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VHF Direction Finder (VDF) Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Report

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May 1994

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16. Abstract

This report provides the results of the Operational Test and Evaluation (OT&E) Integration and OT&E Operational testing that was conducted on the new FA-10121 Very High Frequency (VHF) Direction Finder (VDF) at the Green Bay, WI, Automated Flight Service Station (AFSS). It covers testing accomplished to verify that the system meets the requirements identified in the Direction Finder (DF) Test Verification Requirements Traceability Matrix (TVRTM) from the OT&E Integration and OT&E Operational Test Plan. Based on this testing, it is concluded that the system should be deployed.

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EXECUTIVE SUMMARY

The Direction Finder (DF) network is maintained and operated by the Federal Aviation Administration (FAA) as a position location service for aircraft. The present network is made up of a mix of tube-type and solid-state equipment. The tube-type equipment will be replaced by new solid-state equipment, the FA-10121, which incorporates operator task automation, remote maintenance monitoring, and control and certification capabilities.

Operational Test and Evaluation (OT&E) Integration and OT&E Operational testing was conducted on the Very High Frequency (VHF) Direction Finder (VDF) at the Green Bay, WI, Automated Flight Service Station (AFSS), from March 29 through April 9, 1993, using software release 4.05, and June 21 through June 24, 1993, using VDF software release 4.07. Testing was categorized into the areas of integration and maintenance, display and keyboard functions, and operational flight testing. Flight testing utilized the FAA Technical Center Aero Commander 680E aircraft. Results were generally satisfactory in all test areas. However, some deficiencies exist in the maintenance and operational areas and deviations from volumes I and III of the National Airspace System (NAS) System Specification, NAS-SS-1000, were also noted.

It is concluded that operationally, the system is acceptable for deployment. Institution of a plan of action, to address the observed deficiencies, is recommended.

1. INTRODUCTION.

1.1 PURPOSE.

This report provides the formal results of the Operational Test and Evaluation (OT&E) Integration and OT&E Operational testing that was conducted on the new FA-10121 Very High Frequency (VHF) Direction Finder (VDF) at the Green Bay, WI, Automated Flight Service Station (AFSS). It covers testing accomplished to verify that the system meets the requirements identified in the Direction Finder (DF) Test Verification Requirements Traceability Matrix (TVRTM) from the OT&E Integration and OT&E Operational Test Plan.

1.2 OVERVIEW OF REPORT.

The DF has been the subject of OT&E testing activities performed at the Federal Aviation Administration (FAA) Technical Center, Atlantic City International Airport, NJ, and at the FAA AFSS in Green Bay, WI, at various times between January 1987 and June 1993. This report covers recent testing at Green Bay AFSS in May and June 1993, which emphasized operational performance and functionality, and also served to verify those enhancements made under contract modification 37 to DTFA01-85-01003. Testing was divided into three categories; (1) integration and maintenance, (2) keyboard and display, and (3) operational flight testing. This report covers the methodology used, results of tests compared to test requirements, and provides a rationale for the recommendation for deployment made in section 7.

2. DOCUMENTS.

FAA-PD-420-02a	Purchase Description, Direction Finder Replacement and Modernization, January 1993.
FAA-STD-024a	Preparation of Test and Evaluation Documentation, August 17, 1987.
FAA Order 1810.4b	FAA NAS Test and Evaluation Policy, October 1992.
NAS-SS-1000	Functional and Performance Requirements for the NAS Maintenance and Operations Support Element, Volumes I and III, December 1986, with changes to March and May 1992, respectively.
DOT/FAA/CT-TN91/25	FA-9964 Installed Accuracy Evaluation, September 1991.
FAA MTP	VHF Direction Finding (VDF) System, Master Test Plan, Revised September 1992.

FAA OT&E Plan	VHF Direction Finder Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Plan, March 3, 1993.
FAA OT&E Test	VHF Direction Finder Operational Test and Evaluation Procedures (OT&E) Integration and OT&E Operational Test Procedures, April 5, 1993.
Quick Look	VHF Direction Finder Operational Test and Evaluation Report (OT&E) Integration and OT&E Operational Test Quick Look Report, July 12, 1993.
FAA-D-8h(2)	VDF Air Traffic Specialist, System User Guide, April 29, 1992.
TI 6530.10	VHF Direction Finder, Receiver/Processor Group, July 30, 1991.
TI 6530.11	DF Remote Maintenance, Monitor and Control (RMMC)/Information Display and Control Unit (IDCU) Subsystems, November 16, 1992.
FAA OT&E Test	VHF Direction Finder (VDF) Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Logs and Data, DOT/FAA/CT-TN94/13.

3. SYSTEM DESCRIPTION.

3.1 MISSION REVIEW:

The DF network is maintained and operated by the FAA as a position location service for aircraft. An expanded network operated by Flight Service Station/Automated Flight Service Station (FSS/AFSS) sites is necessary to provide rapid position orientation for aircraft that are uncertain of their position or in distress, and to provide position reference information to aircraft upon request.

The present network is made up of a mix of tube-type and solid-state equipment. The new equipment nomenclature, FA-10121, includes new DF antennas for some antenna sites. At other sites, the existing FA-9964 DF antennas are retained and are interfaced with the FA-10121 operating system. The new system incorporates remote maintenance monitoring (RMM) including control and certification capabilities, between the DF site antennas and the AFSS where the operating position is located.

The new system incorporates DF bearing information from up to 24 remotely located DF antennas (any mix of FA-10121 or FA-9964 antennas), a site specific geographic map, and an aeronautical data base, on a graphic display terminal. These features enhance the specialist's ability to locate aircraft in a timely manner by eliminating the manual plotting of an aircraft's position and by retrieval of reference information.

The VHF DF system operates over a frequency range of 118.000 to 136.975 megahertz (MHz) and provides 760 channels spaced every 25 kilohertz (kHz) with 10 preset channels. The system is capable of receiving an aircraft transmission on one or more DF antenna sites and providing the audio to the operator. It also presents to the operator, in graphical form, position information on the aircraft relative to other points of interest. When triangulation is possible using two or more DFs, the aircraft location is automatically displayed on the operator's display, the Information and Display Control Unit (IDCU). Upon request, the heading and distance to the six nearest airports can be displayed.

3.2 TEST SYSTEM CONFIGURATION.

The tested system as installed at the Green Bay, WI, AFSS was configured with three FA-10121 antennas and four FA-9964 antennas. The seven antennas, with their Receiver/Processor Groups, were at various locations throughout Wisconsin. See figure 3.2-1 for the locations. Information from the antennas is carried by dedicated telephone lines and received by seven modems in the Remote Maintenance Monitor Computer (RMMC) subsystem rack located in the AFSS. An Input/Output Terminal Type 2 (IOT-2), and a printer are attached to the RMMC for maintenance actions. Two IDCUs, which constitute the AFSS Specialists' work station were installed, one in the operations room and another in an adjacent training room. See figure 3.2-2 for a block diagram of the equipment as installed at Green Bay AFSS.

Software utilized in the Very High Frequency Direction Finder (VDF) Preliminary OT&E conducted from March 29 through April 9, 1993, was version 4.05. Computer printouts showed version 4.07, June 14, 1993, in use between June 18 and 24, 1993, for OT&E, and then version 4.07, June 18, 1993, in use on June 25, 1993. A site adaptation and data base software file unique to Green Bay AFSS Flight Plan Area was utilized on both occasions.

3.3 INTERFACES.

3.3.1 Actual.

Actual interfaces utilized during testing consisted of those internal to DF system components, from the DF to aircraft radios, and the computer human interface (CHI) between the DF and the AFSS specialists. This included RMM and Certification capabilities available between the remotely located DF antennas and the AFSS.

3.3.2 Simulated.

During testing conducted at the FAA Technical Center in December 1992, 21 simulated DF antennas were used in addition to 3 actual antennas, to provide a maximum loading of 24 antennas. At Green Bay, no simulated interfaces were required or utilized. All actual interfaces required, except as noted below in paragraph 3.3.3, were installed and tested.

3.3.3 Deferred.

The proposed interface from the DF system to the National Airspace System (NAS) Maintenance Processor Subsystem (MPS) was unavailable and testing of such has been deferred.

