g., ICAO identifier) or name for the depicted aerodrome should be indicated on the display.

### 2.3.3 Display

There are no unique requirements beyond those specified in section 2.2.3.

### 2.3.4 Display Operating Characteristics and Status Indications

#### 2.3.4.1 Layering Prioritization of Aerodrome Map Features

To ensure the availability of appropriate information during surface operations, the order of display layer precedence (in case aerodrome features overlap) should be (higher priority layered on top):

a. Ownship symbol
b. Taxi route
c. Runway identifiers
d. Runways
e. Taxiway identifiers
f. Taxiways

### 2.3.5 Database

1. If the airport map database is separate from the EMD navigation information database, the AMMD shall provide a means to identify the database version, and/or date, and/or valid operating period.

   *Note: An acceptable means of compliance is to require the pilot to acknowledge an out-of-date (or "expired") database upon AMMD start-up. Alternatively, a flight crew procedural check of airport map data base validity would also be acceptable.*

2. The process of updating aerodrome databases shall meet the standards specified in RTCA DO-200A/EUROCAE ED-76[41].

   *Notes:*

   *1. As a component of RTCA DO-200A/EUROCAE ED-76[41] compliance, manufacturers of EMD equipage offering an aerodrome moving map depicting ownship position must define a process enabling their customers to expeditiously report any errors they experience in their display of ownship position solutions. One means of compliance with this requirement is, for aerodromes where customers report suspected errors, a manufacturer's process will define how they will attempt to verify and correct the error(s). As part of the process, the manufacturer will also define how they expeditiously disseminate corrections for the errors back to their customers. This overall process can resemble the processes used for reporting and correcting errors customers see when using other systems such as the Terrain Awareness and Warning Systems (TAWS) and airborne navigation systems.*

   *2. When the manufacturer identifies an error as a potential database error and they do not produce the database in-house, the manufacturer must identify the suspect error to their database supplier as specified in RTCA DO-200A/EUROCAE ED-76[41].*

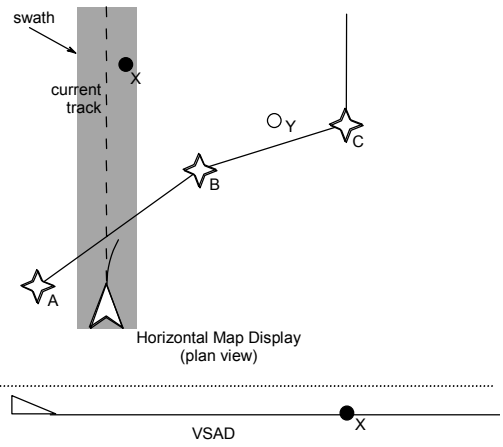
   *3. The database supplier must attempt to verify or deny a reported database error as specified in RTCA DO-200A/EUROCAE ED-76[41].*

## 2.4 Equipment Performance Requirements- Standard Conditions (Vertical Situation Display)

This section contains requirements and guidelines specific to the depiction of vertical profile. These requirements apply in addition to those in sections 2.1 and 2.2. If the EMD does not have a Vertical Situation Display (VSD) the requirements in this section do not apply. The intended function(s) for the vertical situation display is described in section 1.4.

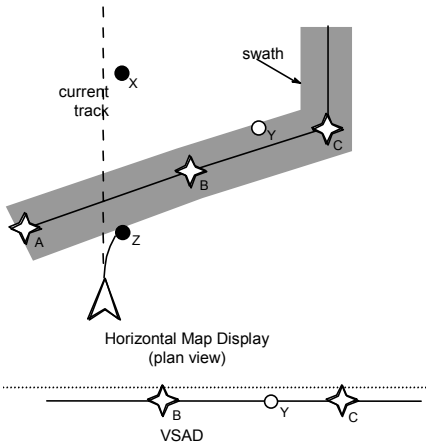
### 2.4.1 Map Depiction

As depicted in Figure 2-5 below, the VSD may depict a projection along the aircraft's current track (track mode), or along the desired path (flight plan mode). In track mode the VSD is oriented along the aircraft's track. In flight plan mode the VSD is oriented along the flight plan.




Track mode

Example of what may be depicted on the plan view and VSD when the display is in track mode. The X and Y symbols indicate a generic symbol (could be airport, navaid, terrain, etc.)




Flight plan mode

Example of what may be depicted on the plan view and VSD when the display is in flight plan mode. The X and Y symbols indicate a generic symbol (could be airport, navaid, terrain, etc.)

**FIGURE 2-5 TRACK MODE VS. FLIGHT PLAN MODE**

1. A single mode (i.e., either track mode or flight plan mode) shall be applied to all information depicted in the VSD at the same time.

*Note: This requirement does not preclude changing modes.*

#### 2.4.1.1 Swath

The swath is the slice of the environment that is depicted on the VSD. That slice may include significant terrain, airports, navaids, other traffic, etc. On the plan view display the swath may or may not be depicted. See Figure 2-5. The swath depicted may be based on a projection along the aircraft's current track (track mode), or along the desired path (flight plan mode).

1. The swath shall be centered along either the predicted flight path (e.g., current track) of the aircraft or the flight plan.

2. The swath should be depicted sufficiently wide to contain the external hazards (e.g., terrain or obstacles) that are relevant to the current phase of flight or flight path yet not so wide that it results in the nuisance indication of hazards (e.g. displays runways below the terrain profile due to the presence of higher terrain within the vicinity of the airport).

   *Note: Consideration should be given to making swath width consistent with the alerting swath used by Terrain Awareness and Warning System (TAWS), if installed.*

3. If the VSD is capable of displaying more than one swath definition (e.g., swath can be defined or based on RNP, Estimated Position Uncertainty, Airway type, TAWS, etc.), the current swath definition shall be available for display.

   *Notes:*

   1. *This requirement is not intended to prohibit multiple swaths of different widths and shapes from being used and depicted simultaneously as long as they are all in the same mode (i.e., track mode or flight plan mode). For example, the VSD may depict one swath width chosen to depict terrain hazards and another chosen to depict off-route waypoints.*
   2. *A single swath definition refers to any consistent concept, logic or parameters used to define the swath width. Examples of a single swath definition include: a) a swath width that matches the RNP type (which changes every time the RNP type changes); b) a swath width based on phase of flight (which changes when the phase of flight changes); and c) a swath width that is a constant percentage of map range.*
   3. *Acceptable means of indicating the swath definition include (a) annunciating the name of the mode, (b) graphically depicting the swath on a plan view display (e.g., representing the swath shape by outlining or shading the area it covers on a plan view portion of the EMD).*
   4. *It is recommended that the system documentation explain that symbols and other information that is depicted on the VSD are not necessarily in front of the aircraft (aligned with aircraft heading). In addition, the documentation should explain that symbols and other information that is in front of the aircraft would not necessarily be depicted on the VSD.*

4. If the VSD is in flight plan mode, the swath width should be related to the width of the segment being flown (e.g., airway, route width, or RNP type).

5. When in track mode, the swath width should be adjusted to look into a turn to provide some look-ahead to the pilot of potential hazards that are likely to be encountered. (See Figure 2.6)

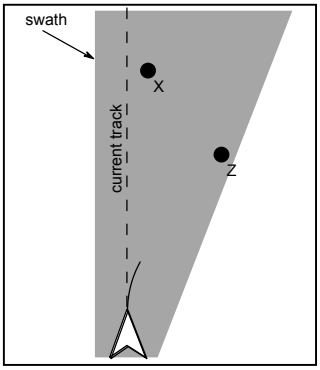



**FIGURE 2-6 SWATH ADJUSTMENT TO LOOK INTO TURN**

6. When in flight plan mode, the swath width should be adjusted to account for any variation in the defined turn (e.g., adjusted for the theoretical transition area associated with the turn or adjusted for the fly-by or fly-over turns) (Reference RTCA DO-236A[45], section 3.2.5.4 and RTCA DO-229C[44] section 2.2.1.3.7.3).

*Note: For EMDs whose flight plan is driven by an external data source, the theoretical transition area may be computed using the references above. This requirement applies to typical defined turns, not holding patterns or procedure turns.*

### 2.4.1.2 Symbols

1. An ownship/aircraft symbol should be provided on the vertical situation display.

2. If the ownship symbol is directional, the symbol orientation shall correctly depict the lateral directional orientation of the aircraft (i.e., towards or away from the objects depicted in the VSD).

*Note: The directionality of the ownship may be simply two directions (towards and away), depicted as left to right, or right to left. It is not intended for the ownship symbol to indicate pitch or attitude of the aircraft.*

3. The VSD ownship symbol should be in a consistent location (e.g., always on the left side of the display) and maintain a consistent direction of motion (left-to-right or right-to-left).

4. If the VSD ownship symbol is not always in a consistent location (e.g., always on the left side of the display) the direction of motion of ownship shall be depicted on the VSD.

*Note: This requirement may be met by having an ownship symbol with directionality on the VSD.*

5. The ownship symbol depicted on the VSD should be of constant size, independent of the selected range of the display.

6. If there is a numeric altitude indication associated with ownship on the VSD, the altitude depicted shall be consistent with the numeric indication on the aircraft's primary altimeter and on the FMS Control Display Unit (CDU) approach page, if installed.

   *Notes:*

   1. *This requirement is intended to prevent potential confusion between VSD altitude and the altitude source approved for use (altimeter). Global Navigation Satellite System (GNSS) altitude cannot be used as the source for the altitude unless the VSD does not indicate a numeric altitude or the altitude is corrected to account for the difference between barometric altitude and geometric altitude.*

   2. *For ownship position based on barometric altitude, this requires that the VSD uses the same altimeter correction used for the altimeter display. This may be accomplished by either having the primary source of altitude feed the VSD or by having a pilot input control on the VSD to manually input the baro corrections.*

7. If the VSD implements a depiction of vertical predictor, the motion of the predictor should be smoothed to reduce the potential for visual distractions.

8. For multi-function or shared display systems, symbols used on the VSD shall be distinct from symbols used on the plan view map display when they represent different things and the same when they represent the same things.

### 2.4.1.3 Flight Plan

1. In flight plan mode, the flight plan, including the desired path and fixes, shall be displayed on the VSD when within the selected VSD map range.

   *Note: In track mode it is acceptable to indicate the portion of the flight plan (or portion of the flight plan leg) in the VSD that is within the swath and selected map range. The portions of the leg depicted in the VSD may or may not include waypoints, depending on if those waypoints are within the swath.*

2. When in track mode and the flight plan is not contained within the swath the flight plan shall not be displayed.

3. If flight plan altitude information is not available, then the VSD shall not depict a vertical path, and shall depict waypoints without altitude restrictions at the aircraft's current altitude.

   *Note: This is to prevent the VSD from implying that vertical path information is available. It is acceptable to depict a flight plan on the VSD when the flight plan does not contain altitude information as long as waypoints are depicted at the aircraft's current altitude.*

4. When operating in flight plan mode, the VSD shall depict the same flight plan as the plan view map depiction.

   *Note: It is acceptable to not have a flight plan depicted on the VSD. It is not acceptable to have a different flight plan depicted on the VSD than on the plan view.*

5. The VSD depiction of ownship position relative to the flight plan shall not conflict with the vertical guidance (e.g., deviations) on the primary flight display.

   *Notes:*

   1. *There can be significant differences between geometric altitude and barometric altitude, due to changes in local pressure and differences from the International Standard Atmosphere that are assumed for barometric altimetry. These differences must be accounted for in order to depict both ownship position and desired path on the VSD, if altimeter data is used for vertical guidance (deviations) and Global Navigation Satellite System (GNSS)-derived data is used for the VSD. See AC 90-97[23] paragraph 9.b for issues and guidance on this topic.*
   2. *ILS approaches have a vertical path based on the ILS signal, which is not directly related to Global Navigation Satellite System(GNSS) or barometric altitude. Thus, depiction of an ILS on the VSD must use the published angle of the glideslope.*
   3. *An acceptable means of complying with this requirement for barometric VNAV approaches is to use barometric altitude to generate ownship and the vertical path depicted. Another acceptable means for all types of approaches is to display the path based on the vertical deviations output by the navigation system, rather than independently computing the path itself.*

6. If depicting the distance to a DME (e.g., on an approach), the VSD shall label the distance as a DME distance and indicate the associated facility.

   *Note: In general a published DME distance indicates the slant range distance between the aircraft and the facility. When determining a fix based on distance, the use of along-track distance has been accepted as equivalent to slant-range distance. If the equipment is intended for use outside of the U.S, consideration should be given to ILS DME facilities that transmit a signal that is calibrated so that the indicated DME distance is the distance to the runway threshold, rather than the distance to the DME facility.*

7. The profile display shall accurately depict, with respect to the scale factors of the display (i.e., vertical and horizontal), all vertical path information displayed, including glide slope, approach path, or angle of descent.

   *Note: For example, it is acceptable to depict a 3 degree flight path descent angle as a 15 degree angle depicted on the VSD, depending upon the selected scale factors or VSD aspect ratio.*

8. If the VSD is in flight plan mode and the aircraft deviates from the flight plan to the extent that it is no longer within the swath, the system shall either 1) switch to track mode, 2) flag the display or 3) remove the ownship symbol from the VSD.

9. If in flight plan mode, all depicted symbols shall be placed based on the total along-path distances (i.e., an "unwound" flight plan), so that distance between fixes is consistent with the distances between the fixes on the plan view map (including published arcs or fixed radius turns).

   *Note: Holding fixes and procedure turns are not required to be "un-wound"*

10. When in flight plan mode and the active flight plan is out of view (i.e., flight plan is above or below the area depicted on the VSD), a means of indicating the vertical direction to intercept the active leg of the flight plan should be provided on the VSD.

    *Note: This situation can be addressed by providing a ghosted arrow or symbol indicating the direction to the active leg in the flight plan.*

**2.4.1.3.1 Desired Path**

1. When in flight plan mode, if the ownship altitude and the desired vertical path are both known, the desired path shall be displayed on the VSD.

   *Note: This may only be done when the altitude information is consistent with the primary altimeter source.*

**2.4.1.3.2 Fixes**

1. Altitude constraints at fixes should be depicted and easily discerned on the VSD.

   *Note: This includes depicting at or above and at or below constraints.*

**2.4.1.4 Display of Additional Information**

1. If lines or posts are used to connect fixes to the ground (i.e., either terrain or artificial horizon line), those lines or posts shall accurately reflect where they touch the ground.

   *Note: This problem exists if fixes and terrain are depicted using different geographic projection techniques. This can result in a vertical line from a fix intersecting the wrong spot on the terrain, which is not acceptable. One means of compliance with this requirement is to ensure that the terrain projection matches the flight projection.*

**2.4.1.4.1 Scales**

1. The VSD shall continuously indicate the current horizontal and vertical map ranges.

*Notes*

1. *One means of compliance with this requirement is to depict a horizontal and vertical display scales on the VSD. These display scales may extend across a portion of the display or the entire display. The requirement to display the vertical range may be satisfied with an altitude tape along the entire vertical dimension of the display provided the altitude tape has the same scale as the vertical dimension.*
2. *It is acceptable for the VSD map range to differ from the plan view map range. This may be desirable in order to enable both maps to depict the same number of waypoints on the flight plan when the VSD is in flight plan mode.*

2. The VSD should depict both a horizontal and a vertical display scale.

3. A horizontal display scale depicted on the vertical profile display shall be in the same units (nautical miles or kilometers) that are used for the plan view map display.

4. If the VSD is capable of depicting a display scale in different units (e.g., nautical miles or kilometers, feet or meters), then the units used on that display scale shall be labeled.

5. The vertical and horizontal display scales should be easily located and unobstructed, and should not obstruct other information.

6. For small map ranges (e.g., distance range less than 30 NM), the ratio between vertical and horizontal display scales should not vary across different map ranges.

*Notes:*

1. *This recommendation is to ensure that the flight path angles are constant for small map ranges, such as those used in the terminal area.*
2. *For map ranges greater than those typically used in the terminal area, the ratio may be allowed to vary such that the vertical map range is adequate to depict vertical flight plan information and relevant external hazards.*

**2.4.1.4.2 Vertical Information Depiction**

1. All indications of altitude information depicted on the VSD shall use the same vertical reference (i.e., cannot intermix barometric data with non-barometric data).

*Note: If ownship position is depicted based on barometric altimeter, an acceptable means to depict terrain or other symbols is based on the relative difference in true height.*

2. If the VSD depicts the vertical predictor, it shall be visually distinctive from any depiction of approach glidepath angle or glide slope.

3. If the following items are displayed on the VSD they shall be consistent with existing vertical information on other flight deck equipment including: depiction of selected altitude, depiction of altitude alert setting, depiction of vertical speed selection.

4. Indicated altitude of the ownship on the VSD shall be consistent with the altitude indicated on the primary flight display.

*Notes:*

1. *GNSS altitude may not be used as the source for the altitude unless the VSD does not indicate a numeric altitude (e.g., vertical scale is not labeled).*
2. *This requirement is intended to prevent potential pilot confusion between GNSS altitude and the altitude source approved for use (altimeter). Acceptable implementations include: baro altitude based ownship or no depicted altitude or altitude scale.*
3. *For ownship position based on barometric altitude, this requires that the VSD uses the same altimeter correction used for the altimeter display. This may be accomplished by either having the primary source of altitude feed the VSD or by having a pilot input control on the VSD to manually input the baro corrections.*

### 2.4.2 Labels

1. If the display indicates height above ground of the ownship on the VSD, the height shall be labeled (e.g. AGL, radio altimeter (RA)).

### 2.4.3 Display

There are no unique requirements beyond those specified in section 2.2.3.

### 2.4.4 Display Operating Characteristics and Status Indications

1. Automatic changes to mode shall be annunciated.

   *Note: It is acceptable to temporarily flash the mode annunciation as a means of complying with this requirement.*

2. If the system has different modes (e.g., flight plan mode and track mode), the current mode shall be clearly and continuously indicated.

