Report No. FAA-CT-81-158

FLIGHT TESTS OF THE AMERICAN ELECTRONIC LABORATORIES, INC. (AEL)/NARCO LOW COST GENERAL AVIATION MICROWAVE LANDING SYSTEM (MLS) RECEIVER

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PROJECT PLAN

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1. INTRODUCTION.

1.1 OBJECTIVE.

The objective is to evaluate performance characteristics of a low cost Microwave Landing System (MLS) receiver (American Electronic Laboratories, Inc. (AEL)/ NARCO Avionics) through comparative flight tests with a standard Bendix receiver. The analog outputs and system flags to the pilot's course deviation indicator (CDI) from both units will be compared for relative performance in the proportional guidance region, the clearance (fly left/right, up/down) region, and out-of-coverage (side lobe suppression (SLS)) region. In addition, comparative flight data will be collected using a number of different MLS ground systems, each in a different locale. Digital angle data will not be collected from both receivers because a special parallel to serial interface unit is not available to modify the nonstandard AEL/NARCO output.

1.2 BACKGROUND.

The MLS time reference scanning beam (TRSB) technique has been accepted by the International Civil Aviation Organization (ICAO) for international implementation. This project will provide receiver performance data in the various coverage regions before the planned MLS Fly-In for general aviation aircraft at Philadelphia International Airport. If the AEL/NARCO receiver performance data are acceptable, a second receiver will be installed in a single-engine general aviation aircraft and used for MLS demonstration flights at the Fly-In as part of the Service Test and Evaluation Program (STEP). STEP is designed to provide operational experience during the transition from MLS research and development (R&D) efforts to actual MLS field implementation. The AEL/NARCO receiver was designed as a low cost receiver for general aviation (GA) use. Thus, the data from this and related efforts in conjunction with STEP may motivate industry to develop low cost MLS Avionics systems that meet GA requirements.

1.3 RELATED DOCUMENTATION/PROJECTS.

The AEL/NARCO receiver is presently being tested by the National Aeronautics and Space Administration (NASA) Ames Research Center, Moffett Field, California, for accuracy in the proportional guidance region using the digital output angle data. Simultaneously, Bendix receiver angle accuracy measurements are also being performed at Moffett Field. The analog data to be collected at the Federal Aviation Administration (FAA) Technical Center will be used to complement the digital accuracy data.

After completion of the effort by NASA, the receiver will be transferred to CALSPAN Corporation, Buffalo, New York. At CALSPAN the receiver will be tested primarily for its susceptibility to multipath (signal reflection) conditions. Personnel from the FAA Technical Center will participate in the CALSPAN tests for receiver familiarization purposes. The primary documents that will be used in this effort are:

a. Bendix Receiver Maintenance Manual, I.B. 1157C.
b. AEL/NARCO Receiver Task III Report, by J.B. Hager and J.P. Van Cleave.
c. Bendix Airborne Test Set Maintenance Manual, T.I. 6850.27.

2. SYSTEM/EQUIPMENT DESCRIPTION.

2.1 MLS SIGNAL FORMAT.

The MLS full signal format is shown in figure 1. The MLS azimuth and elevation signal formats are shown in figures 2 and 3. Presently, two types of signal formats exist for the two types of azimuth systems — the Small Community System for general aviation and the Basic System which provides for expanded coverage and more flexible approach flightpaths than the Small Community System. The Small Community Azimuth System generally provides proportional coverage out to ±10° and clearance or fly right/left pulses out to ±40°. The Basic Systems may provide azimuth proportional guidance out to ±60° but does not transmit fly left/right pulses. Both azimuth systems provide for out-of-coverage signals, i.e., back SLS, right SLS, and left SLS.

The elevation format for both systems, shown in figure 3, does not provide clearance pulses, i.e., fly up/down, and it only provides for an upper SLS signal (out-of-coverage). The Small Community elevation proportional coverage region is 1.9° to 10.67°. The elevation scanning beams are adjusted to provide coverage between the proportional coverage region and the out-of-coverage region, i.e., the clearance region. The elevation beam only scans as high as necessary to provide full-scale deflection on the CDI, i.e., fly up or fly down indication.

2.2 AEL/NARCO Receiver.

A functional block diagram of this receiver is shown in figure 4. This unit uses a remote radiofrequency (RF) signal head with an integral antenna which has an intermediate frequency (IF) output to the panel mounted receiver. The RF head will be mounted just below the base of the windshield on the Technical Center's Aerocommander aircraft (N-50). The CDI analog output from the panel mounted receiver will be fed to a cockpit mounted CDI and an analog strip-chart recorder. The AEL/NARCO receiver has a digital angle output which is at a high rate (250 hertz (Hz)) and parallel, which is not compatible with existing MLS digital data recording equipment installed in the Aerocommander.

2.3 Bendix Receiver.

A functional block diagram of the Bendix receiver is shown in figure 5. The Bendix receiver does not employ a remote RF head but, instead, an omnidirectional antenna mounted between the nose and the base of the windshield of the Aerocommander. Its analog output will be fed to two CDI's and an analog strip chart recorder. In addition, the digital output will be recorded on magnetic tape.

