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Report No. FAA-RD-161, V
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TACAN/DME DIGITAL DATA BROADCAST DESIGN PLAN

Vol. V – Flight Test Program

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September 1974

Final Report

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Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

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Technical Report Documentation Page

1. Report No. FAA-RD-74-161, V	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle TACAN/DME DIGITAL DATA BROADCAST DESIGN PLAN Vol. V - Flight Test Program		5. Report Date September 1974
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
9. Performing Organization Name and Address EDMAC Associates Inc. 333 West Commercial Street East Rochester, New York 14445		10. Work Unit No. (TRAIS) 36336
		11. Contract or Grant No. DOT FA72WA-3080
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Systems Research and Development Service Washington, D. C. 20590		13. Type of Report and Period Covered Final
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The Digital Data Broadcasting Design Plan implements the system engineering process for the purpose of defining with supporting rationale a recommended ground/airborne equipment configuration and flight test program. This plan documents an approach to verify the operational significance and technical feasibility of utilizing existing DME and TACAN to provide the function of broadcasting data to aircraft for use in support of area navigation in addition to its normal function. The Design Plan is structured as follows in five volumes:

Volume I - Operational Analysis
Volume II - Synthesis of the Data Transmission and Formatting Techniques
Volume III - Airborne Equipment
Volume IV - Ground Equipment
Volume V - Flight Test Program

17. Key Words TACAN, Distance Measuring Equipment (DME), Navigation, Area Navigation, Digital Data Broadcasting System		18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Va. 22151.	
19. Security Classif. (of this report) UNCLASSIFIED	20. Security Classif. (of this page) UNCLASSIFIED	21. No. of Pages 34	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

		PAGE NUMBER
5.1	Introduction	1
5.2	Bench Testing	1
5.3	Installation in Aircraft	1
5.4	Preliminary Shakedown Flight Test	2
5.5	Installation of Ground Equipment	2
5.6	Baseline System Evaluation	3
5.7	Final Shakedown Flight Test	3
5.8	Digital Data Broadcast Evaluation Test	4
5.9	Test Instrumentation	4
	5.9.1 Shakedown Test Instrumentation	5
	5.9.2 Flight Test Instrumentation and Data Processing	6
5.10	Airline System Evaluation Test	7
5.11	Schedule	8
Figure 1	General Aviation Flight Test Schedule	9
Figure 2	Airline System Flight Test Schedule	10

5.1 Introduction

The purpose of the Flight Tests are to determine to what extend the broadcasting of Waypoint Rho-Theta data will enhance the use of the R-Nav system, particularly, to what extend cockpit workload is eased and pilot errors are reduced. The flight test program will be conducted as described in the Appendix and will consist of the basic steps described below.

5.2 Bench Testing

When all of the constituent parts of the data broadcast system have been built, delivered to EDMAC Associates, and found to conform to the appropriate subsystem specifications, the equipment will be assembled into a complete data broadcast system. The performance of equipment will be verified on the bench by making use of the VOR signal received from the VOR transmitter located at the Monroe County Airport and the DME/DDB signal from the EDMAC GFE TACAN transponder. At this time, any equipment malfunctions will be detected and corrected. This bench testing will also include check-out of the data recording system described in paragraph 5.9.

5.3 Installation in Aircraft

Following completion of the bench testing, the airborne portion of the system will be installed in the test aircraft. The location of this work, and the personnel employed, will be dependent upon which

aircraft is used as the test aircraft. It is suggested that the Aero-Commander owned by Champlain Technology Inc. be employed. In this case, the work will be performed in West Palm Beach, Florida by the personnel who presently maintain that aircraft. Technical assistance will be provided by EDMAC engineers for installation of the modified avionics, the Decoder/Interface, and the test instrumentation/data recording equipment.

5.4 Preliminary Shakedown Flight Test

Immediately following the installation of the airborne equipment, a preliminary shakedown test will be flown at East Rochester, New York. The purposes of this test are: 1) to disclose any airborne equipment installation defects while using a ground equipment installation which had previously been shown (during bench testing) to be satisfactory and 2) to make preliminary observations of the effects of multipath signals, and other signal radiation effects upon data quality.

5.5 Installation of Ground Equipment

As soon as the preliminary shakedown test has been completed, the ground equipment, i.e. the data generator, monitor, control and transfer, and the transponder modification kit, will be installed at the flight test site. It is expected that this will be NAFEC, although any site selected by the Government will be satisfactory to EDMAC Associates. The installation will be accomplished by EDMAC Associates

personnel in cooperation with the Government personnel responsible for the site.

5.6 Baseline System Evaluation

This test, which is described in Appendix A can be conducted during the time when the ground equipment is being installed since this test does not require the use of the data broadcast equipment. Ideally, this baseline evaluation will be performed using the same R-Nav avionics which will be used for the DDB system evaluation, but operated in the "manual" instead of the "DDB" mode. In this way, any pilot or operator errors which might be aggravated by the location of the controls and displays on the cockpit panel will be the same for both sets of flight tests.

However, in the event schedule problems arise with the delivery of the purchased avionics hardware to EDMAC Associates, it will be possible to make the baseline evaluation using the R-Nav avionics existing in the CTI aircraft. It is anticipated that the degree of difference in the results between the manually controlled (baseline evaluation) and DDB assisted (DDB system evaluation) R-Nav systems will be large enough that the small differences in operator error rates caused by the location of the controls and displays will not be significant.

5.7 Final Shakedown Flight Test

This test, which will be conducted at the flight test site (e.g. NAFEC), will verify the proper operation of the complete DDB system. Primarily, it will check out the ground equipment since the airborne installation had already been verified by the preliminary shakedown test.

5.8 Digital Data Broadcast Evaluation Test

These tests, which will establish the advantages if any of the DDB, will be conducted as described in Appendix A with the following exception:
In Flight Test No. 3, it is suggested that tests be run using two candidate Waypoint naming techniques. As was explained in Volume 3, no other Waypoint naming techniques have been suggested which offer enough potential advantage, or, in fact, are sufficiently different from the one described in Volume 1 to warrant a special test with the exception of the five-letter name favored by some ATA members. This technique is totally incompatible with the Waypoint selection techniques described in Volume 3 and would require an entirely different Decorder/Interface subsystem. Furthermore, the disadvantages to the general aviation user of this alpha nominclature are apparent without conducting flight tests.