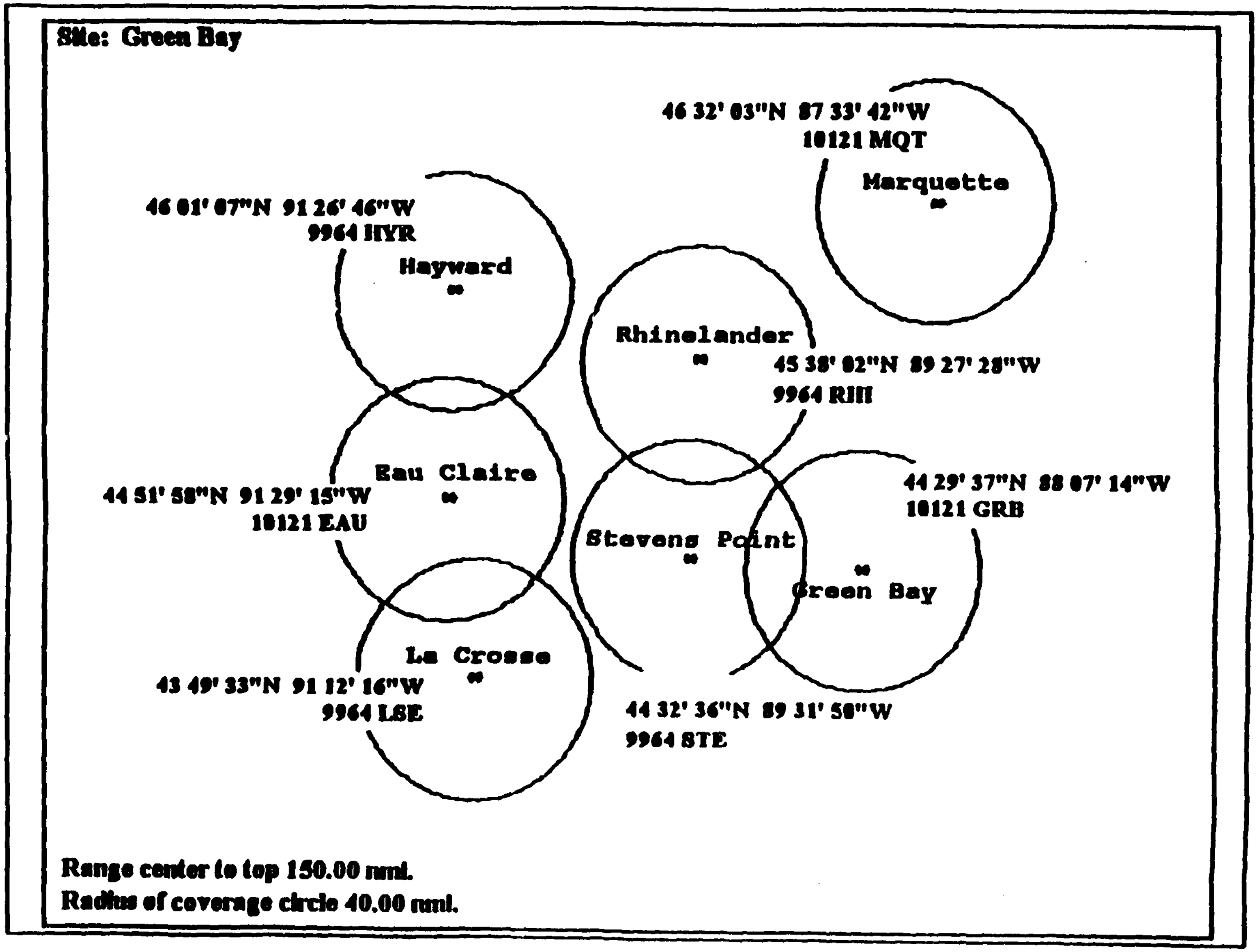

FIGURE 3.2-1. DF ANTENNA LOCATIONS

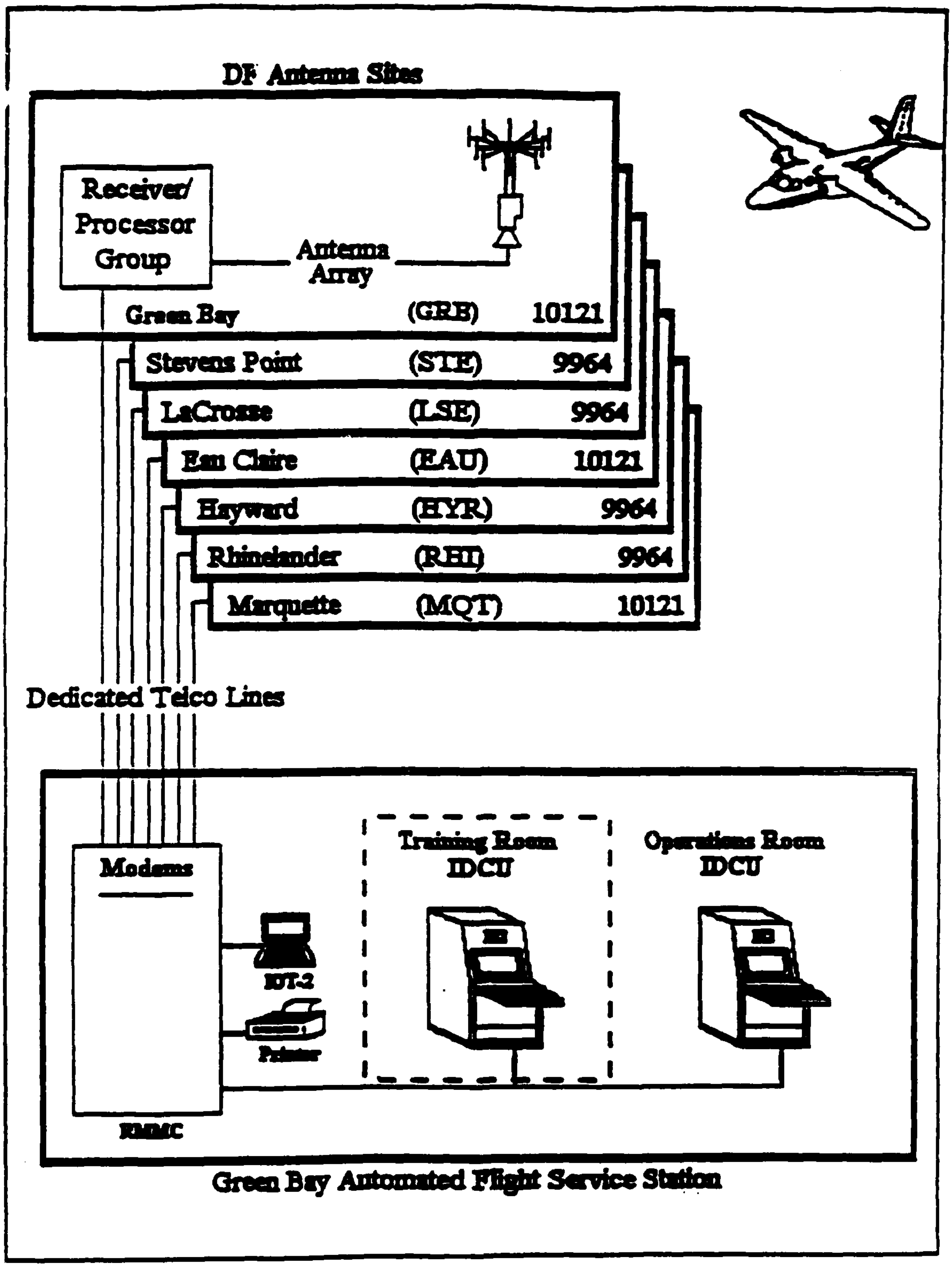

FIGURE 3.2-2. DF EQUIPMENT CONFIGURATION

4. TEST DESCRIPTION.

The OT&E Integration and OT&E Operational testing was conducted at the FAA Technical Center and Green Bay, WI, AFSS. Technical testing of the DF antenna and receiver/processor group components for bearing accuracy was performed in January through March 1987, and was not repeated in this series of tests. However, the flight testing portion of this OT&E, utilizing the complete FA-10121 DF system, did encompass accuracy of position measurements. This test included a comparison of the FA-10121 antenna subsystem and the FA-9964 antenna subsystem within the overall FA-10121 system from an operational viewpoint. Initial OT&E Integration and OT&E Operational testing took place at the FAA Technical Center utilizing 3 actual and 21 simulated DF antenna sites. Subsequently, the DF was tested at the Green Bay, WI, AFSS. At Green Bay, an operational network of seven DF antenna sites was utilized to verify interfaces and operational performance. The FAA Technical Center Aero Commander 680E aircraft was used for airborne testing.

4.1 SCHEDULE AND LOCATION.

The OT&E Integration and OT&E Operational testing activity was conducted at three locations on several dates. Testing took place at the FAA Technical Center and the Millville, NJ, AFSS in 1988. Additional testing was performed at the FAA Technical Center in December of 1989 and 1992. Testing was also performed at Green Bay AFSS during February 1990, and February, April, and June of 1993. In each case, testing locations included the IDCU work station area, the RMMC, and the local or remotely located DF antennas. The VDF has undergone modifications and enhancements over the years including several made under contract modification 37 to DTFA01-85-Y01003. The DF system tested in 1993 encompasses those enhancements and is the subject of this report on the OT&E performed at Green Bay AFSS during April and June of 1993.

