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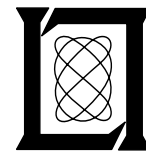
**Project Report
ATC-56**

**Discrete Address Beacon System (DABS)
Test Plan for FY 1976**

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14 November 1975

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16. Abstract <p>The major objectives of the continued DABS testing by Lincoln Laboratory are: (1) design validation and refinement, (2) performance assessment, and (3) the development of a data base of environmental characteristics.</p> <p>This document describes that portion of the test activities that will take place during FY 1976. Also included is a description of the special test facilities and techniques needed to collect and analyze the required data.</p>					
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Preface

Efforts on the DABS program during the past several years have resulted in a design of the DABS sensor and related equipment as defined in the DABS Engineering Requirement (ER) documents. To the extent possible, validation of this design has been carried out through analysis, simulation, and through experimentation using the DABS Experimental Facility (DABSEF). While much has been learned from these activities, the DABSEF site is quite benign in terms of siting and traffic related environmental conditions. To complete the validation process, the design must be exercised in environments more typical of the severe conditions present at many operational FAA sites.

A flexible and cost effective approach to accomplishing this validation is based on utilization of the TMF (Transportable Measurements Facility), which is basically a sensor "front end" plus data recording equipment. Data recorded at various sites by the TMF can be further processed using software that simulates the processing which would take place in a complete sensor. Such an approach permits ready modification of the sensor parameters, thresholds, etc., when required during the validation analyses. A similar approach for airborne measurements uses the AMF (Airborne Measurements Facility).

Once design validation is accomplished, then the next step is to assess the performance of the sensor. The resulting performance data will provide a baseline for comparison with existing ATCRBS equipment as well as with the Phase II sensors during the NAFEC test period. This latter activity will be one means of determining how well the contractor has met the design requirements.

Site environmental data are needed to interpret validation and performance results. This same data base will also permit an extrapolation of the performance of the Phase II sensors from the NAFEC environment to other sites having more severe siting conditions.

This document describes a test plan for accomplishing the objectives indicated above. Also included is a description of the special test facilities and techniques needed to collect and analyze the required data.

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1.0 OVERVIEW

1.1 Background

An effort to design a Discrete Address Beacon System (DABS) has been in progress at Lincoln Laboratory since early 1972. Phase I of this program reached a major milestone in November 1974, with the issuance by the FAA of a series of Engineering Requirements (ER) for the procurement of an engineering development model of DABS. The procurement includes three DABS sensors, a group of airborne transponders (for both general aviation and air carriers) and associated displays. The three sensors will be netted together to form an integrated DABS surveillance and communications system in the vicinity of NAFEC (National Aviation Facilities Experimental Center). Contract award for this procurement is expected to take place during CY 1975 and the Critical Design Review (CDR) is planned for the spring of 1976. Following delivery of the engineering model, Phase II of the DABS program will continue with test and evaluation of the system at NAFEC.

The DABS design specified in the Engineering Requirements documents is based upon a synthesis of many inputs: theoretical analyses, simulations, laboratory subsystem tests, tests at Lincoln Laboratory's DABS Experimental Facility (DABSEF), and study of ARTS and NAS en route data. Based upon all these, the system is expected to work to very high performance levels, and in fact does so at DABSEF insofar as the testing has progressed to date.

The next step in validating the design is to perform tests in areas where substantially greater traffic densities exist and where terrain and man-made structures present a variety of propagation environments.

1.2 Purposes of the Test Program

1.2.1 Design Validation and Refinement

A primary purpose of the test program is to verify that the DABS design performs properly under a wide variety of operational situations. To the extent possible within the limitation of the available time and resources, all subsystem designs will be validated. Outputs of this process will be the verification or adjustment of design parameters for acceptable performance and, where necessary, changes to the specified design. Design validation and refinement (DV&R) will be phased to match the DABS Critical Design Review (CDR). To the maximum extent possible, ER changes will be determined in time for that milestone. It is anticipated, however, that DV&R will continue beyond that time.

1.2.2 System Performance Assessment

A second major purpose is to make a comprehensive characterization of the DABS sensor performance after changes resulting from design validation and

refinement have been made. The major aspects of system performance to be assessed are position measurement accuracy, link reliability, and some characteristics of surveillance processing. Performance will be measured at several sites under a variety of traffic levels and other environmental conditions, and characterized by an appropriate set of figures of merit. Subsidiary to this general purpose, it is desired to develop a data base for a performance comparison between a baseline DABS sensor and the present surveillance subsystems of ARTS III and NAS Enroute.

1.2.3 Environmental Measurements

A third purpose is to develop a data base of environmental characteristics for use in conjunction with Phase II testing at NAFEC. This data base will characterize the environment at both uplink and downlink frequencies for a variety of site, traffic and interference conditions, and will be useful for the extrapolation of performance (as evaluated under test conditions at NAFEC) to future operational environments and sites.

1.3 Test Approach

Throughout the test program, there is emphasis on the selection of a suitable environment for a particular test. By the use of the portable facilities TMF (Transportable Measurements Facility, described in Section 2.2) and AMF (Airborne Measurements Facility, Section 2.3), a wide variety of environments are available so that a number of anticipated types of problem conditions will be encountered. Data collected in these environments will be returned to Lincoln Laboratory for data reduction and analysis using sensor simulation software developed at DABSEF.

The test sequence will be characterized by an orderly progression from the separate evaluation of various subsystems to assessments of overall system performance. This approach contrasts with a "go/no-go" test philosophy, which would be inappropriate for a developmental system, particularly one as complex as a DABS sensor.

The test plan contains a large number of specific test objectives, many of which require measurements under a variety of test conditions at more than one site. A set of tests that matched objectives in a one-for-one manner would therefore be impossibly large. Instead, a plan is presented in which a single test will support portions of different test objectives. Some of the objectives supported by a given test may serve the design validation and refinement purpose, while others simultaneously relate to the performance assessment purpose.

It is not possible to define in advance a complete, rigid test plan. There are two main reasons for this: a) as the design validation and refinement process is carried on, early results may affect the need for later tests; b) the sequence of tests in a schedule depends critically on the availability of facilities, equipment operating problems, logistics of flight plans and TMF installations, etc., which cannot be accurately predicted.

In comparison with the problem of assessing system performance of the ATCRBS mode, evaluation of DABS mode performance is constrained by two limitations: a) the very small number of experimental DABS transponders implies that effects dependent on heavy DABS-equipped traffic levels cannot be directly measured, and b) full DABS mode testing will initially be limited to the vicinity of DABSEF (since the TMF will not have an initial capability for generating the discrete address uplink DPSK waveform). Wherever appropriate, this situation will be addressed by using the analysis of ATCRBS data to produce estimates of DABS mode performance at the various sites.

1.4 Summary Schedule

Figure 1-1 gives the schedule of major test program events. A more complete schedule is given in Section 4.0.