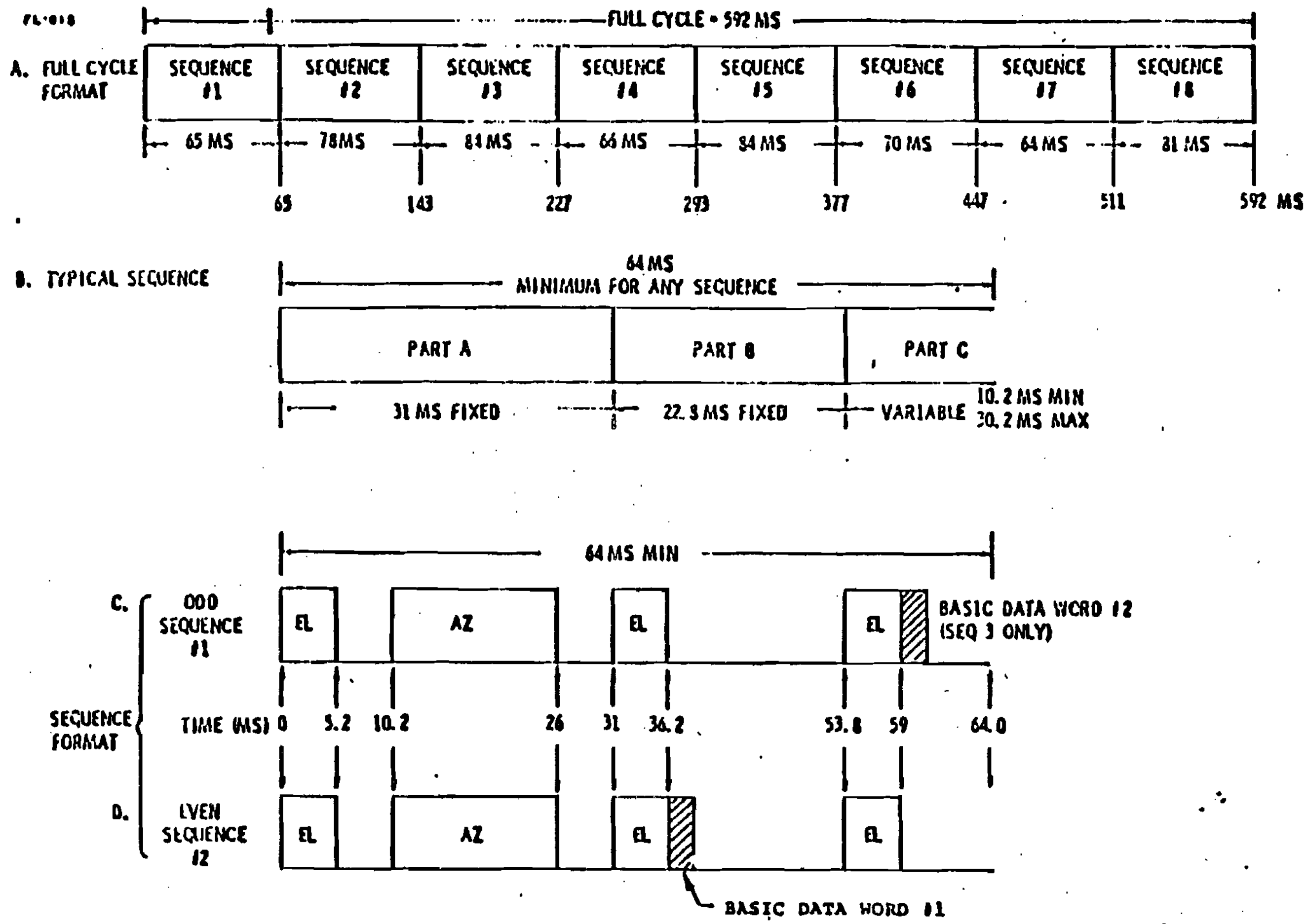

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FIGURE 1. MLS SIGNAL FORMAT

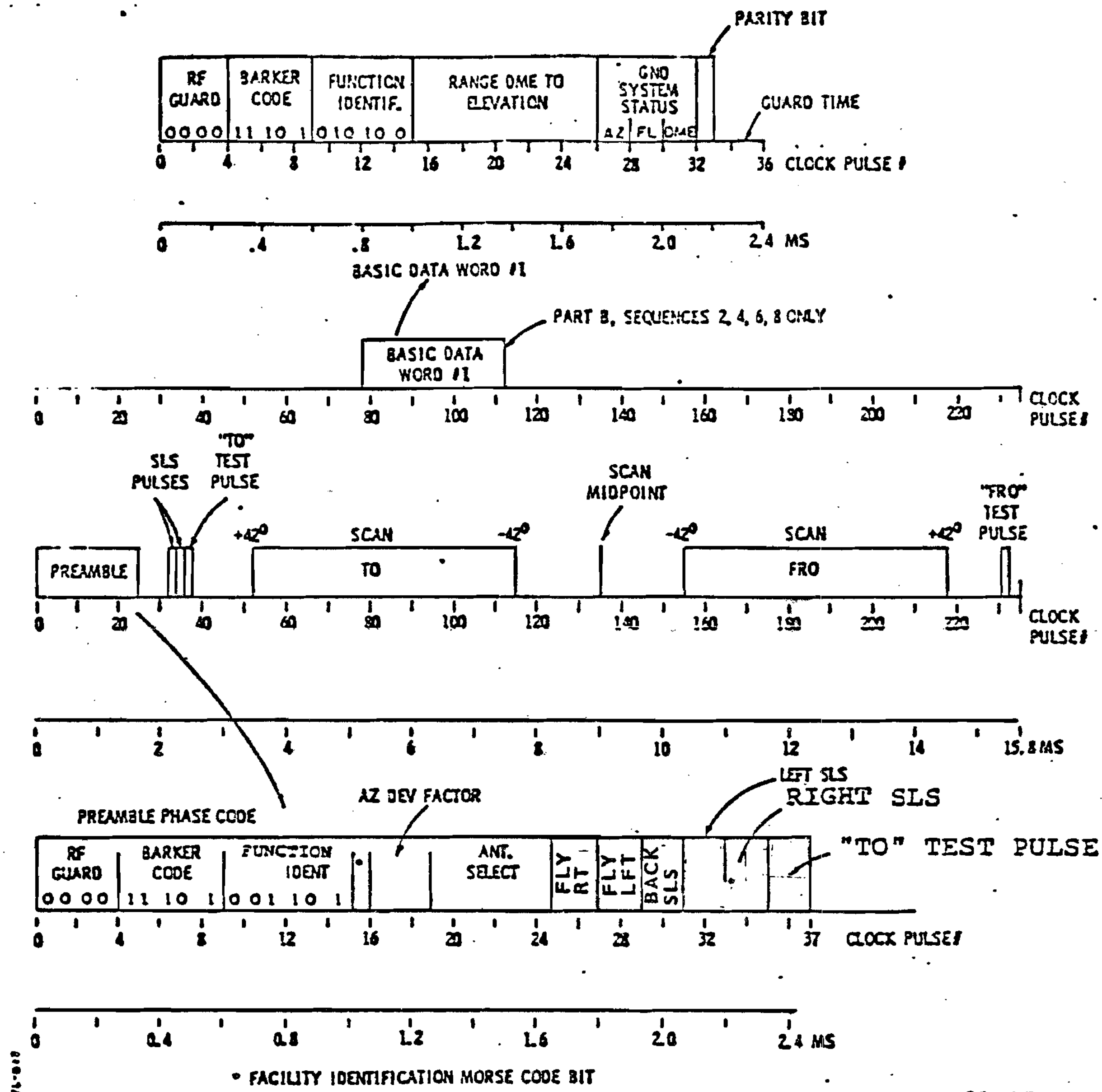

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FIGURE 2. AZIMUTH SIGNAL FORMAT

