Minimum Operational Performance Standards for Cockpit Display of Traffic Information

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1 Purpose and Scope

1.1 Introduction

The purpose of this document is to specify the Minimum Operational Performance Standards (MOPS) for aircraft equipment associated with the Cockpit Display of Traffic Information (CDTI). The CDTI is the pilot interface portion of the surveillance system (see Figure 1-1). The scope of this document is the requirements and recommendations for the CDTI (see Figure 1-2).

CDTI functions are composed of a traffic display function, associated control functions, annunciation functions, and alert functions. The CDTI functions may be implemented in one piece of avionics equipment or distributed throughout an integrated cockpit. It depicts traffic information relative to own-ship. Additional information about the traffic (for example, ground speed, distance, closure rate) may also be presented. Traffic information may be obtained from one or more sources; e.g., automatic dependent surveillance broadcast (ADS-B), traffic information service (TIS), and the surveillance part of the traffic alert and collision avoidance system (TCAS). This information is processed by the airborne surveillance and separation assurance processing (ASSAP) function and is sent to the CDTI (Figure 1-1). (ASSAP MOPS is a companion document under development.)

The CDTI traffic display function may present information on a dedicated display device or a shared/multi-function display (MFD) device. If the CDTI display is implemented as part of a MFD, all of the requirements in this document apply to the traffic presentation on the MFD. While this MOPS specifies requirements for a graphical display of traffic on a head-down display, it is recognized that there may be other methods of "displaying" traffic, including head-up display, aural and text displays. However, this MOPS does not address requirements for those types of displays.

The CDTI requirements specified in this version of the MOPS are based on the following operational applications that are described in the Operational Concepts for CDTI Initial Applications[1]:

a) Enhanced visual acquisition
b) Enhanced visual approaches
c) In-trail (or lead) climb and descent in non-radar airspace (oceanic, en route, and remote)
d) In-trail (or lead) climb and descent to co-altitude in non-radar airspace (oceanic, en route, and remote).

Manufacturers/aircraft operators should consider supporting additional operational applications and the required criticality level. Operational application reference information can be found in RTCA DO-242, Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B)[2].

This version of the MOPS does not categorize CDTI equipment into different classes. Such division may be applied in a future version of the MOPS. It is expected that manufacturers will design and implement equipment with many of the optional features, as well as additional features that are not specified here.

Compliance with standards specified in this document is recommended as one means of assuring that the equipment will perform its intended functions satisfactorily under all conditions encountered in routine aeronautical operations. It may be possible to perform additional operational applications using the equipment developed from the standards specified in this document. Any regulatory application of these standards is the sole responsibility of the appropriate governmental agencies.

If the equipment implementation includes a computer software package, compliance with the guidelines contained in RTCA/DO-178B, Software Considerations in Airborne Systems and Equipment Certification[3], is recommended.

Section 1 of this document provides information and assumptions needed to understand the rationale for equipment characteristics and requirements stated in the remaining sections. It describes typical applications and operational goals and establishes the basis for the standards stated in Sections 2 through Section 3. This section contains definition of terms essential to this document and that may have ambiguous or multiple meanings or that are not normally used in RTCA standards.

Section 2 contains the minimum performance standards for the equipment. These standards specify the required performance under standard operating and environmental conditions. CDTI capabilities and associated performance requirements are provided. Also included are recommended bench test procedures necessary to demonstrate equipment compliance with the minimum requirements.

Section 3 describes the performance required of the installed equipment. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing.

Appendix A contains acronyms and Appendix B contains definition and description of terms. Bibliography and references are provided in Appendix C. A summary of the characteristics of surveillance sources is provided in Appendix D. Appendix E provides guidance information that relates the CDTI features needed to support an initial set of operational applications. The table in Appendix E is derived from the Applications Descriptions for Initial Cockpit Display of Traffic Information (CDTI) Applications [1]. Appendix F provides commentary on the display resolution, display addressability and display accuracy. Appendix G provides guidance on the

use of color on the CDTI display. Examples of CDTI display elements are provided in Appendix H – note that these are examples only and do not imply a preferred implementation.

1.2 System Overview

The CDTI is part of the surveillance system shown in Figure 1-1. The CDTI includes the hardware and software elements needed to display traffic on a display device in the flight deck. It receives position information of traffic and own-ship from the airborne surveillance and separation assurance processing (ASSAP) function. The ASSAP receives information from the surveillance sensors and own-ship sensors.

If the surveillance system receives information from multiple sources, the information from each surveillance source is merged using a data fusion function in the ASSAP (see appendix D for characteristics of the surveillance sources). The merged information is then processed by the surveillance applications (assuming the information meets the quality requirements of the application) and the output of these surveillance applications is passed on to the CDTI. Normally, CDTI receives input from the ASSAP function. ASSAP may direct CDTI to receive information from TCAS. In case of ASSAP failure, TCAS information may be presented directly on the CDTI display instead of going through ASSAP (see Figure 1-2).

The requirements in this document pertain to the display, control, alerts, and other human-machine interface aspects of the CDTI used by the flight crew, not to the sensor(s), or data fusion algorithms needed if multiple sources are used. The data quality requirements may vary based on the application and operational environment for which it is intended. A companion document, the Airborne Surveillance and Separation Assurance (ASSAP) MOPS[15] specifies the data fusion, processing etc. that drive the display elements specified in this document.

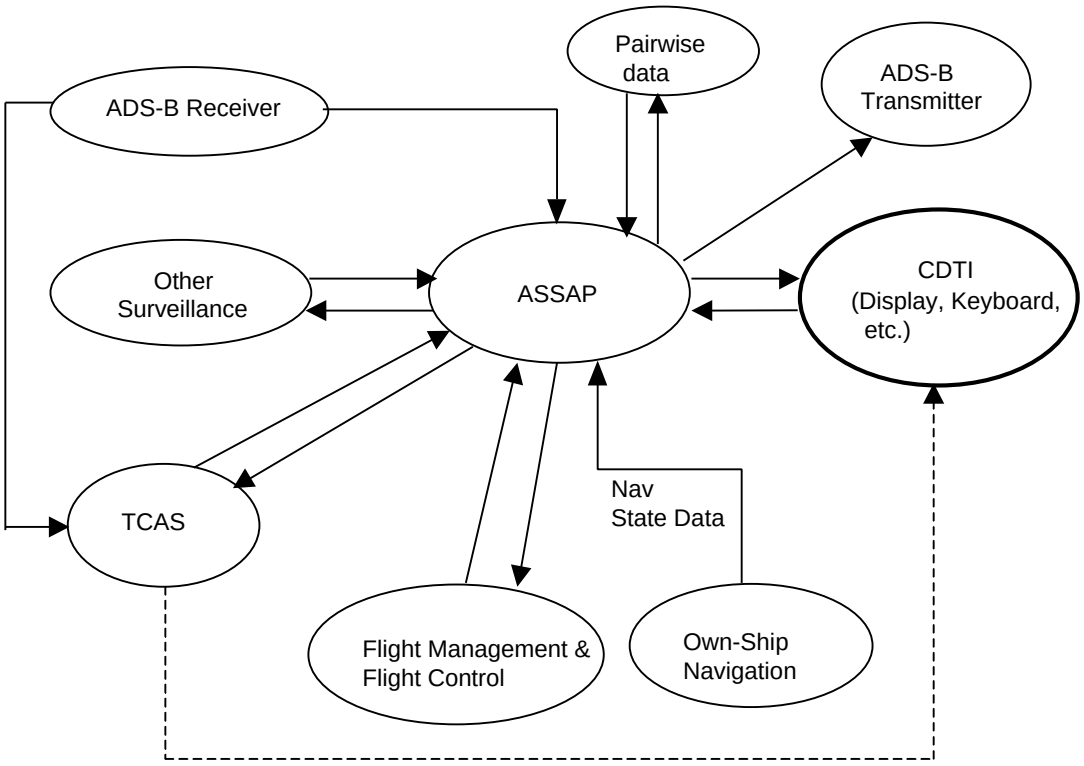
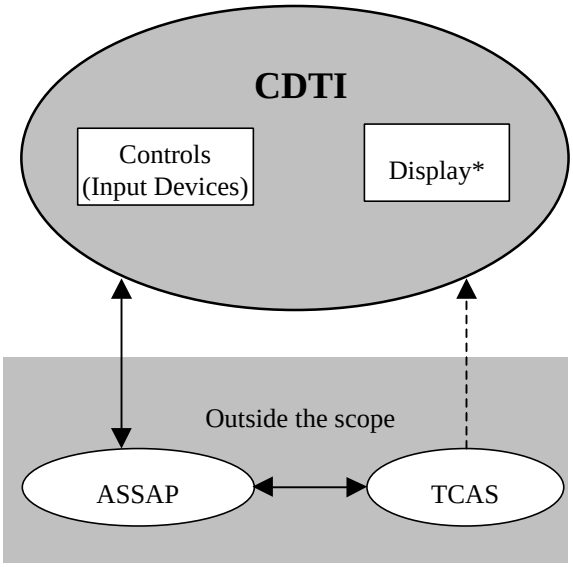


Figure 1-1. Airborne Surveillance System Functional Architecture



* The CDTI can be displayed on a stand-alone display or MFD. MFDs, ASSAP and TCAS are outside the scope of this MOPS.

Figure 1-2. CDTI Scope in the MOPS

1.3 Operational Goals

The operational goals of the CDTI applications are to improve the safety and efficiency of flight operations through an enhanced surveillance capability. The long-term goal for CDTI applications includes obtaining the user benefits of improved safety, efficiency, flexibility, and capacity. Operational goals for the initial applications include the following

1. Increase safety by improving traffic situational awareness.
2. Improve visual traffic acquisition.
3. Aid the positive identification of traffic.
4. Reduce the probability of loss of the visual contact.
5. Aid judgements of closure and encounter geometry and spacing.
6. Enable approach facilities to improve throughput.
7. Increase access to more efficient altitudes and tracks for aircraft in oceanic/remote airspace.

1.4 Assumptions and Limitations

The design and operational performance requirements and guidelines presented in this document were developed based on the following assumptions and limitations:

1. If multiple sources of surveillance data are used, an ASSAP data fusion mechanism will provide the best information available.

2. The CDTI data may be presented on a standalone display dedicated to traffic information only, or part of a shared/multi-function display.

3. This MOPS does not include an exhaustive or comprehensive list of shared/multi-function display considerations or requirements.

4. The requirements are focused on 2-dimensional graphical display depictions. This MOPS does not address 3-dimensional, non-graphical, or head-up displays (HUDs).

5. The CDTI and associated alerting, if any, will be properly integrated with other display functions and will not interfere with critical functions or other alerting.

1.5 Overview of 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 qualifications, into operational use. Three types of test procedures are specified in the following sub-sections.

1.5.1 Environmental Tests

Environmental tests 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 operations. Environmental test requirements will be derived from RTCA/DO-160D, Environmental Conditions and Test Procedures for Airborne Equipment[14].

1.5.2 Bench Tests

Bench tests provide a laboratory means of demonstrating compliance with the requirements of 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. Bench test procedures are specified in Section 2.4.

1.5.3 Installed Equipment Tests

Installed equipment tests are used to demonstrate functional performance in the intended operational environment. The installed test procedures and their associated limits and requirements are specified in Section 3. Although bench and environmental test procedures are not included in the installed equipment tests, their 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 in the aircraft, etc. Installed equipment 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.

1.6 Definition of Terms

This section contains definition of terms used in this document that may have ambiguous or multiple meanings or that are not normally used in RTCA standards. See Appendix B for additional definition of terms and Section 2.4.1 for terms specific to test conditions.

Shall: A mandatory requirement. An approved design must comply with every requirement, which can be assured by inspection, test, analysis, or demonstration.

Should: A recommendation that would typically improve the equipment, but does not constitute a requirement.

May: A permission that would likely improve the equipment, but does not constitute a requirement.

Multi-Function Display (MFD) or shared display: A display that is used for a variety of display functions such as presenting navigation, terrain, and traffic information. The data may be presented as 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.

Traffic: One or more aircraft or surface vehicle(s). (Does not include own-ship)

Traffic Display Criteria: Criteria based on range, altitude, vertical speed (climb, descent) and possibly other parameters. Default criteria may be specified by the manufacturer and may be modified by the flight crew.

Target: Traffic of particular interest to the crew.

Selected Target: Traffic that has become distinguishable (e.g., by being highlighted) as a result of being selected.

Target Selection: Manual process of selecting a target.

Note: Notes are in italic and are used for commentary and clarification of requirements and recommendations.

2. Equipment Performance Requirements and Test Procedures

2.1 General Requirements

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 listed in this section (2.1) may not have particular test procedures specified in the test procedure sub-section (2.4.3).

2.1.1 Airworthiness

In the design and manufacture of the equipment, the manufacturer **shall[1]** provide for installation so as not to impair the airworthiness of the aircraft.

2.1.2 Intended Function

The equipment **shall[2]** perform its intended functions, as defined by the manufacturer, and its proper use **shall not[3]** create a hazard to other users of the National Airspace System.

2.1.3 Federal Communications Commission Rules

All equipment **shall[4]** comply with the applicable rules of the Federal Communications Commission.

2.1.4 Fire Protection

All materials used **shall[5]** be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire.

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

2.1.5 General

1. The operation of CDTI equipment **shall not[6]** adversely affect the operation of other equipment.

2. Display information management should be consistent with the following aerospace accepted practices and aerospace recommended practices as appropriate to the displays and installation.

    a) AC 25-11[18], AC 23.1311a[19]
    b) SAE ARP 4102/4 *Flight Deck Alerting System*[4]
    c) SAE ARP 1874 *Design Objectives for CRT Displays for Part 25 (Transport) Aircraft[5]*
    d) AS 8034 *Minimum Performance Standard for Airborne Multipurpose Electronic Displays[6]*
    e) SAE ARP 4032 *Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays[7]*
    f) SAE ARP 4102/7, *Electronic Displays[8]*
    g) SAE ARP 4102, *Flight Deck Panels, Controls, and Displays.[9]*
    h) SAE ARP 1093, *Guidance on Legibility of Text. Numeral, Letter, and Symbol Dimensions for Aircraft Instrument Display [10]*.

2.1.6 Layout and Operation of Controls

1. The equipment **shall[7]** 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 operation of the aircraft or the reliability of the equipment.

2. Controls **shall[8]** provide feedback (e.g., tactile, visual) when operated.

3. Controls should be resistant to inadvertent activation.

Note: A common and acceptable means of reducing the likelihood of inadvertent operation through key design include the following:

a) Keys should not be spaced so that sequential use is awkward or error prone.
b) Placing fences between closely spaced adjacent controls.
c) Concave upper surface of keys to reduce slippage.
d) Size of control surface sufficient to provide for accurate selection.

4. Controls used in flight **shall[9**] be operable with one hand.

5. If a control can be used for multiple functions, the current function **shall[10]** be indicated.

6. Controls that are normally adjusted in flight **shall[11**] be readily accessible to the flight crew when the crew members are seated in normal positions for flight.

7. To the extent possible, controls / input devices should be organized according to the following principles:

a) Place the most frequently used controls in the most accessible locations.
b) Partition the controls into functional groups.
c) Collocate the controls with the associated displays.
d) Arrange the controls according to the sequence of use.

8. Control operating force should be light enough not to impede intentional rapid sequential use.

9. Use of two or more CDTI controls simultaneously (e.g., pushing two buttons at once) in flight should not be required.

10. Controls that do not require adjustment during flight should not be readily accessible to the flight crew (e.g., maintenance function).

11. Line select function keys should align with adjacent text.

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

2.1.7. 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 CFR 23.1322[20] and 14 CFR 25.1322[19], DOT/FAA/RD-95-1[, AC 25-11[18], AC 23.1311a[19], SAE ARP 4032[7], and SAE ARP 4102/4[4].

1. Whenever color is used to code information, it **shall[12**] be used redundantly with another means of coding information.

   Note: This means that there should be some indication, other than color, about the information that the color is meant to convey, allowing the information to also be conveyed to a person of impaired color vision. Color-coded information should be accompanied by another distinguishing characteristic such as shape, location, or text. When the flight crew is required to remember what a particular color in an item means, the information is considered coded by color. (E.g., A selected traffic symbol can not be distinguished by color alone).

2. No more than six colors should be used for color coding on the display. See ARP4032[7] and Appendix G for color guidelines.

   Note: Color standardization with existing flight deck is highly desirable. Color diversity should be limited to as few colors as practical to ensure adequate color contrast between symbols.