4.2 PARTICIPANTS.

ACW-300A:	Conducted the OT&E. Joseph P. Pino, Associate Program Manager for Test, (APMT); John Dyson, Test Director; Robert Bernheisel, Norman Beauregard, and Sam Barto, Test Technicians; and Ron Lockhart, Flight Test Engineer.
ACN-710:	Provided flight test aircraft and pilot. Theos McKinney.
ATR-130:	Participated as a coordinator and monitor of OT&E. Leonard Hopkins, Gib Shade.
ATZ-120:	Participated as a monitor. Charlie Parks.
ATM-110:	Participated as a monitor. Bill Fish.
ATP-110:	Participated as observer. Gene Higgins
ATR-200:	Observer of OT&E operational aspects. Kevin Harrington.
AOS-240:	Participated as a monitor. Ed Lugo.

AMA-571:	Observer in the area of training education. Rick Akers.
ANN-600:	Attended as observers: Greg Rugila, Bill Swart, Dana Dias.
Green Bay AFSS:	Participated as a host facility, and provided DF operators, and maintenance technicians.
Hughes STX:	Development contractor personnel that participated as observers and provided technical support; John Morris, Rico Honey, and others.

4.3 TEST EQUIPMENT.

4.3.1 Standard.

Standard FAA test equipment was used during testing of the DF antenna subsystems, the RMMC, and modems which included: a VOM, signal generator, and a frequency counter.

4.3.2 Special Test Equipment.

A COMB generator, supplied as a part of the DF system was utilized in DF antenna ground check procedures. An Input/Output Terminal Type 3 (IOT-3), which is a portable personal computer with maintenance software was also used at antenna sites. The IOT-2, part of the DF RMMC system, was used during RMMC testing.

The FAA Technical Center Aero Commander 680E, call sign November 50 (N50), with standard Instrument Flight Rules (IFR) certified equipment was utilized for the operational flight testing. A hand-held Garmin AVD-32A Global Positioning System (GPS) unit was also used on board N50 to establish actual aircraft position during the flight scenarios. An additional IFR certified light aircraft, a Maul XMT-180, call sign N9228L, with two VHF radios, dual VHF Omnidirectional Radio Range (VOR), Distance Measuring Equipment (DME), and Automatic Direction Finder (ADF) was used for the "Two-Aircraft" Flight Scenarios during preliminary OT&E testing.

4.3.3 Simulators.

Contractor provided DF antenna simulators were utilized during testing at the FAA Technical Center in December 1992, to simulate 21 antennas in addition to the 3 actual antennas to provide a maximum loading of 24 antennas.

4.4 TEST OBJECTIVES.

Test objectives were derived from the Test Verification Requirements Traceability Matrix (TVRTM) contained in the OT&E Test Plan, which are derived from volumes I and III of NAS-SS-1000, as specified by the FAA VDF Master Test Plan. Special emphasis was placed on verifying that the required corrections and desired enhancements identified during DF testing in February 1990 have been incorporated into the DF system. Additional objectives were derived from VDF contract modification 37 and AFSS specialists requirements. All of these were carried into the OT&E Test Plan TVRTM and are summarized herein.

4.4.1 Integration and Maintenance Area.

Verification of basic system startup and operation. This included: system power up sequence, initialization, certification, radio reception, diagnostics, and selected maintenance procedures. The verification also checked that the existing FA-9964 and new FA-10121 DF antennas operate properly with the new DF system.

4.4.2 Display and Keyboard Area.

Verification of the operator display and keyboard functions including: maps, scales, symbology, color codes, label functions, data base access, and position calculation and display.

4.4.3 Operational Flight Test Area.

Verification of DF system operational performance including AFSS operator, navigational aids, and aircrew elements of the total system. Areas addressed included: DF operator determination of aircraft position via multiple DF bearings (via DF and a Navigational Aid (NAVAID)), display of geographical features, airports, NAVAIDs, Military Operations Areas (MOA), and creation and display of reference lines. Also, verification that the operator can utilize the position data to: direct the aircraft to an airport, provide pertinent information to the pilot about aircraft position, landmarks, obstructions, and NAVAIDS. Additionally, verification that the DF operator can direct a pilot to an airport in a position from which a safe landing can be made. Emphasis was also given to noting any display inconsistencies between the two installed IDCUs.

4.5 TESTING CATEGORIES.

The following test categories are as listed in the OT&E Test Plan and Test Procedures.

4.5.1 Integration and Maintenance Functions (Category 1).

This category covered the following areas:

a. Physical compatibility
b. Turn on and Power up sequence
c. Initialization
d. Certification
e. Diagnostics
f. RMM of antennas to DF system
g. RMMC switchover
h. IOT-2 and IOT-3
i. COMB generator applications
j. Audio interface
k. Key Line interface
l. Strobe Inhibit

4.5.2 Display and Keyboard Functions (Category 2).

This category covered the following functions:

a. DF Receiver Site Locations
b. VHF Transmission Reception
c. Bearing Strobe
d. Navigational Aids
e. Airport Locations
f. Obstruction Locations
g. Data Base Updates
h. Labels
i. Overwrite
j. Frequency Selection (manual and automatic)

4.5.3 Operational Flight Testing (Category 3).

This category covered the following functions:

a. Aircraft position determination by: DF/VOR, DF/NDB, 2 DF, 3 DF, DF/Reference line, and Time/Distance calculation

b. Guidance of aircraft to: airports, landmarks, NAVAIDS

c. DF station passage and DF approaches

d. Map symbology

e. Two-Aircraft scenario

f. Data base access

g. Emergency aircraft mode

4.6 DATA COLLECTION AND ANALYSIS METHOD.

Data points were collected throughout the test activity utilizing the prepared forms and logs contained in the OT&E Test Procedures.

4.6.1 Integration and Maintenance Functions (Category 1).

Normal setup and initialization procedures were followed according to the DF manufacturers handbooks and the test procedures. The IDCU, IOT-2, IOT-3, and COMB generator were exercised. Test monitors recorded the data generated and displayed by the IOTs and IDCUs in response to test inputs, as well as narrative comments on system operation.

The collected data points were reviewed and compared to system specifications and handbooks to verify proper operation. The OT&E test logs are contained in sections 1 and 2 of VHF Direction Finder (VDF) Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Logs and Data.

4.6.2 Display and Keyboard Functions (Category 2).

At the DF IDCU, an operator exercised keyboard and trackball functions according to the operators manual and test procedures. The IDCU display and readouts were observed for the appropriate responses and consistency with FAA-D-8h(2), the DF Air Traffic Specialist System User Guide. Test monitors logged results consisting of specific IDCU responses and readouts, and general narrative comments.

The collected data points were reviewed and compared to system specifications, handbooks, and known data bases to verify proper display and accuracy of presented data. The OT&E test logs are contained in sections 1 and 2 of VHF Direction Finder (VDF) Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Logs and Data.

4.6.3 Operational Flight Testing (Category 3).

Category 3 testing consisted of exercising operational flight scenarios. A Green Bay AFSS specialist operated the DF system from the IDCU as the FAA Technical Center Aero Commander aircraft proceeded through each of the flight scenarios. The scenarios provided situations requiring the exercising of the various DF operational capabilities. Data points were copied by test monitors directly from the IDCUs and narrative comments on system operation were made on the test forms. The airborne test engineer copied aircraft position data directly from aircraft instrumentation including VOR, DME, ADF, LORAN C, and the hand-held GPS unit carried on board. Visual observations from the aircraft were also recorded. Airborne scenarios and position data are contained in sections 3 and 4 of VHF Direction Finder (VDF) Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Logs and Data. Comparisons were made between: IDCU readouts and displayed locations against the known data base, and of aircraft position reported by VOR Radial/DME, GPS, LORAN C, or visual means.

Additionally, some specific flight testing was performed utilizing orbits flown around the Rhinelander and Stevens Point FA-9964 antennas; and the Marquette and the Green Bay FA-10121 antennas. This provided data to assess overall system accuracy associated with the two different antenna types, and also to assess consistency of bearing displays between the two IDCUs. Orbits were flown at Green Bay and Stevens Point at 5, 10, and 40 nautical miles (nmi), at Marquette at 10 nmi, and at Rhinelander at 10 and 20 nmi. Data points were collected on board the aircraft, and also logged at each IDCU.

The GPS location was translated to distance and azimuth from DF site in order to make the azimuth error analyses. The translated data is combined with data collected from the IDCUs in section 5 of VHF Direction Finder (VDF) Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Logs and Data. Judgements were drawn from debriefings and narrative comments on data sheets and logs concerning system performance.