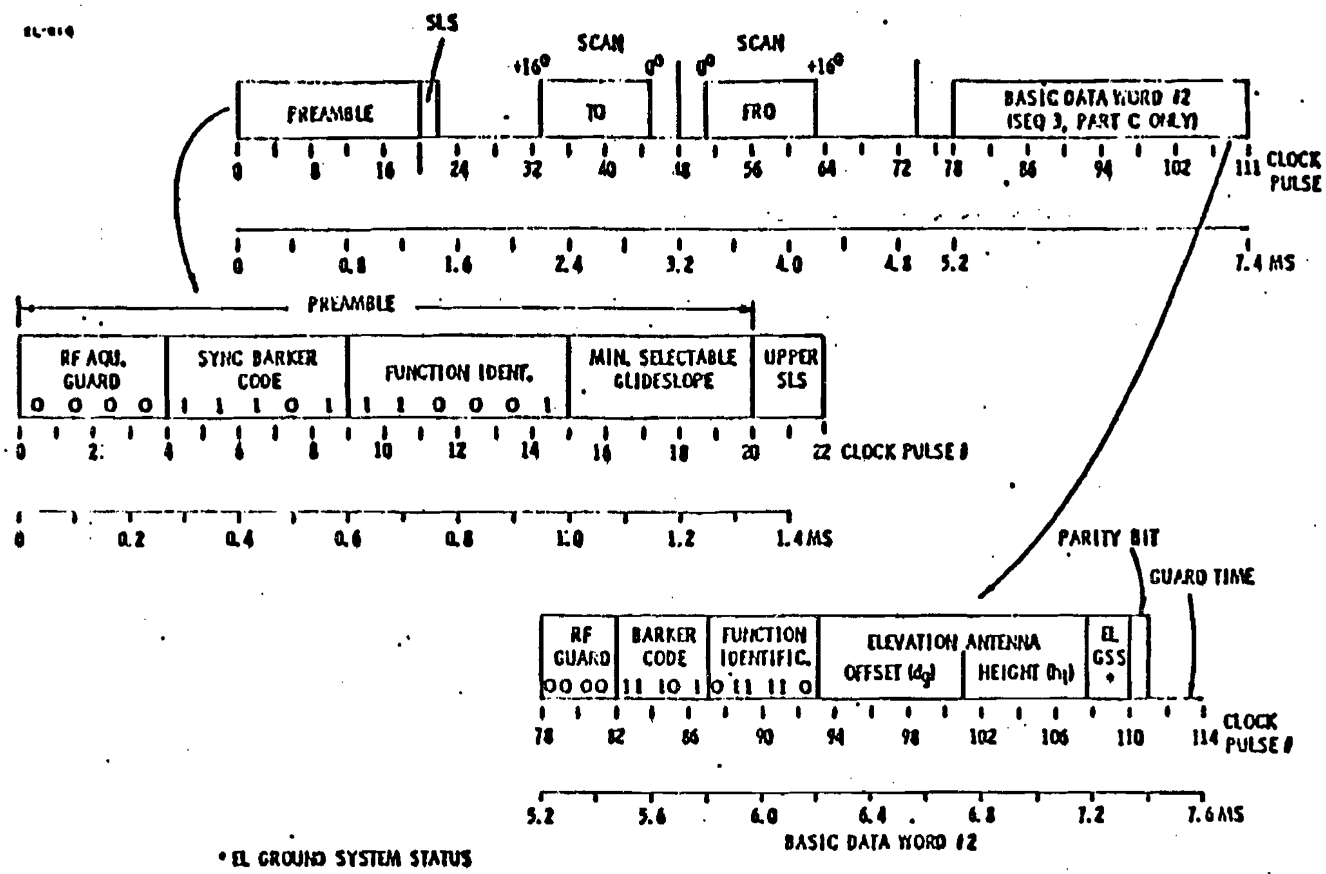

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FIGURE 3. ELEVATION SIGNAL FORMAT