3. Use of additional colors for other purposes should not detract from the ability to identify each of the colors used for coding.

   Note: Color has been successfully used primarily as an aid for visual search or for perceptual grouping of information.

4. If color is used to code information, the selected color set **shall[13**] be discriminable (i.e., can be identified) under the normally expected ambient light conditions.

5. Color-coding should be consistent across all CDTI system displays and controls.

6. When colors are assigned a meaning, each color should have only one meaning.

7. Pure colors (e.g., "royal blue) should not be used when the contrast ratio between that color and its surround is low. (e.g., low contrast ratio between blue and a black surround - see DOT/FAA/AR-99/52[17])

8. Saturated red and blue should not be presented in close proximity to avoid a false perception of depth.

9. When bright highly saturated colors are used those colors should not adversely affect other information on the display.

10. Red **shall[*14*]** be used only for indicating a hazard that may require immediate corrective action.

11. Amber **shall[*15*]** be used for indicating the possible need for future corrective action.

    Note: The use of red and amber colors is consistent with the accepted aviation practice described in 14 CFR 23.1322[20] and 25.1322[19].

12. Green or white should be used to indicate safe operation.

13. Any other color may be used for aspects not described in items 10, 11, and 12 of this section, providing the color differs sufficiently from the colors prescribed in items 10, 11, and 12 of this section to avoid possible confusion.

2.1.8 Effects of Tests

Except as specified, test procedures **shall not[16]** be detrimental to equipment performance following completion of the tests.

2.2 Equipment Performance Requirements - Standard Conditions

Requirements applying to functions and features in the following sub-paragraphs apply only to those that are required for the particular application or are used as optional features within the application or set of applications under test.

2.2.1 Inputs to CDTI

2.2.1.1 Basic Required Inputs

Basic required inputs are expected from the ASSAP function and will also be specified in the ASSAP MOPS document. Where 'traffic' is mentioned in this subsection, the information is required for each traffic element that meets the traffic display criteria. (See Figure1-1).

1. The CDTI **shall[17]** receive an aircraft track identifier when available.

   Note: A track identifier is a unique identifier of the traffic aircraft between ASSAP and the CDTI.

2. The CDTI **shall[18]** receive the relative pressure altitude of the traffic aircraft with reference to own-ship when available.

3. The CDTI **shall[19]** receive traffic position relative to own-ship when available.

4. The CDTI **shall[20]** receive the status of the traffic sensors and processing when available. (For example, an ADS-B receiver failure, TCAS receiver failure, ASSAP processing failure.)

5. The CDTI **shall[21]** receive the traffic on-ground or in-air status (i.e., whether the traffic is on the ground or in the air), when available.

6. The CDTI **shall[22]** receive the quality of data (e.g., actual surveillance performance) for each traffic element when available.

7. The CDTI **shall[23]** receive updates at least once a second when available.

2.2.1.2 Required Inputs Associated with Optional Features

The following inputs are associated with optional CDTI features. When optional features (see Section 2.2.2) are implemented, these inputs are required as appropriate. Where 'traffic' is mentioned in this subsection, the information is required for each traffic element that meets the traffic display criteria. See Appendix E for recommended feature list for each operational application.

1. The CDTI **shall[24]** receive the traffic ground speed when available.

2. The CDTI **shall[25]** receive the traffic ground track angle when available.

   Note: The ground track angle will be used to point the directional traffic symbol and also to determine the direction of the horizontal velocity vector.

3. The CDTI **shall[26]** receive the traffic identification of the traffic when available.

4. The CDTI **shall[27]** receive the pressure altitude of the traffic aircraft when available.

5. The CDTI **shall[28]** receive the traffic pressure altitude correction status (corrected or not corrected to own-ship barometric setting) when available.

6. The CDTI **shall[29]** receive the traffic vertical rate when available.

7. The CDTI **shall[30]** receive the traffic closure rate when available.

8. The CDTI **shall[31]** receive the traffic aircraft category when available.

9. The CDTI **shall[32]** receive the own-ship pressure altitude when available.

10. The CDTI **shall[33]** receive the ground speed of own- ship when available.

11. The CDTI **shall[34]** receive the ground track of own-ship when available.

12. The CDTI **shall[35]** receive the own-ship heading information when available.

13. The CDTI **shall[36]** receive the own-ship navigation reference (magnetic/true) when available.

14. If the traffic surveillance system is capable of operating in different modes, The CDTI **shall[37]** receive the mode status when available.

15. The CDTI **shall[38]** receive the alert status when available. (This includes all alerts implemented that relate to the display of traffic information, including TIS alerts and TCAS alerts.)

    Note: Additional information such as own-ship in-air/on-ground status, and traffic aircraft airspeed may also be made available to the CDTI.

2.2.2 Display Features

1. The CDTI **shall[39**] display the position of traffic relative to own-ship when the traffic display criteria are satisfied.

2. When traffic display criteria (as defined in section 1.6) are satisfied, the following features **shall[40**] be continuously displayed:

    a) Own-ship symbol (see additional requirements in subsection 2.2.2.1.1)
    b) Traffic symbol (see additional requirements in subsection 2.2.2.1.2)
    c) Traffic relative bearing (see additional requirements in subsection 2.2.2.2.10)
    d) Traffic relative range (see additional requirements in subsection 2.2.2.2.9.1)
    e) Traffic altitude (see additional requirements in subsection 2.2.2.2.3).

Note: Items 1 and 2 above are required for all CDTI equipment. Additional features specified in this section may be implemented on the CDTI equipment at the manufacturer's option. Appendix E provides guidance that relates operational applications to display features.

3. If the CDTI is designed to support an application designated in Table E-1, the CDTI **shall[41**] implement, at a minimum, all features designated as required.

    Note: The manufacturer must specify one or more surveillance applications listed in Table E-1. For each supported surveillance application, every feature marked 'required' must be present. If optional features are implemented, they must meet the requirements specified in this document.

4. The requirements in the corresponding sub-sections **shall[42**] be met for any feature that is implemented**.**

2.2.2.1 Symbols

1. Each symbol should only be used for one purpose on the CDTI.

2. If symbols are used to depict elements that have standard symbology (e.g., navigational fixes), the CDTI should use symbols that are consistent with established industry standards. Guidelines for electronic display symbology for navigation aids are provided in SAE ARP 5289.

3. Symbols **shall[43**] be discriminable from a distance of 30 inches under all anticipated lighting conditions.

2.2.2.1.1 Own-Ship Symbol

1. The traffic display **shall[44]** have a symbol representing the location of the own-ship.

2. The own-ship symbol **shall[45**] be directional (e.g., not a circle or square).

Note: The directionality may be based on heading or track.

3. The own-ship symbol **shall[46**] be distinctive from all other symbology.

4. If the CDTI supports more than one own-ship symbol directional reference (e.g., heading vs. track), then the current own-ship symbol reference **shall[47**] be indicated.

2.2.2.1.2 Traffic Symbol

1. The CDTI **shall[48]** display a traffic symbol for each traffic report received from ASSAP that meet the traffic display criteria.

   Note: It is assumed that ASSAP normally provides a single traffic report for each aircraft, based on data from multiple surveillance sources. When multiple traffic reports are received they are assumed to be from different aircraft.

2. The CDTI **shall[49**] position each traffic symbol at a location representing its relative range and bearing with respect to own-ship.

3. The traffic symbol should indicate specific directionality (e.g., chevron) if the accuracy of the directionality (ground track angle) can be determined within 5 degrees.

4. The traffic symbol **shall not [50**] imply specific directionality (i.e., no sharply pointed target symbols like the chevron are to be used) if the accuracy of the directionality (ground track angle) cannot be determined within 5 degrees.

   Note: The directionality is based on the ground track angle, not necessarily the heading of the aircraft. This is important for monitoring traffic such as helicopters that can fly backwards.

5. All traffic symbols **shall[51]** be positioned on the display in their appropriate location representative of their actual range.

6. The traffic relative range **shall[52]** be displayed with a minimum resolution of 3% of the presently active full scale range.

2.2.2.1.2.1 Recommendations for TCAS Symbology Integration

None of the following recommendations affect the TCAS functionality. This subsection provides recommendations, and not requirements, for traffic symbology as shown on the CDTI. It does not affect the TCAS aural alerts and resolution advisory guidance.

1. When TCAS surveillance information exists with no other correlating data, the symbology displayed may be the TCAS symbology.

2. When other surveillance information exists without TCAS surveillance information, the symbology displayed may be the symbology appropriate for the quality of the surveillance information determining the traffic position.

3. When other surveillance information is correlated with TCAS, the symbology displayed may be symbology appropriate for the quality of the surveillance information determining the traffic position.

4. When other surveillance information is correlated with TCAS and a TCAS alert is in effect, the symbology displayed may be symbology appropriate for the quality of the surveillance information determining the traffic position with the color required by the TCAS MOPS. It may be appropriate to use the most accurate surveillance information (possibly not TCAS) to position the traffic symbol.

2.2.2.1.3 Selected Target Symbol

There **shall[53**] be some means of distinguishing the selected target from other traffic.

When a target is selected, additional information on that target may be displayed in a data block or a data tag.

Note: Color has been successfully used primarily as an aid for visual search or for perceptual grouping. The use of color-coding has been found to reduce search times in densely populated displays when compared with performances obtained using size, shape, or brightness coding. SAE ARP 4102/4[4] and DOT/FAA/AR-99/52[17] provide display guidelines for color, size and brightness of symbols.

2.2.2.2 Information Elements

2.2.2.2.1 Data Tags

Data tags show information about the traffic, are located in proximity with the traffic symbol, and move with it. The data tags may contain additional information such as traffic identification.

1. The data tag **shall[54**] be associated with its traffic symbol.

Note: The association may be achieved by color, for example, shared by the traffic symbol and the data tag.

2. If a data tag is displayed, it should include the traffic altitude.

2.2.2.2.2 Data Blocks

Data blocks show additional information (e.g., aircraft category) about the target and are placed at a fixed location on the display irrespective of the location of the target.

If data blocks are displayed, a means **shall[55**] be provided to associate the data block with the traffic symbol.

Note: The association may be achieved by color, for example, shared by the traffic symbol and the data block.

2.2.2.2.3 Traffic Altitude

Traffic altitude may be displayed either as relative or as actual altitude.

1. Altitude values **shall[56**] be displayed for airborne traffic.
2. For traffic determined to be on the ground, an indication the traffic is on the ground **shall[57**] be provided.
3. Altitudes for traffic simultaneously displayed **shall[58**] be consistent, all altitudes being displayed either in actual or relative terms.
4. The CDTI **shall[59**] be capable of displaying relative altitude.
5. The display **shall[60**] indicate whether actual or relative altitude is displayed.
6. In addition to altitude value, the display **shall[61**] indicate whether traffic is above or below own-ship.

Note: One method of indicating whether traffic is above or below own-ship is to show the traffic altitude value above or below the traffic symbol.

7. If the traffic altitude is not available, the altitude information **shall not[62]** be displayed.
8. If the traffic altitude is not available, an indication that it is not available should be displayed (e.g., NO ALT in the data tag).
9. The CDTI should be capable of displaying traffic within a minimum of ± 9900 feet of own-ship.

Note: Normally, the crews are interested in traffic within a smaller altitude band. But it is necessary under some circumstances for the crew to see traffic at much higher/lower altitudes (e.g., while climbing/descending).

10. A capability to select an altitude band within which to display traffic should be provided to the flight crew.
11. The selected altitude band **shall[63**] be continuously displayed, if crew selected.
12. The traffic altitude value **shall[64]** be displayed with a resolution of 100 feet or better.
13. The CDTI should provide the capability to display to the flight crew the own-ship altitude and position being broadcast.

Note 1: It has been noted in some TCAS implementations, when the other aircraft is at co-altitude, the display of the altitude data jumps above and below the aircraft symbol for the other aircraft due to very small altitude changes. This is a nuisance problem and should be corrected in the CDTI design.

Note 2: Altitude derived from GNSS, if available, may be displayed on the CDTI for the pilot. (e.g., to cross check the barometric altitude.)

2.2.2.2.3.1 Actual Altitude

Actual altitude is the displayed altitude for traffic (when the actual altitude mode is selected) that is corrected for the local barometric pressure setting of the own-ship. Actual altitude may be uncorrected (i.e., pressure altitude) if the local barometric pressure setting of the own-ship is unavailable.

1. To display the actual altitude, the pressure altitude should be corrected for the local barometric pressure using the same correction used by the flight crew of own-ship.
2. An indication should be provided on the CDTI whether it is displaying the corrected or uncorrected value.
3. If the pressure altitude is not corrected for the local barometric pressure used by the crew of own-ship, the display of the actual altitude **shall[65**] be limited to a maximum

of 30 seconds if the own-ship is below 18,000 feet (transition altitude, if it is available, may be used instead of the 18,000 feet) before it automatically reverts to the relative altitude.

4. When the display of the actual altitude is selected, an indication that the displayed altitude is actual altitude **shall[66**] be shown on the traffic display.
5. If implemented, the actual altitude **shall[67**] be displayed as a 3-digit number representing hundreds of feet, MSL. For example, 007 represents 700 feet MSL and 250 represents 25,000 feet MSL.

Note: Actual altitude may be positioned above or below the traffic symbol in a manner consistent with the relative altitude.

2.2.2.2.3.2 Relative Altitude

Relative altitude is the difference between own-ship and traffic altitude, which is calculated using the pressure altitude of both aircraft. The relative altitude shown for traffic is positive when the traffic is higher than own-ship and negative when traffic is lower than own-ship. If a numeric readout is used:

1. The relative altitude **shall[68]** consist of at least two digits indicating the altitude difference in hundreds of feet.
2. For traffic above own-ship, the altitude value in the data tag **shall[69**] be preceded by a "+" sign and be placed above the traffic symbol.
3. For traffic below own-ship, the altitude value in the data tag **shall[70**] be preceded by a "-" sign and be placed below the traffic symbol.

   Note: The "+" or "-" character may be emphasized (e.g., by using a slightly larger character set than that used for digits).
4. The data tag for co-altitude traffic (traffic at the same altitude as the own-ship) **shall[71]**be displayed as the digits "00".

   Note: The "+" or "-" tag may be retained with the "00" indication to denote that the system is in the relative altitude mode.
5. The "00" characters should be placed above the traffic symbol if the traffic is closing from above; below the symbol if the traffic is closing from below.
6. If traffic is at co-altitude with own-ship and traffic is not climbing or descending at a rate greater than or equal to 500 fpm, the co-altitude "00" symbol should be placed below the traffic symbol.

2.2.2.2.4 Vertical Rate

The vertical rate indication shows that the traffic is climbing or descending at a rate faster than a specified threshold.

A climb or descent with a vertical velocity greater than or equal to 500 fpm, **shall[72]** be indicated (e.g., indicated using a up or down arrow, as appropriate).

Note: TCAS uses 500 fpm limit for this indication; therefore, this limit has been maintained for consistency.

2.2.2.2.5 Traffic Identification

Traffic identification may also be referred to as flight identification or flight ID. The traffic identification may be, but is not necessarily, the aircraft flight number or the tail number.

Note: Traffic identification may not be available for all traffic.

1. The traffic identification information **shall[73**] be capable of displaying the ICAO standard for aircraft identification that is a maximum of eight alphanumeric characters.

2. The traffic identification information **shall[74**] be associated with the aircraft symbol.

Note: The traffic identification may be displayed as part of a data tag and/or a data block.

2.2.2.2.6 Closure Rate

1. When closure rate is displayed, it **shall**[**75**] be displayed either graphically or alphanumerically.
2. A positive closure rate (i.e. traffic is getting closer) **shall[76]** be distinguishable from a negative closure rate (i.e. traffic is getting farther away).
3. Closure rate information **shall[77]** be distinguishable from other information.

   Note: Since the closure rate and relative altitude have positive and negative values they may be confused with each other if provisions are not made to distinguish between them.
4. If numerical closure rate is displayed as knots the unit of measure is not required to be displayed. If alternative units (i.e., anything other than knots) are used, unit of measure **shall[78**] be displayed
5. If an alphanumeric closure rate is displayed, the CDTI **shall[79]** be capable of displaying it with a minimum resolution of 1 knot or equivalent.
6. If a horizontal only (2-Dimensional) and a horizontal and vertical (3-Dimensional) display of closure rate is available, the selected method **shall[80]** be displayed to the pilot.

7. The traffic display should be capable of displaying closure rates up to at least 99 knots .
8. An indication should be displayed when the maximum closure rate display capability of the CDTI is exceeded.