5. RESULTS AND DISCUSSION.

5.1 INTEGRATION AND MAINTENANCE FUNCTIONS (CATEGORY 1).

Verification of the maintainability aspects of the system and its integration into the NAS were the objectives of this test series. Discrepancies were noted in some test areas and are summarized herein.

Examination of the 6530.11/a Technical Instruction (TI) manual revealed that it had not yet been revised to reflect the current VDF system configuration. The commercial-off-the-shelf (COTS) manuals were sampled and omissions were noted about the FA-9964 type COTS modems. Details of the modified COTS equipment were not contained in the manufacturer's documentation.

Surge protection for the RMMCs and IDCUs according to the requirements of the Purchase Description (PD), FAA-PD-420-02a, section 1-3.6.12 has not been provided by the contractor. Grounding of the VDF equipment racks is considered paramount for reliable and safe system operation and was found to be deficient during preliminary OT&E testing in April 1993. During the June 1993 OT&E test, an inspection of the ground changes made on the equipment racks showed acceptable grounding.

Verification of the actual receiver squelch threshold versus that selected by an operator at IOT-2 demonstrated that the squelch setting was within 3 decibel (db) of the selected -95 decibels above 1 milliwatt (dBm) which is within the requirements of the PD. Squelch break occurred at -117 dBm when -140 dBm was selected at IOT-2. Operation limits beyond -97 dBm are not specified in the PD. From an operational standpoint, the user must be aware that squelch selection is neither accurate nor linear below -97 dBm.

It could not be initially verified via documentation nor nondestructive means whether the Mitsubishi color display monitors being used for the IDCU indicators meet the implosion protection requirement of the PD. Post-OT&E investigation, however, revealed that the displays were implosion protected.

Airway Facilities (AF) technicians demonstrated a satisfactory ability to operate the system and perform limited problem diagnosis. It appeared that the technicians had become more proficient since the preliminary OT&E, however, uncertainty exists in evaluating the actual level of proficiency being attained through the current training course structure.

Induced failures of primary RMMCs during actual system operation resulted in acceptable switchover to the backup units. As expected, an audible alarm and a communication failure message (COMM) were presented at the IDCU. However, an alarm delay period of approximately 20 seconds was noted during which time the operator cannot access the antenna sites or receive bearing updates from them. This alarm period is beyond the 1-second status response time specified in paragraph 3.2.1.3.7.2.5 of NAS-SS-1000, volume III.

Note: NAS Change Proposal 16136 is currently in coordination. DF performance is expected to meet the tailored NAS requirement.

Development and presentation of operator selected diagnostic test and facility data by the VDF was observed to require an average time of 4.5 minutes. This period is beyond the 2-minute average time specified for this function in paragraph 3.2.1.2.9(c) of NAS-SS-1000, volume I.

During diagnostic testing from the IOT-2 maintenance console, reports from FA-10121 sites would sometimes indicate failures at the antenna site(s). However, upon repeating the diagnostic test without corrective action, the failures would sometimes disappear.

Observations during the OT&E concerning maintenance has raised the specter of uncertainty as to whether the 4200 hour mean-time-between-failure (MTBF) requirement is actually demonstrable in the field. Section 6 of VHF Direction Finder (VDF) Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Logs and Data contains miscellaneous data on equipment failures and repairs that occurred during the 6 months of intermittent testing conducted at the Green Bay AFSS.

5.2 DISPLAY AND KEYBOARD FUNCTIONS (CATEGORY 2).

Verification of the IDCU and IOT-2 functions revealed no major problems. Some discrepancies were noted and are highlighted herein.

The IDCU keyboard functions worked as documented on all features available in the Green Bay AFSS display. A super site was created to test some features not in the Green Bay AFFS; keyboard operation on the super site was also correct. Minor discrepancies were noted in the help text of several IDCU functions. There is no operational impact to these text discrepancies though this demonstrates some lack of refinement.

Checkout of the IDCU map revealed some inconsistencies, but no major problems were discernible. This test exercise did highlight and reinforce the importance of verifying the correctness of the maps that will be supplied to field facilities and the requirement for a viable mechanism for updating these maps.

Verification of the security sign-on and alarm control functions revealed no major operational deficiencies. Checkout of IOT-2 FSS facility control, monitor, maintenance, and system management menus revealed minor inconsistencies.

The IDCU display response time, when the calculated position of a VHF radio transmission source is displayed, was noted as 6 to 8 seconds. Paragraph 3.2.1.3.7.2.6 of NAS-SS-1000, volume III, sets this time at a maximum of 3 seconds.

Note: NAS Change Proposal 16136 is currently in coordination. Average DF time to position presentation is within the limits proposed for the tailored NAS requirement.

5.3 OPERATIONAL FLIGHT TESTING (CATEGORY 3).

All five flight scenarios contained in the VHF Direction Finder Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Procedures were executed during the preliminary OT&E test series, while only flight scenarios #1 and #2 were exercised during the formal OT&E. An addition to scenario #4 was instituted during preliminary OT&E testing to allow comparison of VDF operator reported position with Automated Radar Terminal System (ARTS) IIA reports, which was accomplished successfully. Flight scenario #5 utilized two aircraft, the FAA Technical Center Aero Commander 680E and a light rental aircraft, a Maul XMT-180. This scenario evaluated the Air Traffic Control Specialist's (ATCS) ability to handle two aircraft and the capability of the system and procedures in this situation. There were no operationally significant differences in bearings displayed by each IDCU.

The VDF operators successfully demonstrated the ability to direct the aircraft over a DF antenna, report station passage, and provide pertinent information about aircraft position, landmarks, NAVAIDS, and airports. Operators utilized DF approach procedures to direct the aircraft to designated airport runways. The need for operator interpretation of presented data was noted, and was generally successfully accomplished by the operators. DF approaches were made to Green Bay, Marquette, and Eau Claire airports during preliminary OT&E, and to Stevens Point and Eau Claire during formal OT&E, each time by a different operator. All approaches resulted in an aircraft position from which a safe landing could have been made. The VDF system responded satisfactorily to operator commands and provided the necessary information to orient the aircraft safely to an airport.

Table 5.3-1 summarizes the DF System bearing accuracy observed during the flight testing conducted from April 1 through 7, and June 21 and 22, 1993. Table 5.3-1 is derived from the data in section 5 of VHF Direction Finder (VDF) Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Logs and Data, of which the original data is a combination of angle from site as reported by the DF system and angle from site as computed from site and aircraft position. The table depicts, in integral degrees, the mean and standard deviation of the error observed in orbit and operational scenarios. Also shown are the extreme values less than (-) or greater than (+) the actual bearing. Cases where average and standard deviation information is meaningless are marked with n/a.

Orbital data was analyzed with respect to quantifying the overall error to be expected from each antenna site. Figures 5.3-1 through 5.3-3 depict the azimuth error at Green Bay, Rhinelander, and Stevens Point as a function of distance from the site. There is not an obvious difference in the spread of error by distance when the distance is 40 nmi or less. In the case of Marquette only one distance was flown, so no distance comparison was performed. Figures 5.3-4 through 5.3-7 depict the angular error as a function of true azimuth from antenna site to aircraft. There are significant differences in both average error and distribution of the error for FA-9964 versus the new FA-10121 antenna sites. Table 5.3-1 alone does not highlight these obvious differences.

TABLE 5.3-1. SUMMARY OF DF SYSTEM BEARING ACCURACY

(1 of 2)

Antenna Site and Test	# Samples	Extreme Values	Mean Error	Standard Deviation of Error	Range (Nautical Miles)
FA 10121's					
GRB					
Orbit 5 NM 1"xmt	17	-5 to 12	3	3	
Orbit 5 NM 5"xmt	13	1 to 7	4	2	
Orbit 10 NM 5"xmt	15	-2 to 7	4	2	
Orbit 10 NM 10"xmt	13	-1 to 8	4	3	
Orbit 40 NM 5"xmt	17	1 to 5	3	1	
From Orbits of STE GRB Range < 40 NM	12	-4 to 2	n/a	n/a	23.0 to 38.5
From Orbits of STE GRB Range > 40 NM	76	-4 to 3	n/a	n/a	40.2 to 70.3
Scenario 1 < 40 NM	12	2 to 6	n/a	n/a	9.5 to 37.4
Scenario 2 < 40 NM	2	2 to 3	n/a	n/a	21.4 to 39.6
Scenario 1 > 40 NM	4	0 to 5	n/a	n/a	40.5 to 56.1
Scenario 2 > 40 NM	2	-1 to 0	n/a	n/a	54.5 to 62.6
EAU					
Scenario 2 > 40 NM	4	-7 to -1	n/a	n/a	45.2 to 58.3
MQT					
Orbit 10 NM 5"xmt	25	1 to 7	4	1	

Extremes, Mean Error and Standard Deviation columns are in degrees.
xmt Aircraft Radio Transmission Time.
NM Nautical Miles