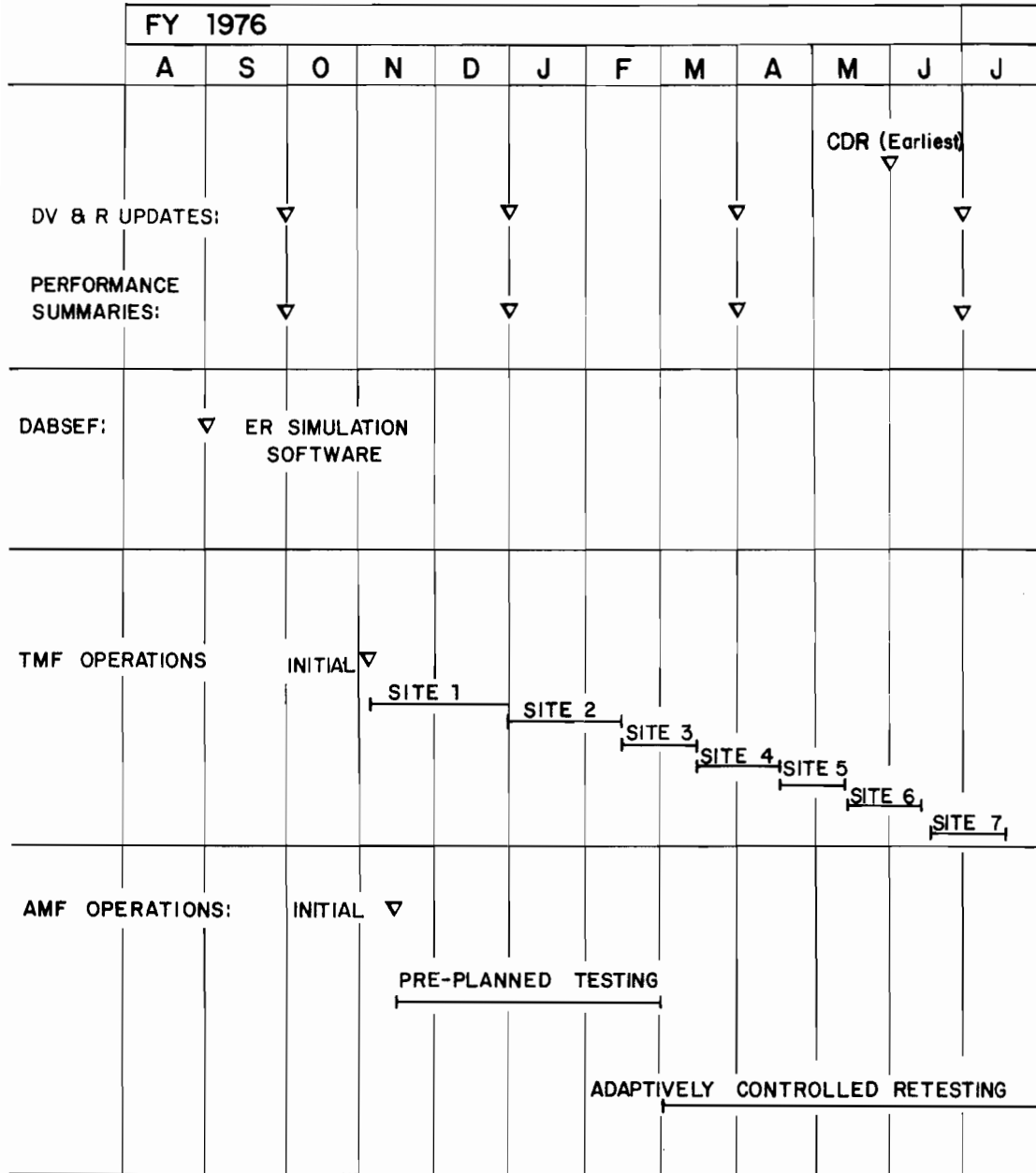


Fig. 1-1. Summary schedule.

2.0 TEST FACILITIES

The test activities detailed in this plan rely heavily on the use of special test facilities that have been developed as part of the DABS program effort. Each of these facilities will be described in turn in the following paragraphs.

2.1 DABS Experimental Facility (DABSEF)

A flexible experimental beacon test facility, commonly referred to as DABSEF (see Figures 2-1 and 2-2), has been implemented during the DABS system definition phase. This facility is located on a hill adjacent to Lincoln Laboratory and overlooking Hanscom Field. The purpose of developing and operating this facility has not only been the simulation of a prototype DABS sensor, but also the provision of a versatile instrument capable of ready adaptation to a wide variety of DABS experiments.

Initial DABSEF activity was directed at establishing DABS RF link parameters, determining the degree of immunity of the signal formats to interference, and selecting antenna characteristics consistent with direction finding accuracy requirements. More recently DABSEF has been augmented, primarily in software and displays, to become the focal point of experimental activities to support the validation of the DABS sensor design as well as evaluation of the IPC concept.

Core elements of DABSEF are a monopulse antenna, monopulse receiver, transmitter, DABS and ATCRBS reply processors, a medium-size general purpose computer, and a large repertoire of real-time control and data processing software programs.

The experimental sensor antenna, an L-Band, 8' x 22', 512-element (16 x 32) mechanically rotated planar array, is normally rotated at 4 seconds per scan, but may be placed in an angle track mode to spotlight targets or ground areas of interest. The antenna has three ports corresponding to three radiation patterns: the normal directional sum pattern (Σ), the monopulse difference pattern (Δ), and an omnidirectional pattern (Ω) for transmit and receive sidelobe suppression.

The monopulse receiving system converts Σ , Δ and Ω antenna output signals to IF and video. The video outputs consist of $\log |\Sigma|$, $\log |\Omega|$, and two outputs pertaining to azimuth estimation, specifically approximations to $\text{Re} (\Delta/\Sigma)$ and $\text{Im} (\Delta/\Sigma)$. A video pulse quantizer accepts video $\log |\Sigma|$ signals and converts to binary quantized video.

DABS and ATCRBS reply processors accept the video and binary quantized video signals and process them to obtain range and azimuth estimates for each reply as well as message bit estimates and an associated confidence bit for



Fig. 2-1. DABS Experimental Facility

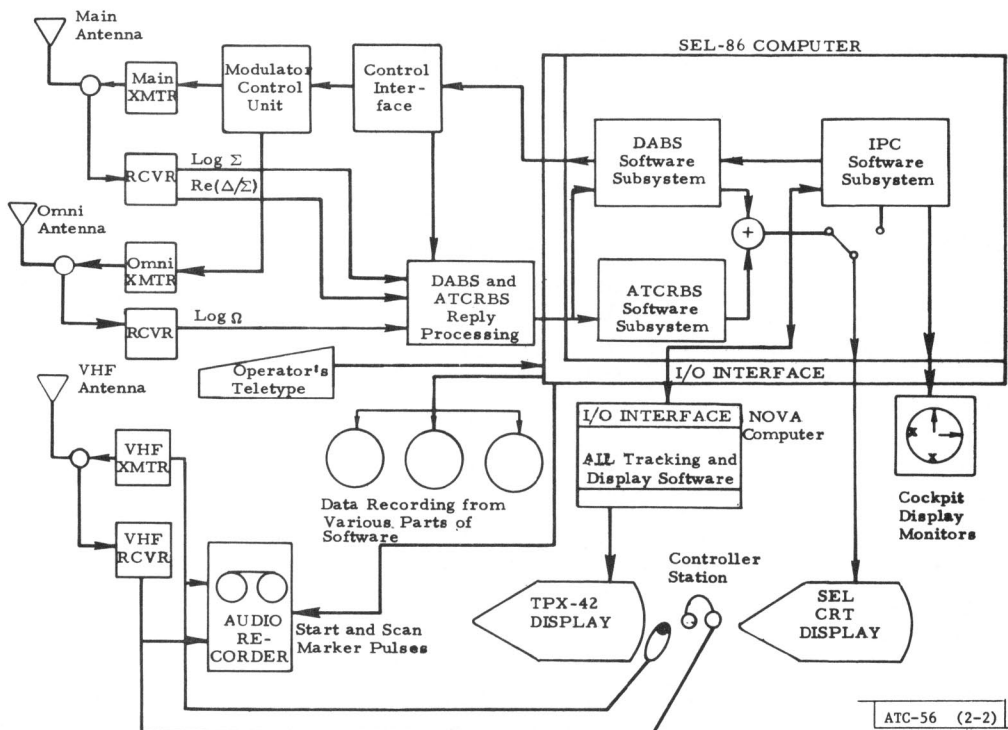


Fig. 2-2. DABSEF block diagram.

ATC-56 (2-2)

each message bit. The DABS processor contains a preamble detector, message bit processor, monopulse estimator and error detection and correction circuitry. The ATCRBS reply processor contains a bracket detector, garble sensing and phantom elimination logic, code extraction logic, and monopulse estimator.

The DABSEF computer is a System Engineering Laboratories (SEL) Model 86, a 32-bit word, medium-size, general purpose machine with high speed I/O channels, eight general registers, a memory cycle time of 600 nanoseconds, and a 65,536-word memory. A number of special peripherals permit off-line data playback, data reduction, x-y printouts, and various types of data analysis. A 22-inch plan-position indicator (PPI) display has been interfaced with the SEL 86 computer.