2.2.2.2.7 Ground Speed

1. The traffic display should be capable of displaying ground speeds up to at least 999 knots.
2. An indication **shall[81]** be displayed if ground speed exceeds the indicator limit.
3. Ground speed **shall[82]** be distinguishable from other information.
4. If numerical ground speed is displayed as knots the unit of measure is not required to be displayed. If alternative units (i.e., anything other than knots) are used, unit of measure **shall[83**] be displayed.
5. If numerical ground speed is displayed, it **shall[84]** be displayed with a minimum resolution of 1 knot.

2.2.2.2.8 Horizontal Velocity Vector

Horizontal velocity vector is the magnitude and direction of horizontal velocity.

1. Traffic horizontal velocity vector information should be depicted graphically.
2. If the horizontal velocity vector is depicted in terms of time, the prediction time should remain the same regardless of the selected display range.
3. If the horizontal velocity vector is displayed for traffic, it should also be displayed for own-ship.
4. When horizontal velocity vector is displayed, units of measurement **shall[85]** be the same between all displayed traffic and own-ship.
5. The units of the horizontal velocity vector should be displayed.

2.2.2.2.9 Display Range

1. The display **shall**[**86**] be adjustable to 10 nm or less in the direction of own-ship travel as measured from the own-ship position to the edge of the viewable screen.

   Note: For future applications, a shorter range may be required.

2. The display **shall[87]** be adjustable to a range of 40 nm or greater in the direction of own-ship travel as measured from the own-ship position to the edge of the viewable screen.

3. The selected display range **shall[88]** be indicated on the traffic display.

4. The capability **shall[89]** exist to adjust (i.e., increase and decrease) the display range.

5. If graphical range references are used, range rings or other range markings at specified radii **shall[90]** be provided from the own-ship symbol.

6. If traffic information is shown on a shared display that does not provide a range reference, the range reference should be provided when the CDTI information is selected.

7. The surveillance display range **shall[91]** be capable of depicting traffic at least 90 nm in any direction from the own-ship.

2.2.2.2.10 Bearing

2.2.2.2.10.1 Relative Bearing

1. The CDTI **shall[92]** position each traffic symbol at a location representing its relative bearing with respect to own-ship heading or own-ship track angle (see "Display Orientation," section 2.2.5.2 below.)
2. The traffic relative bearing placement accuracy
   a) **shall[93]** be equal to or better than 9 degrees at 1/3 distance from own-ship to the edge of the display.
   b) **shall[94]** be equal to or better than 3 degrees at the edge of the display from own ship.
   c) **shall[95]** be 15 degrees or better at the edge of the display from own ship (and the equivalent at 1/3 distance from own-ship to the edge of the display) if the display is intended only for enhanced visual acquisition of traffic.

2.2.2.2.10.2 Off-Display Selected Target Relative Bearing

1. If the selected target is outside of the currently selected display range, an indicator **shall[96]** indicate the relative bearing to the selected target.

Note: The selected target could be outside the selected display range if a target is selected and then the display scale is changed.

2. The relative bearing resolution requirements from section 2.2.2.2.10.1 **shall[97]** apply to the off-display selected target relative bearing.

2.2.2.3 Number of Traffic Elements

1. The CDTI **shall**[**98**] be capable of displaying at least 8 traffic elements.

Note: A traffic element is an aircraft or a surface vehicle.

Note: It is assumed the traffic elements meet the traffic display criteria. In certain situations, for example, on approach to an airport, there may be several (more than 8) aircraft on the ground, but the CDTI should be able to display relevant traffic in the air. The manufacturer is cautioned to have the capability to display many more targets in such situations. Note TCAS also requires the same minimum capability.

2. The CDTI should be capable of displaying all traffic that meets the traffic display criteria.

2.2.3 Controls

1. A means **shall[99**] be provided to adjust the brightness of the display to enable pilots to use the display in all anticipated flight deck illumination conditions.
2. The positions of switches or knobs **shall[100]** be readily discernible by visual inspection.
3. Features that are used most often should have dedicated or easily accessed controls.

2.2.3.1 Target Selector

The flight crew **shall[101]** be able to select a target within the currently selected traffic display criteria.

Note: Additional information about a selected target (e.g., numeric range value) may be presented in a data block.

2.2.4 Menu Items and Menu Logic

1. Menus should be shallow in depth (i.e., few levels) and narrow in breadth (i.e., few items per menu).

2. When a design choice has to be made between depth and breadth, breadth should be preferred over depth.

3. The pilot should not be required to traverse more than three levels in any menu structure, and no more than two levels for frequently performed tasks.

4. Menus should be easily navigable. Prompts and menu options should indicate the action to be executed.

   Note: This can, in part, be accomplished by using familiar, concise, and consistent terminology.

5. Menu options should be positioned toward the top of the menu in proportion to their frequency of use.

6. Menu organization should support specific pilot tasks.

7. An option that is not operationally relevant to the pilot (e.g., a maintenance function) **shall not[102]** be included in the pilot's menu choices.

8. An option that is temporarily unavailable should provide an indication that it is unavailable.

9. When hierarchic menus are used, jumps should be allowed that enable movement to a previous and main menu.

10. Only one action should be required to return to the next higher level.

11. Only one action should be required to return to the menu at the top level.

2.2.5 Display Functionality

2.2.5.1 Display Feature Prioritization

1. In case the traffic symbol and the own-ship symbol overlap,

   a) The own-ship symbol as well as the traffic symbol **shall**[**103**]be displayed (either in full or in part) and
   b) An indication of which aircraft is above and which aircraft is below **shall**[**104**] be displayed.

2. The order of display precedence (in case the symbols overlap) should be (higher priority listed first)

   a) Own-ship symbol (and associated velocity vectors, if available)
   b) Traffic alert symbology
   c) Selected target symbol and associated text (e.g., traffic identification)
   d) Selected target horizontal velocity vector
   e) Traffic symbol and associated text data (e.g., traffic identification)
   f) Traffic symbol horizontal velocity vector

2.2.5.2 Display Orientation

If the pilot has the ability to switch between more than one display orientations (e.g., track up vs. heading up) the selected display orientation **shall[105]** be indicated.

2.2.5.3 Display Update

1. The CDTI **shall[106]** update the display of traffic at least once a second.

   Note 1: The input data to the CDTI is updated at once a second (see section 2.2.1.1 on input).

   Note 2: A higher update rate is recommended when own-ship is turning.

2. Traffic information **shall not [107]** be displayed if the most recent CDTI input data is more than 3-seconds old.

3. The information presented on the display should be visually persistent without fading and flickering under expected lighting conditions.

2.2.5.4 De-clutter

1. The capability **shall[108**] be provided for removing all optional CDTI information (e.g., aircraft identification and horizontal velocity vector) from the display and returning to the basic traffic display features as defined in Section 2.2.2(2).

2. The optional information should be removable by a single action in order to declutter the display area for presentation of the minimum traffic information specified in Section 2.2.2(2).

3. Symbology indicating alerts **shall[109]** be protected from removal by the de-clutter function.

2.2.5.5 Self Test

1. The capability **shall[110]** be provided for a self-test of the CDTI.
2. The system should detect and communicate failures in its operation to the flight crew during the self test.

2.2.5.6 Status Indication

1. The equipment **shall[111]** indicate:

    a) The absence of power (e.g., blank display).
    b) Inadequate or invalid surveillance data that would cause unacceptable traffic information display.
    c) Inadequate or invalid own-ship data that would cause unacceptable traffic information display.

2. The system status **shall[112**] be provided at all times, indicating one of the following system states:

    a) Enabled and functioning normally (e.g., On with no failures annunciated)
    b) Off (e.g., blank display)
    c) Failed (partial or complete)
    d) Enabled and functioning in an off-normal state (e.g., with only partial data available, with reduced accuracy, or with a reduced detection range)
    e) Test (e.g., self-test, built-in test)

Note: Status and failure conditions may be dependent on a particular application needs and/or the implementation of the traffic display. Additionally, other system verification information such as own-ship altitude and position may be displayed to allow validation of other information sources.

3. The color of the annunciations should conform to recommendations in SAE ARP 4102/4[4] reference J information (level 0) or advisory (level 1) annunciation, as appropriate. The color of the level 1 annunciation should be amber or yellow. All status and failure annunciations should be consistent with any other annunciations provided by the display on which they are shown and should have only one meaning for all available display modes.

2.2.5.6.1 Mode Indication

1. If the system has the ability to operate in different modes, the current mode **shall[113]** be continuously indicated.
2. All automated mode changes **shall**[**114**] be communicated to the flight crew.

2.2.5.7 Quality of Data Indication

The CDTI **shall**[**115**] be capable of displaying an indication of the quality of data.

2.2.6 Flight Deck Integration

The CDTI system should be consistent with the rest of the flight deck in terms of color, standardization, automation, symbology, interaction techniques and operating philosophy Reference AC 25-11[18] and AC 23.1311[19].

2.2.7 Traffic Alerting

Traffic alerting (generic term) is a mechanism that attracts the attention of the pilot to a traffic situation. Implementation of alerting is recommended and should be considered by the manufacturer. Though alerting is not required for the surveillance operational applications on which many of the MOPS requirements are based, it is considered beneficial based on initial operational evaluations. This subsection provides requirements and guidance that apply if alerting is implemented. (Also see notes under the section on 2.2.2.1.2 - Traffic Symbol).

Alerting may be implemented in a variety of ways (e.g., aural, visual, tactile). Alerting should be integrated with a spatial presentation of the traffic. For example, with a plan view CDTI format, the specific aircraft involved in generating the alert may be highlighted and the projected point of closest approach may also be highlighted. In

addition, the alerting may also be displayed on a separate section of a CDTI outside of the area dedicated for traffic information.

Note: The requirements in this subsection apply only if the CDTI presents alerts.

1. CDTI alerting should not interfere with other alerting systems.

2. Alerts should be consistent with the flight deck alerting system and philosophy.

3. For those flight decks that utilize an integrated alerting system, the CDTI should be integrated into that system.

4. When alerts are enabled, they **shall[116**] be annunciated without flight crew action.

5. If alerts are disabled by the pilot, the system alert status **shall[117**] indicate that alerts are disabled.

6. CDTI alerts should be consistent with, and capable of being integrated into the flight deck alerting system, giving proper priority to alerts with regard to safety of flight.

7. Non-critical alerts **shall[118**] be inhibited during critical phases of flight (e.g., take-off and landing).

8. Aural alerts **shall[119]** be audible in all expected flight deck ambient noise conditions.

9. Voice alerts **shall[120]** be announced in a high fidelity, distinguishable voice.

10. Symbology or text indicating an alert should be redundantly coded by at least two different coding parameters (e.g., color, size, shape, location).

11. The color of the annunciations should conform to recommendations in SAE ARP 4102/4[4] reference J information (level 0) or advisory (level 1) annunciation, as appropriate

Note: Automatic volume adjustment for ambient conditions is highly recommended. The TCAS MOPS[12] recommends that the volume level of the automatic adjustment provide a range of 0 to 4 watts RMS at 1000 Hz into 8 ohms for a speaker output and the automatic adjustment provide a range of 0 to 40 milliwatts at 1000 Hz into a 600 ohm audio distribution system.

2.2.8 Shared/ Multi- Function Display

Multi-Function Display is a display that is used for a variety of display functions such as presenting navigation, terrain, and traffic information. The data may be presented as a

single, integrated depiction, or the display may be switched from one function to another such that each function is presented alone when it is selected.
The standards below are not an exhaustive or comprehensive list of requirements and guidelines for shared or multi-function displays (MFD). Additional information can be found in ARP 5364[16].

1. If information is integrated with the traffic information on the display, the directional orientation and the range should be consistent among the different information sets.

   Note: For example, heading-up oriented data should not be displayed simultaneously with track-up oriented data. One should be converted prior to display. If an MFD is displaying traffic and weather radar information, the design should not allow the range-scale of the weather data displayed to be different from the range-scale of the traffic data that is simultaneously displayed.

2. Where information on the shared display is inconsistent, the inconsistency **shall[121]** be obvious or annunciated.

3. Symbols should be consistent across all the shared multiple functions.

4. The MFD system should provide the capability to enable and disable display of traffic information.

5. If there are separate range controls for different functions (e.g., weather radar and traffic), one control should affect the range setting for all currently displayed functions.

6. A mechanism should be provided to select the traffic only mode of operation.

   Note: This requirement is intended to prevent the problem with MFDs that weather/terrain display colors interfere with traffic colors (particularly red and yellow) – it is not easy to distinguish the traffic without taking the weather information off the display. The MFD colors should not block out traffic information[16].

2.3 Equipment Performance - Environmental Conditions

Unless otherwise specified, the test procedures applicable to a determination of equipment performance under environmental test conditions are set forth in RTCA Document DO-160D, *Environmental Conditions and Test Procedures for Airborne*

Equipment. General information on the use of RTCA DO-160D is contained in Sections 1.0 through 3.0 of that document.

Table 2-1 indicates the CDTI MOPS requirements that shall be satisfied under the environmental test conditions specified in RTCA DO-160D. A "Y" in the last column of the row associated with the environmental conditions labeled "4.5.1 Low Operating Temperature Test" through "25.0 Electrostatic Discharge" identifies the CDTI requirements that shall be met while the equipment is subjected to those test conditions. An "O" means this test is optional, but shall be conducted if the equipment is expected to encounter such conditions in normal operational use or if the manufacturer wishes to qualify the equipment for these additional environmental conditions. In table 2-1, the columns on "Equipment operating during test?" and "Comments" do not contain requirements and may contain notes and paraphrased information from DO-160D.

The environmental tests specified in Table 2-1 and described in DO-160D 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 aeronautic operations. Not all of the requirements in section 2.2 are required to be tested to the conditions contained in RTCA DO-160D. The primary hardware elements of a CDTI are display hardware, control hardware, processor hardware and interfaces. The manufacturer may write one comprehensive test procedure for demonstrating compliance with this section, that tests the most features and perform that test procedure for all cases in this section when equipment functionality is required to be demonstrated during/after the test. That test procedure shall include display of the own-ship symbol, at least two other traffic symbols positioned at the correct range and bearing from own ship, altitudes for all the traffic (relative or pressure) shown, display brightness control functionality, target selection functionality (if implemented) and at least one function from each control panel implemented (i.e., if there is more than one control panel, they should all be exercised). If switches are implemented separate from control panels, they shall be exercised. If the CDTI is capable of receiving input from more than one source, all the source interfaces shall be exercised. All outputs driving lights/alerts shall also be exercised. The software used during the tests in this subsection may be test software (i.e., it does not have to be production quality software).

Table 2-1. Environmental Tests

DO-160D Section	Equipment operating during test? (Input can be simulated)	Comments	Y = Required Minimum. O = Optional (may be required under some circumstances)
4.5.1 Ground survival Low Temp and Operating Low Temp	Y		Y
4.5.2 Ground survival high temp and short time operating high temp	Y		Y

4.5.3 Operating high temp	Y		Y
4.5.4 In flight loss of cooling	Y		O
4.6.1 Altitude/Pressure	Y		Y
4.6.2 Decompression	Y		O
4.6.3 Overpressure	N		O
5 Temp variation	Y	Can be combined with tests in 4	Y
6. Humidity	N		Y
7.2 Operational Shock	Y	Static testing is sufficient in this case	Y
7.3 Crash safety	N	No need for equipment to function after crash safety test	Y
8.2.1.1 Standard Vibration Test	Y	Must operate during and after test	Y
8.2.1.2 High Level Short Duration Vibration Test	Y	Must operate during and after test	O
8.2.1.3 Robust vibration test	Y	Must operate during and after test	O
9.2 Explosion proof	N (simulated operation)		O
10 Waterproofness (drip, spray, steam)	Y		O
11 Fluid Susceptibility (spray, immersion)	N (but mechanically and electrically connected)		O
12 Sand and Dust	N		O
13 Fungus Resistance	N		O
14 Salt Spray	N		O
15 Magnetic Effect	Y		Y
16 Power Input (several tests)	Y		Y
17 Voltage Spike	Y		Y
18 Audio Freq. Conducted Susceptibility – Power Inputs	Y		Y
19. Induced Signal Susceptibility	Y		Y
20 Radio Frequency Susceptibility (radiated and conducted)	Y		Y
21 Emission of Radio Frequency Energy	Y		Y
22 Lightning Induced Transient Susceptibility	Y		Y

23 Lightning Direct Effects	N		O
24. Icing	Y		O
25 ElectroStatic Discharge	Y		Y

2.4 Equipment Performance Test Procedures

2.4.1 Definition 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 **shall** be conducted with the power input voltage adjusted to design voltage ±2%. The input voltage **shall** 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 power source of essentially constant frequency (e.g., 400 Hz), the input frequency **shall** be adjusted to design frequency ±2%.
2. In the case of equipment designed for operation from an AC power source of variable frequency (e.g., 300 to 1,000 Hz), unless otherwise specified, tests **shall** 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 **shall** 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 the 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 Instrument Precautions – Due precautions **shall** be taken during 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 **shall** be conducted under 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)

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 **shall** be performed with the equipment connected to loads having the impedance values for which it is designed.

h. Warm-up – Unless otherwise specified, all tests shall be conducted after the manufacturers specified warm-up period.

i. Test Methods

1. *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 or performance requirements.