TABLE 5.3-1. SUMMARY OF DF SYSTEM BEARING ACCURACY (Continued)

(2 of 2)

Antenna Site and Test	# Samples	Extreme Values	Mean Error	Standard Deviation of Error	Range (Nautical Miles)
FA 9964's					
LSE					
Scenario 2 < 40 NM	7	-3 to 1	n/a	n/a	13.5 to 37.7
RHI					
Orbit 10 NM 5"xmt	15	-4 to 4	0	2	
Orbit 20 NM 5"xmt	12	-3 to -1	-2	1	
STE					
Orbit 5 NM 1"xmt	15	-6 to 2	-1	2	
Orbit 5 NM 2"xmt	17	-2 to 3	1	1	
Orbit 5 NM 10"xmt	25	-1 to 3	1	1	
Orbit 10 NM 10"xmt	13	-1 to 3	0	1	
Orbit 40 NM 5"xmt	15	-3 to 1	-1	1	
From Orbits of GRB STE Range < 40 NM	17	0 to 3	n/a	n/a	20.5 to 35.3
From Orbits of GRB STE Range > 40 NM	32	-21 to 208	n/a	n/a	50.3 to 68.8
Scenario 1 < 40 NM	9	-2 to 3	n/a	n/a	5.6 to 30.8
Scenario 2 < 40 NM	6	0 to 2	n/a	n/a	19.4 to 39.2
Scenario 1 > 40 NM	8	-19 to 2	n/a	n/a	40.7 to 69.5
Scenario 2 > 40 NM	3	-1 to 0	n/a	n/a	47.8 to 60.6