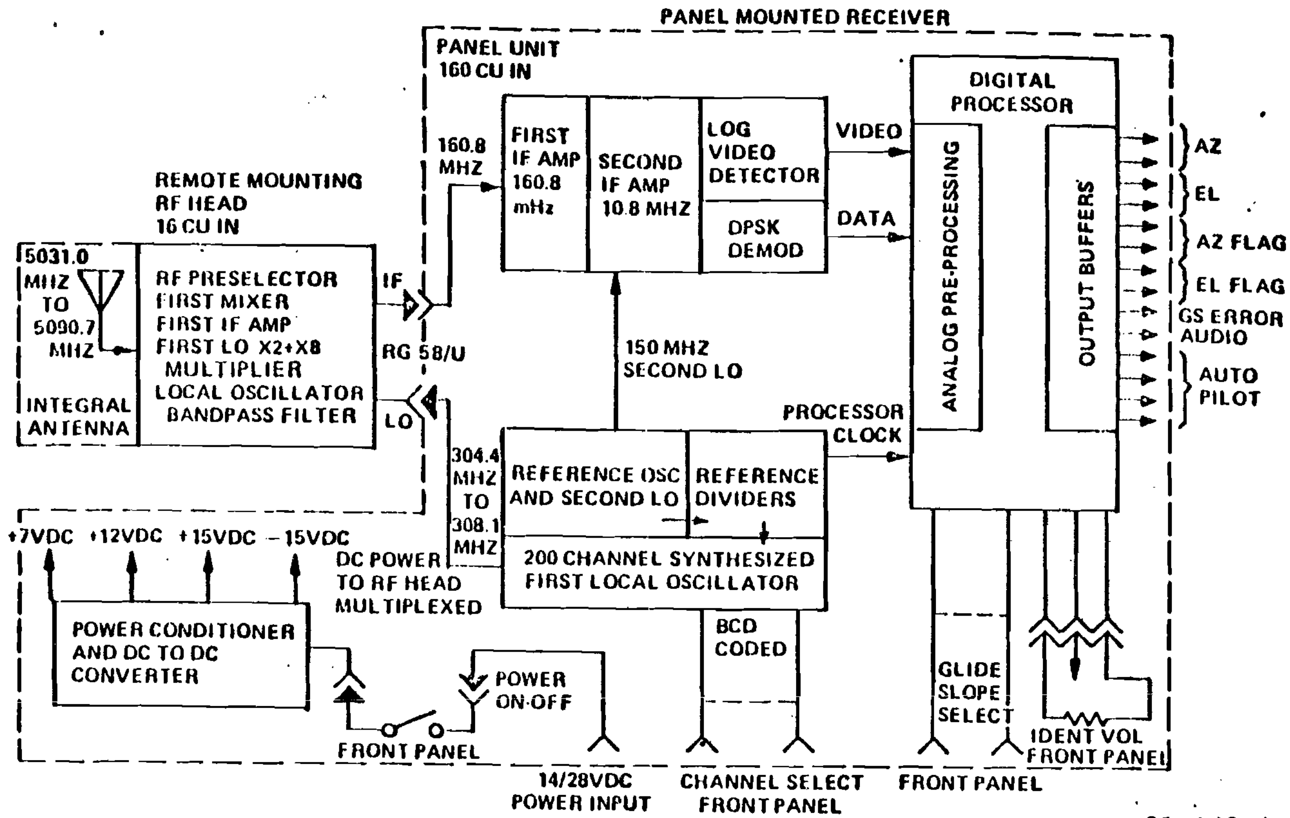

FIGURE 4. LOW COST MLS RECEIVER BLOCK DIAGRAM

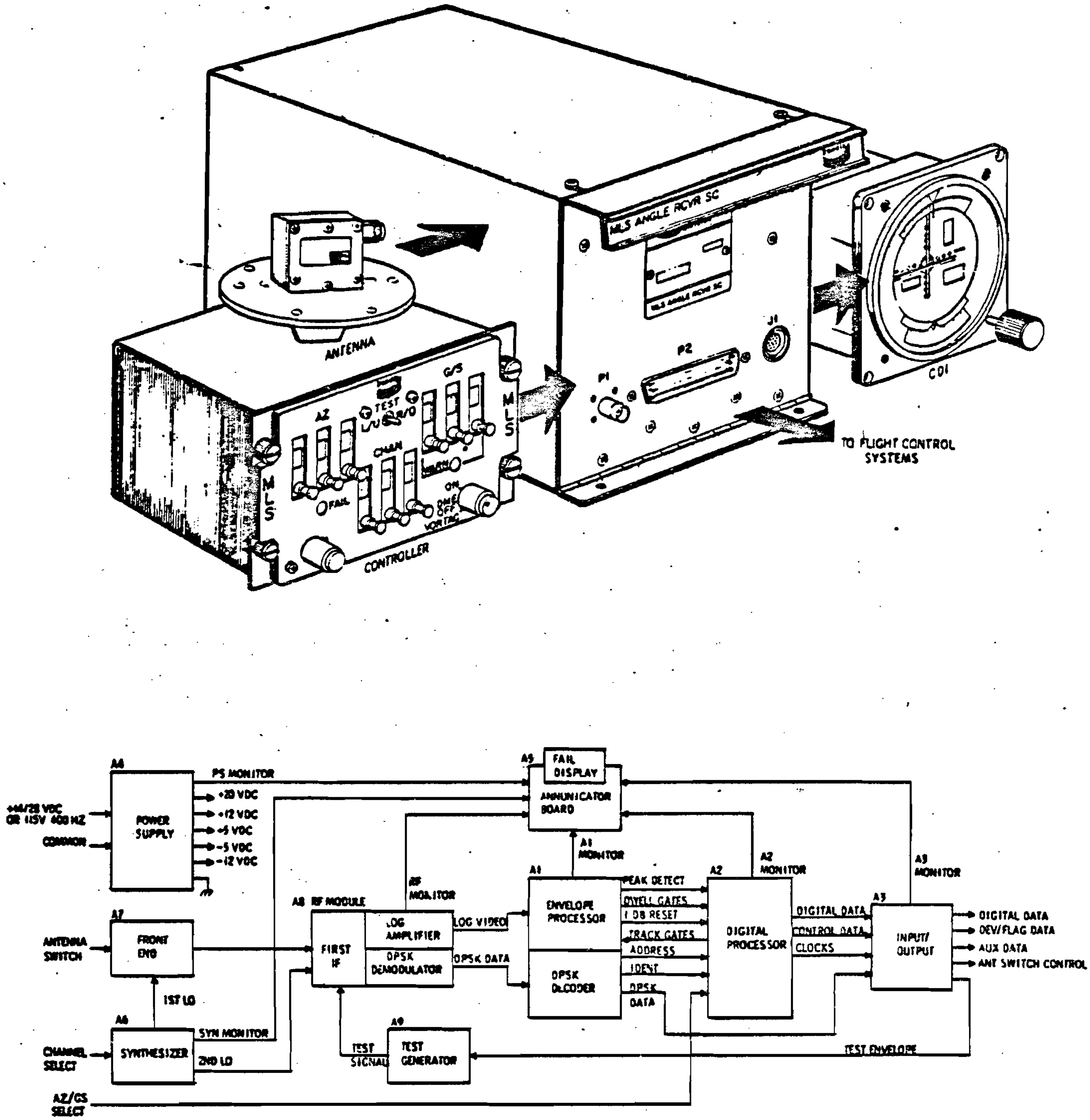

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FIGURE 5. MLS BASIC NARROW ANGLE RECEIVER AND BLOCK DIAGRAM

2.4 Ground Systems.

The ground systems the receivers may be flown against are:

a. The Bendix Test Bed located at the FAA Technical Center on runway 31. It has 1° scanning beams, wide (±60°Az, 0° to 20°El) coverage, hard differential phase shift keying (DPSK) switching, no data words are transmitted, and no elevation SLS. Receivers generally perform better with hard DPSK switching than with soft DPSK switching. DPSK signals are produced by changing the phase of a carrier by 180° at specified times. This is accomplished by switching the full power carrier signal through a delay line (hard switching) or by reducing the carrier power before switching (soft switching).

b. The Meyers Transportation Systems Center Small Community System is located at the Technical Center on runway 35. It has 3°Az 2°El scanning beams designed to meet Small Community GA coverage specifications, utilizes hard DPSK switching, and does not transmit basic data word No. 2 (elevation status), back SLS, or elevation SLS.

c. Texas Instruments' Small Community System located at Philadelphia International Airport on runway 17. It has 3°Az 2°El scanning beams with hard DPSK switching and it transmits all basic data. This unit may be modified for soft switching in order to test the AEL/NARCO receiver response.

d. Bendix's Basic Wide located at Wallops Island, Virginia, on runway 22. It has 1° scanning beams, large volume coverage, utilizes hard DPSK switching, and transmits basic data.

e. The Bendix Small Community which is planned for installation at Washington National Airport on runway 33. It has 3°Az 2°El scanning beams, designed to meet Small Community specifications, utilizes hard switching, and transmits basic data words.

Calibration of both the AEL/NARCO and the Bendix receivers will be performed in a laboratory environment utilizing the Bendix Airborne Test Set shown in figure 6. The output of the unit is at C-band and provides primarily DPSK, scanning beams, status signals, clearance pulses, and SLS pulses. Tests will be performed to show the angles which define the limits of the proportional coverage regions and the receiver minimum sensitivity. The laboratory tests will provide information as to the scale factor (degrees/volts) and angle that will cause full-scale deflection of the CDI's fed by each receiver. The functional block diagram of the test setup is shown in figure 7.