   *Note: An acceptable means of indication is to depict the swath on the plan view map that is displayed with the VSD.*

### 2.4.5 Shared Display Considerations

1. If the VSD has the ability to turn on and off terrain/obstacles, it shall be clearly indicated whether the terrain/obstacles are turned on or off.

*Notes:*

1. *This requirement is to avoid the potential false perception of no terrain, when in fact the terrain is present but that terrain option is turned off.*
2. *A depiction of a horizontal line extending from the airport runway on the VSD may mislead a pilot into thinking that extended line represents flat terrain, when it does not. In contrast, a line attached to the distance scale may be acceptable.*

### 2.4.6 Database

There are no unique requirements beyond those specified in section 2.2.5

## 2.5 Equipment Performance - Environmental

The environmental tests and performance requirements described in this subsection are intended to provide a laboratory means of determining the overall performance characteristics of the equipment under conditions representative of those that may be encountered in actual operations.

Some of the environmental tests contained in this subsection need not be performed unless the manufacturer wishes to qualify the equipment for the particular environmental condition. These tests are identified by the phrase "when required." If the manufacturer wishes to qualify the equipment to these additional environmental conditions, then these "when required" tests will be performed.

Unless otherwise specified, the test procedures applicable to a determination of equipment performance under environmental test conditions are set forth in RTCA DO-160D[38].

Some of the performance requirements in section 2.2 are not required to be tested to all of the conditions contained in RTCA DO-160D[38]. Judgment and experience have indicated that these particular performance parameters are not susceptible to certain environmental conditions and that the level of performance specified in section 2.2 will not be measurably degraded by exposure to these particular environmental conditions.

The following definitions apply to Table 2-2:

1. Mechanical - the EMD equipment does not need to be operating during these tests.
2. System Operating - the EMD equipment must be operating during these tests.
3. Equipment Interfaces - During environmental testing, the appropriate input/output (I/O) devices must be tested to ensure correct operation of the hardware. Loop-back tests or simulated inputs are acceptable means for this testing.

The environmental performance requirements identified in this section must be met for all components in the airborne EMD system.

Table 2-2 indicates the EMD design requirements that shall be satisfied under the environmental test conditions specified in RTCA DO-160D[38]. An “X” in the row associated with the environmental conditions labeled “Temperature and Altitude”

through "Electrostatic Discharge" identifies the EMD requirements that must be met while the equipment is subjected to those test conditions.

**TABLE 2-2 ENVIRONMENTAL AND TEST PERFORMANCE REQUIREMENTS**

| 2.5(1) Mechanical | 2.5(2) System Operating | 2.5(3) Interfaces | 2.2.3 Graphic Device | 2.2.1(1) Map Depiction | RTCA DO-160D[38] Environmental Conditions |
|---|---|---|---|---|---|
| | X | X | X | X | 4.0 Temperature and Altitude |
| | X | X | X | X | 5.0 Temperature Variation |
| | | X | X | | 6.0 Humidity |
| | | X | X | | 7.2 Operational Shock |
| X | | | | | 7.3 Crash Safety |
| | X | X | X | | 8.0 Vibration |
| | X | | | | 9.0 Explosionproofness *(When Required)* |
| | | X | X | | 10.0 Waterproofness *(When Required)* |
| | | X | X | | 11.0 Fluids Susceptibility *(When Required)* |
| | | X | X | | 12.0 Sand and Dust *(When Required)* |
| | | X | X | | 13.0 Fungus Resistance *(When Required)* |
| | | X | X | | 14.0 Salt Spray *(When Required)* |
| | X | | | | 15.0 Magnetic Effect |
| | X | X | X | X | 16.0 Power Input |
| | X | X | X | X | 17.0 Voltage Spike |
| | X | X | X | X | 18.0 Audio Frequency Susceptibility – Power Input |
| | X | X | X | X | 19.0 Induced Signal Susceptibility |
| | X | X | X | X | 20.0 Radio Frequency Susceptibility – Radiated and Conducted |
| | X | | | | 21.0 Emission of Radio Frequency Energy |
| | X | X | X | | 22.0 Lightning Induced Transient Susceptibility |
| | | X | X | | 23.0 Lightning Direct Effects *(When Required)* |
| | X | | | | 24.0 Icing *(When Required)* |
| | X | X | | | 25.0 Electrostatic Discharge |

## 2.6 Equipment Performance Bench Test Procedures

### 2.6.1 Definitions of Terms and Conditions of Test

The following are definitions of terms and the conditions under which the tests described in this subsection should be conducted.

a. **Power Input Voltage:** Unless otherwise specified, all tests will be conducted with the power input voltage adjusted to design voltage plus or minus 2%. The input voltage will be measured at the input terminals of the equipment under test.

b. **Power Input Frequency:**

1. In the case of equipment designed for operation from an AC source of essentially constant frequency (e.g., 400 Hz), the input frequency will be adjusted to design frequency plus or minus 2%.

2. In the case of equipment designed for operation from an AC source of variable frequency (e.g., 300 to 1,000 Hz), unless otherwise specified, tests will be conducted with the input frequency adjusted to within 5% of a selected frequency and within the range for which the equipment is designed.

c. **Adjustment of Equipment:** The circuits of the equipment under test will be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests.

d. **Test Equipment:** All equipment used in the performance of tests should be identified by make, model, and serial number where appropriate, and its latest calibration date. When appropriate, all test equipment calibration standards should be traceable to national and/or international standards.

e. **Test Instrumentation Precautions:** Due precautions will be taken during the tests to prevent the introduction of errors resulting from the connection of voltmeters, oscilloscopes, and other test instruments across the input and output impedances of the equipment under test.

f. **Ambient Conditions**: Unless otherwise specified, all tests will be made within the following ambient conditions:

1. Temperature: +15 to +35 degrees C (+59 to +95 degrees F)

2. Relative Humidity: Not greater than 85%

3. Ambient Pressure: 84 to 107 kPa (equivalent to +5,000 to -1,500 ft) (+1,525 to -460 m)

*Note: When tests are conducted at ambient conditions that differ from the above values, allowances shall be made and the differences recorded.*

g. **Connected Loads**: Unless otherwise specified, all tests will be performed with the equipment connected to loads having the impedance values for which it is designed.

### 2.6.2 Required Test Equipment

The following is a list of equipment that may be used to test the EMD:

- Light Sources (e.g., xenon, halide or quartz halogen lamps).
- Data source as required to exercise all map capabilities.
- Simulated position source to "fly" the displayed flight plan.
- Paper aeronautical charts covering the simulation test area.

### 2.6.3 Detailed Test Procedures

The test procedures set forth below constitute a satisfactory method of determining required performance. Although specific test procedures are cited, it is recognized that other methods may be preferred by the manufacturer. Such alternate methods may be used if the manufacturer can show that they provide at least equivalent information. Therefore, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

#### 2.6.3.1 Static Display Characteristics

The following bench tests may be used to evaluate labeling and the functionality of controls without requiring dynamic flight simulation.

##### 2.6.3.1.1 Initial Conditions

An evaluator wearing a white shirt and seated 30 inches from the display will conduct all control operations using one hand. Map range will be set appropriately for the particular display features being evaluated.

1. Test in the following two conditions using an adjustable illumination source simulating direct light entering:

   a. The right rear window of the flight deck and directed toward the face of the display (testing for washout).

   b. The front window of the flight deck and reflecting off the shirt onto the display (testing for reflectance).

2. All optional map information will be selected for concurrent presentation.

3. Test flight plan (see Table 2-3) will be programmed and displayed.

4. Aircraft position will be set midway on the course between the first two flight plan waypoints (KJFK and IW).

The flight plan shown in Table 2-3 provides for the display of all required symbols and heading changes required to demonstrate the influences of changes in map orientation on flight plan symbology. A comparable flight plan (i.e., using a similar range of fix types) may be substituted in place of the flight plan in Table 2-3 or Table 2-4.

**TABLE 2-3 FIX INFORMATION FOR FLIGHT PLAN NO. 1**

| *Flight plan* | *Fix type* |
|---|---|
| KJFK | Airport |
| IW | NDB |
| DPK | VOR |
| PUGGS | Intersection |
| BDR | VOR |
| BELTT | Intersection |
| KHWV | Airport |

During simulated flight, the tester will load and activate the RNAV 24 approach to KHWV (Shirley, NY) with the 'OCTAV' IAF.

This changes the end of the plan to:

**TABLE 2-4 FIX INFORMATION FOR INSTRUMENT APPROACH**

| *Flight plan* | *Fix type* |
|---|---|
| BELTT | Intersection |
| OCTAV | Waypoint (IAF) |
| ARDIS | Waypoint |
| WEENG | Waypoint (FAF) |
| RW24 | Waypoint (MAP) |
| MAIDS | Waypoint |

*Note: In the following sections, the number in brackets refers to the source for the requirement in this document.*

**2.6.3.1.2 Database**

Verify compliance with the following requirements:

1. The EMD shall provide a means to identify the database(s) version and valid operating period. [2.2.5 (1)]

2. The EMD shall indicate if any data is not yet effective or is out of date. [2.2.5 (2)]

3. The process of updating navigation databases shall meet the standards specified in RTCA DO-200A/EUROCAE ED-76[41]. [2.2.5(5)]

4. WGS-84 position reference system or an equivalent earth reference model shall be used for all displayed data. (Reference RTCA DO-236A[45]; ICAO Annex 15[2]). [2.2.5(6)]

For systems that have an AMMD, verify compliance with the following requirements:

5. If the airport map database is separate from the EMD navigation information database, the AMMD shall provide a means to identify the database version, and/or date, and/or valid operating period. [2.3.5(1)]

6. The process of updating aerodrome databases shall meet the standards specified in RTCA DO-200A/EUROCAE ED-76[41]. [2.3.5(2)]

**2.6.3.1.3 Map and Flight Plan Depiction**

Display programmed flight plan and verify compliance with the following requirements:

1. The EMD shall have the capability of displaying flight plans. [2.2.1.2(1)]

*Note: Flight plans are not required for the AMMD.*

2. The EMD shall display distinctive symbols for different fixes types (waypoints, airports, VORs, NDBs, intersections) and the aircraft (ownship). [2.2.1.1(1)]

3. The EMD shall use symbols similar to those shown on published charts or that are consistent with established industry standards. Guidelines for electronic display symbology are provided in SAE ARP5289[57]. [2.2.1.1(2)]

4. Lines shall be displayed indicating the path to be flown between fixes in a flight plan. [2.2.1.2.1(1)]

5. If the EMD is incapable of representing curves, due to either data or system limitations, then curved path segments shall not be depicted as a single straight line (Reference Figure 2-3). [2.2.1.2.1(3)]

6. If a flight plan is being displayed, and the EMD is receiving an active flight plan from an external navigation system (e.g., an external GNSS navigator or FMS), the active external flight plan shall be displayed, unaltered, on the EMD. [2.2.1.2(2)]

7. If the EMD is used to edit the active flight plan on the EMD, it shall update the flight plan in the external navigator. [2.2.1.2(3)]

8. The way flight plans are depicted in the preview or edit mode shall be distinctive from the normal depiction of the active flight plan. [2.2.1.2(4)]

9. If the EMD receives RNP leg data (i.e., Direct to a Fix (DF), Course to a Fix, (CF), Track between two Fixes (TF), course from a Fix to an Altitude (FA), constant Radius to a Fix (RF)) the EMD shall display the leg type in compliance with RTCA DO-236A[45] or not at all. [2.2.1.2.1(2)]

For systems with a AMMD, while looking at the AMMD verify the following:

10. The capability shall exist to depict runways. [2.3.1.1.1(1)]

11. The depiction of runways shall be distinctive from all other symbology. [2.3.1.1.1(2)]

12. Taxi route information shall be distinguishable from all other AMMD map attributes. [2.3.1.1.3(1)]

13. The way taxi routes are depicted in the preview or edit mode shall be distinctive from the depiction of the active taxi route. [2.3.1.1.3(2)]

14. The AMMD shall contain a symbol representing the location of ownship. [2.3.1.2(1)]

15. If direction/track is not available, the ownship symbol shall not imply directionality. [2.3.1.2(3)]

For systems with a VSD, with a flight plan programmed and active, examine the depiction of the VSD and verify the following: (Note this test should be repeated in all modes. Any items that cannot be done on the ground should be verified during flight.)

16. The swath shall be centered along either the predicted flight path (e.g., current track) of the aircraft or the flight plan. [2.4.1.1(1)]

17. If the VSD is capable of displaying more than one swath definition (e.g., swath can be defined or based on RNP, Estimated Position Uncertainty, Airway type, TAWS, etc.), the current swath definition shall be available for display.. [2.4.1.1(3)]

18. In flight plan mode, the flight plan, including the desired path and fixes, shall be displayed on the VSD when within the selected VSD map range. [2.4.1.3(1)]

19. When in track mode and the flight plan is not contained within the swath the flight plan shall not be displayed. [2.4.1.3(2)]

20. If flight plan altitude information is not available, then the VSD shall not depict a vertical path, and shall depict waypoints without altitude restrictions at the aircraft's current altitude. [2.4.1.3(3)]

21. When operating in flight plan mode, the VSD shall depict the same flight plan as the plan view map depiction. [2.4.1.3(4)]

22. The VSD depiction of ownship position relative to the flight plan shall not conflict with the vertical guidance (e.g., deviations) on the primary flight display. [2.4.1.3(5)]

23. If depicting the distance to a DME (e.g., on an approach), the VSD shall label the distance as a DME distance and indicate the associated facility. [2.4.1.3(6)]

24. The profile display shall accurately depict with respect to the scale factors of the display (i.e., vertical and horizontal) all vertical path information displayed, including glide slope, approach path, or angle of descent. [2.4.1.3(7)]

25. If the VSD is in flight plan mode and the aircraft deviates from the flight plan to the extent that it is no longer within the swath, the system shall either 1) switch to track mode, 2) flag the display or 3) remove the ownship symbol from the VSD. [2.4.1.3(8)]

26. If in flight plan mode, all depicted symbols shall be placed based on the total along-path distances (i.e., an “unwound” flight plan) so that distance between fixes is consistent with the distances between the fixes on the plan view map (including published arcs or fixed radius turns). [2.4.1.3(9)]

27. When in flight plan mode, if the altitude and the desired vertical path are both known, the desired path shall be displayed on the VSD. [2.4.1.3.1(1)]

28. All indications of altitude information depicted on the VSD shall use the same vertical reference (i.e., cannot intermix barometric data with non-barometric data). [2.4.1.4.2(1)]

29. If the VSD depicts the vertical predictor, it shall be visually distinctive from any depiction of approach glidepath angle or glide slope. [2.4.1.4.2(2)]

30. If the following items are displayed on the VSD they shall be consistent with existing vertical information on other flight deck equipment including: depiction of selected altitude, depiction of altitude alert setting, depiction of vertical speed selection. [2.4.1.4.2(3)]

31. Indicated altitude of the ownship on the VSD shall be consistent with the altitude indicated on the primary flight display. [2.4.1.4.2(4)]

#### 2.6.3.1.4 Orientation

For EMDs with multiple orientation options (e.g., actual track-up, heading-up, and North-up), change the orientation of the map depiction from North-up to each other plan-view orientation alternative and verify compliance with the following requirements:

1. The EMD shall have the capability to present map information in at least one of the following orientations: actual track-up or heading-up. [2.2.4(9)]

2. If the system is in North-up, the orientation of the map shall be referenced to true North. [2.2.4(12)]

3. If direction information is referenced to true North this shall be indicated. [2.2.4(14)]

4. Current map orientation shall be clearly, continuously, and unambiguously indicated (e.g., track-up vs. North-up). [2.2.4(17)]

5. All symbols shall be depicted in an upright orientation except for those designed to reflect a particular compass orientation. [2.2.1.1(3)]

6. Symbols indicating a particular compass orientation shall maintain that compass orientation at all times. An example of this is a depiction of a runway symbol that maintains proper compass orientation as the map rotates. [2.2.1.1(4)]

7. Fix labels shall be oriented to facilitate readability. [2.2.2(5)]

8. If the heading or track is available, the aircraft/ownship symbol shall be directional, oriented to either heading or track. [2.2.1.1(8)]

9. If the EMD supports more than one aircraft symbol directional orientation (e.g., heading and track), then the current aircraft symbol orientation shall be indicated. [2.2.1.1(9)]

10. All overlayed data shall be the same map orientation and scale. [2.2.1.3(6)]

#### 2.6.3.1.5 Map Range Control

In all orientation modes, cycle through the full set of selectable map ranges and verify compliance with the following requirements:

1. The EMD shall have the capability of manually changing the map range. [2.2.4(1)]

2. Current map range shall be indicated continuously. [2.2.4(2)]

3. If the EMD is controlling the map range automatically, then the capability shall exist to activate or deactivate the automatic map range. [2.2.4(4)]

#### 2.6.3.1.6 Placement and Orientation Accuracy of Symbols and Graphics

For a representative selection of map ranges in all orientation modes, and map projections (if applicable), verify compliance with the following requirements for cases 1 through 4 below:

1. All displayed symbols and graphics shall be positioned (i.e., drawn or rendered) accurately relative to one another such that placement errors are less than 1% of the selected map range and orientation errors are less than 3° with respect to the values provided by the position and database sources. [2.2.1(1)]

   *Notes:*

   1. *In order to isolate the EMD's performance from that of the position source, database, and other additional data being input into the EMD, the measurements must be compared against the data being received.*
   2. *The figures below (see Figures 2-5- through 2-8) are intended to be engineering schematics, not the entire EMD. The intent is to measure physical dimensions of distance on the display. These sample schematics are heading-up depictions.*

Case 1: Measure the horizontal and vertical placement error of at least one non-rotated symbol (active fix "BLAKE" in the example) with respect to the aircraft symbol (see Figure 2-8).