5.9 Test Instrumentation

Test instrumentation will fall into two categories based upon the intended use of the test data. The first category of data will be for the purpose of monitoring the operation and performance of the data transmission system and equipment and will be concerned with such things as error rates, signal fading, multipath, and circuit performance. This category of data will be collected primarily during the shakedown tests.

The second category of data will be for the purpose of evaluating the DDB as an operational feature and will consist primarily of the data described in Appendix A. This data will be collected during the baseline system evaluation and the DDB evaluation tests.

The instrumentation required for these two categories of data collection are described below.

5.9.1 Shakedown Test Instrumentation

As explained in Volume 3, the Airborne Data Decoder/Interface unit will be designed with a built-in memory feature whereby the desired station and waypoint data will be acquired and stored as soon as it is received and validated. Approximately every 30 seconds, the same data will be broadcast again. If detectable errors occur during any of these subsequent broadcasts, the Airborne Unit retains the information from the first valid data acquisition and will continue to display the initial data.

During the shakedown flight test, it would be desirable to record the transient behavior of the Airborne equipment to ascertain its word-to-word performance in the absence of the previously described "data retention" feature. This will be accomplished by providing a special test made in the Decoder/Interface Unit which will allow a selected waypoint cluster to be erased each time the cluster identifier is received. Two outputs will then be provided to the recorder. The first will be an event indication each time the desired word is correctly received and

validated. When the recorded data is analyzed, the recorder's time base plus the two events specified above will identify the transient behavior of the equipment. In this way, the effects of various signal propagations anomalies can be evaluated. This test can be repeated for various cluster identifiers and waypoint words as well as for station data.

Whenever a condition occurs whereby the cluster identifier is received and validated but the selected word is "lost", it would also be desirable to perform some diagnostic tests to determine the extent of interference caused by the DME Interrogator's Receiver Blanking Gate (See Volume 2). This effect can be tested by running the above experiment once with the DME transmitter operating and a second time with it turned off.

5.9.2 Flight Test Instrumentation and Data Processing

Table 2.3 of Appendix A summarizes the DDBS flight test data recording requirements. EDMAC Associates Inc. recommends that the data be recorded on magnetic tape for subsequent computer processing.

Each of the signals which must be recorded can be classified into one of three broad categories - digital (events, real time etc), low frequency analog (distance, error, heading, etc) or voice. The frequency content of these signals differ by a considerable amount. If voice was not required, the low frequency analog signals could be multiplexed, digitized and combined with the digital signals so that they could be recorded on a slow speed long time base digital recorder.

This would provide high data density and all data would be in digital form, ready to be formatted for computer processing. However, the requirement for recording voice makes the use of a long time base recorder less practical than the use of an FM recorder.

Most commercial FM recorders contain 7 tracks with provisions for multiplexing three signals on each track by means of sub-carrier oscillators. Generally, an entire track is reserved for recording broad band signals such as time of day codes. This still leaves five tracks with the capability of handling 3 signals each and hence, the configuration appears to fulfill the current needs of the program.

The data processing of FM signals is achieved by digitizing the FM data during data playback and performing the formatting function which are necessary to prepare an IBM compatible tape for subsequent computer processing.

Specific recorder types and their cost performance tradeoffs will be investigated in more detail during the next phase of the program. Also to be investigated is the possibility of obtaining suitable GFE Flight Recorders from the NAFEC facility in Atlantic City, New Jersey

5.10 Airline Systems Evaluation Tests

The flight tests for the airline quality R-Nav system will be basically the same as those described above for the general aviation system. However, in the case of the airline system, a significant reduction in workload is not to be expected. Rather, it is hoped to determine whether the data broadcast can form a

satisfactory substitute in the terminal area for the magnetic tape storage normally used. If this proves to be so, a significant economy will accrue to the user.

5.11 Schedule

Figure 1 is a proposed flight test schedule for the general aviation system. The testing program will begin with the delivery and acceptance to EDMAC Associates of the various pieces of avionics equipment and includes the installation and check-out of both the ground and airborne equipment. As can be seen, certain tasks will be performed in parallel. For example, the baseline system evaluation can proceed during the installation of the ground equipment and some final shakedown tests can be conducted concurrently with the baseline system evaluation.

Figure 2 is the schedule leading to the evaluation of the airline-quality DDB system. This schedule assumes that a fully operational airline quality R-Nav system is available, installed and checked-out in a suitable aircraft. This schedule starts with the modification of the R-Nav system to implement DDB. If a new R-Nav system is to be installed, an additional three to five months, depending upon the aircraft chosen, will be required for installation of the R-Nav equipment.