During the more than two-year period in which DABSEF has been in operation, a sizeable repertoire of real-time and off-line programs has been developed for controlling DABSEF and analyzing data. The first programs to be developed were for an experimental mode in which only one or two DABS transponder-equipped aircraft were of interest. This software permitted antenna spotlighting, issuing specially formatted interrogations, tracking a single DABS equipped aircraft, and performing special forms of real-time surveillance processing.

Recently developed "sensor demonstration programs" have extended DABSEF real-time capability to the simultaneous interrogation and tracking of several dozen aircraft (using interleaved ATCRBS/DABS All-Call and DABS discrete interrogations), to the dynamic re-interrogation of aircraft, to improved IPC tracking, to the generation of conflict resolution commands, and to the complete recording of IPC flight data including audio communications. These and other changes currently being implemented will result in an "ER version" of DABSEF, more nearly resembling an engineering development model sensor.

Additional details of DABSEF are presented in Reference 1.

2.2 Transportable Measurements Facility (TMF)

The TMF is basically the "front end" of a DABS sensor including a choice of two antennas, a transmitter and a receiver. The output of the receiver is digitized video, which in an actual sensor would be interfaced with the ATCRBS and DABS reply processors. In the TMF, this digitized video is recorded, along with timing and other information. The TMF data thus recorded at the operational site locations will be returned to Lincoln Laboratory for data reduction and evaluation. This will include playback of the recorded digitized video through simulated ATCRBS and DABS reply processors. The resulting target reports will then be operated upon by the surveillance processing routines. Analysis of the output of these programs will serve to validate and characterize DABS design performance.

As indicated above, the TMF will be operated in problem areas that offer high traffic densities and unusual siting difficulties. A preliminary list of selected sites along with the rationale for site selection is presented in paragraph 4.2.1.

At each location it will be desirable to position the TMF close to and at the same height as an existing ATCRBS sensor in order to experience similar environmental conditions. The distance between the two will be chosen so as not to create interference of any sort to the operational sensor. The length of stay at each location is dependent upon the ability of the TMF to collect adequate data for a reasonable evaluation of the DABS sensor processor. This is anticipated to be on the order of a month.

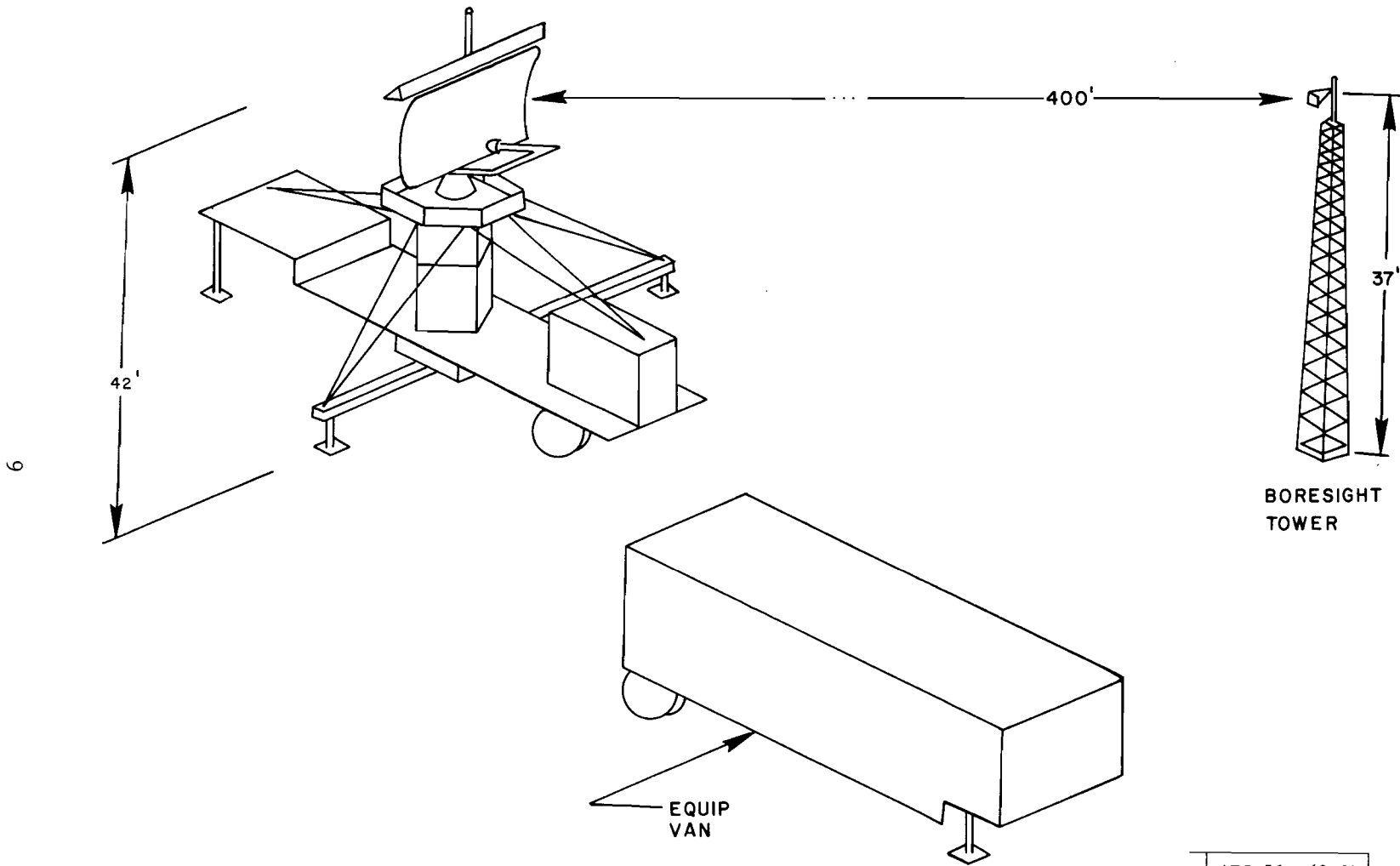
Figure 2-3 is an artist's conception of the TMF facility as configured with the normal tower height. In most instances, the tower height will be chosen to place the center of the TMF antenna level with the existing ATCRBS interrogator antenna. An alternate high tower configuration is provided for areas where the antenna height is required to be up to 54 feet from ground level.

A block diagram of the TMF is presented in Figure 2-4. Additional details of the TMF are provided in Reference 2.

2.3 Airborne Measurements Facility (AMF)

The Airborne Measurements Facility (AMF) provides a means of obtaining recorded data representing pulsed electromagnetic signals received on either of the two ATCRBS frequency bands (1030-MHz uplink, 1090 MHz downlink). This information is necessary in order to characterize the environment present at operating sites. Specifically, AMF has the capability to provide data for the following purposes:

- a) General environmental characterization:
This contributes to the assessment of uplink reliability by providing the distribution of interfering pulses on 1030 MHz.
- b) Site radiation characterization:
This data will support studies of performance issues sensitive to the sensor antenna radiation patterns. Examples are the magnitude of ground reflected signal occurring at various sites, and the occurrence of sidelobe punchthrough due to differential lobing.
- c) Air-to-air characterization:
This data will contribute to performance analysis of the air-to-air link.



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Fig. 2-3. TMF short tower configuration.