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.

3. *Inspection* – Inspection is the method of verification to determine compliance with specification requirements and consists primarily of visual observations or mechanical measurements of the equipment, physical location, or technical examination of engineering support documentation.

4. *Test* – Test is the method of verification that will measure equipment performance under specific configuration load conditions and after the controlled application of known stimuli. Quantitative values are measured, compared against previous predicated success criteria and then evaluated to determine the degree of compliance.

2.4.2 Required Test Equipment

Figure 2-1 provides a functional diagram of the test setup. The manufacturer is responsible for defining the types of instrumentation to be used to collect any quantitative data required to demonstrate compliance with the requirements.

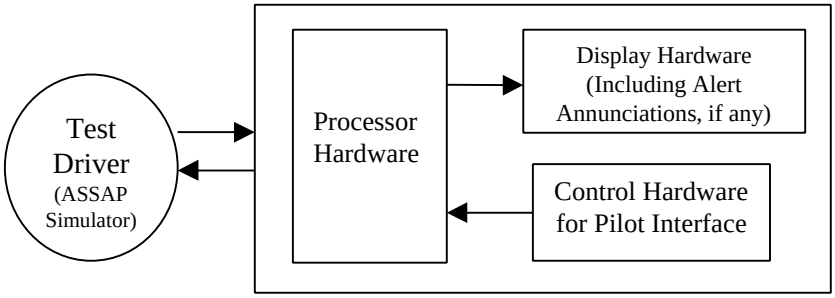


Figure 2-1. Functional Test Setup

2.4.3 Detailed Test Procedures

The test procedures set forth in the following subparagraphs constitute a satisfactory method of verifying the proper implementation of the CDTI requirements. 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.

Table 2-2 provides a matrix for cross-referencing the requirements with the applicable test step/s. It is recognized that not all requirements contained in Section 2.2 will be applicable to each CDTI implementation. The CDTI manufacturer, shall in conjunction with the appropriate certification authority, determine which tests must be performed for any CDTI implementation. In implementations having different pilot selectable display modes, the detailed test procedures that are appropriate for each available mode **shall** be completed.

These tests do not require the presence of an airborne surveillance and separation assurance processing (ASSAP). If an ASSAP is not present, the manufacturer is responsible for defining a set of test drivers which are consistent with the type of interface (i.e., hardware and software protocols) designed into the item under test.

The display drivers and data collection equipment used in these tests should be approved by the appropriate certification authority or a person designated by the certification authority for such approvals (e.g., Designated Engineering Representative or other authorized person), prior to the initiation of these tests. Separate drivers may be used for different display implementations and to complete the testing defined for controls.

The test procedures for the optional CDTI features apply only if a particular feature being tested is implemented. In Table 2-2, "/" is used to denote OR (one of these methods is sufficient to show compliance) and "+" is used to denote AND (all methods are required to show compliance).

TABLE 2-2. Test Cross-Reference Matrix

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
2.1 General Requirements					
1.	2.1.1		I		Installation of the equipment does not impair the airworthiness of the aircraft.
2.	2.1.2		A		Successful completion of all applicable requirements.
3.	2.1.2		A		The proper use of the equipment does not create a hazard to other users of the National Airspace System.
4.	2.1.3		A		Equipment complies with applicable rules of the FCC.
5.	2.1.4		A/I (+D if required)		All materials used, excluding small parts that would not contribute significantly to the propagation of a fire, are self-extinguishing.
6.	2.1.5(1)		D		The equipment does not adversely affect the operation of other equipment.
7.	2.1.6(1)		D		Controls intended for use during flight cannot be operated in any position, combination or sequence that would result in a condition detrimental to the operation of the aircraft or the reliability of the equipment.
8.	2.1.6(2)		I		Controls provide feedback when operated.
9.	2.1.6(4)		I		Controls are operable with one hand.
10.	2.1.6(5)		D		The current function is indicated.
11.	2.1.6(6)		I		Controls that are normally adjusted in flight are readily accessible to the flight crew.
12.	2.1.7(1)		I	1.	Color coded information is used redundantly with another means of coding information.

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
13.	2.1.7(4)		I	42	The selected color set is discriminable under the full range of normally expected ambient light conditions.
14.	2.1.7(10)		D		Red is used only for indicating a hazard that may require immediate corrective action.
15.	2.1.7(11)		D		Amber is used to indicate the possible need for future corrective action.
16.	2.1.8		D		The application of specified test procedures is not detrimental to the equipment performance following the application of these tests.
2.2.1 Inputs to CDTI					
2.2.1.1 Basic Required Inputs					
17.	2.2.1.1(1)		D		An aircraft track identifier is input to the CDTI.
18.	2.2.1.1(2)	2.4.3.1.1(6)	D		The relative pressure altitude of the traffic aircraft in input to the CDTI.
19.	2.2.1.1(3)	2.4.3.1.1(7)	D		The traffic position relative to own-ship is input to the CDTI.
20.	2.2.1.1(4)		D		The status of the traffic sensor and processing is input to the CDTI.
21.	2.2.1.1(5)	2.4.3.1.1(8)	D		The traffic aircraft on-ground or in-air status is input to the CDTI.
22.	2.2.1.1(6)		D		The quality of data for each traffic element is input to the CDTI.
23.	2.2.1.1(7)	2.4.3.1.1(4)	D		The input to the CDTI is updated at least once a second.
2.2.1.2 Optional Required Inputs					
24.	2.2.1.2(1)	2.4.3.2.1(1)	D		The traffic ground speed is input to the CDTI.
25.	2.2.1.2(2)	2.4.3.2.1(2)	D		The traffic ground track angle is input to the

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
					CDTI.
26.	2.2.1.2(3)	2.4.3.2.1(3)	D		The traffic identification of the traffic aircraft is input to the CDTI.
27.	2.2.1.2(4)	2.4.3.2.1(4)	D		The pressure altitude of the traffic aircraft is input to the CDTI.
28.	2.2.1.2(5)	2.4.3.2.1(5)	D		The traffic altitude status of whether it is corrected or not corrected to local barometric correction setting on own-ship is input to the CDTI.
29.	2.2.1.2(6)	2.4.3.2.1(6)	D		The traffic vertical rate is input to the CDTI.
30.	2.2.1.2(7)	2.4.3.2.1(7)	D		The traffic closure rate is input to the CDTI.
31.	2.2.1.2(8)	2.4.3.2.1(8)	D		The traffic aircraft category information is input to the CDTI.
32.	2.2.1.2(9)	2.4.3.2.1(9)	D		The own-ship pressure altitude is input to the CDTI.
33.	2.2.1.2(10)	2.4.3.2.1(10)	D		The ground speed of the own-ship is input to the CDTI.
34.	2.2.1.2(11)	2.4.3.2.1(11)	D		The ground track of own-ship is input to the CDTI.
35.	2.2.1.2(12)	2.4.3.2.1(12)	D		The own-ship heading information is input to the CDTI.
36.	2.2.1.2.(13)	2.4.3.2.1(13)	D		The own-ship navigation reference (mag/true) is input to the CDTI
37.	2.2.1.2(14)	2.4.3.2.1(14)			The mode status is input to the CDTI.
38.	2.2.1.2(15)	2.4.3.2.1(15)			The alert status is input to the CDTI.
2.2.2 Display Features					
39.	2.2.2(1)	2.4.3.1.3(1)	D	48	The traffic positions are displayed relative to the own-ship.
40.	2.2.2(2)	2.4.3.1.1(1)	D	43, 47	The following features are continuously

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
					displayed: • Own-ship symbol • Traffic symbols • Traffic relative bearing • Traffic relative range • Traffic altitude
41.	2.2.2(3)		A+D		All features designated as required are implemented.
42.	2.2.2(4)		A+D		The requirements in the corresponding sub-sections are met for any feature that is implemented.
2.2.2.1 Symbols					
43.	2.2.2.1(3)	2.4.3.3.1(1)	D	13,101	The required symbology is discriminable at a minimum viewing distance of 30 inches under all anticipated lighting conditions.
2.2.2.1.1 Own-Ship Symbol					
44.	2.2.2.1.1(1)	2.4.3.1.2(1)	D	39	The traffic display contains a symbol representing the location of the own-ship.
45.	2.2.2.1.1(2)	2.4.3.1.2(2)	D		The own-ship symbol is directional.
46.	2.2.2.1.1(3)	2.4.3.1.2(3)	D		The own-ship symbol is distinctive from all other symbology.
47.	2.2.2.1.1(4)	2.4.3.4.1(1)	D		The current own-ship symbol orientation is indicated.
2.2.2.1.2 Traffic Symbol					
48.	2.2.2.1.2(1)	2.4.3.1.1(2)	D	39	All 8 simulated traffic symbols are displayed.
49.	2.2.2.1.2(2)	2.4.3.1.3(3)	D	38	Each traffic symbol is positioned at a location representing its relative range and bearing to the own-ship.

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
50.	2.2.2.1.2(4)				7. The traffic symbol **shall not** imply specific directionality (i.e., no sharply pointed target symbols like the chevron are to be used) if the accuracy of the directionality (ground track angle) cannot be determined within 5 degrees.
51.	2.2.2.1.2(5)	2.4.3.1.3(4)	D+T		All traffic symbols are positioned on the display in their appropriate location representing their actual range.
52.	2.2.2.1.2(6)		D+T		The traffic relative range is displayed with a minimum resolution of 3% of the presently active full scale range.
Selected Target Symbol					
53.	2.2.2.1.3	2.4.3.5.1(1)	D		The selected target symbol(s) is distinguishable from other traffic and display information.
2.2.2.2 Information Elements					
2.2.2.2.1 Data Tags					
54.	2.2.2.2.1(1)	2.4.3.1.4(6)	D		The data tag (e.g., aircraft address, altitude) is associated with its traffic symbol.
2.2.2.2.2 Data Blocks					
55.	2.2.2.2.2	2.4.3.5.1(2)	D	52, 55	A means is provided to associate the data block with the traffic symbol.
2.2.2.2.3 Traffic Altitude					
56.	2.2.2.2.3(1)	2.4.3.1.4(1)	D		Altitude values are displayed for airborne traffic.
57.	2.2.2.2.3(2)	2.4.3.1.3(7)	D		The simulated traffic that is located on the ground is indicated as being on the ground.

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
58.	2.2.2.2.3(3)	2.4.3.1.4(2)	D		Altitudes for all simulated traffic are consistent; all altitudes being displayed in either pressure or relative terms.
59.	2.2.2.2.3(4)	2.4.3.1.4(3)	D		The simulated traffic altitudes can be displayed in relative terms.
60.	2.2.2.2.3(5)	2.4.3.1.4(4)	D		The display indicates whether actual or relative altitude is displayed.
61.	2.2.2.2.3(6)	2.4.3.1.3(8)	D		The simulated traffic that is located 9900 feet above the own-ship is indicated on the display as being above the own-ship. The simulated traffic that is located 9900 feet below the own-ship is indicated on the display as being below the own-ship. /Simplify this – tbd/
62.	2.2.2.2.3(7)	2.4.3.1.4(5)	D		The altitude information is not displayed.
63.	2.2.2.2.3(11)	2.4.3.1.3()	D		
64.	2.2.2.2.3(12)	2.4.3.1.3(9)	D		The traffic altitude value is displayed with a minimum resolution of 100 feet
2.2.2.2.3.1 Actual Altitude					
65.	2.2.2.2.3.1(3)		D		
66.	2.2.2.2.3.1(4)		D		
67.	2.2.2.2.3.1(5)		D		The pressure altitude is displayed as a 3-digit number representing hundreds of feet.
2.2.2.2.3.2 Relative Altitude					
68.	2.2.2.2.3.2(1)	2.4.3.1.5(1a)	D		The relative altitude consists of at least two digits indicating the altitude difference in hundreds of feet.
69.	2.2.2.2.3.2(2)	2.4.3.1.5(1b)	D		The altitude value in the data tag of aircraft located above the own-ship is preceded by a "+" sign.

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
70.	2.2.2.2.3.2(3)	2.4.3.1.5(1c)	D		The altitude value in the data tag of aircraft located below the own-ship is preceded by a "-" sign.
71.	2.2.2.2.3.2(4)	2.4.3.1.5(1d)	D		The data tag for traffic that is located at the same altitude as the own-ship is displayed as the digits "00".
2.2.2.2.4 Vertical Rate					
72.	2.2.2.2.4	2.4.3.6.1(1)	D		An indication is provided that the traffic is climbing or descending with a vertical velocity greater than or equal to 500 fpm.
2.2.2.2.5 Traffic Identification					
73.	2.2.2.2.5(1)		D		The traffic identification information is displayed as eight alphanumeric characters.
74.	2.2.2.2.5(2)		D		The traffic identification information is associated with the aircraft symbol.
2.2.2.2.6 Closure Rate					
75.	2.2.2.2.6(1)	2.4.3.2.3(1)	D	76, 77, 78	The closure rate is displayed either graphically or as alphanumeric.
76.	2.2.2.2.6(2)	2.4.3.2.3(2)	D		A positive closure rate is distinguishable from a negative closure rate.
77.	2.2.2.2.6(3)	2.4.3.2.3(3)	D		Closure rate information is distinguishable from other information (e.g., relative altitude).
78.	2.2.2.2.6(4)	2.4.3.2.3(4)	D	Rqmnt 76 **or** 77 must be met if a numerical closure rate is displayed	The closure rate is displayed as knots.
79.	2.2.2.2.6(5)	2.4.3.2.3(5)	T+D		The closure rate is displayed with a minimum resolution of 1 knot.

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
80.	2.2.2.2.6(6)	2.4.3.2.3(6)	D		The selected method of closure rate is displayed to the pilot.
2.2.2.2.7 Ground Speed					
81.	2.2.2.2.7(2)	2.4.3.2.4(1)	D		It is indicated that the ground speed has exceeded the indicator limit.
82.	2.2.2.2.7(3)	2.4.3.2.4(2)	D		The ground speed is distinguishable from other information.
83.	2.2.2.2.7(4)	2.4.3.2.4(3)	D	Rqmnt 82 **or** 83 must be met if a numerical ground speed is displayed.	The ground speed is displayed as knots. The units of the ground speed are displayed
84.	2.2.2.2.7(5)	2.4.3.2.4(4)	D		The ground speed is displayed with a minimum resolution of 1 knot.
2.2.2.2.8 Horizontal Velocity Vector					
85.	2.2.2.2.8(4)	2.4.3.2.5(1)	D		The units of measurement for the horizontal velocity vectors are the same between all displayed traffic and own-ship.
2.2.2.2.9 Display Range					
86.	2.2.2.2.9(1)	2.4.3.8(1)	D		The display is adjustable to 10 nm or less in the direction of own-ship travel as measured from the own-ship position to the edge of the viewable screen.
87.	2.2.2.2.9(2)	2.4.3.8(2)	D		The display is adjustable to a range of 40 nm or greater in the direction of own-ship travel as measured from the own-ship position to the edge of the viewable screen.
88.	2.2.2.2.9(3)	2.4.3.8(3)	D		The selected display range is indicated on the traffic display.
89.	2.2.2.2.9(4)	2.4.3.8(4)	D		The display range is adjustable.