FIGURE 1 GENERAL AVIATION FLIGHT TEST SCHEDULE

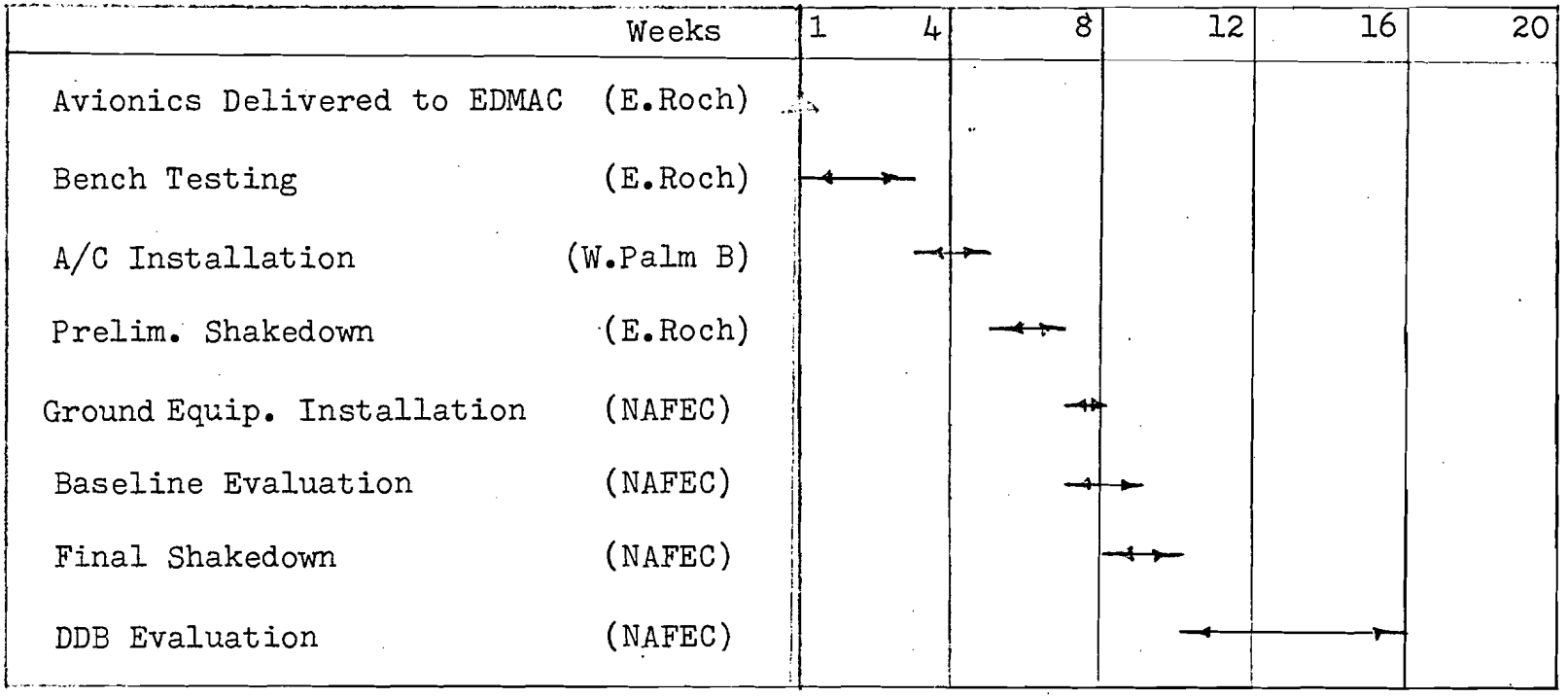
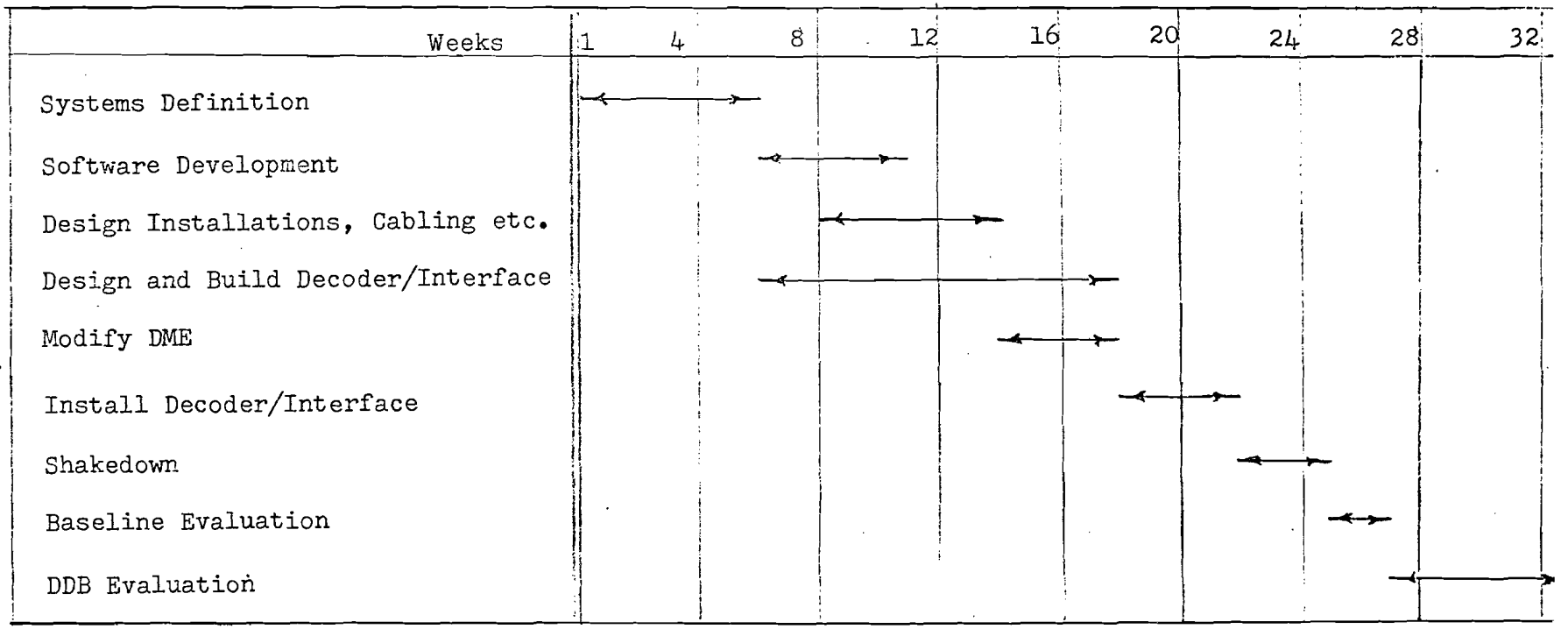


FIGURE 2 AIRLINE SYSTEM FLIGHT TEST SCHEDULE



APPENDIX A

PRELIMINARY FLIGHT TEST PROGRAM FOR EVALUATION OF A DIGITAL DATA BROADCAST SYSTEM

15 May 1973

Prepared under Subcontract No. 2329
Contract DOT-FA72WA-3080

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FOREWORD

This document contains the results of Task C of Subcontract 2329 for EDMAC Associates, Inc. of East Rochester, New York performed by Champlain Technology, Inc. of West Palm Beach, Florida. The report consists of specifying the recommended flight test plans, procedures, environment, and data requirements for the operational evaluation of the Digital Data Broadcast System concepts. The operational analysis of Task A and the system description of Task B of this subcontract were used extensively in defining the detailed test plan.