The flight test effort is primarily concerned with the comparative operational performance of the AEL/NARCO and Bendix receivers in the proportional coverage region, the clearance region, and the out-of-coverage region. The low cost AEL/NARCO receiver is designed to meet GA landing requirements. Thus, a comparison to the more costly and extensively tested Bendix receiver will be performed before inclusion in the STEP program.

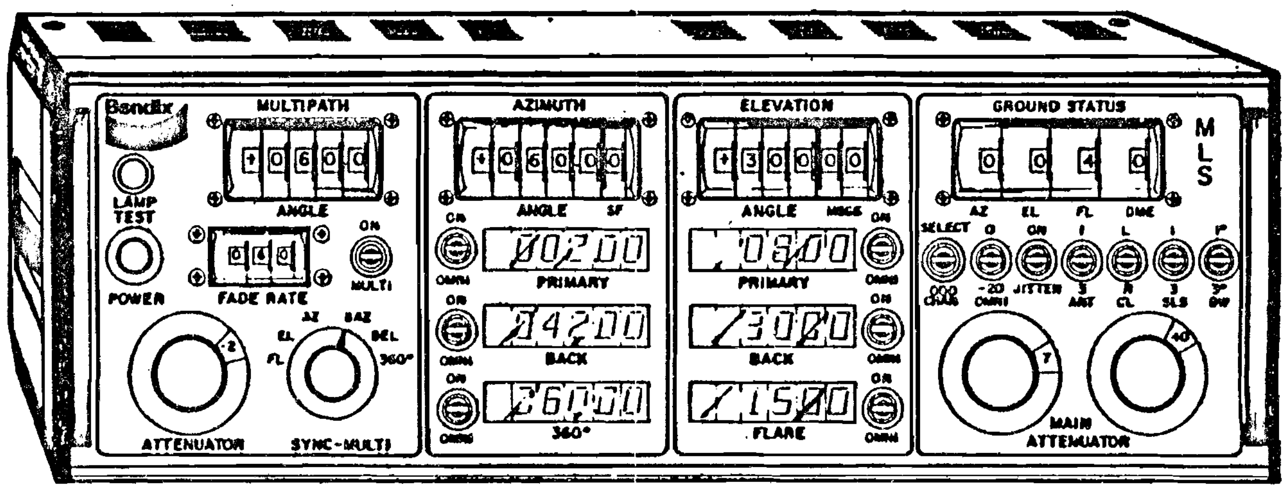

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FIGURE 6. MLS AIRBORNE TEST SET

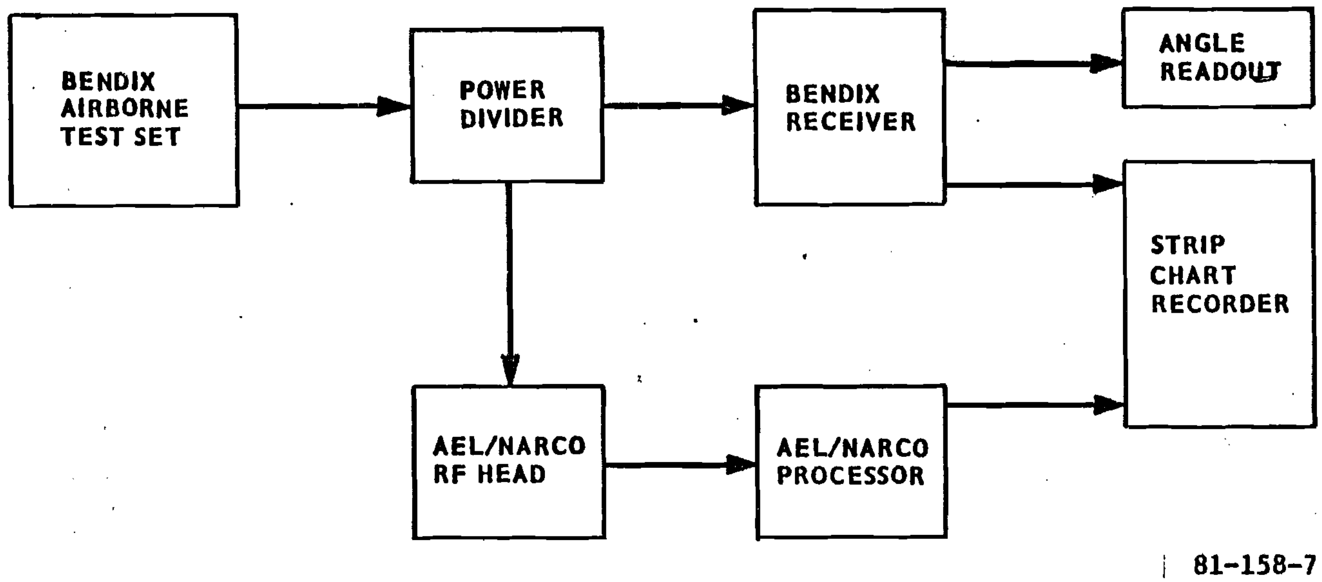


FIGURE 7. LABORATORY DATA COLLECTION BLOCK DIAGRAM

Tracking will be performed primarily at the Technical Center and will employ the Nike/Hercules radar tracker. Tracking may be provided at other sites, if available, such as the laser tracker at Philadelphia and Washington, and a radar tracker at Wallops Island. The tracking data will be utilized in the event of a phenomenon occurring in the airborne MLS data as well as for standard accurate angle data. A block diagram of the airborne data collection system is shown in figure 8.