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
90.	2.2.2.2.9(5)	2.4.3.1.8(1)	D		Range rings or other range markings are provided at specified radii from the own-ship symbol.
91.	2.2.2.2.9(7)	2.4.3.1.1(2)	D		The simulated traffic that is located 90 nm from the own-ship is displayed on the display.
2.2.2.2.10 Bearing					
Relative Bearing					
92.	2.2.2.2.10.1(1)	2.4.3.1.3(5)	D+T	48	Each traffic symbol is positioned at a location representing its relative range and bearing to the own-ship.
93.	2.2.2.2.10.1(2.a)		D+T		The traffic relative bearing resolution is equal to or better than 9 degrees at 1/3 distance from own-ship to the edge of the display.
94.	2.2.2.2.10.1(2.b)		D+T		The traffic relative bearing resolution is equal to or better than 3 degrees at the edge of the display from own-ship.
95.	2.2.2.2.10.1(2.c)				
2.2.2.2.10.2 Off Display Selected Target Relative Bearing					
96.	2.2.2.2.10.2(1)	2.4.3.5.1(4)	D+T		The relative bearing to the selected target is indicated.
97.	2.2.2.2.10.2(2)	2.4.3.5.1(5)	D+T		The off display selected target indication meets the resolution requirements from section 2.2.2.2.10.1
2.2.2.3 Number of Traffic Elements					
98.	2.2.2.3	2.4.3.1.1(3)	D		At least 8 traffic symbols are displayed.
2.2.3 Controls					
99.	2.2.3(1)	2.4.3.3.1(2)	I	42	Control is provided to adjust the display brightness.
100.	2.2.3(2)		I		The positions of switches or knobs are readily

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
					discernible.
2.2.3.1 Target Selector					
101.	2.2.3.1	2.4.3.5.1(3)	D		A target can be selected within the currently selected traffic display criteria.
2.2.4 Menu Items and Menu Logic					
102.	2.2.4(7)		I		Options that are not operationally relevant to the pilot are not included in the pilot's menu choices.
2.2.5 Display Functionality					
2.2.5.1 Display Feature Prioritization					
103.	2.2.5.1(1.a)	2.4.3.1.2(4a)	D		The own-ship symbol and the traffic symbol are displayed either in full or in part.
104.	2.2.5.1(1.b)	2.4.3.1.2(4b)	D		An indication of which aircraft is above and which aircraft is below is displayed.
2.2.5.2 Display Orientation					
105.	2.2.5.2	2.4.3.4.1(2)	D		The selected display orientation is indicated.
2.2.5.3 Display Update					
106.	2.2.5.3(1)		T		The display updates the traffic at least once a second.
107.	2.2.5.3(2)		T		tbd
2.2.5.4 De-clutter					
108.	2.2.5.4(1)		D		All optional CDTI information is removed from the display.
109.	2.2.5.4(3)		D	37	Symbology indicating alerts is not removed by the de-clutter function.
Self Test					
110.	2.2.5.5(1)				
2.2.5.6 Status Indication					
111.	2.2.5.6(1)		D		The equipment indicates:

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
					• The absence of power. • Inadequate or invalid surveillance data that would cause unacceptable traffic information display. • Inadequate or invalid own-ship data that would cause unacceptable traffic information display.
112.	2.2.5.6(2)		D		The system is provided at all times, indicating one of the following system states: • Enabled and functioning normally • Off • Failed • Enabled and functioning in an off-normal state • Test
2.2.5.6.1 Mode Indication					
113.	2.2.5.6.1(1)				The present mode is continuously indicated
114.	2.2.5.6.1(2)		D		Automated mode changes are communicated to the flight crew.
2.2.5.7 Quality of Data Indication					
115.	2.2.5.7		D		
2.2.7 Traffic Alerting					
116.	2.2.7(4)		D		Alerts are annunciated without action.
117.	2.2.7(5)		D		There is an indication that alerts have been disabled.
118.	2.2.7(7)	Non-Critical Phase Alert Inhibit	D		
119.	2.2.7(8)				Aural voice alerts are announced in a high fidelity, distinguishable voice that is audible in

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method (A/D/I/T)	Related Requirement (1)	Pass/Fail Criteria
					all expected flight deck ambient noise conditions.
120.	2.2.7(9)		D		Aural voice alerts are announced in a high fidelity, distinguishable voice that is audible in all expected flight deck ambient noise conditions.
2.2.8 Shared/Multi-Function Display					
121.	2.2.8(2)	2.4.3.1.7(1)	A/D		Inconsistent information on the shared display is obvious or annunciated.

Notes:

(1) The 'Related Requirements' column refers to other requirements that are similar in nature and may be able to be verified by similarity to an existing requirement.

2.4.3.1 Test Setup #1 (Basic Required Inputs)

The following information should be simulated for 8 traffic aircraft*. The inputs to the CDTI should have an update rate of at least once a second. The display portion of the own-ship CDTI should be configured to receive and display this simulated data:

- Aircraft track identifier
- Relative pressure altitude (referenced to own-ship) for 7 of the traffic aircraft. Altitude should not be available for one aircraft.
- Relative position (referenced to the own-ship)
- On-ground or in-air status

* unless specified otherwise.

The traffic should be dispersed within a 90 nm range. The traffic should be at various altitudes and bearings with at least one aircraft positioned at each of the following positions:

- One aircraft positioned 9900 feet above the own-ship (if display is capable).
- One aircraft positioned 9900 feet below the own-ship (if display is capable).
- One aircraft on the ground.
- One aircraft positioned 90 nm from the own-ship.
- One aircraft positioned such that its symbol will overlap that of the own-ship.

2.4.3.1.1 Verification - General

Using Test Setup #1 as specified in 2.4.3.1, verify compliance with the following requirements:

1. When traffic display criteria (as defined in section 1.6) are satisfied, the following features **shall** be continuously displayed: [2.2.2(2)]

    a. Own-ship symbol (subsection 2.2.1.1.1)
    b. Traffic symbol (subsection 2.2.1.1.2)
    c. Traffic relative bearing (subsection 2.2.1.2.10)
    d. Traffic relative range (subsection 2.2.1.2.9.1)
    e. Traffic altitude(subsection 2.2.1.2.3)

2. The surveillance display range **shall** be capable of depicting traffic at least 90 nm in any direction from the own-ship. [2.2.2.2.9.3]

3. The CDTI **shall** be capable of displaying at least 8 targets. [2.2.2.3]

4. The input to the CDTI **shall** be updated at least once a second. [2.2.1.1(7)]

5. The CDTI **shall** receive an aircraft track identifier when available. [2.2.1.1(1)]

6. The CDTI **shall** receive the relative pressure altitude of the traffic aircraft with reference to own-ship when available. [2.2.1.1(2)]

7. The CDTI **shall** receive traffic position relative to own-ship when available. [2.2.1.1(3)]

8. The CDTI **shall** receive the traffic on-ground or in-air status (i.e., whether the traffic is on the ground or in the air), when available. [2.2.1.1(5)]

9. The traffic altitude value **shall** be displayed with a minimum resolution of 100 feet or better. [2.2.2.2.3(11)]

2.4.3.1.2 Verification - Own-ship

Using Test Setup #1 as specified in 2.4.3.1, verify compliance with the following requirements:

1. The traffic display **shall** have a symbol representing the location of the own-ship. [2.2.2.1.1(1)]

2. The own-ship symbol **shall** be directional (e.g., not a circle or square). [2.2.2.1.1(2)]

3. The own-ship symbol **shall** be distinctive from all other symbology. [2.2.2.1.1(3)]
4. In case the traffic symbol and the own-ship symbol overlap,
   a. The own-ship symbol as well as the traffic symbol **shall** be displayed (either in full or in part) and
   b. An indication of which aircraft is above and which aircraft is below **shall** be displayed. [2.2.5.1]

2.4.3.1.3 Verification - Traffic

Using Test Setup #1 as specified in 2.4.3.1, verify compliance with the following requirements:

1. The CDTI **shall** display a traffic symbol for each traffic report received from ASSAP that meet the traffic display criteria. [2.2.2(1)]
2. The CDTI **shall** display all known traffic that meet the traffic display criteria. [2.2.2.1.2(1)]
3. The CDTI **shall** position each traffic symbol at a location representing its relative range and bearing with respect to own-ship. [2.2.2.1.2(2)]
4. All traffic symbols **shall** be positioned on the display in their appropriate location representative of their actual range. [2.2.2.2.9.1(1)]

5. The CDTI **shall** position each traffic symbol at a location representing its relative range and bearing with respect to own-ship. [2.2.2.2.10.1(1)]
6. Traffic information must be displayed unambiguously. Where certain types of display data may be confusing, units, and/or captions **shall** be presented. [2.2.9(6)]
7. A capability to select an altitude band within which to display traffic should be provided to the flight crew. The selected altitude band **shall** be continuously displayed, if crew selectable. [2.2.2.2.3(10)]

2.4.3.1.4 Verification - Traffic Elements

Using Test Setup #1 as specified in 2.4.3.1, verify compliance with the following requirements:

1. Altitude values **shall** be provided for airborne traffic. [2.2.2.2.3(1)]
2. Altitudes for traffic simultaneously displayed **shall** be consistent, all altitudes being displayed either in actual or relative terms. [2.2.2.2.3(3)]
3. The CDTI **shall** be capable of displaying relative altitude. [2.2.2.2.3(4)]
4. The display **shall** indicate whether actual or relative altitude is displayed. [2.2.2.2.3(5)]
5. If the traffic altitude is not available, the altitude information **shall not** be displayed. [2.2.2.2.3(7)]
6. The data tag **shall** be associated with its traffic symbol. [2.2.2.2.1(1)]
7. For traffic determined to be on the ground, an indication the traffic is on the ground **shall** be provided. [2.2.2.2.3(2)]
8. In addition to altitude value, the display **shall** indicate whether traffic is above or below own-ship. [2.2.2.2.3(6)]

2.4.3.1.5 Verification - Numeric Readout of Relative Altitude

Relative altitude is calculated using the pressure altitude of the own-ship and traffic referenced to the standard atmospheric pressure.

Using Test Setup #1 as specified in 2.4.3.1, verify compliance with the following requirements:

1. If a numeric readout is used for relative altitude:
   a. The relative altitude **shall** consist of at least two digits indicating the altitude difference in hundreds of feet. [2.2.2.2.3.2(a)]
   b. For traffic above own-ship, the altitude value in the data tag **shall** be preceded by a "+" sign and be placed above the traffic symbol. [2.2.2.2.3.2(b)]

c. For traffic below own-ship, the altitude value in the data tag **shall** be preceded by a "-" sign and be placed below the traffic symbol. [2.2.2.2.3.2(c)]

d. *Note: The "+" or "-" character may be emphasized (e.g., by using a slightly larger character set than that used for digits).*

e. The data tag for co-altitude traffic (traffic at the same altitude as the own-ship) **shall** be displayed as the digits "00". [2.2.2.2.3.2(d)]

2.4.3.1.6 Verification - Multifunction Display

Using Test Setup #1 and/or Test Setup #2 as specified in 2.4.3.1 and 2.4.3.2, respectively, verify compliance with the following requirements:

1. Where information on the shared display is inconsistent, the inconsistency **shall** be obvious or annunciated, and should not contribute errors in information interpretation. [2.2.8(2)]
2. A mechanism **shall** be provided to select the traffic only mode of operation.

2.4.3.1.7 Verification - Display Range Reference

Using Test Setup #1 and/or Test Setup #2 as specified in 2.4.3.1 and 2.4.3.2, respectively, verify compliance with the following requirements:

1. If graphical range references are used, range rings or other range markings at specified radii **shall** be provided from the own-ship symbol. [2.2.2.2.9.2(1)]
2. If traffic information is shown on a shared display that does not provide a range reference, the range reference **shall** be provided when the CDTI information is selected. [2.2.2.2.9.2(2)]

2.4.3.2 Test Setup #2 (Inputs for Optional Features)

In addition to the simulated inputs specified in 2.4.3.1, additional inputs may be required based on the application the CDTI equipment is being designed to support.

For this test section, the manufacturer should perform the same test setup as specified in 2.4.3.1 *Test Setup #1*. In addition to the simulated inputs specified in *Test Setup #1*, the following data should be simulated for each traffic aircraft as required to support the application of the desired application:

1. Ground Speed
2. Ground Track Angle
3. Traffic ID
4. Pressure altitude (referenced to the standard atmospheric pressure)
5. Barometric Altitude Rate
6. Barometric Altitude Status (whether or not is corrected to local barometric correction setting on own-ship)
7. Closure rate
8. Aircraft category information

The CDTI should receive the following inputs from the own-ship:

1. Pressure Altitude (referenced to the standard atmospheric pressure)
2. Barometric Altitude Rate
3. Ground Speed
4. Ground Track
5. Heading information
6. Navigation Reference (magnetic/true)
7. Barometric Altitude Reference ("baro set")
8. The Mode Status
9. Alert Status

Traffic should be dispersed as specified in *Test Setup #1*. In addition, some traffic should be closing on the own-ship while other traffic is moving away from the own-ship.

2.4.3.2.1 Verification - General

1. The CDTI **shall** receive the traffic ground speed when available. [2.2.1.2(1)]

2. The CDTI **shall** receive the traffic ground track angle when available. [2.2.1.2(2)]

3. The CDTI **shall** receive the traffic identification of the traffic when available. [2.2.1.2(3)

4. The CDTI **shall** receive the pressure altitude of the traffic aircraft when available. [2.2.1.2(4)]

5. The CDTI **shall** receive the traffic pressure altitude correction status (corrected or not corrected to own-ship barometric setting) when available. [2.2.1.2(5)]

6. The CDTI **shall** receive the traffic vertical rate when available. [2.2.1.2(6)]

7. The CDTI **shall** receive the traffic closure rate when available. [2.2.1.2(7)]

8. The CDTI **shall** receive the traffic aircraft category when available. [2.2.1.2(8)]

9. The CDTI **shall** receive the own-ship pressure altitude when available. [2.2.1.2(9)]

10. The CDTI **shall** receive the ground speed of own- ship when available. [2.2.1.2(10)]

11. The CDTI **shall** receive the ground track of own-ship when available. [2.2.1.2(11)]

12. The CDTI **shall** receive the own-ship heading information when available. [2.2.1.2(12)]

13. The CDTI **shall** receive the own-ship navigation reference (magnetic/true) when available. [2.2.1.2(13)]

14. The own-ship navigation reference (magnetic/true), if available, **shall** be input to the CDTI.

15. The barometric altitude reference ("baro set") of own-ship, if available, **shall** be input to the CDTI.

16. If the traffic surveillance system is capable of operating in different modes, The CDTI **shall** receive the mode status when available. [2.2.1.2(14)]

17. The CDTI **shall** receive the alert status when available. (This includes all alerts implemented that relate to the display of traffic information, including TIS alerts and TCAS alerts.) [2.2.1.2(15)]

2.4.3.2.2 Verification - Pressure Altitude

Use Test Setup #2 as specified in 2.4.3.2. Adjust the system such that pressure altitude is being displayed and verify compliance with the following requirements:

1. If the pressure altitude is not corrected for the local barometric pressure used by the crew of own-ship, the display of the actual altitude **shall** be limited to a maximum of 30 seconds if the own-ship is below 18,000 feet (transition altitude, if it is available, may be used instead of the 18,000 feet) before it automatically reverts to the relative altitude. [2.2.2.2.3.1(3)]
2. When the display of the actual altitude is selected, an indication that the displayed altitude is actual altitude **shall** be shown on the traffic display. If implemented, the actual altitude **shall** be displayed as a 3-digit number representing hundreds of feet, MSL. For example, 007 represents 700 feet MSL and 250 represents 25,000 feet MSL. [2.2.2.2.3.1(4)]

   Note: Pressure altitude may be positioned above or below the traffic symbol in a manner consistent with the relative altitude.