TABLE OF CONTENTS

Section		Page
Foreword		ii
Table of Contents		iii
1.0	INTRODUCTION	1-1
2.0	FLIGHT TEST DESCRIPTION	2-1
2.1	Program Summary	2-1
2.2	Data Requirements	2-7
3.0	PROCEDURES AND ENVIRONMENT	3-1
3.1	Pilot Selection	3-1
3.2	Environment	3-1
3.3	Test Pattern	3-2
3.4	ATC Procedures	3-2
3.5	Location of the Test	3-5
4.0	ANTICIPATED RESULTS	4-1

1.0 INTRODUCTION

The requirement for flight test evaluation of the Digital Data Broadcast System concepts results from the desirability of establishing and documenting the operational advantages provided by broadcasting waypoint information. The objectives of the flight test program were defined as a result of the detailed operational analysis of DDBS performed as Task A and the system description performed as Task B of this subcontract. The program contains a number of subject areas critical to the design, development and implementation of DDBS in the anticipated area navigation environment. The flight test program consists of nine dedicated flight tests for which specific objectives have been defined. Each of these dedicated tests includes flights by pilots representative of both ends of the proficiency spectrum. Each flight test will be analyzed not only to evaluate the specified test objectives but also to obtain supplementary knowledge pertinent to introduction and acceptance of DDBS. For example, a flight test dedicated to define the optimum waypoint storage capacity of the DDBS Interface Unit, I/U, will also be instrumented and analyzed to establish a data base for cockpit workload requirements. In addition, each dedicated flight test will include controller initiated maneuvers interjected extemporaneously to evaluate the compatibility of DDBS with current and anticipated operational procedures.

The evaluation of the proposed flight test objectives is an integral part of the airborne DDBS system requirements definition. The results of these tests will establish the answers to operational questions which define the equipment design limitations and isolate areas requiring further development. The flight tests must precede prototype DDBS equipment design to anticipate operational problems in the real world environment and to define prototype hardware functional and performance requirements. The test plans presented are applicable to the evaluation of both the relatively simple, low cost general aviation RNAV equipped aircraft and the more complex ARINC MK. 13 and MK. 2 equipped aircraft using the DDBS.

Although dedicated flight plans are outlined for each of the problem areas, the primary objectives of the DDBS FlightTest Program are to substantiate the predicted reduction in cockpit workload and pilot blunder provided by the addition of broadcast data into the RNAV environment, to assess the feasibility of the DDBS design as configured from the operational analysis and system description tasks and to determine the compatibility of broadcast navigation information with controller initiated procedures. This document

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presents the preliminary outline of a feasibility test program suitable for evaluation of these goals.

2.0 FLIGHT TEST DESCRIPTION

The flight test program required for the feasibility analysis of the preliminary DDBS design consists of nine dedicated flight tests. Each of the dedicated tests requires more than one flight and more than one pilot for each route tested. The flight test procedures, environment and test patterns are discussed subsequently in Section 3.0. The purpose of this section is to delineate the objectives of each of the dedicated flight test plans, to define the data recording requirements and to specify the operational significance and priority of the flight test topics.

2.1 Program Summary

Table 2.1 summarizes the proposed DDBS Flight Test Program including test sequence (in order of priority), test objectives and data requirements. The table proceeds from a basic system shakedown and pilot training test to a dedicated data gathering flight test for direct comparison of area navigation with and without the use of DDBS. The following tests (Nos. 3-9) comprise the evaluation of both hardware design considerations such as performance under weak signal conditions as well as evaluation of operational considerations such as the impact of changing the broadcast traffic flow and evaluation of feasibility model variables effecting both hardware and procedures for example waypoint storage requirements. This section summarizes the desired goals, procedures and priority of each dedicated flight test presented in Table 2.1. In general, each test involves executing specified flight test routes and maintaining normal controller/pilot interaction and flexibility. The data recording requirements for all tests are specified in the following section. The duration of each flight test should be divided into approximately 50% specified route execution and 50% improvised flight maneuvers. The purpose of this split is twofold. First of all, the randomness will preclude rote performance of the specified routes and second, this will enable each flight test to provide data regarding the performance of pilots using DDBS to navigate in the real world environment. It should be emphasized that this is a feasibility analysis of analytically derived system component designs and that alterations in specified procedures and/or goals may be dictated by preliminary data analysis as the program progresses. Following is a description of each flight test specified in Table 2.1.

Preferred Flight Test Sequence	Objectives	Data Requirements Primary	Data Requirements Secondary	DDBS Configuration
1	-Operational/Functional System Checkout of airborne/ground DDBS Equipment -Orientation and familiarization flight for test pilots -Data recording/processing system debugging	Blunder data during transition to DDBS supported RNAV	External factors (weather traffic, etc.)	Baseline
2	-Baseline cockpit workload comparison of RNAV with and without broadcast data -Ease of operation and blunder resistance of DDBS equipment during changeover from non-DDBS RNAV -Complete execution of all DDBS functions	Cockpit workload and blunder	Compatibility with TMA procedures & external factors & FTE	Baseline
3	-Evaluation of the relative merits of two distinct waypoint identification techniques -Establish the operational effectiveness of DDBS	Cockpit Work-load, blunder & procedural compatibility	External factors & FTE	Variable Waypoint Designation
4	-Evaluate DDBS functions under weak signal conditions -Determination of the maximum usable transmittal distance	Navigation data per Table 2.2 & DDBS downtime	Cockpit workload blunder, external factors	Baseline
5	-Waypoint Storage/Broadcast cycle time optimization	Cockpit work-load & blunder TMA compat.	External factors	Variable waypoint storage and broadcast data rate
6	-Documentation of problems and procedures involved in changing the broadcast traffic flow pattern	Procedural compatibility, FTE	Cockpit workload blunder and external factors	Baseline
7	-Automatic waypoint sequencing evaluation	Blunder	Cockpit workload external factors	Waypoints auto-sequenced in DDBS I/U

TABLE 2.1 DDBS FLIGHT TEST SYNOPSIS

Preferred Flight Test Sequence	Objectives	Data Requirements: Primary	Secondary	DDBS Configuration
8	- Evaluate the additional cockpit workload imposed on a VNAV equipped user in the DDBS environment - Determine the increase in blunder errors and blunder rate resulting from overlying the 3D navigation task on 2D RNAV with DDBS - Assess the ability of a sampling of the spectrum of the pilot population to perform VNAV maneuvers with and without DDBS	Cockpit workload, blunder & & FTE (Vert. and Horiz.)	Procedural compatibility, External Factors	Baseline
9	- Compatibility evaluation of the preferred system capabilities as determined from preliminary analysis of test results	Cockpit workload, blunder & TMA compatibility	FTE, External Factors	Candidate prototype configuration

Note: 1. The Baseline DDBS configuration includes a single broadcast traffic flow, 6 waypoint storage capacity, 30 sec max data acquisition time, route numbering waypoint designation technique, 130 nm maximum transmittal distance and manual waypoint sequencing.