3. DATA COLLECTION.

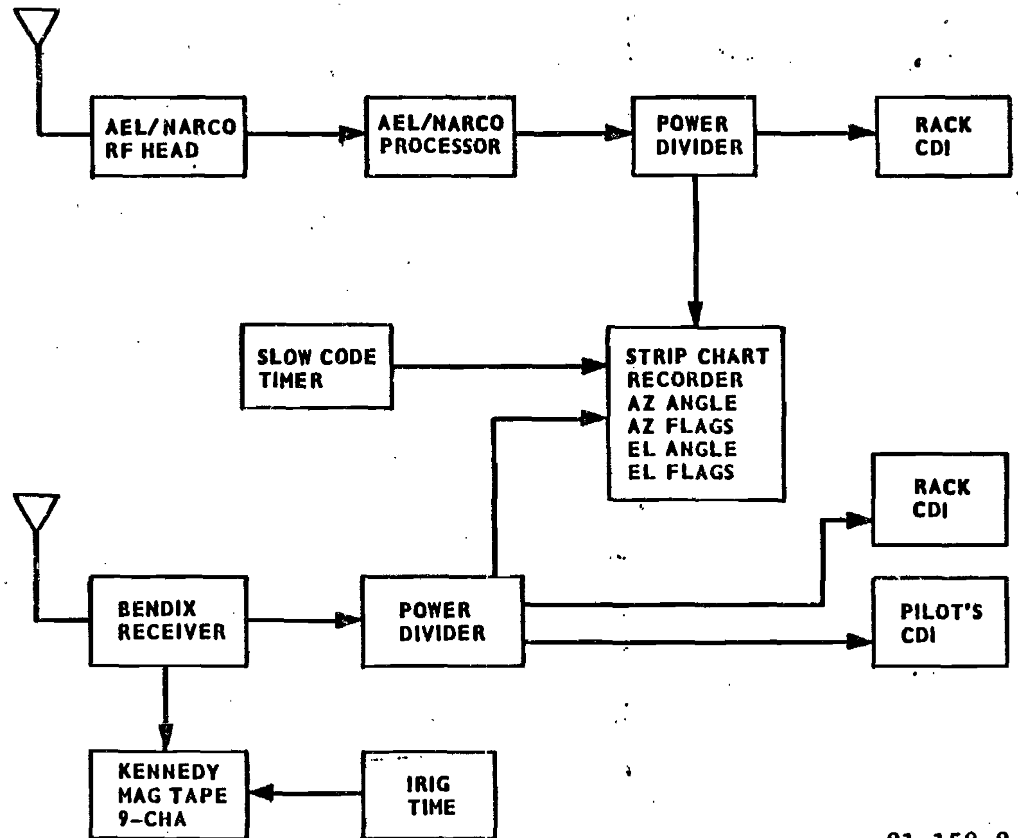
Preliminary tests will be performed in a laboratory environment in order to calibrate both the Bendix receiver and the AEL/NARCO receiver. The comparative calibration tests will measure the minimum sensitivity of each unit and the strip-chart recorder will record the CDI output. These tests will show the voltage versus angle for the proportional guidance region, the clearance area limits, and the out-of-coverage limits for each unit.

The flight test will be performed under normal airport operating conditions. For each ground system there will be three types of patterns flown: orbits, radials, and glide slopes. The orbits (two each at 3°El and 10 nautical miles (nmi)) will primarily show the relative occurrence of the azimuth flags and width of azimuth clearance (full-scale deflection) region. The radials (3,000-foot altitude and starting at 15 nmi) will show the relative occurrence of elevation flags and width of the elevation clearance region or fly-down indication (full-scale deflection on the CDI). The glide slopes (two each at 3°El and 0°Az and two at 5°El and 0°Az) will show the relative occurrence of proportional guidance (noise and bias) for both azimuth and elevation.

For all of these tests, it may be necessary to modify the AEL/NARCO receiver in order for it to accept signals from ground sites that do not transmit certain basic data words (word Nos. 1 and 2).

4. DATA REDUCTION AND ANALYSIS.

Some of the data in the data report will be copies of portions of the analog strip chart showing the relative performance of the angle outputs from each receiver and the relative occurrence of full-scale deflections and flags. It is expected that the data may show differences in angles as to when the flags from each receiver are output to the CDI. As tracking will not be employed at all sites, angles and distances will be estimated from aircraft speed and distance measuring equipment (DME) readings in the event they are needed to understand a phenomenon occurring in the data. Tracking at the FAA Technical Center will be performed in order to determine the angles at which flags occur.



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FIUGRE 8. BLOCK DIAGRAM OF AIRBORNE DATA COLLECTION SYSTEM

The orbit data will be reduced to polar plots showing the direction of flight and the angle at which flags from the Bendix and AEL/NARCO appear. The radials and glide slopes will be plotted on rectilinear paper showing range and elevation angle at which the flags occurred. Any occurrence of unusual flag conditions will be thoroughly analyzed. The performance of the AEL/NARCO receiver and the Bendix receiver under various flight conditions will be compared.