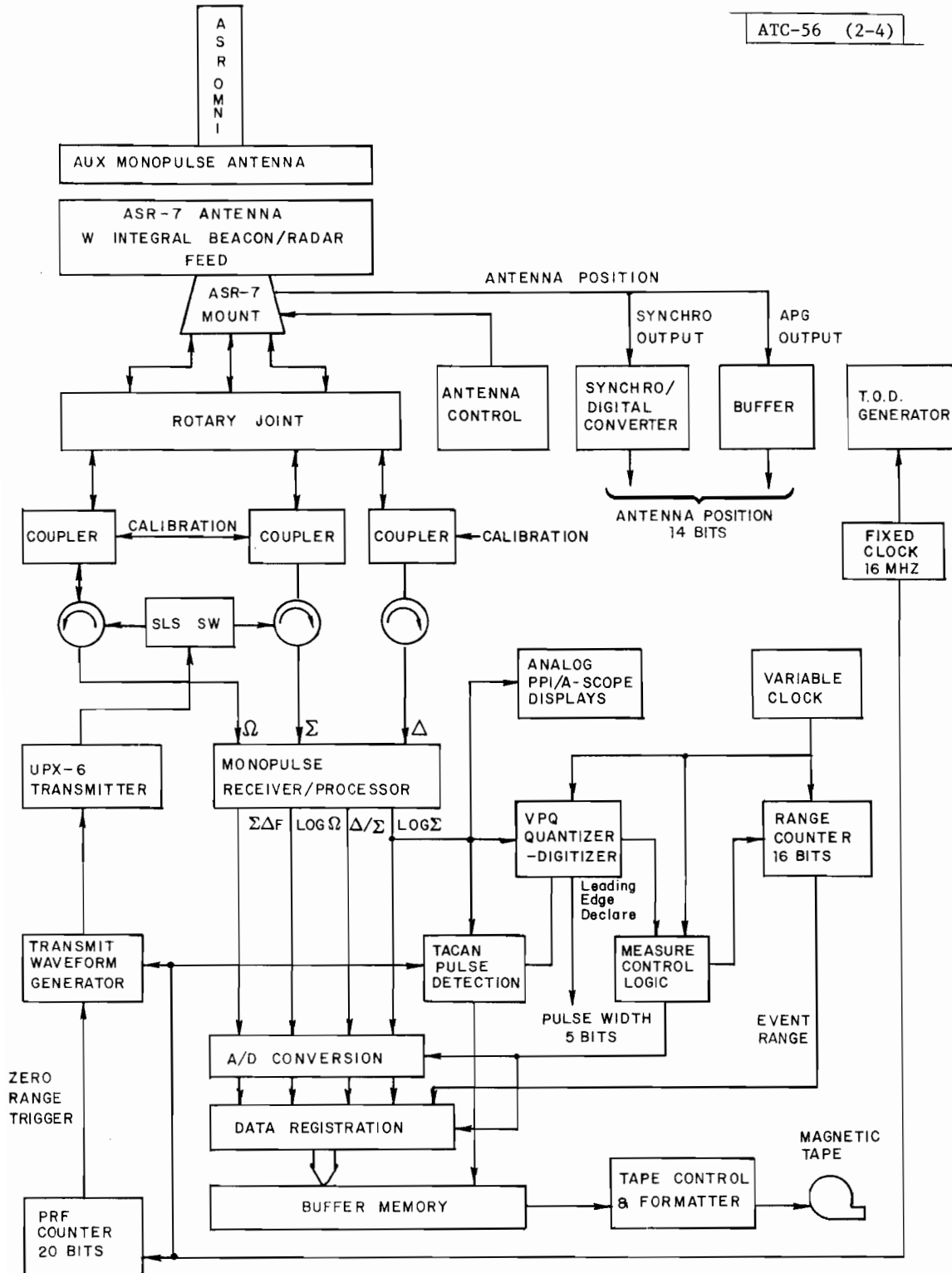


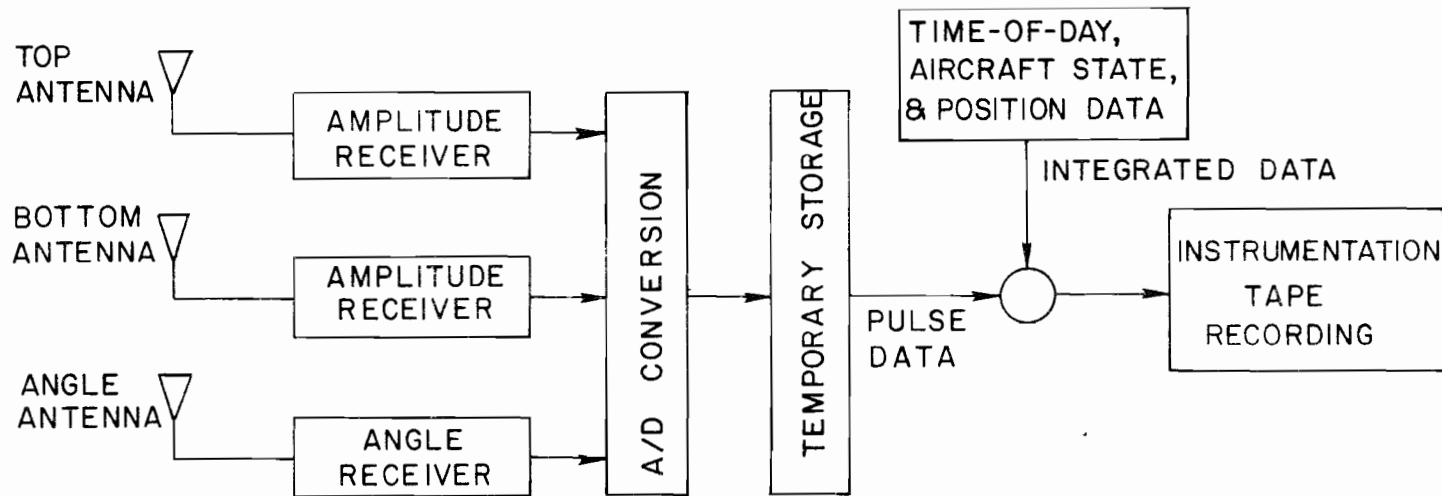
Fig. 2-4. TMF block diagram.

The AMF consists of two subsystems as indicated in Figure 2-5. The airborne subsystem provides for the reception of signals in the selected band, conversion to digital data samples, and storage on instrumentation-type magnetic tape of the digitized signals along with data representing aircraft state and position. The ground subsystem provides a means for playing back the recorded data, an interface that couples the data to an existing mini-computer for data editing and reformatting, and a tape transport and associated controller to re-record the data onto general purpose computer tape. The resultant tape will permit data analysis on a large computer.

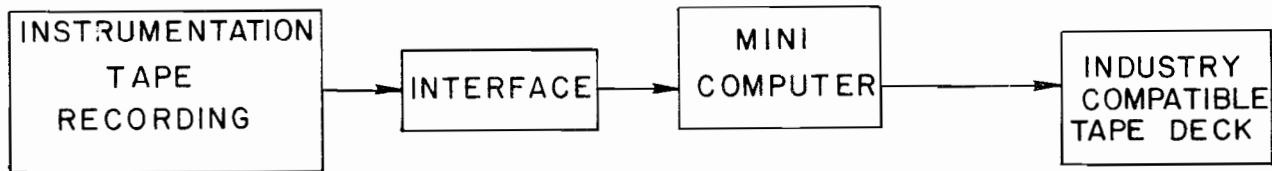
A detailed description of the AMF is given in Reference 3.

2.4 Cooperative Aircraft

Most of the traffic contributing to test measurements will be targets of opportunity. However, certain tests require a cooperating aircraft to fly particular paths, execute particular maneuvers, reply with a DABS waveform, etc. Several general aviation aircraft have been equipped with DABS transponders and other test equipment in support of the IPC test program. These aircraft, as well as the AMF, are available to serve as cooperating flight test aircraft.



AIRBORNE SUBSYSTEM



GROUND SUBSYSTEM

Fig. 2-5. AMF block diagram.

3.0 TEST OBJECTIVES

The first test program objective is to validate the DABS design under a variety of traffic and environmental conditions. If design refinements are required as a result of the testing, they will be implemented. A key input to this effort is the site data provided by the portable measurement facilities.

The section test objective is to assess the performance of the validated sensor design across a spectrum of site environments. This will include comparing the performance of a DABS sensor with that of existing ATCRBS equipment.

The final objective is the development of a data base of environmental measurements. This data base is needed to (1) interpret the results of the validation and assessment activities, and (2) extrapolate the performance of the Phase II sensors from the NAFEC environment to other sites having more severe operating conditions.