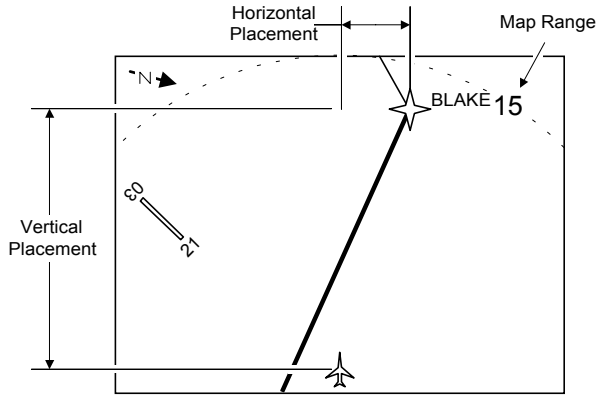



**FIGURE 2-7 NON-ROTATED SYMBOL PLACEMENT ERROR**

Case 2: Measure the horizontal and vertical placement error and orientation error of at least one rotated symbol (Runway 21 in the example) with respect to the aircraft symbol (see Figure 2-8).

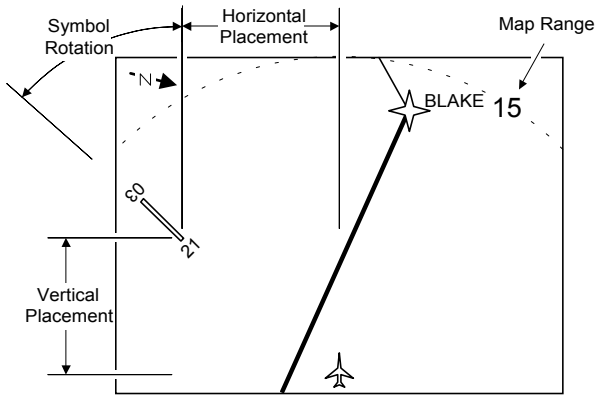



**FIGURE 2-8 ROTATED SYMBOL PLACEMENT AND ORIENTATION ERROR**

Case 3: Measure the orientation error of the desired path with respect to the aircraft symbol (see Figure 2-9).

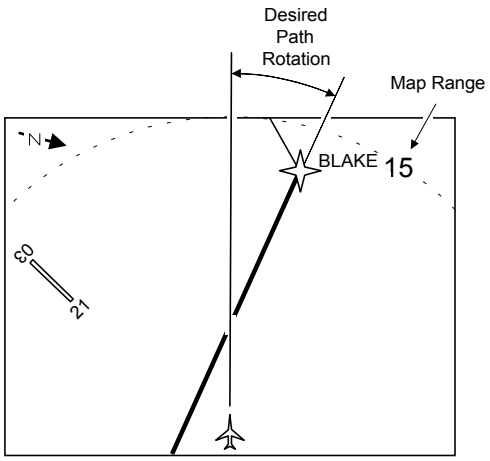



**FIGURE 2-9 DESIRED PATH ORIENTATION ERROR**

Case 4: Measure the cross-track deviation error (see Figure 2-10).

*Note: Cross-track deviation is expressed as the length of a line perpendicular to the desired path intersecting the center of the aircraft symbol.*

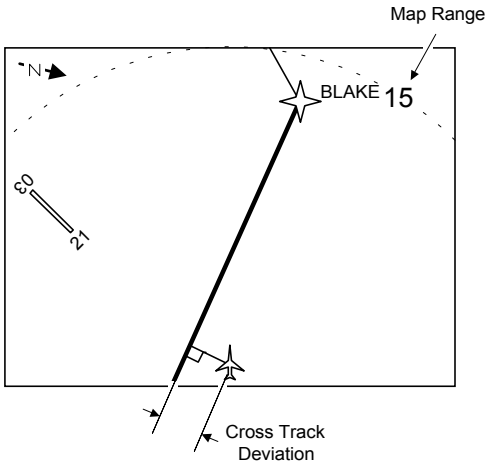



**FIGURE 2-10 CROSS TRACK DEVIATION ERROR**

2. A single mode (i.e., either track mode or flight plan mode) shall be applied to all information depicted in the VSD at the same time. [2.4.1(1)]

3. If the ownship symbol is directional, the symbol orientation shall correctly depict the lateral directional orientation of the aircraft (i.e., towards or away from the objects depicted in the VSD). [2.4.1.2(2)]

4. If the VSD ownship symbol is not always in a consistent location (e.g., always on the left side of the display) the direction of motion of ownship shall be depicted on the VSD. [2.4.1.2(4)]

5. If there is a numeric altitude indication associated with ownship on the VSD, the altitude depicted shall be consistent with the numeric indication on the aircraft's primary altimeter and on the FMS Control Display Unit (CDU) approach page, if installed. [2.4.1.2(6)]

6. For multi-function or shared display systems, symbols used on the VSD shall be distinct from symbols used on the plan view map display when they represent different things and the same when they represent the same things. [2.4.1.2(8)]

7. If lines or posts are used to connect fixes to the ground (i.e., either terrain or artificial horizon line), those lines or posts shall accurately reflect where they touch the ground. [2.4.1.4(1)]

8. A horizontal display scale depicted on the vertical profile display shall be in the same units (nautical miles or kilometers) that are used for the plan view map display. [2.4.1.4.1(3)]

9. The ownship shall be unobstructed. [2.2.1.1(7)]

#### 2.6.3.1.7 Fixes

While reviewing the plan view display, identify the active fix and the next fix, vary the map range, and verify compliance with the following requirements:

1. The active fix shall be uniquely identified and distinctive from other fixes. [2.2.1.2.2(1)]

2. The active fix, the next fix, and their associated labels (e.g., fix identifier) shall be displayed and identifiable, if they are within the selected map range and they exist. [2.2.1.2.2(2)]

3. If the active fix is beyond the selected map range, the fix identifier shall be visible or readily accessible on the EMD. [2.2.1.2.2(3)]

#### 2.6.3.1.8 Labels

Identify all controls and map data and verify compliance with the following requirements:

1. The EMD shall have the capability to display the complete fix identifier (e.g., KBOS, not BOS) for the required minimum symbol set as defined in Table 2.1. [2.2.2(1)]

2. Labels shall be used to identify fixes, other symbols, and other information, depicted on the EMD, where appropriate. [2.2.2(2)]

3. The runway identifiers shall be available for depiction on the display, if available. [2.3.2(1)]

4. The VSD shall continuously indicate the current horizontal and vertical map ranges. [2.4.1.4.1(1)]

5. A horizontal display scale depicted on the vertical profile display shall be in the same units (nautical miles or kilometers) that are used for the plan view map display. [2.4.1.4.1(3)]

6. If the VSD is capable of displaying a scale in different units (e.g., nautical miles or kilometers, feet or meters), then the units used on that display scale shall be labeled. [2.4.1.4.1(4)]

7. Automatic changes to mode shall be annunciated. [2.4.4(1)]

8. If the system has different modes (e.g., flight plan mode and track mode), the current swath mode shall be clearly and continuously indicated. [2.4.4(2)]

9. If the VSD has the ability to turn on and off terrain/obstacles, it shall be clearly indicated whether the terrain/obstacles are turned on or off. [2.4.5(1)]

10. If the display indicates height above ground of the ownship on the VSD, the height shall be labeled (e.g. AGL, radio altimeter (RA)). [2.4.2(1)]

#### 2.6.3.1.9 Graphic Device

Vary the intensity of external illumination through the full range of normally expected flight deck illumination from complete darkness to direct and unfiltered sunlight directed to the face of the display and adjust the brightness control of the display to compensate for this range of illumination. Verify compliance with the following requirements:

1. The operating range of display luminance and contrast shall be sufficient to ensure display readability through the full range of normally expected flight deck illumination conditions (Reference SAE ARP4256[55]). [2.2.3(1)]

2. The display shall be readable through a horizontal viewing angle 30 degrees either side of a line normal to the display surface, and through a vertical angle 20 degrees above and 5 degrees below a line normal to the display surface (Reference SAE ARP4256[55] and also SAE ARP4102[53]). [2.2.3(3)]

3. If color is used for information coding, the selected color set shall be discriminable under the full range of normally expected flight deck illumination conditions and the design viewing angle (Reference SAE ARP4256[53]). [2.2.3(4)]

4. All labels shall be readable at a viewing distance of 30 inches under the full range of normally expected flight deck illumination conditions (Reference MIL STD 1472D[59] and SAE AIR1093[51]). [2.2.2(7)]

5. Required symbols (per Table 2-1) shall be discriminable at a viewing distance of 30 inches under the full range of normally expected flight deck illumination conditions. [2.2.1.1(6)]

6. The display shall be readable through a horizontal viewing angle 30 degrees either side of a line normal to the display surface, and through a vertical angle 20 degrees above and 5 degrees below a line normal to the display surface (Reference SAE ARP4256[55] and also SAE ARP4102[53]). [2.2.3(3)]

7. The EMD shall respond to operator control inputs within 500 msec. [2.2.4(18)]

8. If the EMD can use multiple position sources, other than multiple GNSS sensors, a means of identifying the active source(s) shall be provided. [2.1.10(1)]

#### 2.6.3.1.10 Accuracy

1. The aircraft position sensor horizontal positional accuracy for runways shall be less than 36m. [2.3.1.1.1(5)]

2. The aerodrome total database accuracy for runways shall be 43m or less. [2.3.1.1.1(6)]

3. The aircraft position sensor horizontal positional accuracy for taxiways shall be less than 36m. [2.3.1.1.2(3)]

4. The aerodrome total database accuracy for taxiways shall be 65m or less. [2.3.1.1.2(4)]

5. The AMMD shall provide an indication if the accuracy implied by the display is better than the level supported by the total system accuracy. [2.3.1(1)]

### 2.6.3.2 Simulated Flight EMD Evaluation

The conditions and flight plan (as specified in the initial conditions) in this simulated flight test section may be used to evaluate the dynamic aspects associated with an aircraft flying a programmed flight plan.

#### 2.6.3.2.1 Initial Conditions

The initial conditions for this simulation test are:

1. Test flight plan (see Table 2-3) programmed and displayed.

2. Initial aircraft altitude and ground speed, as appropriate to flight operations.

3. Wind Speed/Direction, 20 knots cross wind relative to track to DPK.

4. Initialization of the system providing the map display data, e.g., navigation system computer, simulated navigation system computer, RNAV system, etc.

5. Simulated position source, when the simulation is stopped to permit measurement of relative placement accuracy of map symbols.

#### 2.6.3.2.2 Display Presentation Evaluation

The system display presentations may be evaluated according to the criteria in this section, following activation of the flight navigation simulation.

##### 2.6.3.2.2.1 Orientation

Change map orientation from North-up to desired track-up, fly across fix IW and make the appropriate heading change to track the desired path. Verify compliance with the following requirements:

1. The EMD shall have the capability to present map information in at least one of the following orientations: actual track-up or heading-up. [2.2.4(9)]

2. Fix labels shall be oriented to facilitate readability. [2.2.2(5)]

3. All symbols shall be depicted in an upright orientation except for those designed to reflect a particular compass orientation. [2.2.1.1(3)]

4. If the heading or track is available, the aircraft/ownship symbol shall be directional, oriented to either heading or track. [2.2.1.1(8)]

5. If the EMD supports more than one aircraft symbol directional orientation (e.g., heading and track), then the current aircraft symbol orientation shall be indicated. [2.2.1.1(9)]

6. If desired track-up orientation is used, the aircraft symbol shall be oriented to actual track or heading. [2.2.4(10)]

7. The default reference for all direction information on the EMD (e.g., heading, track, etc.) shall be magnetic and "MAG" mode need not be annunciated. [2.2.4(13)]

8. If the system is in North-up, the orientation of the map shall be referenced to true North. [2.2.4(12)]

9. If direction information is referenced to true North this shall be indicated. [2.2.4(14)]

#### 2.6.3.2.2.2 Desired Path

Fly a 5-mile offset between PUGGS and DPK and verify compliance with the following requirement:

1. The active desired path shall be differentiated from any other paths displayed (e.g., alternate or inactive desired path, track history, or projected path). [2.2.1.2.1(4)]

### 2.6.3.2.3 Display of Additional Information and De-clutter Control

Select all available categories of information for presentation, review the map depiction, then delete all information except for the required minimum and verify compliance with the following requirement:

1. The EMD shall have the capability for in-flight manual de-cluttering during operational use. [2.2.1.3(1)]

2. If a wind vector is displayed on the map, its orientation shall be consistent with the orientation of the map and pointing in the direction of wind flow. [2.2.1.3(4)]

### 2.6.3.2.4 Display Operating Characteristics

Compare changes in the ownship position of the "aircraft" and the data input signal and verify compliance with the following requirement:

1. Maximum latency of aircraft position data at the time of display update shall be one second, as measured from the time the data is received by the EMD system. [2.2.4 (20)]

2. The EMD shall update the displayed minimum required information set, as defined in Table 2-1, at least once per second. [2.2.4(19)]

Generate a "reduced performance" message from the position-input source and verify compliance with the following requirement:

3. When the EMD receives a "data not valid" or "reduced performance" (e.g., dead reckoning mode) indication from the source, this condition shall be indicated on the EMD within one second. [2.2.4(22)]

Disconnect the position data source and:

4. Verify that EMD indicates that the position is degraded or no longer valid. [2.2.4(22)]

Verify compliance with the following requirements:

5. If aircraft positioning data are not received by the EMD for five seconds (i.e., data timeout), this condition shall be indicated to the flight crew. [2.2.4(23)]

6. If there is an active flight plan and the flight plan data are not received by the EMD for 30 seconds, this condition shall be indicated to the flight crew. [2.2.4(24)]

## 3.0 Installed Equipment Performance

This section describes the minimum acceptable level of performance for the equipment when installed in the aircraft. For the most part, installed performance requirements are the same as those contained in section 2, which were evaluated through bench and environmental tests. However, certain requirements may be affected by the physical installation and can only be verified after installation. Installation and installed performance requirements of the EMD as well as test procedures for evaluating that performance on the ground and in the air are specified below.

The installed equipment must meet the requirements of subsections 2.1 and 2.2 in addition to, or as modified by, the requirements stated below.

## 3.1 Equipment Installation Requirements

This section contains general requirements that may influence the installation, physical location, and integration of the EMD equipment in the aircraft. The term EMD includes electronic map displays depicting in-flight, airport surface, and vertical (profile) information.

While it must be determined that each requirement listed in this section has been complied with, many of these requirements do not lend themselves to detailed test procedures. Thus, the requirements in this section do not have particular test procedures specified in the test procedure subsection.

### 3.1.1 Control Accessibility and Location

The following requirements pertain only to controls and displays intended for use in flight.

1. Controls shall be readily accessible from the pilot's normal seated position.

2. The controls and their identifying labels shall be readily identifiable from the pilot's normal seated position.

3. The controls shall not be operable in any position, combination, or sequence that would result in a condition detrimental to the operation of the aircraft.

4. Appropriate protection shall be provided to avoid inadvertent turnoff of the equipment.

5. The location and operation of the EMD controls shall not interfere with the operation of other equipment.

6. The location of the EMD and EMD controls shall not interfere with the operator's view of other equipment.

7. Line select function keys should acceptably align with adjacent text.

### 3.1.2 Aircraft Environment

1. Equipment shall be compatible with the environmental conditions present in the specific location in the aircraft where the equipment is installed.

### 3.1.3 Display Visibility

1. The display shall be readable under the full range of normally expected flight deck illumination conditions.

   *Note: Visors, glareshields or filters may be an acceptable means of obtaining daylight visibility.*

2. Display luminance shall not interfere with the usability of other flight deck displays nor produce unacceptable glare against the windscreen or other reflective surface.

3. The operator shall have an unobstructed view of displayed data, including data on the EMD and all associated remote status and mode indicators, when in the normal seated position.

### 3.1.4 Failure Protection

1. Any probable failure of the EMD shall not degrade the normal operation of other equipment or systems connected to it beyond degradation due to the loss of the EMD itself.

2. The failure of interfaced equipment or systems shall not degrade normal operation of the EMD equipment beyond degradation due to the loss of data from the interfaced equipment.

   *Note: For instance, the EMD cannot "lock up" due to failure of interfaced equipment. The system should gracefully degrade its display and should remain responsive to user inputs.*

### 3.1.5 Interference Effects

1. The equipment shall not be the source of harmful conducted or radiated interference nor adversely affect or be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

   *Note: Electromagnetic compatibility problems noted after installation of this equipment may result from such factors as the design characteristics of previously installed systems or equipment and the physical installation itself. It is not intended that the equipment manufacturer design for all installation environments. The installing facility will be responsible for working with the manufacturer to resolve any incompatibility between this equipment and previously installed equipment in the aircraft.*

### 3.1.6 Function and Documentation

1. The equipment shall be installed in accordance with its intended function(s).

2. Equipment manufacturers shall document the intended function(s) of the EMD, within the installation instructions and operating manual.

3. For equipment that may not fully display curved path procedures, a note shall be added to the AFM indicating that: curved path procedures (e.g. DME arcs) may not be displayed and to refer to the user documentation for further explanation.

4. For equipment that may not fully display curved path procedures, the user documentation shall provide textual and graphical explanations of what the pilot can expect the EMD to display, including a directive to use the CDI for guidance through the turn.

   *Note: One means of compliance is to include a table listing known supported external equipment and the curved path depictions that will be displayed.*

5. Equipment using raster aeronautical charts (RAC) shall not be used for navigation while the RAC data is being displayed because inaccuracies in chart symbol placement and distortions are introduced by the production process.

## 3.2 Installed Equipment Performance Requirements

This section contains operational and performance requirements that may influence the installation, physical location, and integration of the EMD equipment in the aircraft.

### 3.2.1 Display Readability

1. The display shall be readable under normal conditions of flight.

   *Note: Normal conditions of flight include turbulence and maneuvers, in addition to the illumination conditions.*

### 3.2.2 Equipment Operation

1. Operation of the equipment shall not be adversely affected by aircraft maneuvering encountered in normal flight operations.

2. Operation of the equipment shall not interfere with the usability of other flight deck displays.

### 3.2.3 AMMD System Installed Equipment Performance Requirements

1. The total system accuracy shall be sufficient for the intended operation, and shall not exceed 100 meters (95%). The installed system should be evaluated to confirm compliance with the requirement in section 2.3.1.