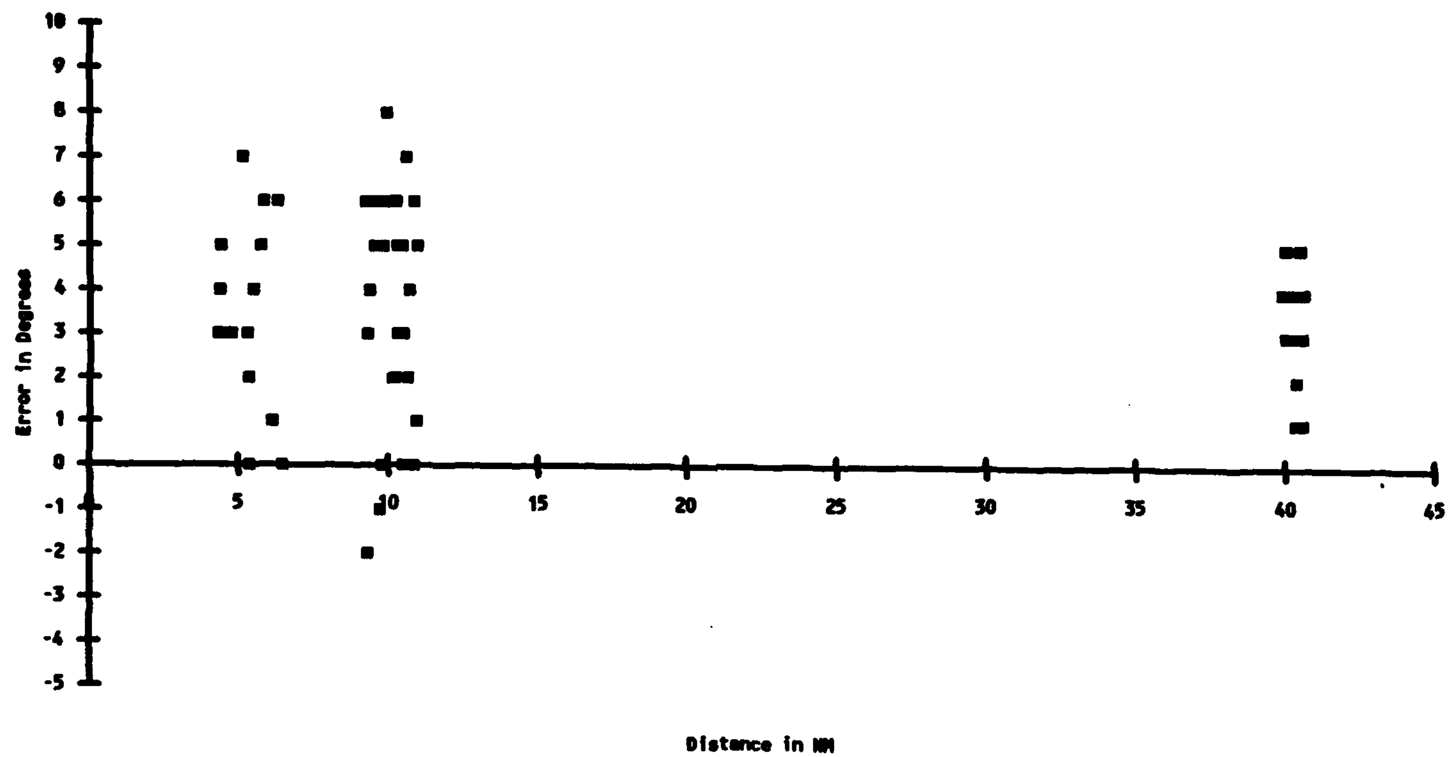

FIGURE 5.3-1. GREEN BAY ERROR AS A FUNCTION OF DISTANCE

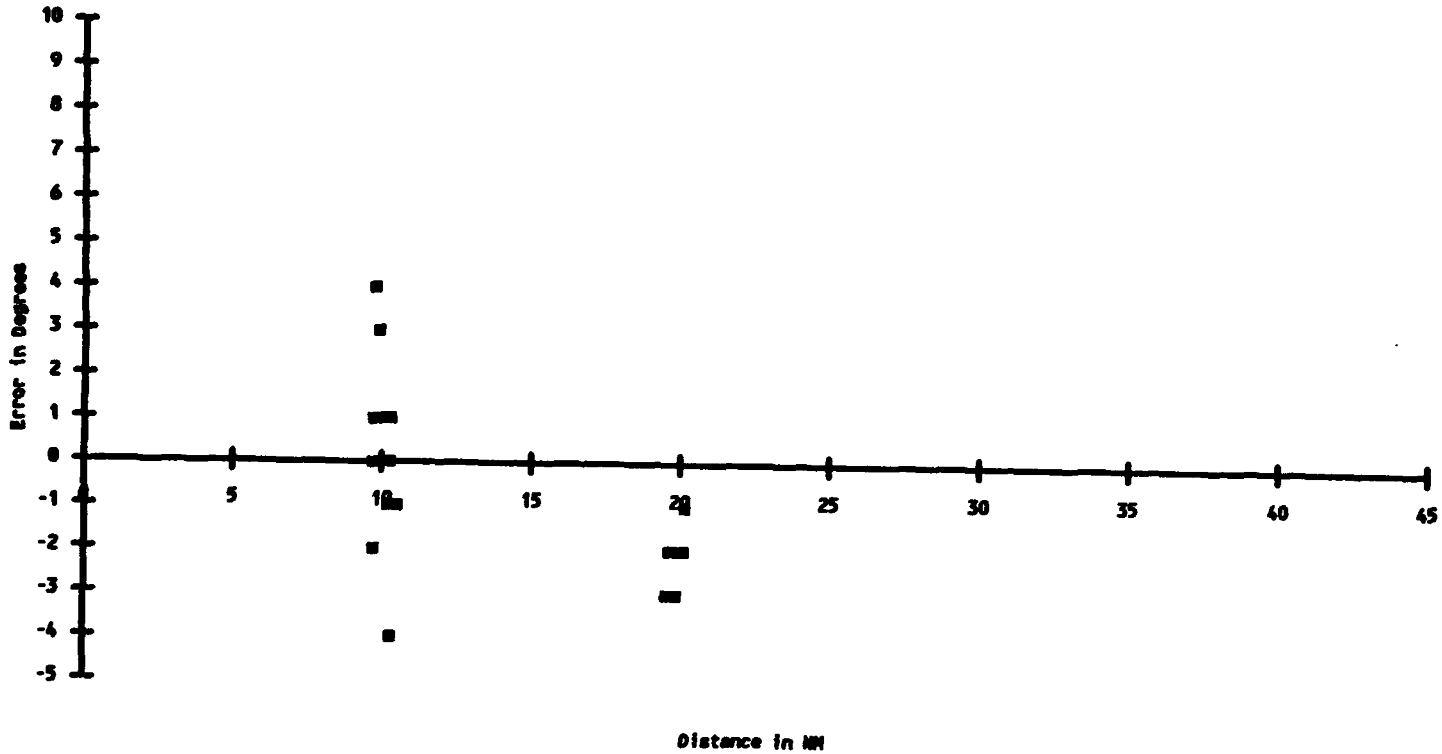

FIGURE 5.3-2. RHINELANDER ERROR AS A FUNCTION OF DISTANCE

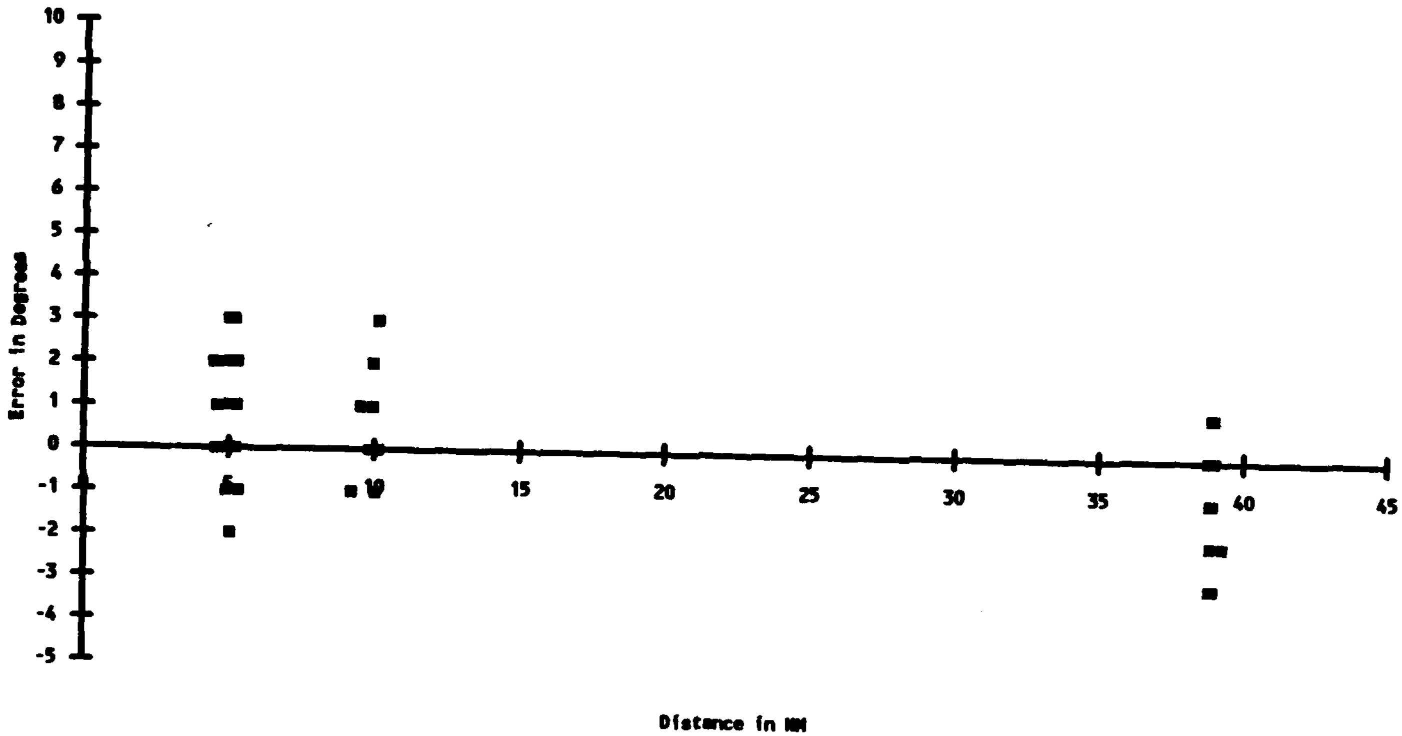

FIGURE 5.3-3. STEVENS POINT ERROR AS A FUNCTION OF DISTANCE

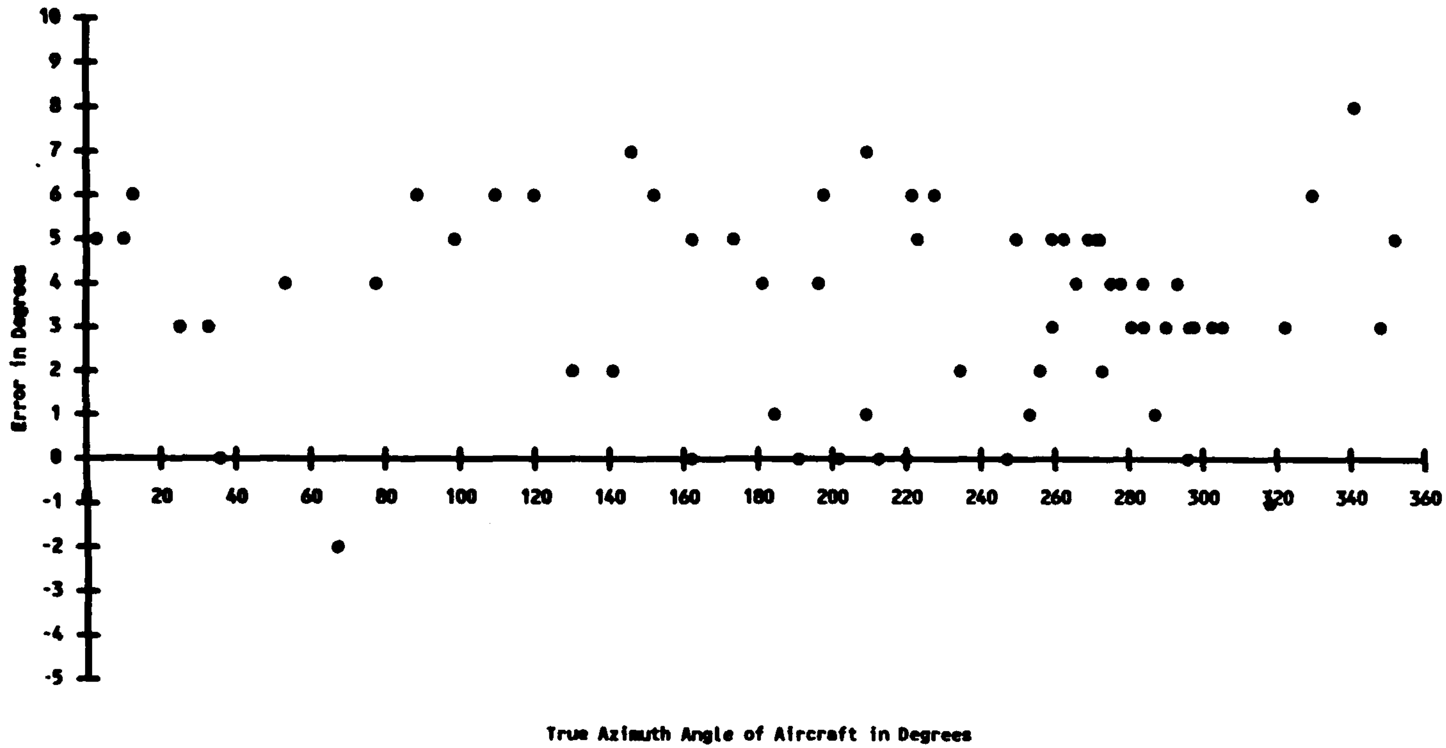

FIGURE 5.3-4. GREEN BAY ERROR AS A FUNCTION OF TRUE AZIMUTH

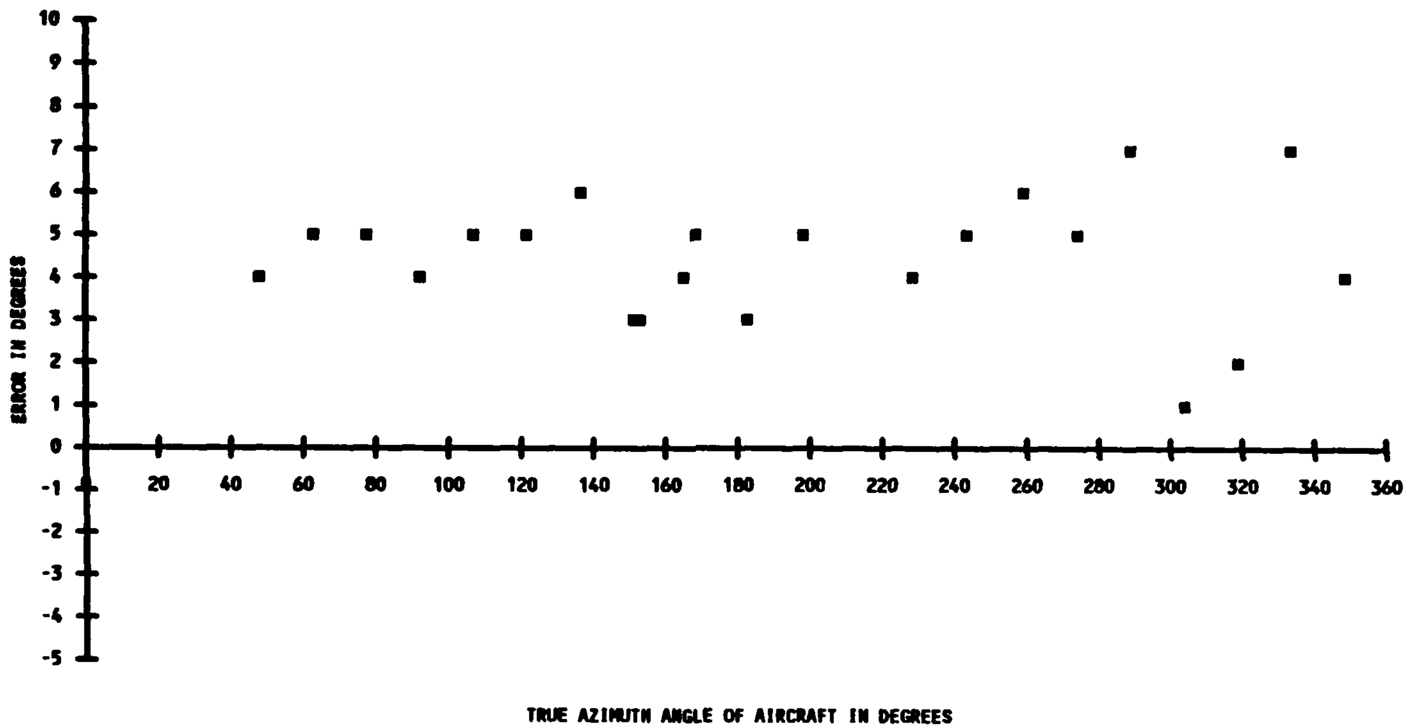

FIGURE 5.3-5. MARQUETTE ERROR AS A FUNCTION OF TRUE AZIMUTH

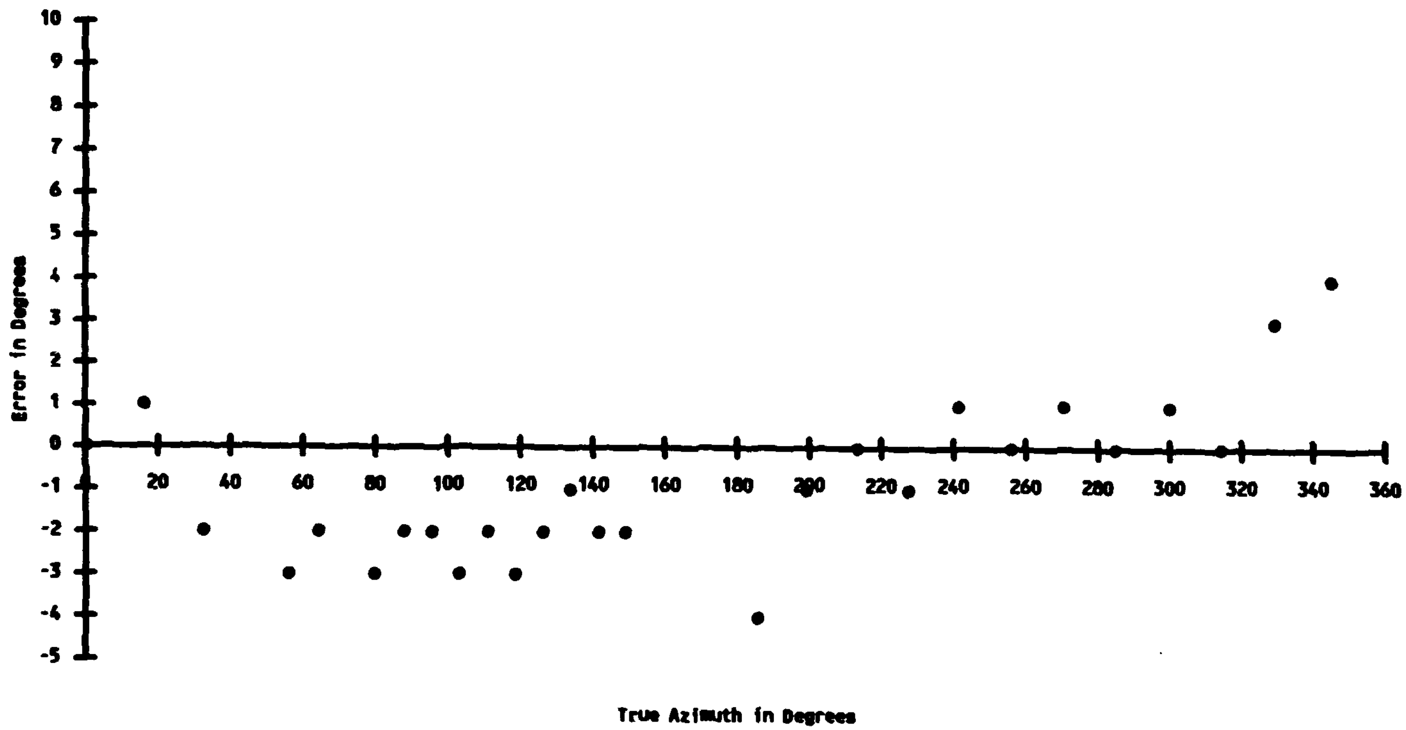

FIGURE 5.3-6. RHINELANDER ERROR AS A F,NCTION OF TRUE AZIMUTH

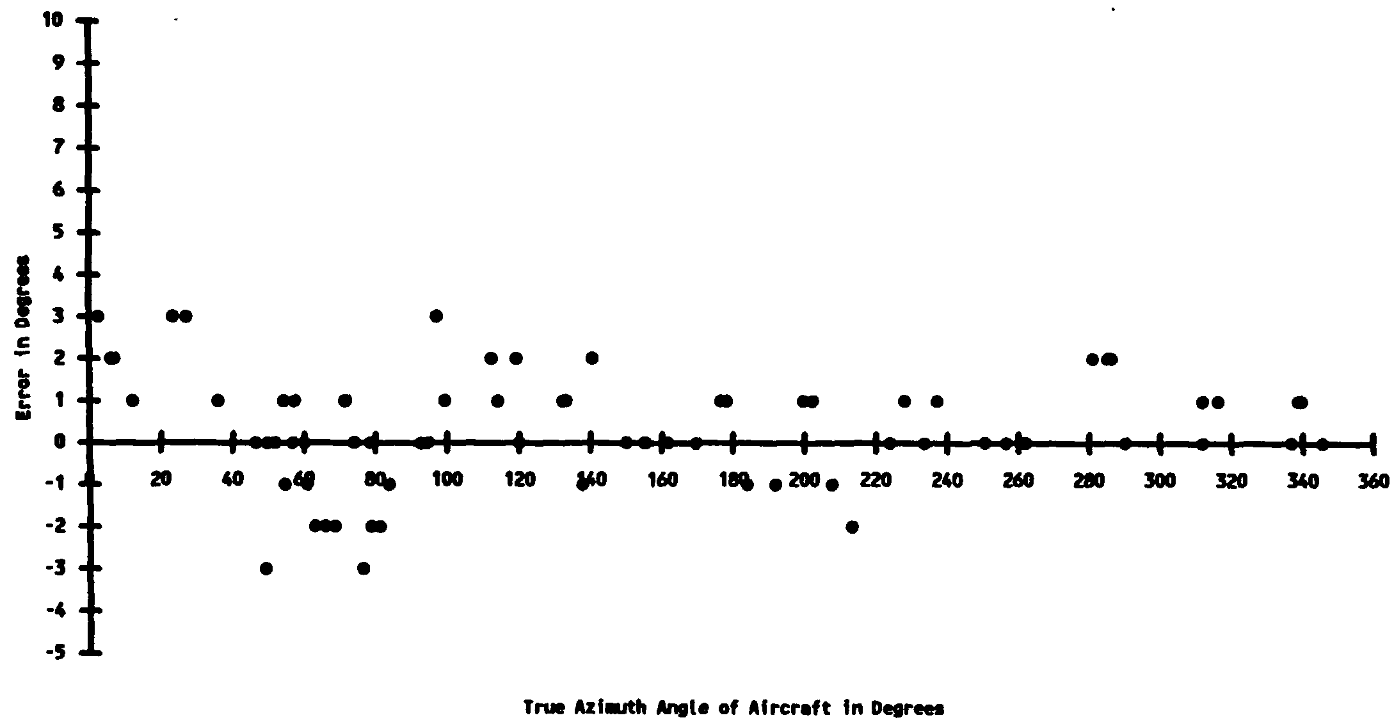

FIGURE 5.3-7. STEVENS POINT ERROR AS A FUNCTION OF TRUE AZIMUTH

It can be seen from section 5 of VHF Direction Finder (VDF) Operational Test and Evaluation (OT&E) Integration and OT&E Operational Test Logs and Data, table 5.3-1 and figures 5.3-4 through 5.3-7, that the FA-9964 antennas have lower average error and lower deviations from average than the newer FA-10121s. However, these figures do not take into consideration the different sites of the respective antennas. It is plausible that the older FA-9964 antennas are located at more favorable sites or that installation of FA-10121 antenna sites have different siting constraints than the FA-9964 systems; therefore, the FAA would need to identify and correct our siting procedures. It should also be noted that the Green Bay and Marquette FA-10121 antenna errors were heavily biased toward the positive with both having an average error of +4 degrees. If the errors were balanced during commissioning flight inspection, accuracy figures would improve. However, the distribution of errors would remain unchanged regardless of average error. Note that the FA-10121 antenna sites were prepared for operation using surveyed target bearings and that the operational rule for current commissioned DF systems is that flight inspection provides the final authority for course alignment.