The first two objectives should logically be accomplished in sequence, since performance assessment cannot be completed until all design features have been validated. However, many design validation tests cannot be performed until data from the TMF sites is available. Because some design refinements could affect the "front end" elements used in the TMF recording, it is necessary for the TMF to collect sufficient data to support both the design validation and performance assessment objective during a single site visit. This means that TMF data must be taken at each site for all combinations of the "front end" design issues open at the time of the measurements.

3.1 Design Validation and Refinement

Design validation and refinement is a process in which the DABS sensor and transponder designs are evaluated experimentally to the extent possible with existing and planned facilities in order to determine the correctness of those designs at various traffic levels and at sites having different propagation (multipath, obstruction) conditions from those normally seen at DABSEF.

3.1.1 Design Validation Performance Measures

The performance measures for validation concern the quality of the sensor output data, i.e., the measures refer to how faithfully the data sent to the ATC facilities represent the actual state of the reported aircraft. The major categories of performance measures are defined as follows:

- a) Position Accuracy - a comparison of the reported position (range, azimuth and altitude) with the true position of the aircraft.
- b) Link Reliability - the success rate of reporting real aircraft each scan ("blip/scan ratio"), and the statistics of run lengths of misses on successive scans.

- c) Report Source Identification - the correctness of track correlation for real returns, flagging of false returns, and elimination of fruit.
- d) Report Data Accuracy - the statistics of downlink data errors.
- e) Surveillance Processing - performance of the surveillance processing algorithms, specifically
 - ATCRBS report-to-track correlation
 - ATCRBS false target flagging (more than one report for a single target)
 - Zenith cone performance (i.e., ability to re-acquire targets after coasting through the zenith cone)
 - DABS target acquisition (i.e., delay between first All-Call reply and establishment of firm track)
 - Azimuth predictions for channel management (i.e., ability of the tracker to support the interrogation scheduling function)

Test data will be compared to criteria based on expected sensor performance in these categories. From this, a judgment will be made as to the acceptability of the performance.

To accomplish the above, it is assumed that the "true" aircraft position and identity can be discerned. Two techniques that have been used before are curve fitting and track linking algorithms, and employment of ARTS or NAS en route data for the same time periods.

In any system that has redundancy or automatic retry capability, an evaluation restricted to only the output performance may not give an accurate assessment of true system operation. In a given test situation, the overall system may perform perfectly while in fact some subsystem may have failed and been replaced by redundant elements, or the subsystem simply tried until it succeeded. Characterization of individual subsystem performance permits an understanding of the extrapolated conditions under which the total system performance will degrade.

Not all redundancy designed into DABS is realized in pre-Phase II equipment. However, certain data can be examined to help infer extrapolated performance at even higher traffic and interference levels than those that can actually be tested in 1975/1976. Examples of the types of data to be taken for this purpose are:

- a) DABS single try round reliability. This indicates how many dynamically scheduled tries are required to get through once per scan.
- b) Frequency of garbled ATCRBS replies, even though the report was satisfactorily reconstructed for that scan. This indicates the severity of interference and permits an extrapolation to other interference levels.

- c) Occurrence of synchronously garbled ATRCBS replies.
- d) Occurrence of range or azimuth splits in the ATRCBS mode.

3.1.2 Environmental Conditions

Each of the aspects of system performance listed above is to be tested under an appropriate set of environmental conditions. These conditions are varied primarily by site selection, and, to a lesser degree, by directing the taking of data to appropriate portions of the air space, flying experimental aircraft at particular times and places, etc. The major types of environmental conditions to be encountered are:

- a) Ideal conditions, defined as the absence of all factors which tend to degrade performance. This situation may be approximated by using a single cooperative aircraft in a low-traffic, low-interference environment with favorable geometry. Performance measurements under these conditions will indicate the limiting performance of which the system is capable and will hence provide reference marks for comparing performance in other environments.
- b) Transponder non-uniformities, particularly transmitter carrier frequency, downlink waveform, reply delay, power, and sensitivity. These effects will be achieved using data from existing traffic regarded as targets of opportunity.
- c) Interference, both uplink and downlink. This factor is divided into two types: external interference (caused by sources other than the DABS experimental interrogator), and synchronous garble (resulting from replies from other transponders triggered by the DABS interrogator).
- d) Multipath, extraneous transmissions caused by reflections of structures or terrain. There are three distinct effects, depending on the character of the reflector and the relative geometry of the interrogator, reflector, and target: discrete (producing replies delayed sufficiently as to be received "in the clear"), garbling (producing replies with shorter delays which overlay the direct path reply), and lobing (producing very short delays which cause link fades by interference with the direct path reply).
- e) Obstruction effects, caused by buildings, towers, trees, and terrain features. It has been learned that many obstructions produce both fading and azimuth errors.

3.1.3 Test Objective Matrix

For each aspect of system performance identified in Section 3.1.1, there is a particular selection of environmental conditions from Section 3.1.2 which is relevant to the test program. These selections comprise a test objective matrix for system performance testing, as shown in Figure 3-1.

SYSTEM ASPECTS TO BE TESTED		ENVIRONMENTAL CONDITIONS							
		Ideal Conditions	Transponder Nonuniformities	INTERFERENCE		MULTIPATH			OBSTRUCTION
				Uplink & Downlink External Interf.	Sync. Garble	Discrete	Garbling	Lobing	
Azimuth Accuracy	DABS	X	X	X			X	X	X
	ATCRBS	X	X	X	X		X	X	X
Range Accuracy	DABS	X		X			X	X	X
	ATCRBS	X	X	X	X		X	X	X
Link Reliability	DABS	X		X			X	X	X
	ATCRBS	X	X	X	X		X	X	X
Report Source Identification		X	X	X	X		X	X	X
Report Data Accuracy		X	X	X	X		X	X	X
Target-to-Track Correlation (ATCRBS)		X	X	X	X				X
False Target Flagging (ATCRBS)				X		X	X		
Zenith Cone Performance	DABS	X		X					
	ATCRBS	X	X	X					
Az. Prediction For Ch. Management (DABS)		X		X					X
Target Acquisition (DABS)		X		X					

Fig. 3-1. Test objective matrix (system performance tests).

3.1.4 Design Refinement

Whenever the validation criteria are not met, the following process begins:

- a) Examine data in greater detail to determine the cause of the performance deficiency.
- b) Develop and implement an appropriate modification.
- c) Subject the refined design to the same test to verify that it now meets the criteria.

Generally, this process of troubleshooting and refinement requires the finest grain look at the data. To provide for this eventuality, much data will be recorded, but only subjected to the fine scrutiny when needed to locate problems.

3.2 System Performance Assessment

The final results of the DV&R testing (described in subsection 3.1) will be summarized by an assessment of the performance of the final system design. The resulting benchmark performance levels will be useful during the later evaluation of DABS engineering development models (Phase II). Emphasis will be placed on characterizing range and azimuth measurement accuracy, link reliability, and surveillance processing (particularly target acquisition and track correlation performance). Environments will be selected to exercise each aspect of performance appropriately, including such factors as transponder non-uniformities, interference, multipath, and obstruction effects.

In connection with this test objective, a comparison is to be made of DABS performance with that of existing FAA beacon systems (principally the surveillance subsystem of ARTS III, but also the en route system using the Common Digitizer and the NAS Stage A tracking algorithms). Two modes of comparison are important: 1) using signals from the TMF antenna and receiver, which are then processed by simulated ARTS III algorithms in comparison with the same data processed by DABS software, and 2) full side-by-side comparison of the two systems. No additional tests are implied beyond those required for DABS performance assessment, but it will be necessary to record matching data from the existing beacon system.

3.3 Supporting Environmental Measurements

It is desired to develop a data base of environmental measurements under various site, traffic and interference conditions. Although many of the measurements can be included in tests carrying out objectives described earlier, they serve a purpose apart from system performance assessment, i.e., the measurements are intended for use in connection with Phase II testing at NAFEC. In that context, analyses of data obtained with the DABS engineering models (at

New Jersey and Philadelphia), together with the environmental data, will permit extrapolations of DABS performance to other sites having more severe environments. The particular kinds of effects to be measured include:

- a) Transponder statistics, including receiver sensitivity, transmitter power, reply frequency, waveform (pulse width and spacing), and reply delay (including jitter, variations caused by signal strength, and Mode A/ Mode C differences)
- b) Interference, uplink and downlink
- c) Site characteristics, including false target reflectors, monopulse characteristics, lobing, garble multipath, and coverage effects
- d) Existing ATCRBS interrogator characteristics, including IISLS performance and antenna patterns
- e) Airborne antenna diversity
- f) Special link characterization (e.g., the environment of the interrogation and reply links when the aircraft is not airborne).