2.4.3.2.3 Verification - De-clutter

Use Test Setup #2 as specified in section 2.4.3.2. In addition, an alert should be generated. Verify compliance with the following requirements:

1. The capability **shall** be provided for removing all optional CDTI information (e.g., aircraft identification and horizontal velocity vector) from the display. [2.2.5.4(1)]
2. The own-ship symbol, range reference and traffic altitude **shall** remain displayed at all times.
3. Symbology indicating alerts **shall** be protected from removal by the de-clutter function. [2.2.5.4(4)]
4. The declutter function **shall not** remove features listed in Section 2.2.2(2). [2.2.5.4(3)]

2.4.3.2.4 Verification - Traffic Identification

Using Test Setup #2 as specified in section 2.4.3.2, verify compliance with the following requirements:

1. The traffic identification information **shall** be capable of displaying the ICAO standard for aircraft identification that is a maximum of eight alphanumeric characters. [2.2.2.2.5(1)]
2. The traffic identification information **shall** be associated with the aircraft symbol. [2.2.2.2.5(2)]

2.4.3.2.5 Verification - Closure Rate

Using Test Setup #2 as specified in section 2.4.3.2, verify compliance with the following requirements:

1. When closure rate is displayed, it **shall** be displayed either graphically or alphanumerically. [2.2.2.2.6(1)]
2. A positive closure rate (i.e. traffic is getting closer) **shall** be distinguishable from a negative closure rate (i.e. traffic is getting farther away). [2.2.2.2.6(2)]
3. Closure rate information **shall** be distinguishable from other information. [2.2.2.2.6(3)]

   Note: Since the closure rate and relative altitude have positive and negative values they may be confused with each other if provisions are not made to distinguish between them.
4. If a numerical closure rate is displayed it **shall** be displayed as knots or the units **shall** be shown. [2.2.2.2.6(4)]

5. If a numerical closure rate is displayed it **shall** be capable of displaying it with a minimum resolution of 1 knot or equivalent. [2.2.2.2.6(5)]

6. If a horizontal only (2-Dimensional) and a horizontal and vertical (3-Dimensional) display of closure rate is available, the selected method **shall** be displayed to the pilot. [2.2.2.2.6(6)]

2.4.3.2.6 Verification - Ground Speed

Use Test Setup #2 as specified in section 2.4.3.2 with the exception that at least one aircraft should be traveling at a speed greater than the indicator limit. Verify compliance with the following requirements:

1. An indication **shall** be displayed if ground speed exceeds the indicator limit. [2.2.2.2.7(2)]

2. Ground speed **shall** be distinguishable from other information. [2.2.2.2.7(3)]

3. If numerical ground speed is displayed as knots, the unit of measure is not required to be displayed. If alternative units (i.e., anything other than knots) are used, unit of measure **shall** be displayed. [2.2.2.2.7(4)]
4. If numerical ground speed is displayed, it **shall** be displayed with a minimum resolution of 1 knot. [2.2.2.2.7(5)]

2.4.3.2.7 Verification - Horizontal Velocity Vector

Using Test Setup #2 as specified in section 2.4.3.2, verify compliance with the following requirements:

When horizontal velocity vector is displayed, units of measurement **shall** be the same between all displayed traffic and own-ship.[2.2.2.2.8(4)]

2.4.3.3 Test Setup #3 (Lighting)

Perform the same test setup as specified in 2.4.3.1 *Test Setup #1* except that the number of aircraft displayed can be reduced to a number determined appropriate by the manufacturer provided at least one aircraft, in addition to the own-ship, is displayed.

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.

2.4.3.3.1 Verification - General

Verify compliance with the following requirements:

1. Required symbology **shall** be discriminable at a minimum viewing distance of 30 inches under all anticipated lighting conditions. [2.2.2.1(3)]
2. Some mechanism **shall** be provided to control display brightness to enable pilots to use the display in all anticipated flight deck illumination conditions. [2.2.3(1)]

2.4.3.4 Test Setup #4 (Orientation)

Perform the same test setup as specified in 2.4.3.1 *Basic Test Setup* except that the number of aircraft displayed can be reduced to a number determined appropriate by the manufacturer provided at least on aircraft, in addition to the own-ship, is displayed.

Change the directional orientation from heading to each other directional orientation.

2.4.3.4.1 Verification - General

Using Test Setup #4, 2.4.3.4, verify compliance with the following requirements:

1. If the CDTI supports more than one aircraft symbol directional orientation (e.g., heading vs. track), then the current own-ship symbol orientation **shall** be indicated. [2.2.2.1.1(4)]
2. If the pilot has the ability to switch between more than one display orientations (e.g., track up vs. heading up) the selected display orientation **shall** be indicated. [2.2.5.2]

2.4.3.5 Test Setup #5 (Target Selection)

Perform the same test setup as specified in 2.4.3.1 *Basic Test Setup* except that the number of aircraft displayed can be reduced to a number determined appropriate by the manufacturer provided at least one aircraft, in addition to the own-ship, is displayed.

Using a selection device, select one of the aircraft being displayed.

2.4.3.5.1 Verification - General

Using Test Setup #5, 2.4.3.5, verify compliance with the following requirements:

1. The selected target symbol(s) **shall** be distinguishable from other traffic and display information. [2.2.2.1.3]
2. If data blocks are displayed, a means **shall** be provided to associate the data block with the traffic symbol. [2.2.2.2.2]
3. The flight crew **shall** be able to select a target within the currently selected traffic display criteria. [2.2.3.1]

2.4.3.5.2 Verification - Off-Display Selected Target Relative Bearing

Use Test Setup #5, 2.4.3.5. After selecting a traffic symbol, adjust the range such that the aircraft is out of the displayed range. Verify compliance with the following requirements:

1. If the selected target is outside of the currently selected display range, an indicator (e.g., half symbol of the target) **shall** indicate the relative bearing to the selected target. [2.2.2.2.10.2]
2. The relative bearing resolution requirements from section 2.2.2.2.10.1 **shall** apply to the off display selected target relative bearing.

2.4.3.6 Test Setup #6 (Vertical Rate)

Perform the same test setup as specified in 2.4.3.1 *Basic Test Setup* with the following exceptions:

- The number of aircraft can be reduced to a number determined appropriate by the manufacturer.
- One aircraft should be climbing at a vertical velocity greater than or equal to 500 fpm.
- One aircraft should be descending at a vertical velocity greater than or equal to 500 fpm.

2.4.3.6.1 Verification - General

Using Test Setup #6, 2.4.3.6, verify compliance with the following requirements:

A climb or descent with a vertical velocity greater than or equal to 500 fpm, **shall** be indicated (e.g., indicated using a up or down arrow, as appropriate). [2.2.2.2.4]

2.4.3.7 Test Setup #7 (Status)

Perform the same test setup as specified in 2.4.3.1 *Basic Test Setup* with the following exceptions.

1. Do SETUP (a) then verify RESPONSE (a),
2. Remove any previous failure condition before executing next test
3. Repeat for SETUP (b) through (h).

<u>SETUP:</u>

a) Fail TCAS input to CDTI. (simulate through ASSAP – CDTI interface or by disconnecting TCAS LRU bus inputs into CDTI/ASSAP LRU.

b) Set TCAS in “Standby Mode”

c) Set TCAS to “OFF”

d) Remove Traffic Alert/ Resolution Advisory valid input discrete to from display/ASSAP system to the TCAS LRU.

e) Set TCAS system into test mode.

f) Fail ADS-B input to CDTI. (simulate through ASSAP – CDTI interface or by disconnecting ADS-B sensor inputs into CDTI/ASSAP LRU.

g) Fail ASSAP/CDTI input (only if ASSAP and CDTI are in separate LRUs).

h) Fail TCAS and ADS-B sensor inputs into the CDTI.

i) Fail altitude input into the ADS-B sensor. Select an application which requires ADS-B sensor data for display.

j) Set up an application which requires ADS-B sensor data. Execute the application, then fail ADS-B sensor input into the CDTI.

k) Set quality of data for the first 3 intruders to different quality levels.

RESPONSE:

a) TCAS FAIL is displayed on the CDTI.

b) TCAS STBY is displayed on the CDTI

c) TCAS OFF is displayed on the CDTI

d) TCAS FAIL is displayed on the CDTI.

e) TCAS TEST is displayed on the CDTI

f) ADS-B fail annunciation is displayed on the CDTI.

g) ASSAP fail annunciation is displayed on the CDTI

h) Either TCAS FAIL and ADS-B fail annunciations are displayed (if in different locations) or the highest priority failure annunciation is displayed if co-located.

i) Verify the appropriate annunciation indicating the application is not currently available or data required to support application is not of sufficient quality.

j) Verify appropriate application is at first displayed, then when mode is removed the mode change is annunciated as appropriate.

k) Select each target in turn and verify the correct “quality of data” annunciation is correct for the levels set.

2.4.3.7.1 Verification - Status Indication

Using Test Setup #7, 2.4.3.7, verify compliance with the following requirements:

1. The status of the traffic sensors and processing shall be input to the CDTI. (For example, the ADS-B receiver failure, TCAS receiver failure, ASSAP Processing Failure.) [2.2.1.1(4)]
2. The CDTI **shall** receive the quality of data (e.g., actual surveillance performance) for each traffic element when available. [2.2.1.1(6)]
3. The equipment **shall** indicate: [2.2.5.6(1)]
    a. The absence of power.
    b. Inadequate or invalid surveillance data that would cause unacceptable traffic information display.
    c. Inadequate or invalid own-ship data that would cause unacceptable traffic information display.
4. The system status **shall** be provided at all times, indicating one of the following system states: [2.2.5.6(2)]
    a. Enabled and functioning normally
    b. Off (e.g., blank display)
    c. Failed
    d. Enabled and functioning in an off-normal state (e.g., with only partial data available, with reduced accuracy, or with a reduced detection range)
5. The system **shall** be capable of annunciating operating modes and failure conditions.[2.2.5.6.1]
6. If the system has the ability to operate in different modes, the present mode **shall** be continuously indicated. [2.2.5.6.1(1)]
7. All automated mode changes **shall** be communicated to the flight crew. [2.2.5.6.1(2)]
8. The CDTI **shall** be capable of displaying an indication of the quality of data. [2.2.5.7]
9. If any of the minimum data or application dependent data cannot be provided, or cannot be provided with the proposed resolution requirements, the system **shall** indicate the degradation appropriately. [2.2.9(4)]

2.4.3.8 Display Range

Cycle through the full set of selectable ranges and verify compliance with the following:

1. The display **shall** be adjustable to 10 nm or less in the direction of own-ship travel as measured from the own-ship position to the edge of the viewable screen. [2.2.2.2.9(1)]

2. The display **shall** be adjustable to a range of 40 nm or greater in the direction of own-ship travel as measured from the own-ship position to the edge of the viewable screen.[2.2.2.2.9(2)]

3. The selected display range **shall** be indicated on the traffic display. [2.2.2.2.9(3)]

4. The capability **shall** exist to adjust (i.e., increase and decrease) the display range. [2.2.2.2.9(4)]

2.4.3.9 Test Setup #8 (Resolution)

Perform the same test as specified in 2.4.3.1 *Basic Test Setup* with the following exceptions: Test (d) need only be performed if directional symbols are used. The position of the symbol may be verified by absolute position if available from the CDTI display or with a transparent overlay which can be placed over the CDTI display.

SETUP:

a) Set CDTI display range to 40NM

b) Set target #1 at 20 NM, bearing 90 degrees to the left of own-ship, with a ground track angle accuracy of 3 degrees.

c) Select (highlight) target #1 for display.

RESPONSE:

a) Verify target #1 is displayed at a bearing 90 degrees to the left of the own-ship at 20 NM.

b) Verify symbol is positioned on the CDTI display within +/- 9 degrees of absolute position.

Change CDTI display range to 20NM and bearing of target to 0 degrees from own-ship.

c) Verify symbol is displayed at edge of display +/- 0.6 NM.

d) Verify it is positioned on the CDTI display within +/- 3 degrees of absolute position.

Change CDTI display range to 80NM

e) Verify symbol is displayed at 20 +/- 2.4 NM on the display

Change CDTI display range to 40NM and set target ground track angle to an accuracy of 5.1 degrees.

f) Verify target symbol is not displayed as a directional symbol.

2.4.3.9.1 General

Using Test Setup #8 as specified in 2.4.3.9, verify compliance with the following requirements:

The traffic symbol **shall not** imply specific directionality (i.e., no sharply pointed target symbols like the chevron are to be used) if the accuracy of the directionality (ground track angle) cannot be determined within 5 degrees. [2.2.2.1.2(4)]

2.4.3.10 Menu Items and Menu Logic

Navigate through the menu items and verify compliance with the following requirements:

An option that is not operationally relevant to the pilot (e.g., a maintenance function) **shall** not be included in the pilot's menu choices. [2.2.4(7)]

2.4.3.11 Self Test

The manufacturer shall provide a test plan to verify that the self-test function operates as specified in subparagraph 2.2.5.5. Procedures for self-test verification may, whenever appropriate, use the results of tests performed under subparagraph 2.4.3.7.1.

2.4.3.12 Test Setup #9 (Traffic Alerting)

Perform the same test setup as specified in 2.4.3.1 *Basic Test Setup* with the following exceptions:

- The traffic should be distributed such that alerts will be generated. The number of alerts should be sufficient to test each type of alert that has been implemented in the system (e.g., aural, visual, tactile)

The test should be setup such that critical phases of flight (e.g., take-off and landing) can be simulated.

2.4.3.12 Verification – Traffic Alerting

Using Test Setup #9 as specified in 2.4.3.12, verify compliance with the following requirements:

1. When alerts are enabled, they **shall** be annunciated without flight crew action. [2.2.7(4)]

2. Non-critical alerts **shall** be inhibited during critical phases of flight (e.g., take-off and landing) [2.2.7(7)]

3. Voice alerts **shall** be announced in a high fidelity, distinguishable voice. [2.2.7(9)]

   Disable the alerts and verify the following:

4. When alerts are disabled by the pilot, the system alert status **shall** indicate that alerts are disabled. [2.2.7(5)]

3.0 Installed Equipment Performance

This section states 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 verified through bench and environmental tests. However, certain requirements may be affected by the physical installation (e.g., antenna patterns, receiver sensitivity, etc.) and can only be verified after installation. The installed performance limits stated below take into consideration these situations.

3.1 Equipment Installation

The installed equipment must meet the performance requirements stated in section 2 as well as the performance stated in this section.

3.1.1 Accessibility

1. Controls and displays provided for in-flight operation **shall[122**] be readily accessible from the pilot's normal seated position.

2. If two pilots are required to operate the aircraft, the controls **shall[123]** be readily accessible from each pilot’s seated position.

3.1.2 Aircraft Environment

Equipment **shall[124]** 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 appropriate flight crew member(s) **shall[125]** have an unobstructed view of displayed data when in the seated position.

2. The brilliance of any display **shall[126]** be adjustable to levels suitable for data interpretation under all cockpit ambient light conditions ranging from total darkness to reflected sunlight.

3. Text size and font **shall[127]** be legible for appropriate flight crew members when in the seated position.

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

3.1.4 Dynamic Response

Operation of the equipment **shall[128**]not be adversely affected by aircraft maneuvering or changes in attitude encountered in normal flight operations.

3.1.5 Failure Protection

Any probable failure of the equipment **shall not[129**] degrade the normal operation of equipment or systems connected to it. Likewise, the failure of interfaced equipment or systems **shall not**[**130**] degrade normal operation of this equipment.

3.1.6 Interference Effects

This equipment **shall not[131]** be the source of harmful conducted or radiated interference nor be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

Note: Interference 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 resolving any incompatibility between this equipment and previously installed equipment in the aircraft.

3.1.7 Inadvertent Turnoff

Appropriate protection **shall[132]** be provided to avert the inadvertent turnoff of the equipment.

3.1.8 Aircraft Power Source

The voltage and voltage tolerance characteristics of the equipment **shall[133]** be compatible with the aircraft power source of appropriate category as specified in RTCA/DO-160D[14].

3.2 Installed Equipment Performance Requirements

The installed equipment **shall[134]** meet the requirements specified in Section 2.2 as well as the requirements specified in this section.

3.2.1 Visual Display Indication

If a message intended for visual display is greater than the available display area and only part of the message is displayed, a visual indication which does not require a pilot action to view **shall[135**] be provided to the pilot which indicates the presence of additional message information.

3.3 Conditions of Test

The following subparagraphs define conditions under which tests, specified in paragraph 3.4, **shall[136]** be conducted.

3.3.1 Safety Precautions

Personnel and/or equipment safety precautions due to any unique characteristics of the equipment or installation **shall[137]** be observed.

3.3.2 Power Input

Unless otherwise specified, tests **shall[138]** be conducted with the equipment powered by the aircraft's electrical power generating system.

3.3.3 Associated Equipment or Systems

Unless otherwise specified, all aircraft electrically operated equipment and systems **shall[139**] be turned on before conducting interference tests.

3.3.4 Environment

During tests, the equipment **shall not[140]** be subjected to environmental conditions that exceed those specified by the equipment manufacturer.

3.3.5 Adjustment of Equipment

Circuits of the equipment under test **shall[141]** be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests.

3.3.6 Warm-up Period

Unless otherwise specified, tests **shall[142**] 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 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 shall be tested to demonstrate compliance with the minimum requirements stated in Subsection 2.2. In order to meet this requirement, test results supplied by the equipment manufacturer or other proof of conformity may be accepted in lieu of bench tests performed by the installing activity.

Table 3-1 indicates the correspondence between the operational requirements in section 3.1 and 3.2 and the tests in this section.