2. FTE - Flight Technical Error

3. Flight test Number 1 should be performed under VFR conditions with the subject pilot flying under simulated IFR by means of the standard training hood. The remaining flight tests (2-8) should be performed in a realistic environment taking advantage of actual IFR weather to the extent practical, otherwise, simulated IFR conditions should be maintained.

TABLE 2.1 DDBS FLIGHT TEST SYNOPSIS (Continued)

FLIGHT TEST NO. 1: SHAKEDOWN TEST

The primary purpose of this test is the operational and functional system checkout of the airborne and ground DDBS equipment. This flight test will also provide pilot orientation and familiarization training as well as a complete checkout of the data recording system and hopefully debugging of both primary system components and instrumentation.

Blunder data may be of interest from the standpoint of training requirements, ease of transition and orientation provided by DDBS.

FLIGHT TEST NO. 2: BASELINE SYSTEM EVALUATION

This test defines the workload required to execute the desired flight patterns in an RNAV environment with and without DDBS. Identical routes will be flown for a baseline workload and blunder assessment. The ease of operation and blunder resistance of DDBS equipment during transition from non-DDBS area navigation will be evaluated.

It should be pointed out that within the scope of the DDBS flight test program it is impossible to devote the time, manpower or money necessary to define a broad, statistically significant data base for conventional RNAV. For this reason, the cockpit workload, blunder and compatibility evaluation will be limited to comparing DDBS data acquired in the six subsequent tests to the baseline defined by flight test number 2. The applicability of workload and blunder data obtained for conventional RNAV from this test must be verified as to its representativeness prior to proceeding with flight test number 3. If, for some reason, the conventional data appears questionable, additional data gathering without DDBS will be required. This test is of prime importance to the satisfactory completion of the remainder of the DDBS flight test program. The second half of this flight test consists of repeating the patterns flown with conventional RNAV only using the DDBS functions in an attempt to reduce pilot workload, blunder, etc. Although this test will provide a necessary back to back comparison of RNAV with and without DDBS, all subsequent flights will expand the data base of DDBS assisted RNAV.

FLIGHT TEST NO. 3: WAYPOINT NOMENCLATURE EVALUATION

Flight test number 3 is the first test dedicated to evaluation of a hardware design consideration as well as an operationally significant feasibility analysis. This test will be performed entirely in the DDBS mode. The two candidate waypoint naming techniques developed in Supplement No. 1 to the Task A Report will be used to execute routes defined by both preflight planning and improvised ATC maneuvers. The attendant cockpit workload, blunder resistance and procedural compatibility of each technique will be assessed.

FLIGHT TEST NO. 4: WEAK SIGNAL PERFORMANCE

The purpose of this test is to determine the effect of weak transmission signals on the performance of the DDBS system. Deterioration in the data received, the acquisition rate or the inability to receive the data will be recorded. The test should be executed by performing a series of RNAV SIDs followed by constant altitude cruises at selected altitudes of 4000, 6000, 8000 and 10000 ft out to a line of sight range of at least 100 nm or until the ability to receive the broadcast data is terminated. In addition to the information on system performance under weak signal conditions, the absolute maximum transmittal distance should be derived from this flight test.

FLIGHT TEST NO. 5: WAYPOINT STORAGE/DATA CYCLE TIME OPTIMIZATION

The primary objective of this test is to optimize the waypoint storage required of the DDBS I/U and corresponding optimal data broadcast route. Obviously, the single waypoint RNAV systems (zero DDBS I/U storage) would require infinitesimal data broadcast cycle times. Similarly, a six waypoint storage provision might define the cycle time as one or two minutes. For this reason a matrix of these variables must be tested. This test will consist of eight flights by each of the test pilots as indicated in Table 2.2. The order of the flights defining the matrix should be varied for each pilot. Cockpit Workload, blunder rate and compatibility with existing and anticipated TMA operations will be used to define the optimum combination of these two important variables. This combination will be checked for compatibility with other test results in Flight Test No. 9 prior to final prototype hardware design specifications.

TABLE 2.2 DATA STORAGE/CYCLE TIME MATRIX

Broadcast Data Cycle Time	WAYPOINT STORAGE CAPACITY 0	2	4	6
10 sec*	X	X		
30 sec	X	X	X	X
60 sec**	X	X		

* or minimum obtainable

** or maximum obtainable

FLIGHT TEST NO. 6: TRAFFIC FLOW TRANSITION

The basic operational analysis of the applications of the DDBS concepts recommended broadcasting a single traffic flow pattern in a given terminal area to reduce the broadcast data requirements. This is consistent with current procedures in complex TMAs such as New York. However, the successful demonstration of the procedures involved, elapsed time required and problems encountered will establish the creditability of this recommendation. The flight procedures for this test should include several flights by each pilot while in the DDBS navigation mode. Both SIDS and STARS should be executed during which the broadcast ground station data is changed to simulate an alternate traffic flow pattern. The ATC required maneuvers for the DDBS test aircraft should be documented as well as any problems such as DME outages reported by conventionally equipped aircraft in the TMA at the time of the traffic flow change. Pilot workload, blunder and FTE should also be monitored.

FLIGHT TEST NO. 7: AUTO SEQUENCING TEST

The purpose of this test will be to define the need for automatic waypoint sequencing by the DDBS I/U. Both printed routes and impromptu routes must be flown and data taken with complete manual I/U update and waypoint data insertion. Then, the routes should be repeated employing the automatic I/U update of active waypoint based on a To/From signal provided by the OBS or by the passage of zero DME distance.

FLIGHT TEST NO. 8: VNAV CAPABILITY ANALYSIS

Data taken thus far in the flight test program defines the feasibility of using broadcast data in the 2D RNAV environment. The purpose of this test is to determine whether or not the addition of 3D navigation responsibility is plausible using DDBS. The basic routes used for FLIGHT TEST No. 2 should be executed in random order by the five subject pilots only for this test specified waypoint altitudes will be imposed. The performance of the 3D maneuvers will be evaluated not only from the vertical deviation measured but also from the change in cross track error compared to the results of FLIGHT TEST NO. 2. This test should be run as late as possible in the overall program since in reality, a 3D equipped user will be proficient in 2D RNAV and it is desired to eliminate any RNAV or DDBS training effect errors as far as they influence the 3D capability.