*Notes:*

1. *The accuracy is sufficient for the intended function if, when the aircraft is on a runway or taxiway, the AMMD displays the ownship on that runway or taxiway. This may mean that the symbol itself is depicted overlapping the true aircraft location, or that the aircraft's true location stays within the depicted accuracy circle.*

2. *The accuracy includes the effects of how latent data manifests itself into ownship position errors at the time of display. This includes the effects of a) not compensating vehicle movement during the latency period, b) not completely compensating (e.g., partial compensation), and/or c) errors in the compensation.*

3. *The accuracy includes the effects of the aircraft reference point, defined as the accuracy of the location on the aircraft used to position the ownship symbol, or used in a surveillance position report.*

4. *It is understood that the most significant error source of the total system error is the available survey data for airports. The achieved accuracy of the data is primarily an operational issue. More accurate survey data will eventually become available, and errors in the existing survey data will be culled as error reports are generated and resolved as described in section 2.3.5.*

5. *The total system accuracy requirement is consistent with the runway separation criteria for large airports (see Appendix I). An example error allocation is: position accuracy of 36 meters (see section 2.3.1.1.1), data accuracy of 65 meters (taxiways, section 2.3.1.1.2), latency effects of 4.5 m, display errors of 0.5 m, and aircraft reference point bias of 25 m. The resulting total system accuracy under these assumptions is:*

   $[(36\ m)^2 + (65\ m)^2 + (4.5\ m)^2 + (0.5m)^2]^{1/2} + 25 = 100\ m$

   *These values are only an example, and errors can be allocated differently (e.g., runway database accuracy can be less stringent if the aircraft reference point accuracy error is a smaller value). The runway and taxiway criteria in Appendix I can be used to establish accuracy objectives for specific operations typically indicates position accuracy is less than 15 meters, and the aircraft reference point error can be eliminated through calibration.*

### 3.2.4 Vertical Situation Display Installed Equipment Performance Requirements

1. The flight plan depicted on the VSD shall be consistent with the flight plan depicted on the primary flight display.

2. The vertical information depicted on the VSD shall be consistent with the vertical information depicted on the primary flight display.

   *Note: This includes the depiction of the ownship altitude information, altitude scale, and relative height of the ownship above terrain (if depicted).*

## 3.3 Conditions of Test

The following subparagraphs define conditions under which tests specified in section 3.4 shall be conducted.

### 3.3.1 Power Input

Unless otherwise specified, tests shall be conducted with the equipment powered by the aircraft's electrical power generating system.

### 3.3.2 Associated Equipment or Systems

Unless otherwise specified, all aircraft electrically operated equipment and systems shall be turned on before conducting interference tests.

### 3.3.3 Environment

During tests, the equipment shall not be subjected to environmental conditions that exceed those specified by the equipment manufacturer.

### 3.3.4 Adjustment of Equipment

Circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests.

### 3.3.5 Warm-up Period

Unless otherwise specified, tests shall be conducted after a warm-up (stabilization) period of not more than fifteen minutes.

## 3.4 Test Procedures for Installed Equipment Performance

The following test procedures provide one means of determining installed equipment performance. Although in some instances specific test procedures are cited, it is recognized that other methods may be preferred by the installing activity. These alternate procedures may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures. The equipment must be tested to demonstrate compliance with the minimum requirements stated in sections 2.2, 3.1, and 3.2. In order to meet this requirement, test results supplied by the equipment manufacturer or other proof of conformity may be accepted in lieu of tests performed by the installing activity.

### 3.4.1 Ground Test Procedures

#### 3.4.1.1 Conformity Inspection

Visually inspect the installed equipment to determine the use of acceptable workmanship and engineering practices.

Verify that the proper mechanical and electrical connections have been made and that the equipment has been located and installed in accordance with the manufacturer's recommendations.

#### 3.4.1.2 Display Luminance

Exclude all external light from the flight deck, turn on all avionics and verify compliance with the following requirement:

1. Display luminance shall not interfere with the usability of other flight deck displays nor produce unacceptable glare against the windscreen or other reflective surface. [3.1.3(2)]

#### 3.4.1.3 Equipment Function

Vary all controls of the equipment through their full range to determine that the equipment is operating according to the manufacturer's instructions and that each control performs its intended function(s).

#### 3.4.1.4 Interference Effects

With the equipment energized, operate each of the other electrically operated aircraft equipment and systems and verify the following:

1. The equipment shall not be the source of harmful conducted or radiated interference nor adversely affect or be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft. [3.1.5(1)]

Evaluate all reasonable combinations of control settings and operating modes. Operate communication and navigation receiver/transmitter equipment on the low, high, and at least one, but preferably four mid-band frequencies. Make note of systems or modes of operation that also should be evaluated during flight. If appropriate, repeat tests using emergency power with the aircraft's batteries alone and the inverters operating.

#### 3.4.1.5 Power Supply Fluctuations

Under normal aircraft conditions, cycle the aircraft engine(s) through all normal power settings and verify proper operation of the equipment as specified by the equipment manufacturer.

### 3.4.2 Flight Test Procedures and Demonstrations

A flight test will be conducted to verify satisfactory operation and usability of the installed equipment in flight. The evaluation should take place during all phases of flight including taxi, takeoff roll, climb, cruise, descent, approach and landing.

The display presentation evaluation will be conducted while flying a flight plan that is representative of actual flying conditions and use. The flight should include several off-course maneuvers to permit evaluation of the EMD presentation.

The test procedures set forth below constitute a satisfactory method of determining required performance. Although specific test procedures are cited, it is recognized that other methods may be preferred. Such alternate methods may be used if the manufacturer can show that they provide at least equivalent information. Therefore, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

**3.4.2.1 Interference Effects**

For aircraft equipment and systems that can be checked only in flight, determine that significant conducted or radiated interference does not exist. (See interference tests in section 3.4.1.4).

Evaluate all reasonable combinations of control settings and operating modes. Operate communication and navigation receiver/transmitter equipment on the low, high, and at least one, but preferably four mid-band frequencies.

**3.4.2.2 Equipment Accessibility and Function**

Operate all EMD controls through their full range and verify compliance with the following requirements:

1. Operation of the equipment shall not interfere with the usability of other flight deck displays. [3.2.2(2)]

**3.4.2.3 Displayed Data Readability**

Determine that normal conditions of flight do not significantly affect the readability of displayed data. This should include testing under bright sunlight. Maneuver the aircraft through a series of heading changes that allow the sunlight to enter the flight deck directly through each of the flight deck windows and verify compliance with the following requirements:

1. The display shall be readable under normal conditions of flight. [3.2.1(1)]

2. The display shall be readable under the full range of normally expected flight deck illumination conditions. [3.1.3(1)]

3. The operator shall have an unobstructed view of displayed data, including data on the EMD and all associated remote status and mode indicators, when in the normal seated position. [3.1.3(3)]

4. The ownship symbol shall be unobstructed. [2.2.1.1(7)]

**3.4.2.4 Map Depiction**

Flight testing will be conducted with the map configured in all available orientations (e.g., North-up, desired track-up, track-up, and heading-up). Verify compliance with the following requirement:

1. The EMD shall respond to operator control inputs within 500 msec. [2.2.4(18)]

**3.4.2.4.1 Aircraft Maneuvering**

In order to test all components of the EMD, aircraft maneuvering will be conducted in the air and on the airport surface. While on the ground, taxi in several areas on the airport surface. While in-flight fly several maximum bank angle turns (normal maneuvering) across the desired path involving 45 degree heading changes while climbing and descending. During heading and altitude changes verify compliance with the following requirements:

1. All displayed symbols and graphics shall be positioned (i.e., drawn or rendered) accurately relative to one another such that placement errors are less than 1% of the selected map range and orientation errors are less than 3° with respect to the values provided by the position and database sources. [2.2.1(1)]

2. All symbols shall be depicted in an upright orientation except for those designed to reflect a particular compass orientation. [2.2.1.1(3)]

3. Symbols indicating a particular compass orientation shall maintain that compass orientation at all times. An example of this is a depiction of a runway symbol that maintains proper compass orientation as the map rotates. [2.2.1.1(4)]

4. If heading or track is available, the aircraft/ownship symbol shall be directional, oriented to either heading or track. [2.2.1.1(8)]

5. Operation of the equipment shall not be adversely affected by aircraft maneuvering encountered in normal flight operations. [3.2.2(1)]

For systems with an AMMD, verify compliance with the following requirement:

6. The total system accuracy shall be sufficient for the intended operation, and shall not exceed 100 meters (95%). [3.2.3]

For systems with a VSD, with a flight plan programmed and active, compare it with information depicted on the primary flight display to ensure compliance with the following requirements:

7. The flight plan depicted on the VSD shall be consistent with the flight plan depicted on the primary flight display. [3.2.4(1)]

8. The vertical information depicted on the VSD shall be consistent with the vertical information depicted on the primary flight display. [3.2.4(2)]

## 4.0 Equipment Operational Performance Characteristics

### 4.1 Required Operational Performance Requirements

To assure the operator that operations can be conducted safely and reliably in the expected operational environment, there are specific minimum acceptable performance requirements that shall be met. The following paragraphs identify these requirements.

#### 4.1.1 Power Input

Prior to flight, verify that the equipment is receiving primary input power necessary for proper operation.

#### 4.1.2 Equipment Operating Modes

The equipment shall operate in each of its operating modes.

### 4.2 Test Procedures for Operational Performance Requirements

Operational tests may be conducted as part of normal pre-flight tests. For those tests that can only be run in flight, procedures should be developed to perform these tests as early during the flight as possible to verify that the equipment is performing its intended functions(s).

#### 4.2.1 Power Input

With the aircraft's electrical power generating system operating, energize the equipment and verify that electrical power is available to the equipment.

#### 4.2.2 Equipment Operating Modes

Verify that the equipment performs its intended function(s) for each of the operating modes available to the operator.

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# Navigation Standards

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| John Schmitt | Honeywell International, Inc. |
| Lou Selk | Honeywell International, Inc. |
| Ralph Sexton | Innovative Solutions International, Inc. |
| Peter Skaves | Federal Aviation Administration |
| Bernald Smith | Soaring Society of America/FAI |
| Eugene St. Clair | ARINC, Inc. |
| Victor Strachan | Litton Industries, Inc. |
| Abdul Tahir | Aviso, Inc. |
| Tom Teetor | Defense Concept Associates, Inc. |
| Thomas Tomaszek | Rockwell Collins, Inc. |
| Tin Truong | Federal Aviation Administration |
| Stephen Van Trees | Federal Aviation Administration |
| Jon Velle | Honeywell International, Inc. |
| Lou Volchansky | Federal Aviation Administration |
| James Walton | United Parcel Service |
| Thorsten Wiesemann | DIEL Avionik Systeme GmbH |
| Steve Whittemore | Garmin |
| David Williams | Evans & Sutherland |
| Lyle Wink | Federal Aviation Administration |
| Christopher Wolf | Federal Aviation Administration |
| Michelle Yeh | Volpe National Transportation System Center |
| Michael Zuschlag | Volpe National Transportation System Center |

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# APPENDIX A

# ABBREVIATIONS

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If you choose to use abbreviations, the following abbreviations should be used for the terms below, including use in checklists, messages, identification and labels for control functions. These abbreviations should not be used to represent a different term. These standards should be used consistently in the pilot handbook supplements, quick reference checklists, on the equipment controls, displays, and associated labels (Reference RTCA DO-229C[44]).

*Note: It is not the intent of this list to require upper case abbreviations, as many of these abbreviations may be clearly represented in a combination of upper and lower case type. In all cases the meaning should be easily construed and remain consistent in a given piece of equipment.*

| DO-229C[44] Word(S) To Be Abbreviated | DO-229C[44] Recommended Abbreviation(S) | ICAO 8400/5[3] Recommended Abbreviation | ICAO 8400/5[3] Word(S) To Be Abbreviated |
|---|---|---|---|
| Acknowledge | ACK | ACK | Acknowledge |
| Active, Activate | ACT, ACTV | ACT | Active Or Activated Or Activity |
| Airport | APT | AP | Airport |
| | | | |
| Air Traffic Control | ATC | ATC | Air Traffic Control (In General) |
| Alert/Alerting | ALRT | ALR | Alerting (Message Type Designator) |
| Altitude | ALT | ALT | Altitude |
| Along-Track Distance | ATD | | |
| Along-Track Error | ATE | | |
| Along-Track | ATK | | |
| Approach, Approach Control | APPR, APR | APCH | Approach |
| Area Navigation | RNAV | RNAV | Area Navigation |
| Arm, Armed | ARM | | |
| Barometric Setting | BARO | | |
| Bearing | BRG | BRG | Bearing |
| Cancel | CNCL | CNL | Cancel Or Cancelled |
| Center Runway | C | C | Centre (Runway Identification) |
| Centigrade | C | C | Celsius (Centigrade), Degrees |
| Clear | CLR | CLR | Clear(S) Or Cleared To... Or Clearance |
| Coordinated Universal Time | UTC | UTC | Coordinated Universal Time |
| Course | CRS | | |
| Course Deviation Indicator | CDI | | |
| Course To Fix | CF | | |
| Cross-Track | XT, XTK | | |
| Cross-Track Error | XTE | | |
| Cursor | CRSR | | |
| Database | DB | | |

| DO-229C[44] Word(S) To Be Abbreviated | DO-229C[44] Recommended Abbreviation(S) | ICAO 8400/5[3] Recommended Abbreviation | ICAO 8400/5[3] Word(S) To Be Abbreviated |
|---|---|---|---|
| Dead Reckoning | DR | DR | Dead Reckoning |
| Decision Altitude | DA | DA | Decision Altitude |
| Delete | DEL | | |
| Departure, Departure Control | DEP | DEP | Depart Or Departure |
| Desired Track | DK, DTK | | |
| Destination | DEST | DEST | Destination |
| Dilution Of Precision | DOP | | |
| Direct, Direction | DIR | DCT | Direct (In Relation To Flight Plan Clearances And Type Of Approach) |
| Direct-To | direct symbol Direct To (D▸ ) D with arrow | | |
| Direct-To Fix | DF | | |
| Distance | DIS, DIST | DIST | Distance |
| East | E | E | East Or Eastern Longitude |
| Emergency Safe Altitude | ESA | | |
| En Route | ENR | ENR | En Route |
| En Route Safe Altitude | ESA | | |
| Enter | ENT | | |
| Estimated Time Of Arrival | ETA | ETA | Estimated Time Of Arrival Or Estimating Time Of Arrival |
| Estimated Time Of Departure | ETD | ETD | Estimated Time Of Departure Or Estimating Departure |
| Estimated Time En Route | ETE | | |
| Fahrenheit | F | | |
| Feet, Foot | ', FT | FT | Feet (Dimensional Unit) |
| Feet Per Minute | FPM | FPM | Feet Per Minute |
| Final Approach Fix | FAF | FAF | Final Approach Fix |
| Final Approach Waypoint, For Waypoint Identifiers | f, FA, FAWP | FAP | Final Approach Point |
| Flight Level | FL | FL | Flight Level |
| Flight Plan | FPL | PLN | Flight Plan Cancellation (Message Type Designator) |
| From | FR | FM | From |
| Full-Scale Deflection | FSD | | |
| Global Positioning System | GPS | GPS | Global Positioning System |
| Greenwich Mean | GMT | | |

| DO-229C[44] Word(S) To Be Abbreviated | DO-229C[44] Recommended Abbreviation(S) | ICAO 8400/5[3] Recommended Abbreviation | ICAO 8400/5[3] Word(S) To Be Abbreviated |
|---|---|---|---|
| Time | | | |
| Ground Speed | GS | GS | Ground Speed |
| Heading | HDG | HDG | Heading |
| Height Above Threshold | HAT | | |
| | | HGT | Height Above |
| Hold, Holding, Holding Pattern | HLD | HLDG | Holding |
| Horizontal Alert Limit | HAL | | |
| Horizontal Protection Limit | HPL | | |
| Horizontal Situation Indicator | HSI | | |
| Horizontal Uncertainty Level | HUL | | |
| Initial Approach Waypoint, For Waypoint Identifiers | i, IA, IAWP | IAF | Initial Approach Fix |
| Instrument Flight Rules | IFR | IFR | Instrument Flight Rules |
| Intermediate Waypoint | IWP | | |
| Intersection | INT | INT | Intersection |
| Knots | KT | | |
| Latitude | LAT | LAT | Latitude |
| Left | L, LFT | | |
| Left Runway | L | L | Left (Runway Identification) |
| Localizer | LOC | LLZ | Localizer |
| Localizer-Type Directional Aid | LDA | | |
| Longitude | LON | LONG | Longitude |
| Magnetic | M, MAG | MAG | Magnetic |
| | | QRD | Magnetic Bearing |
| Mean Sea Level | MSL | MSL | Mean Sea Level |
| Message | MSG | MSG | Message |
| Meters | M | M | Meters (Preceded By Figures) |
| Military Operating Area | MOA | MOA | Military Operating Area |
| Millibars | mB | | |
| Minimum Decision Altitude | MDA | MDA | Minimum Descent Altitude |
| Minimum En Route Altitude | MEA | MEA | Minimum |
| Minimum Safe Altitude | MSA | MSA | Minimum Sector Altitude |
| Missed-Approach Holding Waypoint | h, MH, MAHWP | | |