Table 3-1. Operational Requirements and Corresponding Test Matrix

Shall Number	Requirement Paragraph	Test Section/Paragraph	Test Method	Related Requirement	Pass/Fail Criteria
	3.1.1(1)	3.4.1.2, 3.4.2.1	Demonstration		All controls are accessible and all displays are visible
	3.1.1(2)	3.4.1.2, 3.4.2.1	Demonstration		All controls are accessible and all displays are visible from each pilot position
	3.1.2	2.3, 3.4.1.1	Analysis, Conformity inspection (Demonstration)		Environment conforms to Qualification criteria, Acceptable workmanship and engineering practices used
	3.1.3(1)	3.4.1.5, 3.4.2.1	Demonstration		Display is visible to (all) crew member positions
	3.1.3(2)	3.4.1.5, 3.4.2.1	Demonstration		Display is adjustable and readable
	3.1.3(3)	3.4.1.5, 3.4.2.1	Demonstration		Text of different font sizes is visible.
	3.1.4	2.3, 3.4.2.1	Analysis/Demonstration		Passes appropriate Environmental testing in section 2.3 (Table 2-1) (4.6.1, 7.2, 8.2.1.1, 15 to 22 and 25)
	3.1.5	3.4.1.1	Analysis (Demonstrate if required)		Probable failures of equipment does not affect interfacing equipment and vice versa.
	3.1.6	3.4.1.3, 3.4.2.2	Demonstrate		No operationally significant interference detected.
	3.1.7		Inspection		Equipment can not be turned off inadvertently
	3.1.8	2.3	Analysis		Passes appropriate Environmental testing in section 2.3 (Table 2-1) (16)

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 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 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.

3.4.1.3 Interference Effects

With the equipment energized, individually operate each of the other electrically operated aircraft equipment and systems to determine that significant conducted or radiated interference does not exist. Evaluate all reasonable combinations of control settings and operating modes. Operate communication and navigation equipment on the low, high and at least one but preferable four mid-band frequencies. Make note of systems or modes of operation that should also be evaluated during flight. If appropriate, repeat tests using emergency power with the aircraft's batteries alone and the inverters operating.

3.4.1.4 Power Supply Fluctuations

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

3.4.1.5 Equipment Accessibility

Determine that all equipment used during flight is readily accessible.

3.4.2 Flight Test Procedures

Although not required, a flight demonstration or simulator testing should be conducted to verify satisfactory operation of the installed equipment. The test should be structured to demonstrate that all available functions of the installed equipment operate as intended.

3.4.2.1 Displayed Data Readability

Determine that normal conditions of flight do not significantly affect the readability of displayed data.

3.4.2.2 Interference Effects

For aircraft equipment and systems checked only in flight, determine that operationally significant conducted or radiated interference does not exist. Evaluate all reasonable combinations of control settings and operating modes. Operate communications and navigation equipment on the low, high and at least one but preferably four mid-band frequencies.

Appendix A

Acronyms Used in this Document

AC	Advisory Circular
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance-Broadcast
AIP	Aviation Information Publications
ARP	Aerospace Recommended Practices
ASSAP	Airborne Surveillance and Separation Assurance Processing
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
CDTI	Cockpit Display of Traffic Information
CFR	Code of Federal Regulations
CNS	Communications, Navigation and Surveillance
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
fpm	Feet Per Minute
HF	High Frequency
Hz	Hertz
ICAO	International Civil Aviation Organization
LRU	Line Replaceable Unit
MASPS	Minimum Aviation System Performance Standards
MFD	Multi-Function Display
MOPS	Minimum Operational Performance Standards
MSL	Mean Sea Level
NAS	United States National Airspace System
nm, nmi	Nautical Mile
RF	Radio Frequency
RMS	Root Mean Square

SAE	Society of Automotive Engineers
TCAS	Traffic Alert and Collision Avoidance System
TIS	Traffic Information Service
TIS-B	Traffic Information Service-Broadcast
TSO	Technical Standards Order

Appendix B

Definition of Terms

Actual altitude. Displayed altitude for traffic (when the actual altitude mode is selected) that is corrected for the local barometric pressure setting of the own-ship. Actual altitude may be uncorrected (i.e., pressure altitude) if the local barometric pressure setting of the own-ship is unavailable.

Advisory. An annunciation that is generated when crew awareness is required and subsequent crew action may be required; the associated color is unique but not red or amber/yellow. (Source: Advisory Circular AC 25 – 11[18]).

Applications. Specific use of systems that address particular user requirements. For the case of CDTI, applications are defined in terms of specific operational scenarios.

Barometric Altitude. Geopotential altitude in the earth's atmosphere above mean standard sea level pressure datum surface, measured by a pressure (barometric) altimeter (i.e., indicated altitude with the altimeter set to local station pressure (QNH)).

Actual Surveillance Performance. The current achieved level of surveillance performance, as determined by real time processing based on inputs received.

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. (AIM)

Directionality. Directionality is based on the ground track angle, not necessarily the heading of the aircraft.

Display Accuracy. A measure of the difference in units of display addressability, between the displayed position and the source reported position (assumed as the true position).

Display Addressability. The ability to control and direct illumination of lowest addressable point of display versus illumination of adjacent lowest addressable point on the display.

Note: This is usually a pixel, however, some displays allow for addressability finer than at the pixel level, which then affects how anti-aliasing algorithms work that can partially light pixels. Among other things, this can give the illusion of a smooth diagonal line, as opposed to a ratchety, staircase line when the line being drawn is stepping against the grid of pixels.)

Display Resolution. Ability to distinguish between two points on the display, fine enough to distinguish that 2 points are adjacent to each other.

En Route. A phase of navigation covering operations between departure and termination phases. En route phase of navigation has two subcategories: en route domestic/continental and en route oceanic.

Flight Deck. Cabin containing one or more pilots. In smaller aircraft, this phrase denotes the (area of the aircraft with) instruments and controls with which the pilot interacts.

Heading. The orientation of the aircraft's longitudinal fixed axis in the horizontal plane, with respect to magnetic or true north.

Horizontal Velocity Vector. A vector depicting the actual flight path of an aircraft over the surface of the earth.

In-Trail Climb. In-trail climb procedures enables trailing aircraft to climb to a preferred altitude .

In-Trail Descent. In-trail descent procedures enables trailing aircraft to descend to a preferred altitude .

Own-ship. The reference aircraft on which this equipment is installed.

Pressure Altitude. The altitude above Mean Sea Level (MSL) of an aircraft referenced to standard atmospheric pressure (i.e., 29.92 inches of mercury or equivalent).

Reliability. The probability of performing a specified function without failure under given conditions for a specified period of time.

Relative Altitude. The altitude of other traffic with respect to own-ship.

Required Surveillance Performance. Requirements on surveillance data, including integrity, accuracy, continuity, and availability, which support required separation assurance processing performance.

Resolution. The smallest increment reported on the display.

Selected Target. Traffic that has become distinguishable (e.g., by being highlighted) as a result of being selected.

Target. Traffic of particular interest to the crew.

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 (AIM).

Track Angle. Angle measured from either true or magnetic north to the aircraft's track.

Traffic Element. An aircraft or a surface vehicle.

Warning. An annunciation that is generated when immediate recognition and corrective or compensatory action is required; the associated color is red. (Source: Advisory Circular AC25 - 11)

Appendix C

Bibliography and References

The documents listed in Section C.1 are referenced in this MOPS. The documents listed in Section C.2 are from SAE ARP and are referenced for general guidance. The documents listed in section C.3 are associated FAA documents. A bibliography of literature relevant to this document is presented in Section C.4.

C.1. References

[1] RTCA, Applications Descriptions for Initial Cockpit Display of Traffic Information (CDTI) Applications, DO-259, Washington, DC.

[2] RTCA, *Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B)*, DO-242, Washington, DC, February 1998.

[3] RTCA, *Software Considerations in Airborne Systems and Equipment Certification*, DO-178B, Washington, DC, December 1992.

[4] SAE ARP 4102/4, *Flight Deck Alerting System.*

[5] SAE ARP 1874, *Design Objectives for CRT Displays for Part 25 (Transport) Aircraft.*

[6] AS 8034, *Minimum Performance Standard for Airborne Multipurpose Electronic Displays.*

[7] SAE ARP 4032, *Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays.*

[8] SAE ARP 4102/7, *Electronic Displays, Appendix A – Electronic Display Symbology for EADI/PFD; Appendix B – Electronic Display Symbology for EHSI/ND; Appendix C – Electronic Display Symbology for Engine Displays*.

[9] SAE ARP 4102, *Core Document, Flight Deck Panels, Controls and Displays.*

[10] SAE ARP 1093, *Guidance on Legibility of Text. Numeral, Letter, and Symbol Dimensions for Aircraft Instrument Display.*

[11] RTCA, *Minimum Operational Performance Standards for Traffic Information Service (TIS) Data Link Communications*, DO-239, Washington DC, April 1997.

[12] RTCA, *Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II (TCAS II) Airborne Equipment*, DO-185A, Washington DC, 1997.

[13] RTCA, *Guidance for Initial Implementation of Cockpit Display of Traffic Information*, DO-243, Washington, DC, February 1998.

[14] RTCA, *Environmental Conditions and Test Procedures for Airborne Equipment, DO-160D*, Washington DC, July 1997.

[15] *RTCA, Minimum Operational Performance Standards for Airborne Surveillance and Separation Assurance (ASSAP)*, Draft, 2000.

[16] *SAE ARP 5364, Human Factors Criteria For The Design Of Multifunction Display For Civil Aircraft.*

[17] *DOT/FAA /AR-99/52. Guidelines for the Use of Color in ATC Displays (Cardosi and Hannon, 1999). Cambridge, MA. VOLPE National Transportation Systems Center.*

[18] FAA AC 25-11 Transport Category Airplane Electronic Display Systems

[19] FAA AC23.1311 Installation of Electronic Display Instrument Systems In Part 23 Airplanes

[20] 14 CFR 25.1322

[21] 14 CFR 23.1322

C.2 Applicable SAE Documents

AS264	Instrument and Cockpit lighting for Commercial Transport Aircraft
SAE ARP268	Location and Actuation of Flight Deck Controls for Transport Aircraft
AS425C	Nomenclature and Abbreviations for Use on the Flight Deck
SAE ARP571	Flight Deck Controls and Displays for Communication and Navigation Equipment for Transport Aircraft
SAE ARP1068	Flight Deck Instrumentation, Display Criteria and Associated Controls for Transport Aircraft
SAE ARP1161	Crew Station Lighting Commercial Aircraft
SAE ARP1782	Photometric and Colorimetric Measurement Procedures for Direct View CRT Displays
SAE ARP4033	Pilot System Integration
SAE ARP4101	Core Document, Flight Deck Layout and Facilities

SAE ARP4101/2	Pilot Visibility from the Flight Deck
SAE ARP4105	Abbreviations and Acronyms for Use on the Flight Deck
SAE ARP4107	Aerospace Glossary for Human Factors Engineers
SAE ARP4153	Human Interface Criteria for Collision Avoidance Systems in Transport Aircraft
SAE ARP4256	Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft
SAE ARP4260	Photometric and Colorimetric Measurement Procedures for Airborne Direct View Flat Panel Displays (when approved)

C.3 FAA Publications

FAARD8138II	Aircraft Alerting System Standardization Study: Volume II Aircraft Alerting System Design Guidelines (Berson, et. al.,1981)
DOT/FAA/PS89/1	Flight Status Monitor Design Guidelines (Anderson, et. al. 1989)
FAA AC23.13091A	Equipment, Systems, and Installations in Part 23 Airplane
FAA AC25.13091A	System Design Analysis
FAR Part 23	Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes
FAR Part 25/	Airworthiness Standards: Transport Category Airplanes
FAR Part 27	Airworthiness Standards: Transport Category Rotorcraft
TSO-C113	Airborne Multipurpose Electronic Displays

C.4 Bibliography

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Appendix D

Summary Characteristics of Surveillance Sources

D.1 ADS-B

Automatic Dependent Surveillance-Broadcast (ADS-B) is a function on an aircraft or surface vehicle that periodically broadcasts position, altitude, velocity vector and other information for use by other aircraft, vehicles, or by ground facilities. See ADS-B MASPS[1] for additional information.

D.2 Traffic Information Service

Traffic Information Service (TIS) is a Mode S data link[2] service through which ground based radar surveillance information is sent to an airborne cockpit display. The TIS data link function provides automatic display to the pilot of nearby traffic and warnings of potentially threatening conditions. Transponder equipped aircraft within five nautical miles and 1200 feet altitude are uplinked. TIS generates alerts for any aircraft in Mode S coverage that carry a transponder (ATCRBS or Mode S). TIS provides relative range, altitude, and bearing of proximate aircraft that can be displayed to the pilot. It also provides trend information (climb or descent rate greater than a threshold amount) and traffic advisories similar to those of TCAS I.

The TIS service is available to Mode S equipped aircraft in Mode S surveillance coverage. The TIS software within a Mode S sensor provides the user with information on up to eight other transponder equipped aircraft in proximity. Sensor algorithms also provide the threat advisories and altitude trend information. The TIS uplink data is detailed in the TIS MOPS[2].

D.3 TIS-Broadcast (TIS-B)

Traffic Information Service-Broadcast (TIS-B) is a service in which the positions of all aircraft within a broad coverage area are broadcast to users. Each user, having knowledge of its own position, could calculate the relative position of traffic. During the transition to ADS-B, TIS-B would provide traffic information derived from ground sensors.

D.4 TCAS

TCAS is a collision avoidance system that uses a transmitter/receiver to interrogate nearby aircraft transponders. TCAS determines traffic range very accurately from the time to reply to the interrogation. TCAS roughly determines the relative bearing of the traffic with a directional antenna system. TCAS uses the altitude fields of transponder replies, if present, to determine traffic altitude.

There are two basic systems with varying capabilities. The TCAS I system was designed as a lower cost system for use on commuter and GA aircraft. It provides a traffic display to aid in visual acquisition of traffic and assist in differentiation of the traffic's threat level and enhance the pilot's situation awareness regarding nearby traffic. A minimum TCAS I tracks aircraft within a range of about 5 miles. Some systems have a much greater range. All systems may be subjected to interference limiting, which can reduce the operating range. The pilot is alerted to traffic posing a collision threat through a traffic advisory.

The TCAS II system[3] was designed for collision avoidance, and is more capable than the TCAS I system. TCAS II has a range of about 20 miles, as well as a higher bearing accuracy. As with TCAS I, some systems have a greater range, and all are subject to interference limiting, which can reduce the operating range. TCAS II also provides a traffic display. TCAS II not only alerts the pilot to traffic posing a collision threat, but also calculates a vertical avoidance maneuver to avoid a potential collision, coordinates this maneuver with the traffic's TCAS II (if so equipped), and issues resolution advisories to the pilot.

D.5 Differences Among Surveillance Sources

Each of the surveillance sources discussed above has different operating characteristics. These differences are summarized in Table D1 below. In addition, the following differences are worth noting:

- TCAS position errors are different from ADS-B errors, particularly in relative bearing. TIS errors are also different from ADS-B errors. TIS errors may be particularly noticeable in azimuth, especially inside of 2 nmi range from the client aircraft. TCAS range is very accurate

- The range for detection and display of ADS-B traffic may be greater than that for TCAS traffic. At ranges where ADS-B traffic are detected without TCAS reinforcement, only ADS-B equipped traffic will be displayed (i.e., if the equipage rate is low, there is less confidence that all existing traffic will be displayed). TIS provides proximate traffic information within 5 nmi of subject aircraft. Depending on the maximum display range, the pilot may be able to select ranges larger than the nominal TIS range. However, no TIS proximate traffic information will be provided beyond 5 nmi

- TIS is only available when the client and traffic are within coverage of a TIS equipped Mode S sensor, whereas ADS-B and TCAS data can be provided independent of radar coverage.

Coverage from Mode S sensors may become unreliable at low altitudes (e.g., pattern altitudes), where ADS-B coverage remains reliable

- ADS-B can only detect cooperating traffic. Until a large proportion of aircraft are ADS-B equipped, many aircraft will remain undetected by ADS-B alone

- ADS-B can support detection at low altitudes and on the airport surface, where TCAS functionality is diminished or disabled

- TCAS can only detect cooperating traffic. TCAS can detect most transponder equipped aircraft.