FLIGHT TEST NO. 9: PREFERRED DESIGN SUBSTANTIATION

Based on the flight test experience and preliminary on-line data analysis, the best estimate of the preferred DDBS equipment design should be evaluated. The results from tests 3 through 8 will define the preferred waypoint nomenclature, maximum usable distance, waypoint storage, cycle time and sequencing procedures. These results must be evaluated for compatibility and verification purposes. Upon satisfactory completion of Flight Test No. 9, firm prototype DDBS hardware design specifications will be recommended.

2.2 Data Requirements

The information required to support the analysis of the DDBS Flight Test Program is outlined in Table 2.3. Three broad categories of data acquisition have been defined. Navigation data is required to verify aircraft position and maneuver accuracy both with and without broadcast supported RNAV and during preplanned and improvised route execution. Blunder data should be acquired in two broad categories describing total number of blunders, blunder rate per flight and blunder type (procedural navigation error or data handling errors). Finally, cockpit workload data including the number and frequency of required communications, navigation equipment operations and total head down time must be continually recorded to satisfy the prime objective of this test program, that is, quantified documentation of the advantages provided the pilot by application of DDBS to RNAV.

TABLE 2.3 DATA RECORDING REQUIREMENTS

NAVIGATION DATA

1. Cross Track Error - CDI needle deflection & sensitivity
2. Along Track Distance to Waypoint
3. Bearing with respect to the VOR
4. Distance to DME station - Distance and Slant Range Correction Specified
5. Altitude
6. Ground Speed (off DME)
7. Heading
8. Real Time
9. Event Marker for Time Correlation
10. Vertical Deviation - CDI needle deflection

BLUNDER DATA

Detailed handwritten or voice recording of:

1. Procedural Errors (turned wrong direction, improperly executed the clearance, etc.
2. Input Errors (improperly tuned frequency, bearing or OBS setting).

COCKPIT WORKLOAD

1. Record pilot/controller communications workload (total number of transmittals, total transmission time).
2. Record cockpit activity attendant to DDBS operations, RNAV system operations and outside influences such as weather, traffic, etc.
3. Record head down time.

3.0 PROCEDURES AND ENVIRONMENT

3.1 Pilot Selection

The individual pilots ability to utilize the DDBS capability is expected to vary with the total experience and currency of the subject. For purposes of this flight evaluation of DDBS the subject pilots should represent a range of experience and proficiency consistent with that of an average cross section of IFR qualified pilots. The subject pilots should possess a current instrument and multi-engine land rating.

As explained in section 2.0, the objective of the first flight will be to train the subject pilot to use the DDBS system, as well as orient the pilots to the flying qualities of the test aircraft. This portion of the flight test will also be utilized to perform the DDBS system checkout and will not be considered a data gathering flight for Flight Technical Error, FTE, and workload evaluation. This phase of the flight test will include five subject pilots orientation flights of approximately two hours each as well as contractors orientation and system check. The time allotted for this program is two weeks.

After the orientation flight the subject pilot should fly at least ten test patterns representing terminal area maneuvers for a duration of approximately one hour. This phase of the flight test will involve five subject pilots flying ten hours of data gathering flights over a period of two months. This will result in a total of 60 hours of flight test time.

In the subsequent flight tests the subject pilot will handle all aircraft control, communication, and navigation functions. The safety pilot will only intervene on situations that affect the safety of the flight. The safety pilot will be pilot in command.

3.2 Environment

The initial orientation flights should be made in VFR conditions with the subject pilot flying under simulated instrument conditions by means of an instrument training hood. After the DDBS system has been flight checked and the subject pilots are experienced in the operation of the aircraft and DDBS equipment, the experiment will proceed to the FTE and workload data gathering phase.

As weather conditions are one of the major variables known to influence pilot performance, this phase of the flight test should be set in as realistic an operational environment as possible and should take advantage of actual IFR weather conditions to the amount practicable during the two months of the test evaluation.

Another variable that should be investigated in this series of tests is the advantage of DDBS over conventional RNAV during a simulated flight emergency. During a simulated emergency, such as an engine failure, the pilot should have a lighter workload in his terminal area navigation with DDBS as opposed to conventional RNAV. The simulated emergency should reflect the difference in terms of FTE and workload in a time of abnormal level of cockpit workload and stress.

For each flight a space should be provided on the data log to enter pertinent environmental records. These records will include such factors as ceiling and visibility, surface wind and winds aloft, turbulence, and actual weather conditions, (snow, rain, fog).

3.3 Test Pattern

A test pattern will be generated for the terminal area in which the test will take place that reflects the standard RNAV terminal design model as described in The Task Force Report. See Figure 3.1.

For purposes of the flight test a subset of the idealized flow will be used. An example of the Palm Beach traffic flows for the east configuration at PBI is included for illustrative purposes, Figure 3.2.

3.4 ATC Procedures

The flight test should be organized so that on approximately fifty percent of the data gathering flights the subject will perform some form of ATC initiated delay maneuver such as delay fan, trombone or parallel offset as described in Sec. 2.3 of the Task A Report. For purposes of this experiment ATC should use the RNAV methods for spacing in place of Radar Vector on their own initiative to sequence the test aircraft with other IFR and VFR traffic.

Arrangements should be made with ATC to change runway configurations on each subject at least twice during the course of the experiment. This change would be after the pilot is established on an RNAV STAR but before reaching the Initial Approach Fix. This maneuver would be valuable for gathering data on the ability of the pilot to reorient himself using DDBS on a complex terminal area maneuver without the aid of a Radar Vector.

Another area of investigation should deal with transitions to satellite airports using a DDBS STAR and transitioning to conventional RNAV for the final transition and approach into the satellite field.