| DO-229C[44] Word(S) To Be Abbreviated | DO-229C[44] Recommended Abbreviation(S) | ICAO 8400/5[3] Recommended Abbreviation | ICAO 8400/5[3] Word(S) To Be Abbreviated |
|---|---|---|---|
| Missed-Approach Waypoint, For Waypoint Identifiers | m, MA, MAWP | MAPT | Missed Approach Point |
| Nautical Mile | nm, NM | NM | Nautical Miles |
| | | | |
| Nearest | NRST | | |
| Non-Directional Beacon | NDB | NDB | Non-Directional Radio Beacon |
| Non-Precision Approach | NPA | | |
| North | N | N | North Or Northern Latitude |
| Off Route Obstacle Clearance Altitude | OROCA | | |
| Offset | OFST | | |
| Omni-Bearing Selector | OBS | | |
| Outer Marker | OM | OM | Outer Marker |
| Parallel Track | PTK | | |
| Precision Approach | PA | | |
| Present Position | PPOS, PP | PPSN | Present Position |
| Procedure | PROC | PROC | Procedure |
| Procedure Turn | PT | PTN | Procedure Turn |
| Radial | R, RAD | RDL | Radial |
| Radial/Distance | R/D | | |
| Radius To Fix | RF | | |
| Range | RNG | RG | Range (Lights) |
| Receiver Autonomous Integrity Monitoring | RAIM | | |
| Relative Bearing | RB | | |
| Required Navigation Performance | RNP | RNP | Required Navigation Performance |
| Reverse, Revision, Revise | REV | | |
| Right | R, RT | RITE | Right Turn Of Direction |
| Right Runway | R | R | Right (Runway Identification) |
| Route | RTE | RTE | Route |
| Runway | RWY | RWY | Runway |
| Selective Availability | SA | | |
| Sequence, Sequencing | SEQ | | |
| Setup | SET | | |
| South | S | S | South Or Southern Latitude |

| DO-229C[44] Word(S) To Be Abbreviated | DO-229C[44] Recommended Abbreviation(S) | ICAO 8400/5[3] Recommended Abbreviation | ICAO 8400/5[3] Word(S) To Be Abbreviated |
|---|---|---|---|
| Special Use Airspace | SUA | | |
| Standard Terminal Arrival Route | STAR | STAR | Standard Instrument Arrival |
| Suspend | SUSP | | |
| Temperature | TEMP | T | Temperature |
| Test | TST | | |
| Threshold Crossing Height | TCH | | |
| Time To Alert | TTA | | |
| To | TO | TO | To... (Place) |
| To/From | T/F | | |
| Tower | TWR | | |
| Track | TK, TRK | TR | Track |
| Track To Fix | TF | | |
| Track Angle Error | TKE | | |
| Transition Altitude | TA | TA | Transition Altitude |
| Transition Level | TL | TRL | Transition Level |
| True | T | | |
| True Airspeed | TAS | TAS | True Airspeed |
| | | QTE | True Bearing |
| True Heading | TH | | |
| Variation | VAR | | |
| Vector | VECT | | |
| Vector To Final | VTF | | |
| Vertical Navigation | VNAV, VNV | | |
| Vertical Protection Level | VPL | | |
| Vertical Speed | VS | | |
| Vertical Track | VTK | | |
| Vertical Track Error | VTE | | |
| Vertical Uncertainty Level | VUL | | |
| VHF Omni-Directional Range | VOR | VOR | VHF Omnidirectional Radio Range |
| Warning | WARN, WRN | WRNG | Warning |
| Waypoint | WPT | | |
| West | W | W | West Or Western Longitude |
| Wide Area Augmentation System | WAAS | | |
| World Geodetic System | WGS | | |

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# APPENDIX B

# ACRONYMS AND GLOSSARY

## B.1 ACRONYMS

The following is a list of acronyms used in the document.

| | |
|---|---|
| AC | Advisory Circular |
| AMMD | Aerodrome Moving Map Display |
| ARINC | Aeronautical Radio Incorporated |
| ARP | Aerospace Recommended Practice |
| CDI | Course Deviation Indicator |
| CF | Course to a Fix |
| CFR | Code of Federal Regulations |
| CNS/ATM | Communication Navigation Surveillance/ Air Traffic Management |
| DF | Direct to a Fix |
| DME | Distance Measuring Equipment |
| EMD | Electronic Map Display |
| FAA | Federal Aviation Administration |
| FA | Course from a Fix to an Altitude |
| FGDC | Federal Geographic Data Committee |
| GAMA | General Aviation Manufacturers Association |
| GNSS | Global Navigation Satellite System |
| GPS | Global Positioning System |
| ICAO | International Civil Aviation Organization |
| IFR | Instrument Flight Rules |
| MIL ST | Military Standard |
| MFD | Multi-Function Display |
| NAVAID | Navigational Aid |
| NAV | Navigation |
| NDB | Non-directional Beacon |
| NVIS | Night Vision Imaging System |
| QWERTY | QWERTY standard typewriter keyboard layout |
| RAC | Raster Aeronautical Charts |
| RF | Constant Radius to a Fix |
| RNAV | Area Navigation |
| RNP | Required Navigational Performance |
| SAE | Society of Automotive Engineers |
| SAE AIR | Society of Automotive Engineers Aerospace Information Report |
| SAE ARP | Society of Automotive Engineers Aerospace Recommended Practice |
| SAE AS | Society of Automotive Engineers Aerospace Standard |
| TACAN | Tactical Air Navigation |
| TIFF | Tagged-Image File Format |
| TF | Track between two Fixes |
| TSO | Technical Standard Order |
| VSD | Vertical Situation Display |
| VFR | Visual Flight Rules |
| VOR | VHF Omni-directional Range |
| VORTAC | Omnidirectional Range/Tactical Air navigation |
| WG | Working Group |
| WGS | World Geodetic System |

## B.1 GLOSSARY

The following is a glossary of terms in the document. Additional words that have a special or unique meaning in this document are contained in section 1.8.

**Accuracy:** a degree of conformance between the estimated or measured value and the true value. Note: for measured positional data, the accuracy is normally expressed in terms of a distance from a stated position within which there is a defined confidence of the true position falling. (Reference ICAO Annex 14[1]).

*Note: relative accuracy is defined with reference to a geodetic datum.*

**Active Fix:** The fix or waypoint that is the current navigation reference for the host aircraft.

**Aerodrome (Airport):** a defined area on land or water (including any buildings, installations, and equipment) intended to be used either wholly or in part for the arrival, departure, and surface movement of aircraft. (Reference ICAO Annex 14[1]).

**Aerodrome Moving Map Display:** An EMD which depicts the aerodrome and ownship position on the airport surface.

**Aeronautical Database**: any data that is stored electronically in a system that supports airborne or ground based aeronautical applications. An Aeronautical Database may be updated at regular intervals. (Reference DO-200A/ED-76[41])

**Altitude Tape:** A fixed-pointer moving-scale linear altimeter display.

**Analysis:** Analysis is the method of verification which consists of comparing hardware or software design with known scientific and technical principles, technical data, or procedures and practices to validate that the proposed design will meet the specified functional and performance requirements.

**Bearing:** The horizontal direction to or from any point, usually measured clockwise from true North, magnetic North, or some other reference point through 360 degrees. (Definition from the Airman's Information Manual)

**Data Quality**: a degree or level of confidence that the data provided meets the requirements of the data user in terms of accuracy, resolution and integrity. (Reference ICAO Annex 15[2]).

**Demonstration:** Demonstration is the method of verification where qualitative versus quantitative validation of a requirement is made during a dynamic test of the equipment. In general, software functional requirements are validated by demonstration since the functionality must be observed through some secondary media.

**Desired Path:** The path that the flight crew and air traffic control can expect the aircraft to fly, given a particular route, leg, or transition.

**Desired Track:** The planned or intended track between two waypoints. It is measured in degrees either magnetic or true North. The instantaneous angle may change from point to point along the great circle track between waypoints.

**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 (e.g., 1 inch = 100 nautical miles)

**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.

**Flight Plan Mode:** See section 2.4.1.

**Horizontal Positional Accuracy:** The difference between a target's measured horizontal position and its true horizontal position. It is specified in terms of the 95 percent horizontal performance accuracy.

**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 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 (e.g., the distance covered by the map representation in either the vertical or horizontal direction).

**Metadata:** Metadata describe the content, quality, condition, and other characteristics of data. Metadata help a person to locate and understand data.

**Next Fix:** The waypoint or fix immediately following the active fix in a flight plan or published flight procedure.

**Navigation**: The process of planning, recording, and controlling the movement of a craft or vehicle from one place to another. (ICAO definition)

**Ownship:** The aircraft in which the EMD function is resident.

**Plan view:** Conventional horizontal top down birds's eye view map display.

**Required Navigation Performance (RNP):** A statement of the navigation performance accuracy necessary for operation within a defined airspace. Note that there are additional requirements, beyond accuracy, applied to a particular RNP type. See RTCA DO-236A[45] (Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation).

**Runway:** A defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft. [ICAO Annex 14[1]]

**Taxiway**: A defined path on a land aerodrome established for the taxiing of aircraft and intended to provide a link between one part of the aerodrome and another, including (RTCA DO-272[48]):

a. *Aircraft stand taxilane.* A portion of an apron designed as a taxiway and intended to provide access to aircraft stands only.

b. *Apron taxiway.* A portion of a taxiway system located on an apron and intended to provide a through taxiway route across the apron.

c. *Rapid exit taxiway.* A taxiway connected to a runway at an acute angle and designed to allow landing aeroplanes to turn off at higher speeds than are achieved on other exit taxiways thereby minimizing runway occupancy times.

**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) (ICAO definition). The actual flight path of an aircraft over the surface of the earth (Reference the Airman's Information Manual).

**Track Mode:** See section 2.4.1

# APPENDIX C
# BIBLIOGRAPHY AND REFERENCES

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The following is a list of documents referenced in this document. Each time one of the references below appears superscript numbers for each referenced document should correlate to one of the numbers below.

## C.1 INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO) PUBLICATIONS:

1. ICAO Annex 14, *International Standards and Recommended Practices – Aerodromes (Vol. I – Aerodrome Design Operations)*, second edition, ICAO, Montreal, Canada, July 1995.

2. ICAO Annex 15. *World Geodetic System-1984 (WGS-84), International Standards and Recommended Practices, Aeronautical Information Services*, Annex 15 to the Convention on International Civil Aviation, 10th Edition, July 1997.

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6. Title 14 of the Code of Federal Regulations (CFR), Part 25, Appendix F.

7. Title 14 of the Code of Federal Regulations (CFR) 27.1322, *Warning, Caution, And Advisory Lights.*

8. Title 14 of the Code of Federal Regulations (CFR) 29.1322, *Warning, Caution, And Advisory Lights.*

9. Title 14 of the Code of Federal Regulations (CFR) 91, *General Operating And Flight Rules.*

10. Title 14 of the Code of Federal Regulations (CFR) 121, *Operating Requirements: Domestic, Flag, And Supplemental Operations.*

11. Title 14 of the Code of Federal Regulations (CFR) 125, *Certification and Operations: Airplanes Having A Seating Capacity Of 20 Or More Passengers Or A Maximum Payload Capacity Of 6,000 Pounds Or More; And Rules Governing Persons On Board Such Aircraft.*

12. Title 14 of the Code of Federal Regulations (CFR) 129, *Operations: Foreign Air Carriers and Foreign Operators Of U.S.-Registered Aircraft Engaged In Common Carriage.*

13. Title 14 of the Code of Federal Regulations (CFR) 135, *Operating Requirements: Commuter and On Demand Operations and Rules Governing Persons On Board Such Aircraft.*

14. FAA Advisory Circular (AC) 20-130A *Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors.*

15. FAA Advisory Circular (AC) 20-131A, *Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders.*

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20. FAA Advisory Circular (AC) 25.1309-1A, *System Design Analysis.*

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32. FAA Technical Standards Order (TSO)-C146a, *Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented by the Wide Area Augmentation System (WAAS).*

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## C.3 RTCA, INC. DOCUMENTS:

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39. RTCA DO-178B, *Software Considerations in Airborne Systems and Equipment Certification.*

40. RTCA DO-187, *Minimum Operational Performance Standards for Airborne Multi-sensor Navigation Systems.*

41. RTCA DO-200A/EUROCAE ED-76, *Standards for Processing Aeronautical Data.*

42. RTCA DO-201A/EUROCAE ED-77, *Industry Requirements for Aeronautical Information.*

43. RTCA DO-208, *Minimum Operational Performance Standards For Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS).*

44. RTCA DO-229C, *Minimum Operational Performance Standards For Global Positioning System/Wide Area Augmentation System Airborne Equipment.*

45. RTCA DO-236A, *Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation.*

46. RTCA DO-247, *The Role of GNSS in Supporting Airport Surface Operations*.

47. RTCA DO-267, *Minimum Aviation System Standards (MASPS) for Flight Information Services Broadcast (FIS-B) Data Link.*

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# APPENDIX D

# LIST OF SHALLS

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In the tables below "No #" means that the item does not have a number in the document. "NA" in the test section column means not applicable.

## D.1 GENERAL REQUIREMENTS

Most of the requirements in sections 2.1 and 3.1 do not have particular test procedures specified in the test procedure subsection, and thus are labeled "NA" in the test section column below. This is provided as a quick reference for the requirements in the document. Notes and figures which provide additional guidance on interpreting the requirements from the body of the document are not replicated in this appendix.

| Shall# | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 1. | 2.1.1 | No # | In the design and manufacture of the equipment, the manufacturer shall provide for installation so as not to impair the airworthiness of the aircraft. | NA | |
| 2. | 2.1.2 | No # | The equipment shall perform its intended function(s) as defined by the manufacturer, and its proper use shall not create a hazard to the aircraft or its occupants. | NA | |
| 3. | 2.1.3 | No # | All equipment shall comply with the applicable rules of the Federal Communications Commission. | NA | |
| 4. | 2.1.4 | No # | All materials used shall be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets, and small electric parts) that would not contribute significantly to the propagation of a fire. | NA | |
| 5. | 2.1.5.1 | 1 | The equipment shall be designed so that controls intended for use during flight cannot be operated in any position, combination or sequence that would result in a condition detrimental to the reliability of the equipment or operation of the aircraft. | NA | |
| 6. | 2.1.5.1 | 2 | Controls shall provide feedback when operated. | NA | |
| 7. | 2.1.5.1 | 3 | Controls shall be resistant to inadvertent activation. | NA | |
| 8. | 2.1.5.1 | 6 | Manual controls used in flight shall be operable with one hand. | NA | |
| 9. | 2.1.5.1 | 8 | If a control can be used for multiple functions, the current function shall be indicated either on the EMD or on the control. | NA | |
| 10. | 2.1.5.1 | 10 | Labels shall be used to identify the functions of all controls used to manipulate the information content and operating characteristics of the EMD. | NA | |

| Shall# | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 11. | 2.1.5.2 | 1 | Controls that are normally operated by the flight crew shall be readily accessible. | NA | |
| 12. | 2.1.6 | 3 (A) | Red shall be used only for indicating a hazard that may require immediate corrective action. | NA | |
| 13. | 2.1.6 | 3 (B) | Amber shall be used only for indicating the possible need for future corrective action. | NA | |
| 14. | 2.1.6 | 5 | The color of any required symbol shall be the same on the plan view EMD and vertical situation display if they are on the same display or part of a multi-function display. | NA | |
| 15. | 2.1.7 | No # | The equipment shall be designed so that the application of specific test procedures is not detrimental to equipment performance following the application of those tests, except as specifically allowed. | NA | |
| 16. | 2.1.8 | No # | The equipment shall be designed to the appropriate design assurance level(s) based on the intended function(s) of the equipment and aircraft class in which it is to be installed. | NA | |
| 17. | 2.1.9 | 2 | Where information on the shared display is inconsistent, the inconsistency shall be obvious or annunciated, and should not contribute to errors in information interpretation. | NA | |
| 18. | 2.1.10 | 1 | If the EMD can use multiple position sources, other than multiple GPSs, a means of identifying the active source(s) shall be provided. | NA | |
| 19. | 3.1.1 | 1 | Controls shall be readily accessible from the pilot's normal seated position. | NA | |
| 20. | 3.1.1 | 2 | The controls and their identifying labels shall be readily identifiable from the pilot's normal seated position. | NA | |
| 21. | 3.1.1 | 3 | The controls shall not be operable in any position, combination, or sequence that would result in a condition detrimental to the operation of the aircraft. | NA | |
| 22. | 3.1.1 | 4 | Appropriate protection shall be provided to avoid inadvertent turnoff of the equipment. | NA | |

| Shall# | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 23. | 3.1.1 | 5 | The location and operation of the EMD controls shall not interfere with the operation of other equipment. | NA | |
| 24. | 3.1.1 | 6 | The location of the EMD and EMD controls shall not interfere with the operator's view of other equipment | NA | |
| 25. | 3.1.2 | 1 | Equipment shall be compatible with the environmental conditions present in the specific location in the aircraft where the equipment is installed. | NA | |
| 26. | 3.1.3 | 1 | The display shall be readable under the full range of normally expected flight deck illumination conditions. | 3.4.2.3 | 2 |
| 27. | 3.1.3 | 2 | Display luminance shall not interfere with the usability of other flight deck displays nor produce unacceptable glare against the windscreen or other reflective surface. | 3.4.1.2 | 1 |
| 28. | 3.1.3 | 3 | The operator shall have an unobstructed view of displayed data, including data on the EMD and all associated remote status and mode indicators, when in the normal seated position. | 3.4.2.3 | 3 |
| 29. | 3.1.4 | 1 | Any probable failure of the EMD shall not degrade the normal operation of other equipment or systems connected to it beyond degradation due to the loss of the EMD itself. | NA | |
| 30. | 3.1.4 | 2 | The failure of interfaced equipment or systems shall not degrade normal operation of the EMD equipment beyond degradation due to the loss of data from the interfaced equipment. | NA | |
| 31. | 3.1.5 | 1 | The equipment shall not be the source of harmful conducted or radiated interference nor adversely affect or be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft. | 3.4.1.4 | 1 |
| 32. | 3.1.6 | 1 | The equipment shall be installed in accordance with its intended function(s). | NA | |
| 33. | 3.1.6 | 2 | Equipment manufacturers shall document the intended function(s) of the EMD, within the installation instructions and operating manual. | NA | |

| Shall# | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 34. | 3.1.6 | 3 | For equipment that may not fully display curved path procedures, a note shall be added to the AFM indicating that: curved path procedures (e.g. DME arcs) may not be displayed and to refer to the user documentation for further explanation | NA | |
| 35. | 3.1.6 | 4 | For equipment that may not fully display curved path procedures, the user documentation shall provide textual and graphical explanations of what the pilot can expect the EMD to display, including a directive to use the CDI for guidance through the turn. | NA | |
| 36. | 3.1.6 | 5 | Equipment using raster aeronautical charts (RAC) shall not be used for navigation while the RAC data is being displayed because inaccuracies in chart symbol placement and distortions are that introduced by the production process. | NA | |