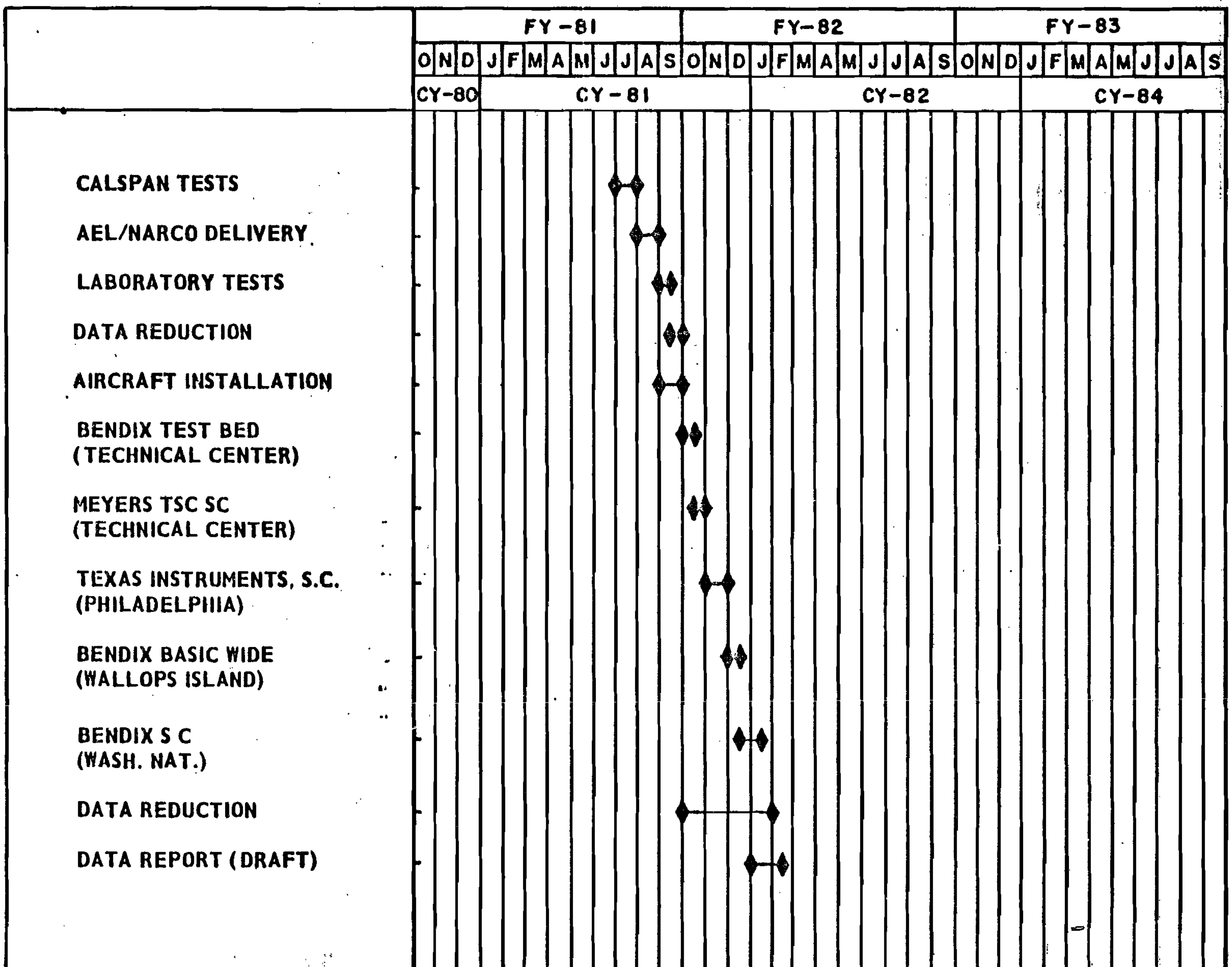
5. INSTRUMENTATION AND FACILITIES.

It may be necessary to build an interface to increase the flag voltage levels out of the AEL/NARCO receiver in order to drive relays used with the event markers on the strip chart recorder. It will be necessary to install the remote RF head on the aircraft and to provide required wiring to the receiver. The major facility to be used from the Technical Center is the Nike/Hercules radar tracking facility and possibly the laser tracker at other sites.

6. COORDINATION AND AREAS OF RESPONSIBILITY.

ACT-100E will provide the instrumentation, coordinate test flights at the Technical Center and field sites, collect the raw airborne data, analyze the data, and write the data report. ACT-600 will provide the Aerocommander (N-50) and pilots, and installation of the AEL/NARCO RF head and related wiring. ACT-700 will provide the tracking and data processing.

7. SCHEDULE.


FY-81
FY-82
FY-83
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S
CY-80
CY-81
CY-82
CY-84
CALSPAN TESTS
AEL/NARCO DELIVERY
LABORATORY TESTS
DATA REDUCTION
AIRCRAFT INSTALLATION
BENDIX TEST BED (TECHNICAL CENTER)
MEYERS TSC SC (TECHNICAL CENTER)
TEXAS INSTRUMENTS, S.C. (PHILADELPHIA)
BENDIX BASIC WIDE (WALLOPS ISLAND)
BENDIX S C (WASH. NAT.)
DATA REDUCTION
DATA REPORT (DRAFT)