LAEWP	Low Altitude Enroute Waypoint	DLTWP	Downwind Leg Turning Waypoint
HAAWP	High Altitude Arrival Waypoint	BLTWP	Base Leg Turning Waypoint
HADWP	High Altitude Departure Waypoint	IF	Intermediate Waypoint or Fix
LAAWP	Low Altitude Arrival Waypoint	DF	Departure Waypoint or Fix
LADWP	Low Altitude Departure Waypoint		

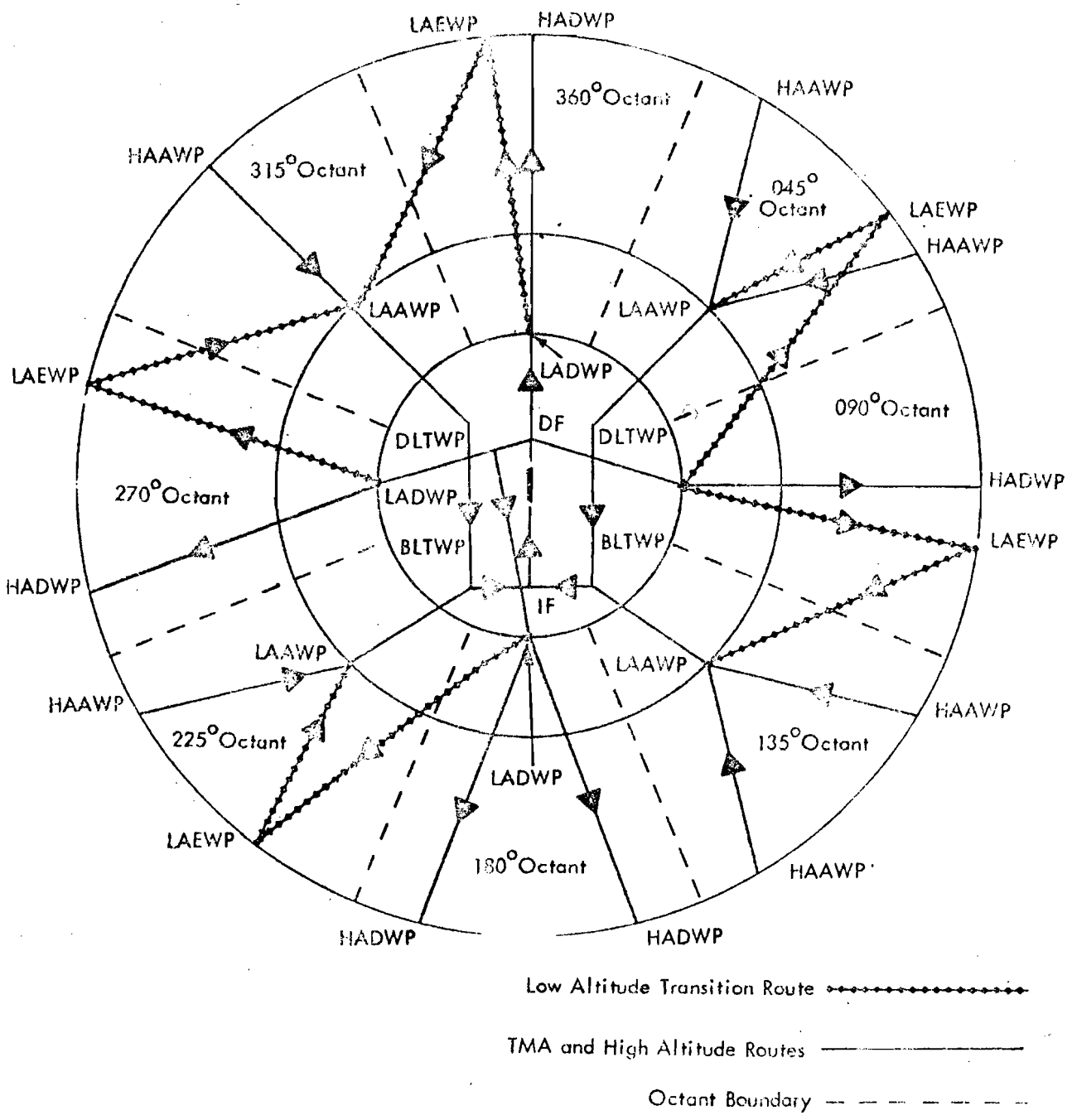

Figure 3.1 Standard RNAV Terminal Area Design

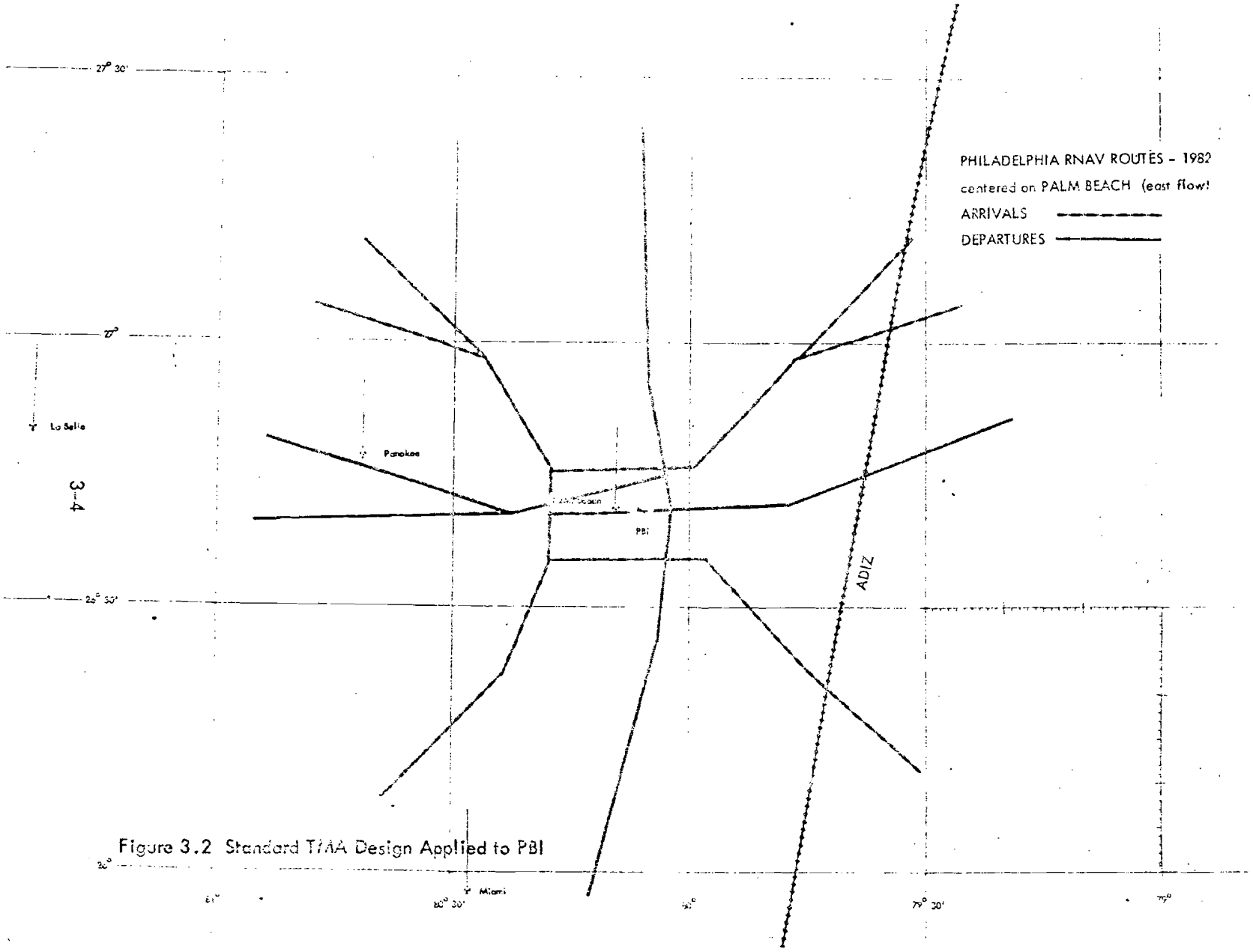

Figure 3.2 Standard TAA Design Applied to PBI

3.5 Location of the Test

The location of the DDBS flight test program has not been finalized at this time. However, several broad criteria are available as inputs to the final decision. This section describes those criteria and suggests two alternatives based on the current knowledge regarding the general criteria.

The first consideration impacting the choice of flight test execution is the magnitude of ground station modifications required to overlay the DDBS data on the existing DME signal structure. Corresponding to this criteria and of equal importance would be the difficulties incurred both during modification and during the program execution. Of primary concern is the anticipated VORTAC downtime and the support required to maintain satisfactory ground station performance for the entire duration of the flight tests.

The second criteria affecting test location should be the desirability of evaluating the DDBS concepts in a real world environment. Ideally, the test location should be a high density terminal area such as New York, Chicago, Los Angeles, etc. in order to demonstrate the most advantageous application of DDBS. Realizing the impracticalities of evaluating the DDBS concepts in any of these prime locations, the final choice should be made for the most realistic flight test environment as far as terminal area density is concerned.

A final basic consideration is overall program cost for both DDBS equipment, support personnel, aircraft and pilot subjects.

Regarding the first criteria, i.e., ease of modification and mod support during flight test, preliminary discussion during project coordination has produced the conclusion that the VORTAC modifications are relatively straightforward and little, if any, flight test support of the ground station would be required. Taking this as a base, the remaining criteria can be used as evaluation tools. Although this list of criteria is far from comprehensive, two alternative locations can be considered at this time. As additional criteria are developed, the choice of either one of these alternatives or some other location may evolve as predominantly advantageous. The current candidate locations are the NAFEC facilities at Atlantic City, New Jersey and the Palm Beach International Airport, PBI, in West Palm Beach, Florida. Following is a brief evaluation of each of these facilities based on the aforementioned preliminary criteria.

Performing the DDBS flight testing at the NAFEC facility offers the advantages of abundant technical assistance for both installation, debugging and maintenance of the

airborne DDBS & RNAV equipment. The possibility exists of obtaining data gathering assistance in the form of GFE'd instrumentation and experience and perhaps the data reduction effort. NAFEC also offers an abundance of suitable pilot subjects for evaluation of the DDBS operation. The disadvantages of flight testing at NAFEC include the fact that it represents a relatively low density test base rather than a close approximation to the real world "high density" TMA environment desired. In addition, the logistics and cost involved in supporting the DDBS flight test data acquisition and analysis with personnel assigned for the entire 2 month duration might prove prohibitive.