**D.2 EQUIPMENT PERFORMANCE REQUIREMENTS**

The table contains the "shall" requirements from sections 2.2 through 2.4 and 3.2. This is provided as a quick reference for the requirements in the document. Notes from the body of the document are not replicated in this appendix.

| Shall # | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 37. | 2.2.1 | 1 | All displayed symbols and graphics shall be positioned (i.e., drawn or rendered) accurately relative to one another such that placement errors are less than .013 inches of the map depiction or 1% of the shortest axis (i.e., horizontal and vertical dimension) of the map depiction, and orientation errors are less than 3° with respect to the values provided by the position and database sources. | 2.6.3.1.6 and 3.4.2.4.1 | 1 and 1 |
| 38. | 2.2.1.1 | 1 | The EMD shall display distinctive symbols for ifferent types of fixes (waypoints, airports, VORs, NDBs, intersections) and the aircraft (ownship). | 2.6.3.1.3 | 2 |
| 39. | 2.2.1.1 | 2 | The EMD shall use symbols similar to those shown on published charts or that are consistent with established industry standards. Guidelines for electronic display symbology are provided in SAE ARP5289[57]. See Appendix H. | 2.6.3.1.3 | 3 |

| Shall # | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 40. | 2.2.1.1 | 3 | All symbols shall be depicted in an upright orientation except for those designed to reflect a particular compass orientation. See Figure 2-2. | 2.6.3.1.4 and 2.6.3.2.2.1 and 3.4.2.4.1 | 5 3 2 |
| 41. | 2.2.1.1 | 4 | Symbols indicating a particular compass orientation shall maintain that compass orientation at all times. An example of this is a runway symbol that maintains an accurate depiction of its direction as the map rotates. See Figure 2-2. | 2.6.3.1.4 and 3.4.2.4.1 | 6 3 |
| 42. | 2.2.1.1 | 6 | Required symbols (per Table 2-1) shall be discriminable at a viewing distance of 30 inches under the full range of normally expected flight deck illumination conditions. | 2.6.3.1.9 | 5 |
| 43. | 2.2.1.1 | 7 | The ownship symbol shall be unobstructed. | 2.6.3.1.6 and 3.4.2.3 | 9 and 4 |
| 44. | 2.2.1.1 | 8 | If the heading or track is available, the aircraft/ownship symbol shall be directional, oriented to either heading or track. | 2.6.3.1.4 and 2.6.3.2.2.1 and 3.4.2.4.1 | 8 4 4 |
| 45. | 2.2.1.1 | 9 | If the EMD supports more than one aircraft symbol directional orientation (e.g., heading and track), then the current aircraft symbol orientation shall be indicated. | 2.6.3.1.4 and 2.6.3.2.2.1 | 9 5 |
| 46. | 2.2.1.2 | 1 | The EMD shall have the capability of displaying flight plans. | 2.6.3.1.3 | 1 |
| 47. | 2.2.1.2 | 2 | If a flight plan is being displayed, and the EMD is receiving an active flight plan from an external navigation system (e.g., an external GNSS navigator or FMS), the active external flight plan shall be displayed, unaltered, on the EMD. | 2.6.3.1.3 | 6 |
| 48. | 2.2.1.2 | 3 | If the EMD is used to edit the active flight plan on the EMD, it shall update the flight plan in the external navigator. | 2.6.3.1.3 | 7 |
| 49. | 2.2.1.2 | 4 | The way flight plans are depicted in the preview or edit mode shall be distinctive from the normal depiction of the active flight plan. | 2.6.3.1.3 | 8 |
| 50. | 2.2.1.2.1 | 1 | Lines shall be displayed indicating the path to be flown between fixes in a flight plan. | 2.6.3.1.3 | 4 |
| 51. | 2.2.1.2.1 | 2 | If the EMD receives RNP leg data (i.e., Direct to a Fix (DF), Course to a Fix, (CF), Track between two Fixes (TF), course from a Fix to an Altitude (FA), constant Radius to a Fix (RF)) the EMD shall display the leg type in compliance with RTCA DO-236A[45] or not at all. | 2.6.3.1.3 | 9 |

| Shall # | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 52. | 2.2.1.2.1 | 3 | If the EMD is incapable of representing curves, due to either data or system limitations, then curved path segments shall not be depicted as a single straight line (Reference Figure 2-3). | 2.6.3.1.3 | 5 |
| 53. | 2.2.1.2.1 | 4 | The active desired path shall be differentiated from any other paths displayed (e.g., alternate or inactive desired path, track history, or projected path). | 2.6.3.2.2.2 | 1 |
| 54. | 2.2.1.2.2 | 1 | The active fix shall be uniquely identified and distinctive from other fixes. | 2.6.3.1.7 | 1 |
| 55. | 2.2.1.2.2 | 2 | The active fix, the next fix, and their associated labels (e.g., fix identifier) shall be displayed and identifiable, if they are within the selected map range and they exist. | 2.6.3.1.7 | 2 |
| 56. | 2.2.1.2.2 | 3 | If the active fix is beyond the selected map range, the fix identifier shall be visible or readily accessible on the EMD. | 2.6.3.1.7 | 3 |
| 57. | 2.2.1.3 | 1 | The EMD shall have the capability for manual de-cluttering during operational use. | 2.6.3.2.3 | 1 |
| 58. | 2.2.1.3 | 4 | If a wind vector is displayed on the map, its orientation shall be consistent with the orientation of the map and pointing in the direction of wind flow. | 2.6.3.2.3 | 2 |
| 59. | 2.2.1.3 | 6 | All overlayed data shall be the same map orientation and scale. | 2.6.3.1.4 | 10 |
| 60. | 2.2.2 | 1 | The EMD shall have the capability to display the complete fix identifier (e.g., KBOS, not BOS) for the required minimum symbol set as defined in Table 2.1. | 2.6.3.1.8 | 1 |
| 61. | 2.2.2 | 2 | Labels shall be used to identify fixes, other symbols, and other information, depicted on the EMD, where appropriate. | 2.6.3.1.8 | 2 |
| 62. | 2.2.2 | 5 | Fix labels shall be oriented to facilitate readability. | 2.6.3.1.4 and 2.6.3.2.2.1 | 7<br>2 |
| 63. | 2.2.2 | 7 | All labels shall be readable at a viewing distance of 30 inches under the full range of normally expected flight deck illumination conditions (Reference MIL STD 1472D[59] and SAE AIR1093[51]). | 2.6.3.1.9 | 4 |

| Shall # | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 64. | 2.2.3 | 1 | The operating range of display luminance and contrast shall be sufficient to ensure display readability through the full range of normally expected flight deck illumination conditions (Reference SAE ARP4256[55]). | 2.6.3.1.9 | 1 |
| 65. | 2.2.3 | 3 | The display shall be readable through a horizontal viewing angle 30 degrees either side of a line normal to the display surface, and through a vertical angle 20 degrees above and 5 degrees below a line normal to the display surface (Reference SAE ARP4256[55] and also SAE ARP4102[53]). | 2.6.3.1.9 | 6 |
| 66. | 2.2.3 | 4 | If color is used for information coding, the selected color set shall be discriminable under the full range of normally expected flight deck illumination conditions and the design viewing angle (Reference SAE ARP4256[50]). | 2.6.3.1.9 | 3 |
| 67. | 2.2.4 | 1 | The EMD shall have the capability of manually changing the map range. | 2.6.3.1.5 | 1 |
| 68. | 2.2.4 | 2 | Current map range shall be indicated continuously. | 2.6.3.1.5 | 2 |
| 69. | 2.2.4 | 4 | If the EMD is controlling the map range automatically, then the capability shall exist to activate or deactivate the automatic map range. | 2.6.3.1.5 | 3 |
| 70. | 2.2.4 | 9 | The EMD shall have the capability to present map information in at least one of the following orientations: actual track-up or heading-up. | 2.6.3.1.4 and 2.6.3.2.2.1 | 1<br>1 |
| 71. | 2.2.4 | 10 | If desired track-up orientation is used, the aircraft symbol shall be oriented to actual track or heading. | 2.6.3.2.2.1 | 6 |
| 72. | 2.2.4 | 12 | If the system is in North-up, the orientation of the map shall be referenced to true North. | 2.6.3.2.2.1 | 8 |
| 73. | 2.2.4 | 13 | The default reference for all direction information on the EMD (e.g., heading, track, etc.) shall be magnetic, and "MAG" mode need not be annunciated.. | 2.6.3.2.2.1 | 7 |
| 74. | 2.2.4 | 14 | If the direction information is referenced to true North, this shall be indicated. | 2.6.3.2.2.1 | 9 |
| 75. | 2.2.4 | 17 | Current map orientation shall be clearly, continuously, and unambiguously indicated (e.g., track-up vs. North-up). | 2.6.3.1.4 | 4 |

| Shall # | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 76. | 2.2.4 | 18 | The EMD shall respond to operator control inputs within 500 msec. | 2.6.3.1.9 and 3.4.2.4 | 7 1 |
| 77. | 2.2.4 | 19 | The EMD shall update the displayed minimum required information set, as defined in Table 2-1, at least once per second. | 2.6.3.2.4 | 2 |
| 78. | 2.2.4 | 20 | Maximum latency of aircraft position data at the time of display update shall be one second, measured from the time the data is received by the EMD system. | 2.6.3.2.4 | 1 |
| 79. | 2.2.4 | 22 | When the EMD receives a "data not valid" or "reduced performance" (e.g., dead reckoning mode) indication from the source, this condition shall be indicated on the EMD within one second. | 2.6.3.2.4 | 3 and 4 |
| 80. | 2.2.4 | 23 | If aircraft positioning data are not received by the EMD for five seconds (i.e., data timeout), this condition shall be indicated to the flight crew. | 2.6.3.2.4 | 5 |
| 81. | 2.2.4 | 18 | If there is an active flight plan and the flight plan data are not received by the EMD for 30 seconds, this condition shall be indicated to the flight crew. | 2.6.3.2.4 | 6 |
| 82. | 2.2.5 | 1 | The EMD shall provide a means to identify the database(s) version and valid operating period. | 2.6.3.1.2 | 1 |
| 83. | 2.2.5 | 2 | The EMD shall indicate if any data is not yet effective or is out of date. | 2.6.3.1.2 | 2 |
| 84. | 2.2.5 | 5 | The process of updating navigation databases shall meet the standards specified in RTCA/DO-200A/EUROCAE ED-76[41]. | 2.6.3.1.2 | 3 |
| 85. | 2.2.5 | 6 | WGS-84 position reference system or an equivalent earth reference model shall be used for all displayed data. (Reference RTCA DO-236A[45] and ICAO Annex 15[2]). | 2.6.3.1.2 | 4 |
| 86. | 2.3.1 | 1 | The AMMD shall provide an indication if the accuracy implied by the display is better than the level supported by the total system accuracy. | 2.6.3.1.10 | 5 |
| 87. | 2.3.1.1.1 | 1 | The capability shall exist to depict runways. | 2.6.3.1.3 | 10 |
| 88. | 2.3.1.1.1 | 2 | The depiction of runways shall be distinctive from all other symbology. | 2.6.3.1.3 | 11 |

| Shall # | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 89. | 2.3.1.1.1 | 5 | The aircraft position sensor horizontal positional accuracy for runways shall be less than 36m. | 2.6.3.1.10 | 1 |
| 90. | 2.3.1.1.1 | 6 | The aerodrome total database accuracy for runways shall be 43m or less. | 2.6.3.1.10 | 2 |
| 91. | 2.3.1.1.2 | 3 | The aircraft position sensor horizontal positional accuracy for taxiways shall be less than 36m. | 2.6.3.1.10 | 3 |
| 92. | 2.3.1.1.2 | 4 | The aerodrome total database accuracy for taxiways shall be 65 m or less. | 2.6.3.1.10 | 4 |
| 93. | 2.3.1.1.3 | 1 | Taxi route information shall be distinguishable from all other AMMD map attributes. | 2.6.3.1.3 | 12 |
| 94. | 2.3.1.1.3 | 2 | The way taxi routes are depicted in the preview or edit mode shall be distinctive from the depiction of the active taxi route. | 2.6.3.1.3 | 8<br>13 |
| 95. | 2.3.1.2 | 1 | The AMMD shall contain a symbol representing the location of ownship. | 2.6.3.1.3 | 14 |
| 96. | 2.3.1.2 | 2 | If direction/track is not available, the symbol shall not imply directionality. | 2.6.3.1.3 | 15 |
| 97. | 2.3.2 | 1 | The runway identifiers shall be available for depiction on the display, if available. | 2.6.3.1.8 | 3 |
| 98. | 2.3.5 | 1 | If the airport map database is separate from the EMD navigation information, the AMMD shall provide a means to identify the database version, and/or date, and/or valid operating period. | 2.6.3.1.2 | 5 |
| 99. | 2.3.5 | 2 | The process of updating aerodrome databases shall meet the standards specified in RTCA DO-200A/EUROCAE ED-76[41]. | 2.6.3.1.2 | 6 |
| 100. | 2.4.1 | 1 | A single mode (i.e., either track mode or flight plan mode) shall be applied to all information depicted in the VSD at the same time. | 2.6.3.1.6 | 2 |
| 101. | 2.4.1.1 | 1 | The swath shall be centered along either the predicted flight path (e.g., current track) of the aircraft or the flight plan. | 2.6.3.1.3 | 16 |

| Shall # | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 102. | 2.4.1.1 | 3 | If the VSD is capable of displaying more than one swath definition (e.g., swath can be defined or based on RNP, Estimated Position Uncertainty, Airway type, TAWS, etc.), the current swath definition shall be available for display. | 2.6.3.1.3 | 17 |
| 103. | 2.4.1.2 | 2 | If the ownship symbol is directional, the symbol orientation shall correctly depict the lateral directional orientation of the aircraft (i.e.,towards or away from the objects depicted in the VSD). | 2.6.3.1.6 | 3 |
| 104. | 2.4.1.2 | 4 | If the VSD ownship symbol is not always in a consistent location leg, always on the left side of the display, the direction of motion of ownship shall be depicted on the VSD. | 2.6.3.1.6 | 4 |
| 105. | 2.4.1.2 | 6 | If there is a numeric altitude indication associated with ownship on the VSD, the altitude depicted shall be consistent with the numeric indication on the aircraft's primary altimeter and on the FMS Control Display Unit (CDU) approach page, if installed. | 2.6.3.1.6 | 5 |
| 106. | 2.4.1.2 | 8 | For multi-function or shared display systems, symbols used on the VSD shall be distinct from symbols used on the plan view map display when the represent different things and the same when they represent the same things. | 2.6.3.1.6 | 6 |
| 107. | 2.4.1.3 | 1 | In flight plan mode, the flight plan, including the desired path and fixes, shall be displayed on the VSD when within the selected VSD map range | 2.6.3.1.3 | 18 |
| 108. | 2.4.1.3 | 2 | When in track mode and the flight plan is not contained within the swath the flight plan shall not be displayed. | 2.6.3.1.3 | 19 |
| 109. | 2.4.1.3 | 3 | If flight plan altitude information is not available, then the VSD shall not depict a vertical path, and shall depict waypoints without altitude restrictions at the aircraft's current altitude. | 2.6.3.1.3 | 20 |
| 110. | 2.4.1.3 | 4 | When operating in flight plan mode, the VSD shall depict the same flight plan as the plan view depiction. | 2.6.3.1.3 | 21 |
| 111. | 2.4.1.3 | 5 | The VSD depiction of ownship position relative to the flight plan shall not conflict with the vertical guidance (e.g., deviations) on the primary flight display. | 2.6.3.1.3 | 22 |

| Shall # | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 112. | 2.4.1.3 | 6 | If depicting the distance to a DME (e.g., on an approach), the VSD shall label the distance as a DME distance and indicate the associated facility. | 2.6.3.1.3 | 23 |
| 113. | 2.4.1.3 | 7 | The profile display shall accurately depict, with respect to the scale factors of the display (i.e., vertical and horizontal), all vertical path information displayed, including glide slope, approach path, or angle of descent. | 2.6.3.1.3 | 24 |
| 114. | 2.4.1.3 | 8 | If the VSD is in flight plan mode and the aircraft deviates from the flight plan to the extent that it is no longer within the swath, the system shall either 1) switch to track mode, 2) flag the display or 3) remove the ownship symbol from the VSD. | 2.6.3.1.3 | 25 |
| 115. | 2.4.1.3 | 9 | If in flight plan mode, all depicted symbols shall be placed based on the total along-path distances (i.e., an "unwound" flight plan), so that distance between fixes is consistent with the distances between the fixes on the plan view map (including published arcs or fixed radius turns). | 2.6.3.1.3 | 26 |
| 116. | 2.4.1.3.1 | 1 | When in flight plan mode, if the ownship altitude and the desired vertical path are both known, the desired path shall be displayed on the VSD. | 2.6.3.1.3 | 27 |
| 117. | 2.4.1.4 | 1 | If lines or posts are used to connect fixes to the ground (i.e., either terrain or artificial horizon line), those lines or posts shall accurately reflect where they touch the ground. | 2.6.3.1.6 | 7 |
| 118. | 2.4.1.4.1 | 1 | The VSD shall continuously indicate the current horizontal and vertical map ranges. | 2.6.3.1.8 | 4 |
| 119. | 2.4.1.4.1 | 3 | A horizontal display scale depicted on the vertical profile display shall be in the same units (nautical miles or kilometers) that are used for the plan view map display. | 2.6.3.1.8 | 5 |
| 120. | 2.4.1.4.1 | 4 | If the VSD is capable of depicting a display scale in different units (e.g., nautical miles or kilometers, feet or meters), then the units used on that display scale shall be labeled. | 2.6.3.1.8 | 6 |
| 121. | 2.4.1.4.2 | 1 | All indications of altitude information depicted on the VSD shall use the same vertical reference (i.e., cannot intermix barometric data with non-barometric data). | 2.6.3.1.3 | 28 |

| Shall # | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 122. | 2.4.1.4.2 | 2 | If the VSD depicts the vertical predictor, it shall be visually distinctive from any depiction of approach glide path angel or glide slope. | 2.6.3.1.3 | 29 |
| 123. | 2.4.1.4.2 | 3 | If the following items are displayed on the VSD they shall be consistent with existing vertical information on other flight deck equipment including: depiction of selected altitude, depiction of altitude alert setting, depiction of vertical speed selection . | 2.6.3.1.3 | 30 |
| 124. | 2.4.1.4.2 | 4 | Indicated altitude of the ownship on the VSD shall be consistent with the altitude indicated on the primary flight display. | 2.6.3.1.3 | 31 |
| 125. | 2.4.2 | 1 | If the display indicates height above ground of the ownship on the VSD, the height shall be labeled (e.g., AGL, radio altimeter (RA)). | 2.6.3.1.8 | 10 |
| 126. | 2.4.4 | 1 | Automatic changes to mode shall be annunciated. | 2.6.3.1.8 | 7 |
| 127. | 2.4.4 | 2 | If the system has different modes (e.g., flight plan mode and track mode), the current mode shall be clearly and continuously indicated. | 2.6.3.1.8 | 8 |
| 128. | 2.4.5 | 1 | If the VSD has the ability to turn on and off terrain/obstacles, it shall be clearly indicated whether the terrain/obstacles are turned on or off. | 2.6.3.1.8 | 9 |
| 129. | 3.2.1 | 1 | The display shall be readable under normal conditions of flight. | 3.4.2.3 | 1 |
| 130. | 3.2.2 | 1 | Operation of the equipment shall not be adversely affected by aircraft maneuvering encountered in normal flight operations. | 3.4.2.4.1 | 5 |
| 131. | 3.2.2 | 2 | Operation of the equipment shall not interfere with the usability of other flight deck displays. | 3.4.2.2 | 1 |
| 132. | 3.2.3 | 1# | The total system accuracy shall be sufficient for the intended operation, and shall not exceed 100 meters (95%). | 3.4.2.4.1 | 6 |
| 133. | 3.2.4 | 1 | The flight plan depicted on the VSD shall be consistent with the flight plan depicted on the primary flight display. | 3.4.2.4.1 | 7 |

| Shall # | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 134. | 3.2.4 | 2 | The vertical information depicted on the VSD shall be consistent with the vertical information depicted on the primary flight display. | 3.4.2.4.1 | 8 |