General azimuth accuracy of DF system-generated positions was found to be independent of distance within the 40 nmi operational radius. Beyond 40 nmi, the error of the FA-9964 sites becomes unpredictable, therefore, a reported azimuth could be good or unusable. The FA-10121 sites appear to provide useable data beyond 40 nmi, which is possibly a result of a better algorithm for discarding data when conflicting signals arrive at the antenna site. It should be noted that atmospheric conditions, as well as site conditions can bias these long-range results.

It was also found that transmissions of approximately 1 second in duration were less reliable at the Stevens Point FA-9964 site than at the Green Bay FA-10121 site. A look at the data shows that a single point biases the results, however the point is within expected variation and so there is no reason to discard it. At the Stevens Point FA-9964 site, all data taken at the 2-second and greater transmission durations showed azimuth errors similar between sets. Data from the 1-second transmission duration tests was not included in figures 5.3-1 to 5.3-7 data in order to prevent a slight biasing of the results.

The VDF was operated in both automatic and manual mode during scenario execution. Most ATCSs appeared to prefer the automatic mode. It was observed that the system placed a new aircraft position when an ATCS communicated with an aircraft while in manual mode, even though key line inhibit was activated. The key line inhibit design tested during OT&E does not meet the intent of the PD.

Comments and recommendations for system operating procedures and system operating features were received from the ATCSs and were provided to the FAA Headquarters AT representatives. For example, sudden changes in aircraft position were observed at times. These sudden changes take the form of a leap of several miles between two transmissions closely spaced in time. However, this was not considered an operational problem by the ATCSs since the displacements were obviously inaccurate. Sudden changes are usually the result of the system placing an aircraft using bearings from an antenna well beyond 40 nmi. In this situation, the ATCS requests another transmission from the aircraft to update the IDCU display.

Several unsuccessful attempts were made to obtain reliable strobe information from the VDF from an aircraft Emergency Locator Transmitter (ELT) transmitting on 121.5 MHz. The aircraft was placed at various locations at the Green Bay Airport. In most circumstances, the aircraft was in line of sight with the Green Bay VDF antenna which was tuned to 121.5 MHz. However, the VDF was unable to generate a reliable strobe from the ELT. In all cases, the ELT warbling tone was audible through the DF antenna at the IDCU position.

Two theories for the inability of the VDF system to locate the ELT beacon were suggested:

a. Several airport buildings would act as reflectors for the VHF signal.

The line of site transmission would in any case provide a relatively clear signal at the antenna. Any reflected signal incident on the antenna should cause a multiple signal detect (MSD) condition. The VDF system is designed to identify MSD at the antenna. Contrary to theory 1, the system gave conflicting azimuth information rather than MSD indication. At the operator console, an MSD is depicted by "---" in place of an azimuth number. Some of the aircraft positions gave the MSD indication, but not all of them.

b. The warbling tone of the audio is incompatible with the antenna site hardware.

The antenna site hardware does make use of certain audio frequencies in its processing of an azimuth. This theory will require considerable effort to prove one way or the other. However, the presence of azimuths, even if conflicting, argues against the theory.

The failure to place ELT transmissions remains unexplained.

6. CONCLUSIONS.

The Very High Frequency (VHF) Direction Finder (VDF) system is operationally satisfactory in terms of mission effectiveness. Some deficiencies exist in the maintenance and operational areas, and deviations from volumes I and III of the National Airspace System (NAS) System Specification, NAS-SS-1000, were also noted. Noted deficiencies are:

a. The VDF Technical Instruction (TI) manual and associated documentation do not reflect the current system configuration.

b. The VDF fails to meet NAS-SS-1000, volume III, paragraphs 3.2.1.3.7.2.5 (status response) and 3.2.1.3.7.2.6 (display response).

c. The VDF fails to meet NAS-SS-1000, volume I, paragraph 3.2.1.2.9(c) (maintenance and operations support performance characteristics).

d. The VDF keyline closure equipment is not finalized.

e. An insufficient number of Input/Output Terminal Type 3 (IOT-3) computers to support effective site maintenance.

f. The VDF lacks both a current software audit and a fully developed plan for software maintenance. No current methodology for regression testing future VDF software releases.

g. Absence of a fully developed plan for map verification.

h. The VDF lacks finalization of a plan for accommodating the 56-day map update period.

i. The VDF lacks a methodology for certifying Direction Finder (DF) antenna alignment and for verification of antenna installation.

j. Absence of surge protection for the RMMCs and IDCUs according to the requirements of the Purchase Description (PD).

While Information Display Control Unit (IDCU) and associated keyboard functions are satisfactory from an operator interface aspect, requests for changes were made by the Green Bay Automated Flight Service Station (AFSS) ATCSs. Most ATCSs considered the FA-10121 VDF to be an improvement over the currently fielded FA-9964 and FA-5530 DFs. The inability of the VDF to locate an aircraft Emergency Locator Transmitter (ELT) signal is not seen as an operationally significant issue by AT representatives.

Training of ATCSs appeared to be satisfactory. However, the complexity of the VDF as compared to previous generation DFs, requires additional emphasis on proficiency training. Development of the VDF simulator trainer equipment to support this increased training requirement is currently well underway.

7. RECOMMENDATIONS.

Deployment is recommended even though some deficiencies presently exist. Institution of a plan of action to address the deficiencies is recommended. The following recommendations are noteworthy:

a. Conduct regression test of Very High Frequency (VHF) Direction Finder (VDF) software revisions.

b. Closely scrutinize FA-10121 Direction Finder (DF) site maintenance during initial fielding efforts.

c. Consider balancing observed antenna bearing errors during commissioning flight inspections. A detailed airborne analysis of the site error by azimuth should be conducted during the first installations, starting with the three sites already installed. Any special case problems should be identified and corrected. Changes to site selection procedure and installation instructions could be derived from the analysis of the site errors.

8. ACRONYMS AND ABBREVIATIONS.

ADF	Automatic Direction Finder
AF	Airway Facilities
AFSS	Automated Flight Service Station
APMT	Associate Program Manager for Test
ARTS	Automated Radar Terminal System
AT	Air Traffic
CHI	Computer Human Interface
COTS	Commercial Off-the-Shelf
CPU	Central Processor Unit
dB	decibel
dBm	decibels above 1 milliwatt
DF	Direction Finder
DME	Distance Measuring Equipment
EAU	Eau Claire VDF Antenna Site
ELT	Emergency Locator Transmitter
FAA	Federal Aviation Administration
GPS	Global Positioning System
GRB	Green Bay VDF Antenna Site
IDCU	Information Display Control Unit
IFR	Instrument Flight Rules
IOT	Input/Output Terminal
kHz	kilohertz
LAT	Latitude
LONG	Longitude
LSE	Lacrosse VDF Antenna Site
MDT	Maintenance Data Terminal
MOA	Military Operations Area
MHz	megahertz
MPS	Maintenance Processor Subsystem
MQT	Marquette VDF Antenna Site
MSD	multiple signal detect
MTBF	Mean Time Between Failures
MTP	Master Test Plan
MSD	Multiple Signal Detect
NAS	National Airspace System
NAVAID	Navigational Aid
NDB	Nondirectional Radio Beacon
nmi	nautical mile
OT&E	Operational Test and Evaluation
PD	Purchase Description
PM	Preventative Maintenance
RHI	Rhinelander VDF Antenna Site
RMM	Remote Maintenance Monitoring
RMMC	Remote Maintenance Monitor Computer
STE	Stevens Point VDF Antenna Site
TI	Technical Instruction
TVRTM	Test Verification Requirements Traceability Matrix
VDF	Very High Frequency (VHF) Direction Finder
VHF	Very High Frequency
VOR	VHF Omnidirectional Radio Range
VFR	Visual Flight Rules