On the other hand, executing the flight test program at PBI would eliminate the data handling logistics problems and reduce the cost involved in providing analytical supporting personnel considerably. In addition, the PBI terminal area is a medium density operational base which more closely approximates the desired test environment suitable for a feasibility evaluation than does NAFEC. Finally, the DDBS flight test program closely relates to other CTI proposed flight test programs under consideration by the FAA at the present time. The inherent attractiveness of evaluating the DDBS concepts in the same environment and possibly for identical routes relates directly to the limitation of Flight Test No. 2 described earlier, that is, establishing a conventional RNAV data base suitable for a statistically significant evaluation of the advantages of DDBS. The major disadvantage of modifying the PBI VORTAC revolves about the basic criteria for ground station support. Should the DDBS modifications encounter reliability or maintainability problems, support of the necessary engineering and technician personnel could be costly.

4.0 ANTICIPATED RESULTS

The primary outcome of the DDBS flight test program will be the verification of the operational significance of DDBS concepts through flight test demonstrations and documentation. The reduction in cockpit workload provided by the additional waypoint storage capacity of the Interface Unit, the streamlining of the navigation task by reducing the number of required inputs and by simplifying the waypoint designation technique and the reduced blunder inherent in the DDBS environment will be determined through objective data analysis. In general, the operational and procedural feasibility of the application of the Digital Data Broadcast System concepts to RNAV will be evaluated. The specific analysis will include presentation of the following results:

1. DDBS hardware interface problems
2. Blunder data during transition from conventional RNAV to DDBS RNAV
3. Baseline cockpit workload comparison
4. "Head Down Time" requirements summary (RNAV with and without DDBS)
5. Pilot Questionnaire results
6. Procedural compatibility problems
7. Preferred DDBS equipment design configuration

These results will be presented in graphical and tabular form consistent with existing RNAV flight test data format to facilitate comparison with previous flight test results. The data analysis will provide answers to several existing questions. The conclusions to be drawn will take the form of direct answers to these questions. For example,

- DDBS reduces (or does not reduce) cockpit workload.
- DDBS reduces (or does not reduce) pilot blunders.
- DDBS reduces (or does not reduce) controller communications requirements.
- DDBS reduces (or does not reduce) Flight Technical Error.
- The preferred waypoint designation technique is the Route Numbering Concept (or the Discrete Waypoint Numbering Concept).
- DDBS does (or does not) offer significant operational advantages.
- The preferred waypoint storage capacity is _____.
- The optimum broadcast data stream cycle time is _____.
- Automatic waypoint sequencing is (or is not) desirable.
- VNAV imposes (or does not impose) too high a workload on the RNAV/DDBS user.