## D.3 CONDITIONS OF TEST REQUIREMENTS

The table below contains the conditions of the tests of the requirements ("shall" items from sections 2.3 and 3.3). These requirements are conditions, and thus do not have particular test procedures specified in the test procedure subsection. Therefore, they are labeled "NA" in the test section column below.

| Shall # | Section | Req. # | Requirement | Test Section # | Test Item # |
|---|---|---|---|---|---|
| 135. | 2.5 | No # | Table 2-2 indicates the EMD design requirements that shall be satisfied under the environmental test conditions specified in DO-160D. | NA | |
| 136. | 3.3 | No # | The following subparagraphs define conditions under which tests specified in section 3.4 shall be conducted. | NA | |
| 137. | 3.3.1 | No # | Unless otherwise specified, tests shall be conducted with the equipment powered by the aircraft's electrical power generating system. | NA | |
| 138. | 3.3.2 | No # | Unless otherwise specified, all aircraft electrically operated equipment and systems shall be turned on before conducting interference tests. | NA | |
| 139. | 3.3.3 | No # | During tests, the equipment shall not be subjected to environmental conditions that exceed those specified by the equipment manufacturer. | NA | |
| 140. | 3.3.4 | No. # | Circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests. | NA | |
| 141. | 3.3.5 | No # | Unless otherwise specified, tests shall be conducted after a warm-up (stabilization) period of not more than fifteen minutes. | NA | |

# APPENDIX E

# GUIDANCE FOR THE USE OF COLOR ON ELECTRONIC MAP DISPLAYS

## E.1 POTENTIAL ISSUES AND LIMITATIONS

The various uses of color come with a number of limitations that restrict the extent to which color should be depended upon for object identification or differentiation.

The extreme brightness that is possible within the flight deck can washout and drastically alter the appearance and discriminability of color. Differences among individuals concerning how colors are perceived are quite large. Research indicates that regions of relatively high color confusion exist between red and magenta, magenta and purple, yellow and amber, and cyan and green. An ideal color set would not include both members of these pairs.

The size of colored symbols has been found to interfere with the color discrimination for small visual fields. Also, normal aging of the eye can reduce the ability to sharply focus red objects or differentiate between blue and green.

In, general no more than six or seven colors should be used for symbols on electronic displays with high information content. In addition, gray, brown, or blue may be used for fill-in colors. Caution should be taken to ensure that colors used for background or fill applications do not interfere with the detection or recognition of adjacent color-coded symbols.

From a display point of view, pure blue is problematic for a number of reasons, particularly for observers over 50. While blue text is usually not impossible to read, it is still best to avoid it for text, small symbols, and fine lines on dark background. Reference DOT/FAA/AR-99/52[37].

Display colors must be highly distinct if they are to be correctly identified by all flight crews under the full range of normally expected flight deck illumination conditions.

## E.2 CONVENTIONS

A well-researched color set commonly recommended for flight deck applications includes: red, tan/brown, amber, yellow, green, cyan, blue, magenta, and white.

It is acceptable for the following display features to be coded as follows (or with similar colors), provided that the display can produce distinctive and recognizable renditions of the chosen colors:

| | |
|---|---|
| Fixed reference symbols and current data values | white |
| Selected data values/normal status | green/cyan or white |
| Selected heading | magenta or white |
| Active route/flight plan | magenta |
| Warnings | Red |
| Cautions/abnormal conditions | yellow/amber |

For additional detail concerning the use of color with electronic displays the designer should refer to SAE ARP4032[52] (Human Engineering Considerations In The Application

Of Color To Electronic Aircraft Displays), AC 25-11[19] (Transport Category Airplane Electronic Display Systems And Displays), and AC 23.1311-1A[17] (Installation of Electronic Displays In Part 23 Airplanes).

## E.3 RECOMMENDATIONS

The colors that are used for attention getting and alerting should be identifiable through the full range of normally expected flight deck illumination conditions.

Pure blue should not be used for the display of small, detailed symbols.

Red and blue should not be presented adjacent to each other more than momentarily.

Adjacent colors should not be equal in luminance when discrimination of edges or detail is important.

The colors and brightness of the display should not interfere with the readability of other flight deck instrumentation.

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# APPENDIX F

# RASTER AERONAUTICAL CHARTS

## F.1 INTRODUCTION

This appendix contains guidance and information related to Raster Aeronautical Chart (RAC) accuracy, processing, and metadata. The most common application of a raster dataset is the display of scanned aeronautical charts. However, it is not the intent of this appendix to determine which raster data sources are appropriate for use on EMD systems. Provided that the requirements for data content and legibility are met by the resulting system, the primary goal in the use of raster data is that the data be presented accurately with respect to the aircraft symbol, and with respect to any other data that may be overlaid. The following requirements and guidelines are intended to provide assistance with this goal.

## F.2 VALIDITY

If aeronautical data is included in the raster image, then the following also apply:

- The source material must be approved for use in flight
- The EMD must annunciate the use of data from an expired source

  *Note: this annunciation need not be continuously displayed.*

If non-aeronautical charts are used as source material, the following should be considered:

- Reliability of the source – should be a government organization or maintain equivalent or better standards
- Accuracy standards of the provider – charts should not contain gross errors or inconsistencies
- Suitability of the chart contents – should be suitable for use in flight
- Currency of map or chart contents: data should not be significantly outdated (for example, USGS Topographic Maps have an update cycle which is often 10-20 years, data this outdated will likely be unacceptable

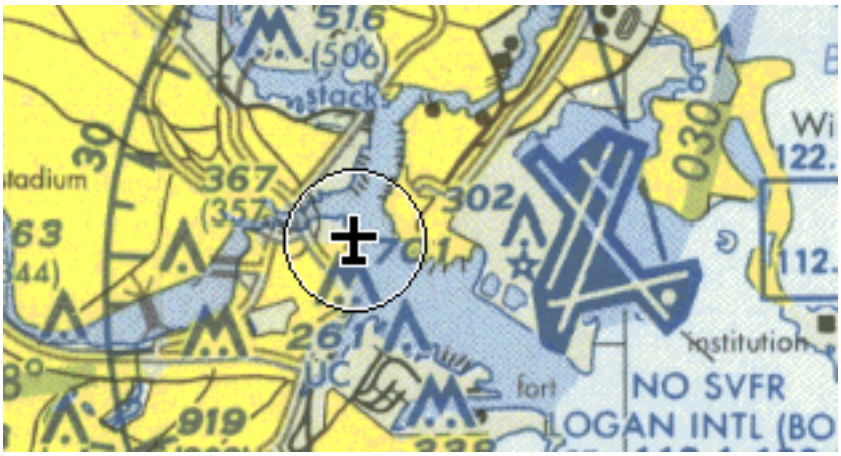
## F.3 ACCURACY

The accuracy of the raster dataset is dependent on a number of factors: the accuracy of the source data, the quality of the digitizing process, the accuracy of the geo-referencing process, and the correctness and sophistication of any warping and palette reduction applied. Errors significant to navigation are likely to exist in any RAC dataset. It is important that the inherent inaccuracies of RAC displays be made apparent to the user.

The recommended method for accomplishing this is to depict a “circle of uncertainty” around the aircraft symbol. This circle of uncertainty serves to remind the user that the depicted position is subject to a certain degree of doubt, and further to provide a quantitative indication of this uncertainty.

The radius of the circle should consider feature placement standards of the originating charting agency and errors introduced by the processing steps. It is recommended that the radius indicate a 2-sigma (95%) confidence level based on a numerical analysis of the inherent errors.

In addition, accuracy is affected by the position sensor. It is assumed that Global Navigation Satellite System (GNSS) or equivalent will be used as the position sensor for RAC displays. When this is the case, sensor error need not be considered because GNSS position errors will be insignificant in comparison with map errors. If a position source other than GNSS is used, the position error inherent in the position sensor system must be taken into account and a corresponding increase of the radius of the circle of uncertainty may be required.




In addition to the above technique, it is recommended that manufacturers include text similar to the following in the user manual and/or on a product identification screen.

> *Note: Discrepancies [of up to Xnm] in the placement of airport and navigational aid symbols are known to exist in the source material. This product is not intended for navigation guidance.*

### F.3.1 CHART ACCURACY

The producers of paper charts generally allow a tolerance in the placement of chart symbols. This enhances readability and the determination of proximate relationships (e.g. an airport symbol may be moved slightly so that it is clearly shown to be adjacent to a river or road). Such movement of features is restricted by policies implemented by the chart producer.

Other errors in the source charts may include cartographic error and projection error. Such errors are likely to be small in comparison to those introduced by feature placement. The applicant should determine the symbol placement and accuracy standards of the supplier and apply these to the calculation of the "radius of uncertainty"

As an example, the following limits apply to VFR charts produced by the Federal Aviation Administration:

- World Aeronautical Charts (1:1,000,000) should have a 3 NM radius.

- Sectional Aeronautical Charts (1:500,000) should have a 1.5 NM radius.

- Terminal Area Charts (1:250,000) should have a .75 NM radius.

- Helicopter Route Charts (1:125,000) should have a .375 NM radius.

## F.4 PROCESSING

The manufacturer of an EMD system using RACs is likely to be involved in the production of data for the system. This may be as extensive as receiving paper charts and producing an electronic raster dataset, or as minimal as receiving the processed data from a third-party supplier. In either case there is a standard of quality and formal process definition that must be observed and followed by the manufacturer.

RTCA DO-200A/EUROCAE ED-76[41] defines a standard for the processing of aeronautical data. This document was written to support vector data. The following guidelines have been developed to supplement RTCA DO-200A/EUROCAE ED-76[41] and address the processing of RAC data.

The processor must define procedures to ensure that each step is carried out accurately and consistently, with the goal of consistent data quality. A Quality Management program must also be defined and implemented, as required by RTCA DO-200A/EUROCAE ED-76[41]. For the processing of Raster Aeronautical Charts, the following definitions are applied to the RTCA DO-200A/EUROCAE ED-76[41] process steps.

**Receive:** A procedure will be defined to receive the paper charts. This should involve checking of received vs. expected charts, verification of quality (material should be clean and free of blemishes and printing errors) and validity (e.g. expiration dates), and possibly entry of details into a production database for initiation of the production process.

**Assemble/Translate:** The steps in the production of a machine-readable, georeferenced data files are generally as follows:

*Notes:*

1. *The following steps present one possible means for processing RAC data. Variations are acceptable provided that the accuracy of the result is not diminished below acceptable levels.*
2. *Attention to detail in these steps is critical to reduce the introduction of processing errors.*

- Chart Preparation: Charts that are received folded must be flattened to reduce errors introduced by creases in the paper.

- Scanning: The scanner must be calibrated and in good working order, with no scratches or other blemishes on the scanning surface. Scan resolution should be sufficient to ensure important details on the chart (e.g. text labels) are not made illegible in the raster dataset. Similarly, the scanner will need to use enough colors to make possible a faithful reproduction of the chart's content. The suggested minimum scanning resolution is 125 dots per inch.

- Georeferencing: A sufficient number of georeferencing points should be placed with sufficient accuracy to ensure an accurate mathematical fit can be computed for the data. The maximum error between the computed fit and the raw data points (generally reported by the georeferencing tool) should not be greater than 2 pixels.

- Projection (warping): Image warping modifies the scanned image to make it conform to the computed mathematical fit, and may involve projection to a different coordinate system. Such a process should not reduce the legibility of the image to the degree where chart details are illegible.

  The warping stage improves accuracy but may not be necessary if the target system can use the chart's native projection, and can fit the raw georeferencing data at run-time.

**Select:** Refers to the selection of a subset of the entire data set, usually based on geographic regions. This step may occur after the format phase.

**Format:** Takes the results of the assemble/translate phase and formats the data for use on the target system. This phase may not be necessary if the assemble/translate phase produces target-ready data. Generally this phase will include such steps as conversion to a target-readable graphics format, application of palette reduction and/or other compression techniques, and generation of data validity checks (e.g., checksum). If palette reduction is applied, the color set used should not reduce color discriminability to the degree where the final product does not sufficiently resemble the original paper chart.

**Distribute:** As with all aeronautical data providers, the provider of Raster Aeronautical Data will have a procedure to distribute the data in an accurate and timely manner. Transfer validation (e.g. by checksum) should take place after each data file is loaded onto the user equipment, before its first use. Use of the data should be disabled if such a check fails.

As required by DO-200A/EUROCAE ED-76[41], each step will need to include some form of validation. Due to the reliance on software tools in the assemble/translate and format phases, it is important that a final, thorough verification is carried out on the final image prior to distribution. Due to the raster nature of the image, this would ideally include viewing of the entire image using the target software, with a number of spot-checks to verify that positional accuracy is within tolerance. Spot checks should include "off-graticule" checks. That is, the points used in georeferencing should not be the only points used to verify the final image.

## F.5 METADATA:

In producing a RAC, it is essential to develop adequate metadata. This section provides a brief introduction to metadata, followed by recommended guidelines for RAC metadata.

The "Content Standard for Digital Geospatial Metadata", FGDC-STD-001-1998[65], and the "Content Standards for Digital Orthoimagery" FGDC-STD-008-1999[66], produced by the Federal Geographic Data Committee (FGDC) are used extensively as reference for defining these requirements. The "Spatial Data Transfer Standard"[67] produced by the FGDC is another useful source of information. These documents are available on the Internet and can be downloaded through the FGDC web site http:/www.fgdc.gov/fgdc.html.

The metadata requirements will differ depending on the data source. The metadata requirements for data providers (third party sources) will be identified first, followed by the requirements for EMD manufacturers producing their own RACs.

The metadata supplied by data providers should ensure sufficient information for manufacturers of EMD equipment to acquire, assess for fitness of use, and transfer the data as needed.

*Notes:*

1. *The use of standard raster image file types is encouraged (e.g., TIFF, GeoTIFF, etc.)*
2. *If compression is used, a loss-less algorithm should be applied.*

The metadata supplied by data providers should include the following: identification, data quality, transfer, and distribution information.

1. Identification information should include basic information about the data set including; title, aerial extent of the data, and rules for acquiring and using the data.

2. Data quality information should include; accuracy, currency, resolution (e.g., 125 dpi), compiled scale of source data, date of next update, and source of the data used for the image (e.g., 65th Edition of the U.S. Department of Commerce "Washington Sectional Aeronautical Chart[74]", Effective February 25, 1999). Data completeness should also be indicated (i.e., missing insets or ocean areas).

3. If geometric corrections are performed to "warp" the image, the image transformation algorithm type should be identified (e.g., nearest neighbor, bilinear interpolation, cubic convolution, etc.) in addition, the number of points used for the transformation should be identified.

4. If multiple images based on different sources are mosaicked, a means of identifying the location of each different source image in the mosaic should be made available. In addition, a complete set of metadata for each source image used to create the mosaic image should be provided.

5. Transfer information should include spatial reference information, which includes projection and horizontal datum. The horizontal datum should be ICAO Annex 15 , World Geodetic System 1984 (WGS-84)[2]. In addition, transfer information should include the number of pixels per row, the total number of columns, and if the image is "georeferenced," the geographic coordinates of the first pixel in the first row and column. These coordinates should represent the position of the center of the pixel.

6. Distribution information should include information on obtaining updates. Distribution information should also include a point of contact with the purpose of

providing the data producer with a means of feedback for the identification and correction of errors. The data producer should also identify the frequency of updates (production cycle).