Table D-1. Comparison of Information from Different Surveillance Sources

Parameter	ADS-B	TCAS	TIS	TIS-B
Aircraft position	– latitude – longitude – altitude	– relative range – altitude – bearing	– relative range – relative altitude bearing	tbd (8)
Nominal range (nmi)	10 120 (1)	14 30	5 (3)	tbd (8)
Nominal received update period (sec.)	3, 1.5 for surface and simultaneous approach (2)	1 5	4 12 (4)	tbd (8)
Aircraft equipment required	ADS-B transmitter	Mode A/C or mode S transponder	Mode A/C or mode S transponder	tbd (8)
Additional aircraft information	– aircraft ID – aircraft category – address (6) – class code (5) – velocity – acceleration (on surface) – position and velocity uncertainty – emergency status – intent	– TCAS internally assigned aircraft ID (7) – aircraft mode S address – vertical rate – traffic advisory or threat status	– vertical rate indication (climbing or descending) – traffic advisory status –	tbd (8)

Notes.

1. The minimum range for the least capable ADS-B system is 10 nmi; a range of 50-100 nmi is expected for most ADS-B systems. See ADS-B MASPS Table 3.31(a).
2. The transmission rate of an ADS-B system may be higher to guarantee a high certainty of reception within the nominal rates. See ADS-B MASPS.
3. TIS provides traffic information and traffic alerts for traffic within 5 nmi and 1200 ft. For traffic outside this range, only a traffic alerting capability is provided. The TIS message indicates range up to 7 nmi and can indicate if the traffic is beyond 7 nmi.
4. The TIS update period is dependent on the scan rate of the Mode S sensor operating the service.

The ADS-B Mode Status report includes a class code that indicates the capability of the participant to support specific application categories. See ADS-B MASPS, paragraph 3.4.3.2.

5. For details on address information, refer to the ADS-B MASPS, paragraph 2.1.2.1.2.
6. TCAS tracks individual aircraft and maintains an internal aircraft ID, called a surveillance number. This ID could be used by the data fusion function to correlate traffic reports. However, see the TCAS MOPS for limitations due to possible track drops.
7. TIS-B tbds will be resolved by SC-186, WG-2.

D.5 References

[1] RTCA, *Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B)*, DO242, Washington, DC, February 1998.

[2] RTCA, Minimum Operational Performance Standards for Traffic Information Service (TIS) Data Link Communications, DO239, Washington DC, April 1997.

[3] RTCA, *Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II (TCAS II) Airborne Equipment*, DO185A, Washington DC, 1997.

Appendix E

CDTI Features for Surveillance Applications

The table below is consistent with the Operational Concepts for CDTI Initial Applications[1]. The requirements that relate the surveillance applications to the control or display element requirements are shown in Table E-1.

Table E-1. CDTI Features for Surveillance Applications

CDTI Features		**Surveillance Application** (DO-242[2] Reference Number)			
		Enhanced Visual Acquisition (D.1.19 & D.1.15)	Enhanced Visual Approach (D.1.10)	In Trail (or lead) Climb/Descent in Non-Radar Airspace (Oceanic, En Route, and Remote) (D.1.1)	In Trail (or lead) Climb/Descent to Co-Altitude in Non-Radar Airspace (Oceanic, En Route, and Remote) (Derived from D.1.1 & D.1.2)
Symbols (Sec 2.2.2.1)	Own-Ship	R	R	R	R
	Traffic	R	R	R	R
	Selected Target		R	R	R
Traffic Information Elements (Sec 2.2.2.2)	Altitude	R	R (Note 3)	R	R
	Vertical Rate				
	Identification		R	R	R
	Selected Target Closure Rate		R (Note 1)	R (Note 1)	R (Note 1)
	Selected Target Ground Speed		R (Note 1)	R (Note 1)	R (Note 1)
	Horizontal Velocity Vector		R		
	Traffic Relative Range	R	R	R	R
	Display Range Reference		R	R	R
	Extended Display Range				R (Note 2)
	Relative Bearing	R	R	R	R
	Traffic Category				
	Off-Display Selected Target Relative Bearing				
Controls (Sec 2.2.3)	Target Selector		R	R	R

Notes:

R = Required

1 Either closure rate or ground speed, but not both, are required for the selected target.

2 At least 90 nm range is required.

3 When Available

E. 1 References

[1] RTCA, Operations Concept for CDTI Applications, DRAFT, SC-186.

[2] RTCA, Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B), DO-242, Washington, DC, February 1998.

Appendix F

Commentary on Display Resolution, Addressability and Accuracy

The ability of the flight crew to correctly perceive, discern and interpret the presentation of traffic and its related components is dependent on many factors. The color, size, and spacing of information directly affect how well the crew can utilize the information. By providing display controls, such as range adjustment and declutter mechanisms, the crew can improve the visual presentation of the information on the display.
SAE ARP 4102/7 suggests that figures and letters should subtend not less than the following vertical angles at the design eye position (DEP) of the pilot who normally uses the instrument:

- Primary Data 6 milliradians
- Nonessential and Secondary data 4 milliradians
- Minor descriptive legends 3 milliradians

Since resolution requires the ability to distinguish between objects, the placement of graphical data is based on the engineering judgement that 1.5 milliradians of space is required between two objects to differentiate between them. (At design eye position of 42" this would equate to about 0.06" of space between two objects)

It is this engineering judgement, with the factoring in of the display accuracy (see definition below) that was used to provide guidance on the minimum resolution needs for graphical values, found in the corresponding requirements sections.

Display Resolution: Ability to distinguish between two points on the display, fine enough to distinguish that 2 points are adjacent to each other and not co-located.

The mathematical definition of a point is a location that takes up no space. A display will approximate a point by "covering" a larger area both in physical display space and in the geographical area that the display is representing. Therefore, at different display ranges, different display resolution capabilities will exist. For example, if 100 miles distance is covered on a display over 100 pixels, two points that are within 0.2 miles of each other will have a high probability of addressing to the same pixel to represent their location.

Display Addressability: The ability to control and direct illumination of lowest addressable point of display versus illumination of adjacent lowest addressable points on the display.

If a display has control to the pixel level, then the display can do no better than lighting the correct pixel to convey information to the user. Some displays have sub-pixel addressability, which is then used to provide anti-aliasing to smooth diagonal lines by using partial pixel

illumination techniques. In these displays, the display addressability is considered to be at a lower than pixel to pixel addressability. Another way of thinking about this is to overlay a detailed matrix of points over each physical pixel.

Display Accuracy: a measure of the difference between the displayed position and the source reported position (assumed to be the true position).

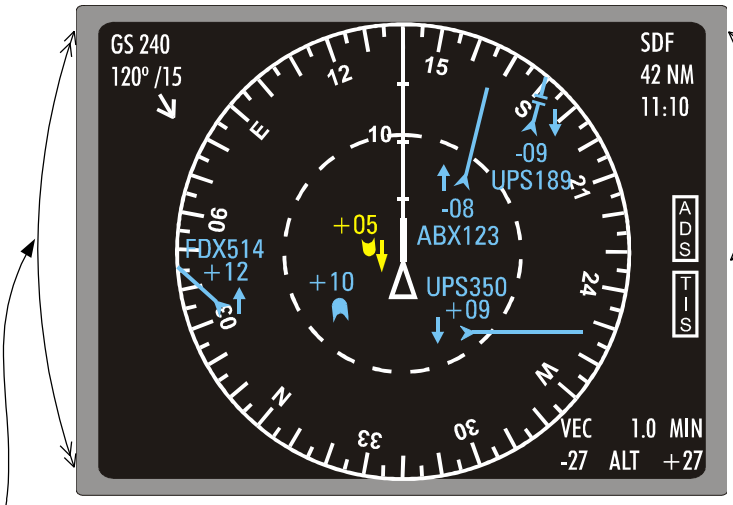
Display accuracy should meet the following rule: The centroid of the symbol should be placed on the correct addressable element. Assuming the addressable element is a pixel, this would imply it would be placed on the correct pixel or on an adjacent pixel.

The following table gives a picture of this:

Z	Z	Z	Z	Z
Z	Y	Y	Y	Z
Z	Y	X	Y	Z
Z	Y	Y	Y	Z
Z	Z	Z	Z	Z

X – correct pixel on which ideally the symbol centroid should map to given infinite calculation and precision in defining where the pixel mapping of the symbol centroid should be placed.
Y – Within 1 pixel adjacent to the “X” pixel. This is an acceptable placement of the symbol centroid.
Z – 2 or more pixels distant from the “X” pixel. This is an unacceptable placement for the symbol centroid.

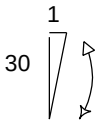
Using a representative example CDTI display with the following characteristics:



Distance from Ownship reference point to top of display region, approximately 1.5", or 100 pixels.

Total vertical heigth of display = 3", 200 pixels

A target at 1/3 distance from ownship, will be approximately 30 pixels distance.



The minimum display resolution in degrees bearing from own ship, can be measured as the arctangent of the x/y where x is the minimum offset (1 pixel) and y is the distance in pixels from ownship. Therefore, the arctan(1/30) = 1.9 deg. Allowing for pixel placement given display accuracy rules, adds a pixel on either side for placement error, or approximately 6 deg. The resulting 9 degrees for traffic relative bearing provides a buffer for minimum capability display.

Appendix G

Guidance for the Use of Color

G.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 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.

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

G-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 (Table G-1):

Table G-1. Color Conventions

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, AC 25-11, and AC 23.1311.

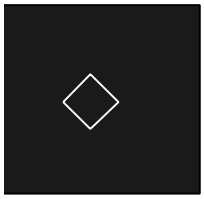
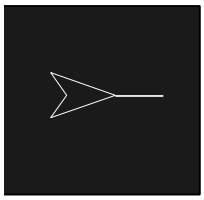
Appendix H

Example CDTI Elements

Table H-1 provides samples of CDTI symbols. The table is provided for information only and is not intended to imply requirements.

Table H-1. Example of CDTI Symbols

Symbol		Description
OWN-SHIP		Example of the Own-ship Being Depicted by a Triangle Own-ship may be depicted by a triangle. In this example, the apex of the triangle is the reference point for the relative position of the other symbols on the display. {Reference Section: 2.2.2.1.1}
TRAFFIC		Example of Traffic Being Depicted by a Chevron Symbol Traffic may be depicted by a chevron symbol when directionality can be determined. Colors may be used to indicate additional information with respect to the traffic. For example, a chevron symbol with a white outline and no fill could indicate that the traffic is at the same altitude as the own-ship. Furthermore, a blue outline with no fill or a green outline with no fill could indicate that the traffic is above or below the own-ship, respectively. Likewise, fill colors could represent various traffic alert conditions. For example, a yellow filled chevron could be an alert indication that the own-ship's course may be intercepting that of another aircraft's. {Reference Section: 2.2.2.1.2}

Symbol		Description
TRAFFIC		<u>Example of Traffic Being Depicted by a Diamond Symbol</u> Traffic may be depicted by a diamond symbol when directionality can not be determined (i.e., TCAS traffic). Color coding may be applied the same as that described for the chevron symbol. {Reference Section: 2.2.2.1.2}
SELECTED TARGET		<u>Example of a Selected Target Being Depicted by an Outlined Chevron Symbol</u> An outlined chevron symbol may designate traffic that has been selected through the use of a selection device. An outlined diamond symbol may be used for traffic where directionality can not be determined. {Reference Section: 2.2.2.1.3}
HORIZONTAL VELOCITY VECTOR		<u>Example of a Horizontal Velocity Vector</u> A horizontal velocity vector may be depicted as a straight line extending out in front of a traffic symbol. This vector represents where the traffic will be, based on the current ground speed and direction. {Reference Section: 2.2.2.2.8}
DATA TAG • Traffic Identification • Relative Traffic Altitude		<u>Example of a Data Tag</u> A data tag is shown in proximity with the traffic symbol and moves with the symbol. The data tag shows additional information about the traffic. This example contains the flight identification and the relative altitude being presented above a chevron symbol. The traffic identification is indicated as an alpha and/or numeric number (e.g., ABC350). At least two digits preceded by a "+" or "-"sign (e.g., +09) indicate the altitude difference with respect to the own-ship (relative altitude).

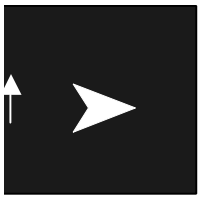
Symbol		Description
		{Reference Section: 2.2.2.2.1}
VERTICAL RATE		Example of Vertical Rate Being Depict with an Arrow A vertical velocity in excess of 500fpm can be indicated with an arrow pointing up, indicating a climb, or an arrow pointing down, indicating a descent. {Reference Section: 2.2.2.2.4}
DATA BLOCK • Ground Speed • Range • Traffic Identification • Type		Example of a Data Block A data block shows additional information about the selected target and is placed in a fixed location on the display. Some of the data elements presented in the data block may be the same as those presented in a data tag. This example contains the ground speed (GS 175), the range (R 0.8), the traffic identification (ABC123) and the aircraft type (LRG). {Reference Section: 2.2.2.2.2}

Figure H-2 depicts an example that is a representation of how CDTI might be displayed on a navigational display. This figure is provided as information only.

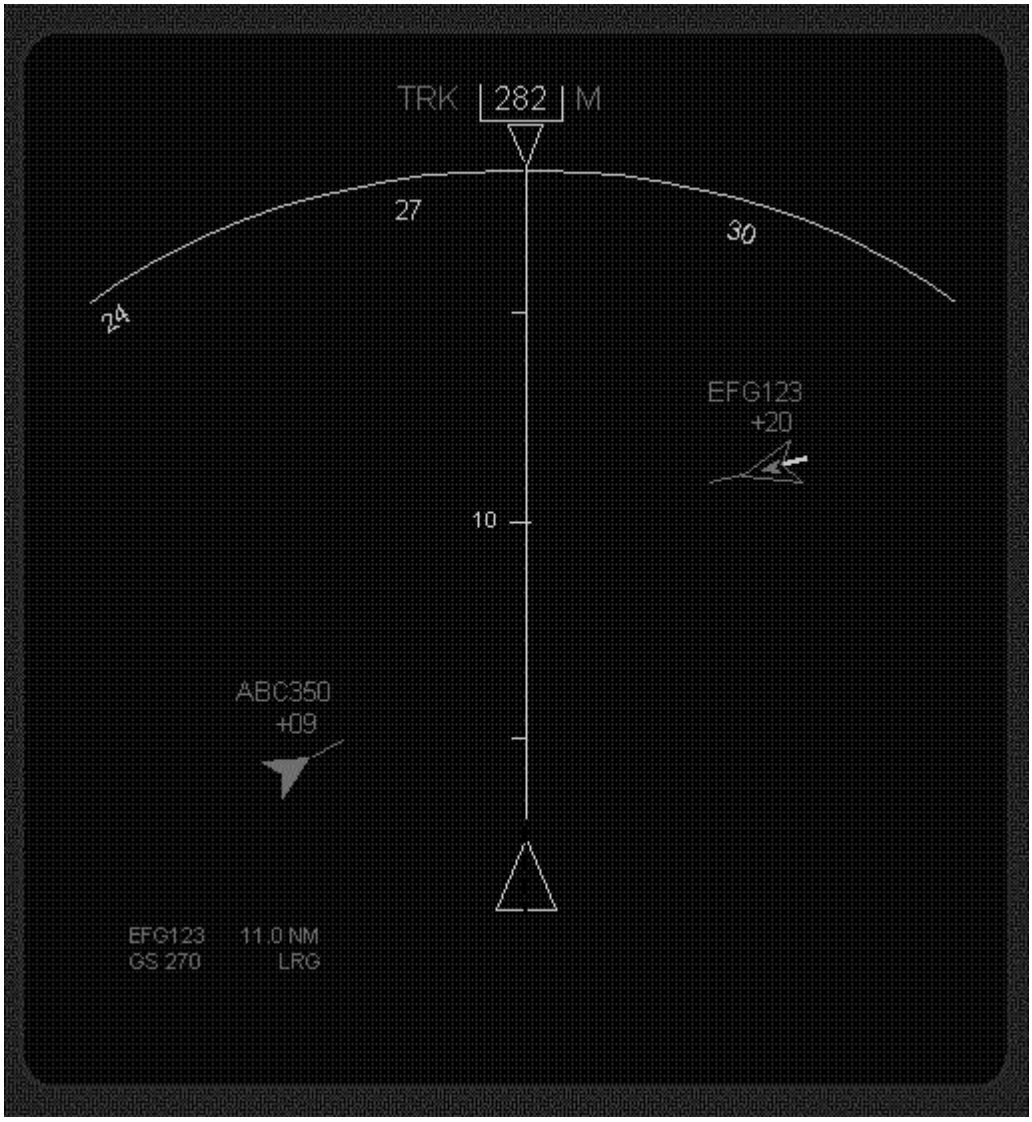


Figure H-2. Display Example

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