4.0 GENERAL TEST PLAN

The previous sections of this plan have described the DABS test facilities and test objectives. The manner in which the facilities will be used to accomplish these objectives is addressed in this section.

4.1 Sequence of Tests

Each test objective from Section 3.0 has been associated with a test facility or facilities to be used in acquiring the necessary data. This association is given in Table 4-1. The test sequence for each facility, according to present plans, is diagrammed in Figure 4-1. The diagram shows the scheduled changes in test facility locations, indicates the nature of tests as a function of time, and also shows the scheduled times of related events such as reports, performance updates, and DV&R (design validation and refinement) updates. The test sequence as planned is a consequence of many considerations, primarily those summarized in the following paragraphs.

4.1.1 Reasons for Carefully Sequencing Tests

Careful sequencing of the tests is important for several reasons:

- a) Certain objectives are more time-critical than others (e.g., those relating to possible hardware changes in the ER-240-26 design), and should be scheduled for a time early in the test program.
- b) Some measurements require "controlled" or single-variable tests.
- c) There is a possibility that changes in a subsystem may invalidate tests already performed.
- d) Equipment availability imposes constraints on the test sequence, e.g., the use of the DABS-equipped aircraft must be coordinated with IPC test plans involving these same aircraft.

The degree of impact resulting from a design change depends on how near the changed system element is to the sensor front end (i.e., antenna or receiver). Subsystems near the output end, if changed, will impact the fewest tests of the other subsystems. It follows that the test sequence should emphasize the subsystems near the front end early in the program.

Although there is a need for controlled tests, it is expected, nevertheless, to be possible for investigations of several subsystems to be carried out simultaneously using common data tapes. This simultaneous use of data tapes will be accomplished by systematic use of "frozen" subsystem design versions.

Table 4-1. Objectives vs facilities.

OBJECTIVE	ASSOCIATED TEST FACILITIES							
	DABSEF	TMF					AMF	COOPERATIVE AIRCRAFT
		NORMAL	MULTIPATH	INTER-FERENCE	DENSE TRAFFIC	OBSTRUCTION		
<u>DV & R</u>	X	X	X	X	X	X		X
<u>SYSTEM PERFORMANCE</u>	X	X	X	X	X	X		X
·PERFORMANCE MEAS.								
·COMPARISON WITH ARTS/CD			X	X	X	X		
<u>ENVIRON.-- TRANSPONDER STAT.</u>	X	X						
·SENSITIVITY, POWER		X						
·PULSE WIDTH, SPACING, FREQ. DELAY		X						
<u>--INTERFERENCE</u>							X	
·UPLINK								
·DOWNLINK				X				
<u>--SITE CHARACT.</u>	X		X					
·FALSE TARGETS								
·MONOPULSE	X		X			X		X
·FADING	X		X			X	X	X
·GARBLE MULTIPATH			X				X	
·COVERAGE		X					X	X
<u>--EXISTING SENSORS</u>							X	
·IISLS								
·ANTENNA PATTERNS							X	
--AIR DIVERSITY	X						X	X
--SPECIAL LINK CHARACT.		X	X				X	X

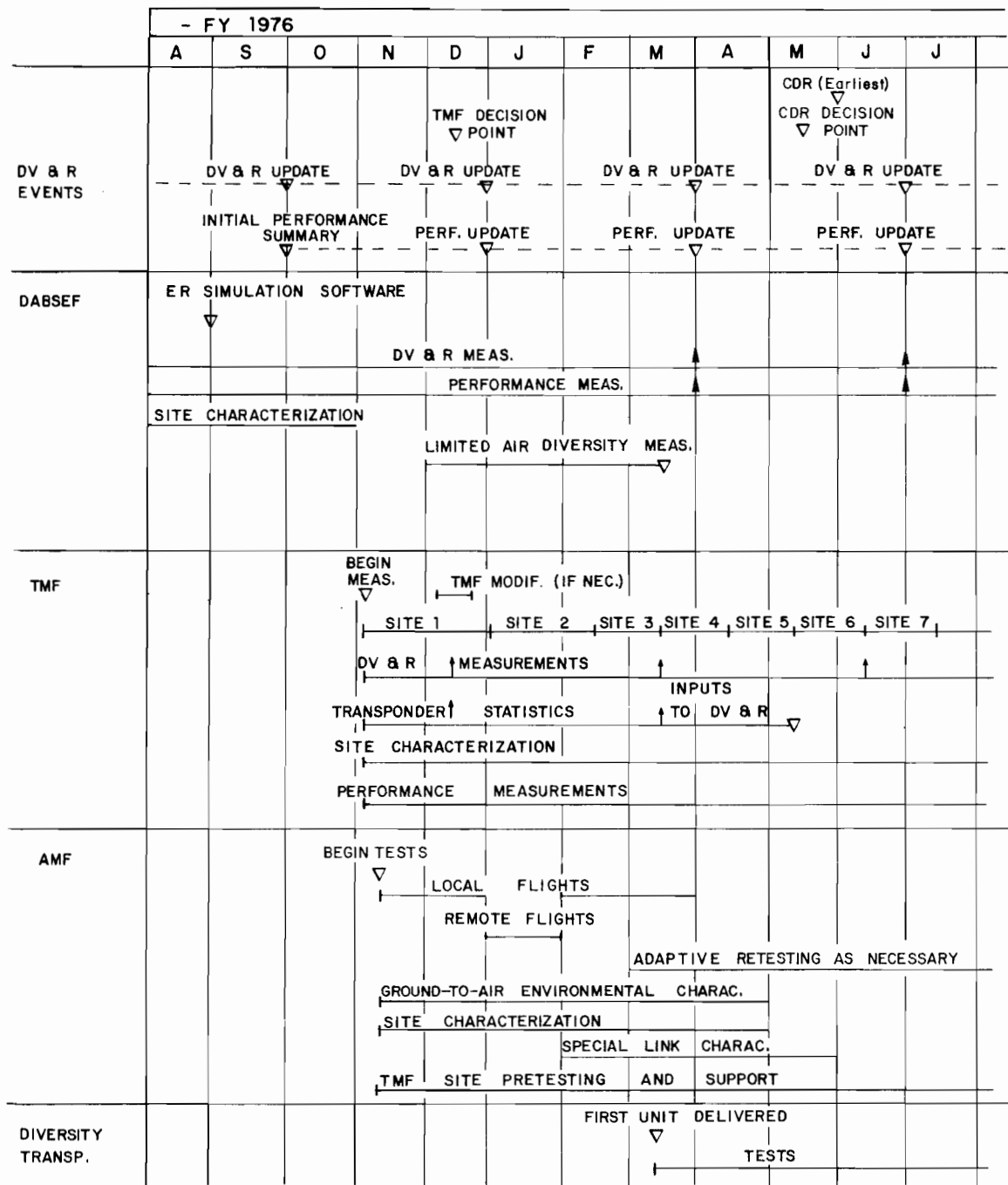


Fig. 4-1. Overall test sequence.

4.1.2 Identification of the Most Time-Critical Objectives

The objectives that are most time-critical fall into three categories:

- a) DV&R objectives which are needed by CDR
- b) DV&R objectives which may affect TMF recording
- c) Performance summary figures of merit for use in guiding DV&R.