The raster aeronautical chart metadata requirements of the equipment manufacturers are assumed to apply only in terms of that manufacture's moving map display. If the equipment manufacturer provides raster aeronautical charts to other equipment manufacturers or users, the metadata requirements of a data provider are required.

The metadata required of equipment manufactures using "in-house" raster aeronautical chart data need only indicate identification information, data quality, distribution information, and spatial reference information.

1. Identification information should include basic information about the data set including; geographic area covered by the data and rules for acquiring and using the data.

2. Data quality information should include; currency, resolution, compiled scale of source data, date of next update, and source of the data used for the image (e.g., 65th Edition of the U.S. Department of Commerce "Washington Sectional Aeronautical Chart" Effective February 25, 1999[74]).

3. Distribution information should include how updates can be obtained.

4. Spatial reference information should include projection and horizontal datum.

*Note: Special consideration should be given to images that are mosaicked or composited. Each component part of the composite should have its own set of metadata. Each component part of the mosaic should be easily determined. One means of defining the aerial extent of each component part of the composite image would be through thorough documentation in the composite image's metadata. Special care should be taken to ensure that only the most current information is depicted in the composite image. This requires careful attention to the "seams" of the composite image. For example, if two overlapping Sectionals produced by the FAA's National Aeronautical Charting Office with effective dates three months apart are used as source for a mosaic, the overlapping information on one of the charts has data that is three months less current than the other image. It is in this overlapping area that special care is needed to insure the mosaic contains only the most current data.*

## F.6 DISPLAY CONSIDERATIONS:

Special attention must be given to changes of map range and the display of raster geographic coordinates. It is likely that users of raster aeronautical charts will display the data at a scale other than the chart's compiled scale. Although, "zooming out" (effectively creating a smaller scale image) generally causes no use problems other than congestion, "zooming in" (effectively creating a larger scale image) may cause problems.

Users should be warned whenever they are viewing an image at a scale greater than its compiled scale. In addition, it is recommended that no system permit "zooming in" beyond a point where the viewed scale has been increased greater than twice its compiled scale.

If the system allows for geographic point queries of the raster data (i.e., operator moves a cursor on the screen and can receive a geographic position output) the system should output geographic coordinates in intervals based on the resolution of the source raster image.

# APPENDIX G

# RASTER/ PIXEL- TYPE (E.G., NON-STROKED) DISPLAY ERROR CONSIDERATIONS

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## G.1 PLACEMENT ACCURACY ON A PIXEL DISPLAY

It is important to understand the effect on accuracy imposed by the resolution and size limitations of a raster/pixel-type (non-stroked) display. The following examples provide one means of quantitatively evaluating these factors.

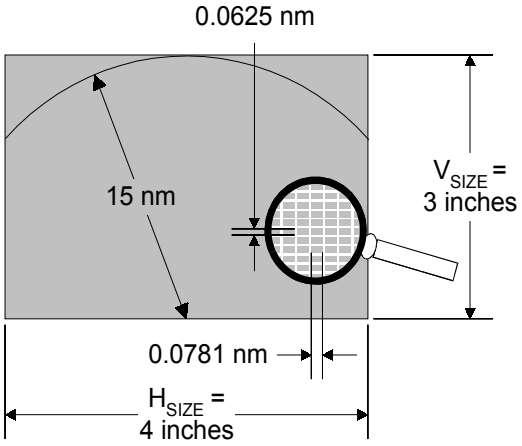
### G.1.1 ASSUMPTIONS AND CONSIDERATIONS

- Raster display type (e.g., LCD, non-stroked CRT)
- Display has fixed dimensions
- Display has fixed vertical and horizontal resolution
- Computational errors are not addressed in this appendix, however, computational precision may need to be considered.
- Errors are the difference between the calculated placement and the actual placement on the screen
- The EMD map display error may either preclude or limit its use for RNP based operations, unless the display has a course deviation indicator (CDI) integrated or is used with another approved navigation system that meets the appropriate performance standards.
- RTCA DO-236A[45] (Minimum Aviation System Performance Standards: Required for Area Navigation) addresses error sources and error terms that make up the total system error budget.

### G.1.2 DEFINITIONS

- $V_{size}$ and $H_{size}$ are the physical dimensions of the viewable screen area along the Vertical and Horizontal axis.
- $V_{resolution}$ and $H_{resolution}$ are the number of pixels along the vertical and horizontal axis.
- $V_{pitch}$ is the distance between pixel centers along the vertical axis and is described by the ratio of $V_{size}$ and $V_{resolution}$
- $H_{pitch}$ is the distance between pixel centers along the horizontal axis and is described by the ratio of $H_{size}$ and $H_{resolution}$.
- $V_{scale}$ is the ratio of the vertical dimension of the viewable screen area to the nautical miles this measurement represents.
- $H_{scale}$ is the ratio of the horizontal dimension of the viewable screen area to the nautical miles this dimension represents.
- Vertical Granularity is the ratio of $V_{scale}$ and $V_{pitch}$.
- Horizontal Granularity is the ratio of $H_{scale}$ and $H_{pitch}$.
- Horizontal error is the map range on the displays horizontal axis (i.e., physical dimension of the display) divided by the horizontal granularity.
- Vertical error is the map range on the displays vertical map axis (i.e., physical dimension of the display) divided by the vertical granularity.

3. Example 1:




a) $V_{resolution}$ = 240 pixels and $H_{resolution}$ = 256 pixels

b) $V_{pitch}$ = 240 pixels / 3 inches = 80 pixels / inch

c) $H_{pitch}$ 256 pixels / 4 inches = 64 pixels / inch

d) $V_{scale} = H_{scale}$ = 15 nm / 3 inches = 5 nm / inch

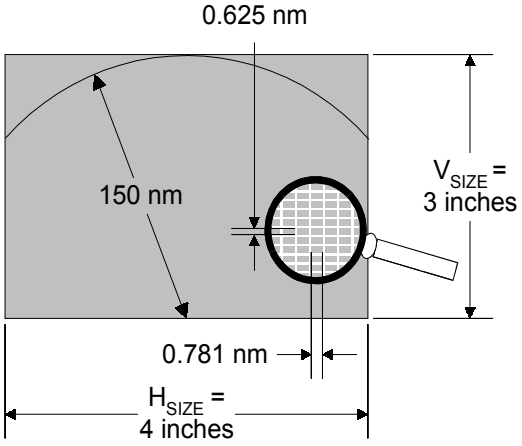
e) Vertical Granularity = 5 (nm / inch) / 80 (pixels / inch) = 0.0625 nm / pixels

f) Vertical Placement Error = 0.4% of the current map range

g) Horizontal Granularity = 5 (nm / inch) / 64 (pixels / inch) = 0.0781 nm / pixels

h) Horizontal Placement Error = 0.5% of the current map range

4. Example 2:




a) $V_{resolution}$ = 240 pixels and $H_{resolution}$ = 256 pixels

b) $V_{pitch}$ = 240 pixels / 3 inches = 80 pixels / inch

c) $H_{pitch}$ = 240 pixels / 3 inches = 64 pixels / inch

d) $V_{scale} = H_{scale}$ = 150 nm / 3 inches = 50 nm / inch

e) Vertical Granularity = 50 (nm / inch) / 80 (pixels / inch) = 0.625 nm / pixels

f) Vertical Placement Error = 0.4% of the current map range

g) Horizontal Granularity = 50 (nm / inch) / 64 (pixels / inch) = 0.781 nm / pixels

h) Horizontal Placement Error = 0.5% of the current map range

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# APPENDIX H

# RECOMMENDED SYMBOLOGY

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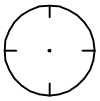
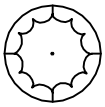
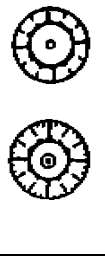
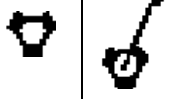
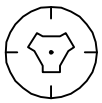
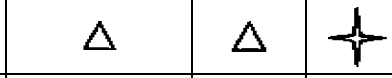
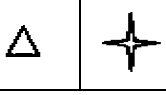
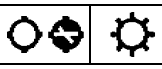
The following table depicts the SAE ARP5289[57] (Electronic Aeronautical Symbols) recommended symbology for the minimum required navigation symbol set for use on electronic map displays. In addition, the table includes symbols shown on published charts and other sources that are currently in use. In the table below "T" is used for terminal and "E" is used for en route.

**TABLE H-1 RECOMMENDED SYMBOLOGY**

| # | | *Jeppesen* *(T ) (E) | | *FAA/DMA* (T ) | (E) | *ICAO* (T ) | (E) | *Boeing* (T ) | (E) | *Airbus* | ***SAE ARP 5289[57]*** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | VOR |  |  |  |  |  | |  | |  |  |
| 2 | DME |  |  |  | |  | |  | |  |  |
| 3 | TACAN |  |  |  |  |  | |  | |  |  |
| 4 | VORDME |  |  |  |  |  | |  | |  |  |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5 | VORTAC |  |  |  | |  |  |  |  |
| 6 | NDB |  |  |  |  |  |  |  |  |
| 19 | Intersection |  | |  | |  | | NA |  |
| 22 | Waypoint |  | |  | |  |  | NA |  |
| 26 | Airport |  | |  | |  |  | NA |  |

** Jeppesen symbols are copyright © Jeppesen Sanderson, Inc*

*Notes:*

1. *It is recognized that fly-over and fly-by waypoint symbology is being used. This MOPS does not include recommended symbology for those waypoints since a standard set of symbols has not been harmonized. The MOPS recommendations are not intended to conflict with the outcome of the ICAO Obstacle Clearance Panel recommendations for fly-over / fly-by symbology.*
2. *For the recommended VOR symbol, the symbol does not need to be rotated. However, if another VOR symbol is used where North is indicated, it must be rotated. ARINC 702A[63] specifies the following symbol orientations:*

| Upright Symbol | Rotated Symbol |
|---|---|
| • VOR, DME, TACAN, VOR/DME, VORTAC | • Runway |
| • Waypoint | • Marker Beacon |
| • Airfield | • Holding Pattern |
| • Intersection | • Procedure Turn |
| • Reference Point | |

# APPENDIX I

# AERODROME CHARACTERISTICS

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## I.1 INTRODUCTION

A brief overview of selected aerodrome characteristics is provided here for consideration with respect to the accuracy requirements described in sections 2.3.1.1.1 (Runways), 2.3.1.1.2 (Taxiways), and in section 3.2.3 (AMMD System Installed Equipment Performance Requirements). This section contains a compilation of guidance material related to accuracy on the airport from various sources including ICAO Annex 15[2] and RTCA DO-272[48].

## I.2 DATABASE

Aerodrome map database requirements are defined in RTCA DO-272/EUROCAE ED-99[48]. RTCA DO-272/EUROCAE ED-99[49] defines three categories of aerodrome map data: *Fine*, *Medium*, and *Coarse*. The categories are groupings for the quality of the database, where database quality is assessed in terms of accuracy, resolution, and integrity. A brief description of these terms is provided below:

**Accuracy:** Accuracy is defined as the degree of conformance between the estimated or measured value and the true value. For measured positional data, the accuracy is expressed in terms of a distance from a stated position within which there is a defined confidence of the true position falling. The relative accuracy is defined with reference to a geodetic datum.

**Resolution:** Resolution is the number of units or digits to which a measured or calculated value is expressed and used.

**Integrity:** For the purposes of this document, the integrity classifications are listed below and are consistent with ICAO Annex 15, WGS-84[2].

- Critical data (C)-- There is a high probability when using corrupted critical data that the continued safe operation of an aircraft would be severely at risk with potential for catastrophe. Required level of data integrity is $10^{-8}$ or better.

- Essential data (E)-- There is a low probability when using corrupted essential data that the continued safe operation of an aircraft would be severely at risk with potential for catastrophe. Required level of data integrity is $10^{-5}$ or better.

- Routine data (R)-- There is a very low probability when using corrupted routine data that the continued safe operation of an aircraft would be severely at risk with the potential for catastrophe. Required level of data integrity is $10^{-3}$ or better.

## I.3 AERODROME PHYSICAL CHARACTERISTICS

Aerodromes are categorized by using two parameters including aerodrome reference code numbers and code letters. These parameters are defined in ICAO Annex 14[1], section 1.3 and reproduced below in Figure I-1. This categorization provides a simple method for interrelating the numerous specifications concerning airport characteristics to provide a means to identify which aircraft may be suitable for operating at the airport.

| Code Element 1 | | Code Element 2 | | |
|---|---|---|---|---|
| **Code Number** (1) [b] | **Airplane Reference Field Length** (2) | **Code Letter** (3) | **Wing Span** (4) | **Outer Main Gear Wheel Span** [a] (5) |
| 1 | Less than 800 m | A | Up to but not including 15 m | Up to but not including 4.5 m |
| 2 | 800 m up to but not including 1 200 m | B | 15 m up to but not including 24 m | 4.5 m up to but not including 6 m |
| 3 | 1 200 m up to but not including 1 800 m | C | 24 m up to but not including 36 m | 6 m up to but not including 9 m |
| 4 | 1 800 m and over | D | 36 m up to but not including 52 m | 9 m up to but not including 14 m |
| | | E | 52 m up to but not including 65 m | 9 m up to but not including 14 m |

*Notes: a. Distance between the outside edges of the main gear wheels.*
*b. (x) indicates column number.*

**FIGURE I-1 AERODROME REFERENCE CODE NUMBERS AND LETTERS [Reference ICAO Annex 14[1], section 1.3]**

Based on the aerodrome categorization described above, a summary of the minimum distance between aerodrome features is provided here.

1. Minimum Distance Between Parallel Runways

   Where parallel runways are intended for simultaneous use, the distance between their center lines should be greater than or equal to the values indicated in Figure I-2 according to ICAO Annex 14[1] (sections 3.1.10 and 3.1.11).

| **Runway** | **Condition** | **Minimum Distance Between Parallel Runways (meters)** |
|---|---|---|
| Non – Instrument Runways | Aerodrome Code Number 1 | 120 |
| | Aerodrome Code Number 2 | 150 |
| | Aerodrome Code Number 3 or 4 | 210 |
| Instrument Runways | Segregated Parallel Operations * | 760 |
| | Independent Parallel Departures | 760 |
| | Dependent Parallel Approaches | 915 |
| | Independent Parallel Approaches | 1035 |

**Note: For segregated parallel operations the specified minimum distance may be decreased by 30 m for each 150 m that the arrival runway is staggered toward the arriving aircraft, to a minimum of 300 m; and should be increased by 30 m for each 150 m that the arrival runway is staggered away from the arriving aircraft.*

**FIGURE I-2 MINIMUM DISTANCE BETWEEN PARALLEL RUNWAYS [Reference ICAO Annex 14[1], section 3.1.10 & 3.1.11]**

3. Minimum Separation Distance Between Taxiways

The minimum separation distances between the center line of a taxiway and the centerline of a parallel taxiway or an object should not be less than the appropriate dimension given in Figure I-3 according to ICAO Annex 14[1] section 3.8.7.

| Code letter[a] | Distance between taxiway center line and runway center line [b, c] (meters) | | | | | | | | Taxiway center line to taxiway center line [b, c] (meters) | Taxiway, other than aircraft stand taxilane, center line to object [b, c] (meters) | Aircraft stand taxilane center line to object [b, c] (meters) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Instrument runways Code Number [a] | | | | Non-instrument runways Code Number [a] | | | | | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | – | – | – |
| *(1)* | *(2)* | *(3)* | *(4)* | *(5)* | *(6)* | *(7)* | *(8)* | *(9)* | *(10)* | *(11)* | *(12)* |
| A | 82.5 | 82.5 | – | – | 37.5 | 47.5 | – | – | 23.75 | 16.25 | 12 |
| B | 87 | 87 | – | – | 42 | 52 | – | – | 33.5 | 21.5 | 16.5 |
| C | – | – | 168 | – | – | – | 93 | – | 44 | 26 | 24.5 |
| D | – | – | 176 | 176 | – | – | 101 | 101 | 66.5 | 40.5 | 36 |
| E | – | – | – | 182.5 | – | – | – | 107.5 | 80 | 47.5 | 42.5 |

*Notes: a) Refer to Figure I-1 for a definition of the Aerodrome code letters and code numbers.*
*b) Separation distances shown in columns (2) to (9) represent ordinary combinations of runways and taxiways.*
*c) It may be permissible to operate with lower separation distances at an existing aerodrome if an aeronautical study indicates that such lower separation distances would not adversely affect the safety or significantly affect the regularity of airplane operations.*

**FIGURE I-3 TAXIWAY MINIMUM SEPARATION DISTANCES [Reference ICAO Annex 14[1], section 3.8.7]**

4. Minimum Separation Distance from Runway to Holding Positions

The minimum distance between a holding bay, taxi-holding position established at a taxiway/runway intersection or road-holding position and the centerline of a runway shall be in accordance with Figure I-4 based on ICAO Annex 14[1] and Reference RTCA DO-201A/EUROCAE ED-77, section 3.11.5.

| Type of runway | Code Number [c] | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **4** |
| Non-instrument | 30m | 40m | 75m | 75m |
| Non-precision approach | 40m | 40m | 75m | 75m |
| Precision approach category I | 60m [b] | 60m [b] | 90m [a, b] | 90m [a, b] |
| Precision approach categories II and III | – | – | 90m [a, b] | 90m [a, b] |
| Take-off runway | 30m | 40m | 75m | 75m |

*Notes:*

1. *If a holding bay, taxi-holding position, or road-holding position is at a lower elevation compared to the threshold, the distance may be decreased 5 m for every meter the bay or holding position is lower than the threshold, contingent upon not infringing the inner transitional surface.*
2. *This distance may need to be increased to avoid interference with radio navigation aids, particularly the glide path and localizer facilities.*
3. *Refer to Figure I-1 for a definition of the Aerodrome code numbers.*

**FIGURE I-4 MINIMUM DISTANCE FROM RUNWAY CENTERLINE TO HOLDING BAY, TAXI-HOLDING POSITION, OR ROAD-HOLDING POSITION**
**[Reference RTCA DO-201A/EUROCAE ED-77[42], section 3.11.5]**