Since data recorded by the TMF are already conditioned by the receiver and video pulse quantizer (VPQ), it follows that design changes in these subsystems could invalidate data already recorded at the time of the change. As a consequence, certain activities and events constrain the TMF test plan, e.g., in early use of the TMF some tapes will be recorded without sensitivity time control (STC) or dynamic threshold for the purpose of channel measurement rather than for direct application of the DABS signal processing functions. Suitable parameter settings for STC and dynamic threshold will be determined from these channel measurements. In addition, at each site multiple TMF data tapes will be recorded, one for each of several receiver/VPQ options. As an additional precaution, a decision point in mid-December is defined for the purpose of revising the TMF recording conditions if necessary.

System performance summaries are considered time-critical because of the role they play in guiding DV&R activities. When a design improvement becomes identified, the judgment as to whether or not to actually adopt the change in design will be based on, among other things, the degree of improvement in overall system performance that would result.

4.1.3 Milestones

Several program milestones and decision points have been adopted to reflect the time-critical nature of the above objectives.

- a) TMF Decision Point, 15 December 1975. Best decisions will be made as of this date on the issues affecting TMF recording. If necessary, the TMF will be correspondingly modified.
- b) CDR Decision Point, 1 June 1976 at the earliest (six months after award of contract). Best decisions as of the CDR date will be made on all design issues.

4.2 Test Site Selection and Data Recording

4.2.1 TMF

The selection of TMF test sites is based on three considerations:

- a) Validation of the DABS design in realistic environments which include problems found at today's ATCRBS sites

- b) Side-by-side comparisons with the existing ATCRBS equipment
- c) The acquisition of site characterization data in a form that indicates the extent to which performance can be improved by local siting changes (i.e., relocation within several miles)

When a list of TMF sites is selected to exercise the DABS design in realistic problem environments, then this same list will serve the purpose of enabling side-by-side comparisons. In addition, one or more sites must be added to the list because of consideration (c), siting changes vs performance.

The various site and other environmental characteristics that affect sensor operation are present to varying degrees at different sites, e.g., the Los Angeles Airport site is generally associated with false targets and a high traffic load, and the Las Vegas Airport site is generally associated with garbling multipath; whereas the DABSEF site is generally benign in these respects. Figure 4-2 tabulates an association according to present information of the site and environmental characteristics of interest vs site location. Based on this information and various practical considerations, the following TMF site selections have been made.

- TMF site 1 -- Boston, Logan Airport
- TMF site 1A -- Boston, Deer Island
- TMF site 2 -- Washington National Airport
- TMF site 3 -- Las Vegas, McCarran Field
- TMF site 3A -- Las Vegas, enroute
- TMF site 4 -- Los Angeles International Airport
- TMF site 5 -- North Platte, enroute
- TMF site 6 -- Miami International Airport
- TMF site 7 -- NAFEC

An example of a practical consideration which affected the list is the fact that the existing Newark and New York ATCRBS installations do not have the capability of generating ARTS III or comparable tapes (tapes that include reply-by-reply data). The Deer Island and Las Vegas enroute sites have been placed on the list because of consideration (c) above. The NAFEC site is included to provide baseline data for assessment of the performance of the Phase II sensors.

It should be recognized that the site vs environment information indicated in Figure 4-2 is incomplete to a considerable degree; the large majority of existing FAA sites have not been analyzed in a way that would indicate the prevalence of these environmental characteristics. As a result, the above TMF site list is preliminary and may be revised as new information becomes available.

Prior to recording in the TMF, signals are processed by the monopulse receiver and the VPQ. At this point, the signals are recorded digitally onto magnetic tape in a computer-compatible format. The maximum rate at which

ENVIRONMENTAL CHARACTERISTICS

TRAFFIC	FALSE TARGETS	GARBLE MULTIPATH	VERTICAL LOBING	OBSTRUCTION	INTERFERENCE	
	X		X	X		BOSTON, LOGAN AIRPORT
X					X	PHILA, INTL. AIRPORT
X	X				X	TREVOSE, ENROUTE
X	X				X	NEWARK AIRPORT
X					X	N.Y., KENNEDY AIRPORT
X			X		X	CHICAGO, O'HARE AIRPORT
	X					N. PLATTE, ENROUTE
	X	X		X		LAS VEGAS AIRPORT
X	X		X	X	X	LOS ANGELES INTL. AIRPORT
	X			X		WASH. INTL. AIRPORT
			X			MIAMI INTL. AIRPORT

RADAR BEACON INTERROGATOR SITE

Fig. 4-2. Environmental characteristics of interest at each sensor site.

information can be recorded is such that with an interrogation rate of 100 per second and an antenna beamwidth of 6 degrees, the ATRBS target load can be as high as approximately 200 aircraft with a 4:1 azimuth bunching factor (including a proportionate amount of ATRBS fruit). When recording is performed at this rate, a single reel of tape will be filled in approximately 3 or 4 minutes.

The sequence of recording operations at one site will include the following: (a) data over the full range out to 100 miles, (b) data covering at least 20 minutes continuous time, obtained by reducing the range and/or azimuth windows as necessary, (c) data exercising receiver and VPQ design variables for DV&R investigations, (d) data for certain nonstandard receiver and VPQ design variable settings to guard against the need for re-testing later, (e) data taken in the continuous sampling (free-running) mode for channel measurement purposes, (f) data that includes DABS All-Call replies, and (g) data taken with the alternate TMF antenna. Current plans call for the following recording sequence.

- a) Begin with the ASR antenna, normal sampling mode, and targets of opportunity. Record one full tape over the full 100-nmi-range window (or a reduced range window if necessary to prevent data rate overload). Obtain simultaneous ARTS/CD data.
- b) If tape (a) is less than approximately 20 minutes of real time, then record a 20-minute tape by reduction of the range and/or azimuth windows. Obtain simultaneous ARTS/CD tape.
- c) Record one tape exercising other receiver/VPQ variables for DV&R purposes.
- d) Repeat (a) in the free-running mode including a DABS All-Call target.
- e) Repeat (d) without STC and dynamic threshold (for channel measurement).
- f) Repeat (a) for a number of receiver/VPQ design options.
- g) Site characterization measurements using dedicated aircraft targets.
- h) Repeat (a) using the alternate antenna.

4.2.1.1 Typical TMF Cycle for One Site

The cycle of events which will occur beginning when the TMF is packed and ready to be transported to the next site includes the following activities (each with a nominal time estimate).

- a) Transportation (by road), 1 to 4 days

- b) Set up, 3 to 4 days depending on the use of the antenna tower (with anchor points to be prepared in advance)
- c) Checkout (including equipment checkout and electromagnetic compatibility with existing FAA facilities), 2 days
- d) Measurement (including antenna changes, and simultaneous tests with the collocated FAA sensor; primarily using targets of opportunity)
- e) Data reduction and feedback (including transportation of data tapes to Lincoln Laboratory)
- f) Adaptive retesting (which may involve a change in test procedure and equipment modification, and/or tests with dedicated targets)
- g) Pack up, 2 to 3 days

} 3 weeks

The actual times that will be required for these steps cannot be predicted accurately because of contingencies that can develop as a result of weather, coordination with cooperative aircraft, coordination with trucking and crane services, and equipment debugging. The time estimates given here are applicable to a case in which major contingencies do not occur; however, the estimates do include allowances for routine minor contingencies. Altogether these estimates add up to a full cycle time of approximately a month.

4.2.2 AMF

Selection of flight areas and flight paths for the AMF is based on the AMF test objectives presented earlier in Table 4-1. Figure 4-3 lists these AMF objectives in somewhat more detail, with the list divided according to the two basic AMF capabilities: measurement of the full uplink environment, and measurement of the radiation characteristics of particular interrogators. The figure also gives an association of the objectives with flight areas and flight paths. Based on this information, it is tentatively decided to carry out AMF tests in the following areas:

Local flights

- Boston-N.Y.-Washington, D.C. (including, for air-to-air tests, paths over ocean, city, suburbs, farmland, and mountains)

Remote flights

- Chicago
- Los Angeles
- Las Vegas
- North Platte

AMF MEASUREMENT OBJECTIVES

MISC.	MEASUREMENTS FOCUSING ON PARTICULAR INTERESTS				MEASUREMENTS OF FULL UPLINK ENVIRONMENT					
	MEASURE GROUND-TO-AIR MULTIPATH	MEASURE INTERROGATOR ANTENNA PATTERNS	MEASURE VERTICAL LOBING & COVERAGE	INVESTIGATE ISSUES ANOMALY	MEASURE TRANSPONDER REPLY PROBABILITY	MEASURE POPULATION OF INTERROGATORS	HIGH-INTERFERENCE ANALYSIS	HIGH INTERROGATION-RATE ANALYSIS	MEASURE AVERAGE SIGNAL RATES	
			X							BOSTON
					X			X	X	NEW YORK
					X		X	X	X	PHILADELPHIA
				X			X	X	X	WASH., D. C.
			X				X	X	X	CHICAGO
		X								LAS VEGAS
			X		X		X	X	X	LOS ANGELES
		X								N. PLATTE
X										OVER OCEAN, MOUNTAINS
		X	X		X	X	X	X	X	UNSTRUCTURED FLIGHTS OVER MAJOR CITIES
				X						RADIAL FLIGHTS
				X						CONSTANT-RANGE FLIGHTS
X	X									TWO-AIRCRAFT FLIGHTS
X										TYPICAL TAXI ROUTES

FLIGHT AREAS OF SPECIAL INTEREST

APPROPRIATE AIR-CRAFT PATHS

Fig. 4-3. AMF objectives vs flight areas and flight paths.

In addition, the AMF will be used to pretest TMF sites, and may be used in cooperation with the TMF to monitor the uplink during TMF measurements, or simply as a dedicated target.

The AMF is considerably more flexible than the TMF in its ability to gather data over a large geographical area within a short period of time and to move to an entirely new geographical area on short notice. As a result, AMF tests will take advantage of a high degree of adaptability in response to data reduction results.

The AMF testing schedule, according to present plans, was diagrammed in Figure 4-1.

Information from Figure 4-3 can also be used to plan AMF flight paths. It is evident from the figure that most of the objectives can be satisfied with unstructured flights passing over major cities. It is planned that such flights will constitute the backbone of the AMF flight program. Additional flights planned are the following:

- a) Radial and constant-range flights centered about each of two existing ATCRBS installations -- Logan Airport and Washington National Airport (for lobing and coverage measurements)
- b) Radial flights for each of the following existing ATCRBS installations -- Andrews AFB, JFK Airport, Hartford Bradley Field, Trevoise enroute interrogator, Chicago O'Hare Airport, Las Vegas Airport, North Platte enroute interrogator, and Los Angeles Airport
- c) Flights combined with a second dedicated aircraft for air-to-air diversity measurements and cross-link multipath measurements over ocean, city, mountains, etc.

The AMF records digital information on a constant-speed tape recorder that can be set at any of four speeds. When operated at the highest recording speed, the AMF can handle incoming pulse rates up to approximately 32,000 pulses per second, and in this case a full tape is completed in approximately 15 minutes. The other recording speeds trade pulse rate for real-time duration of a tape by factors of 2, 4, and 8. It is expected that the two highest speeds will not be necessary in most flight areas. However, in certain high activity areas (notably around Philadelphia) the second highest and possibly the highest speed will be required.

4.3 Data Processing

The major data processing capabilities that are to be used in conjunction with DABSEF, the TMF, and the AMF are diagrammed in Figure 4-4. Most of the computer programs illustrated are already in existence, having been developed over the past year in connection with DV&R activities underway and in antici-

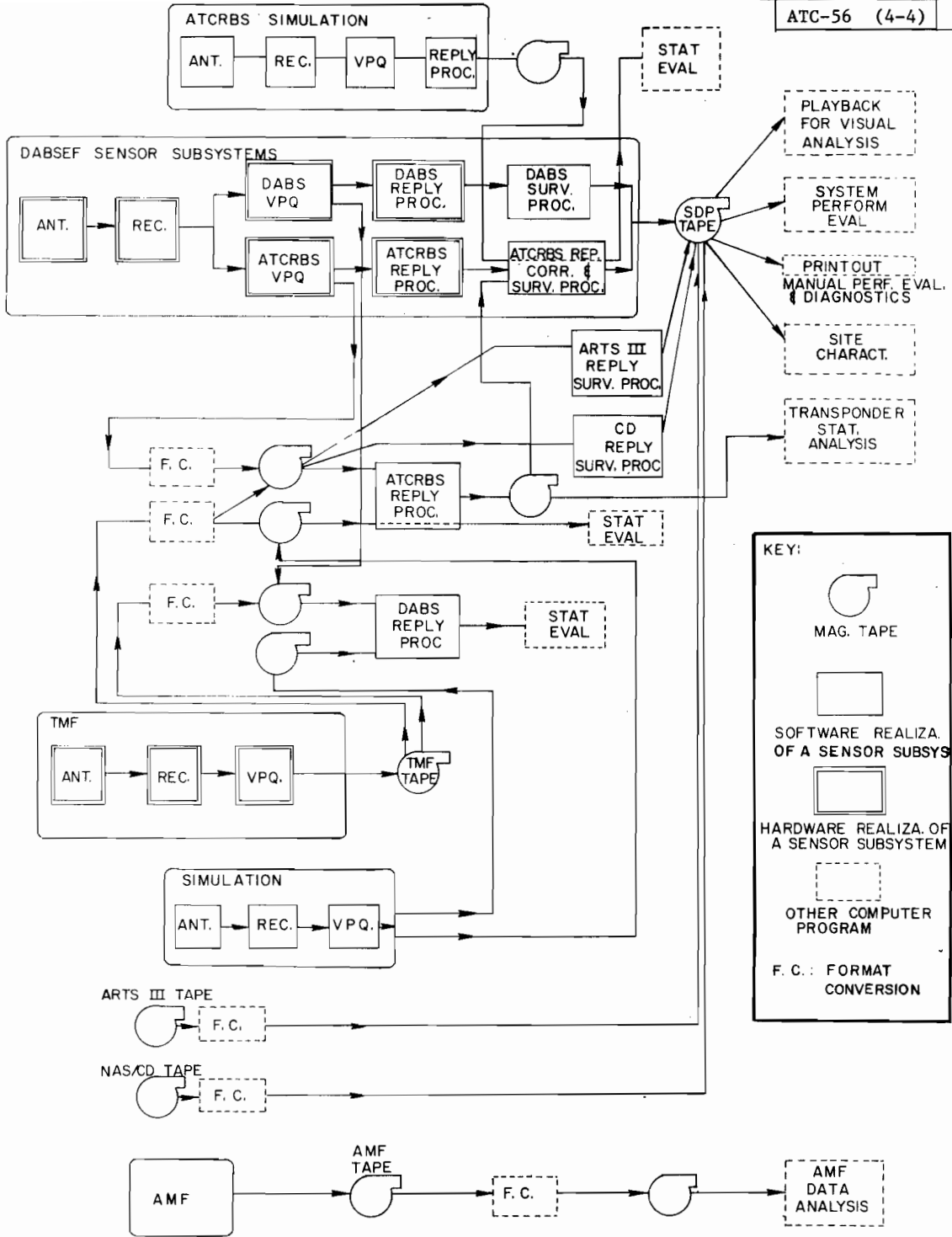


Fig. 4-4. Data reduction capabilities.

pation of the availability of AMF and TMF data. The programs related to DV&R, performance evaluation, and side-by-side comparison are interconnected to a large degree; whereas the AMF related programs are generally disjoint from these. As shown in the diagram, some of the programs represent subsystems of a DABS sensor while other programs are for data handling or data evaluation purposes. Taken together these programs allow both DABSEF and TMF data to be subjected to the functions and algorithms of each of the subsystems of a DABS sensor and then allow the resulting performance to be examined in detail.

4.4 Reporting of Results

DV&R and performance results will be reported quarterly as part of the regular DABS Quarterly Technical Summary. These reports will cover the following topics:

- a) Changes in the DABS E.R.'s
- b) DABS performance
- c) Statistics of ATCRBS transponders
- d) Ground-to-air link measurements
- e) Beacon site characterization
- f) Special link characterization
- g) Air-diversity measurements (this report will be combined with results from an analytical investigation in progress based on model aircraft measurements)

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