

FAA TECHNICAL CENTER LETTER REPORT

MICROWAVE LANDING SYSTEM FLIGHT TESTS
RUNWAY 21, BENEDUM AIRPORT, CLARKSBURG, W. VA.

FEDERAL AVIATION ADMINISTRATION

TEST PLAN

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by

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APRIL 1982

**U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
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OBJECTIVE

The objective of these tests is to determine if the Hazeltine Small Community Microwave Landing System (SCMLS) installed to service runway 21 at Benedum Airport in Clarksburg, West Virginia, meets the accuracy tolerances as outlined in FAA-ER-700-8C, Change 2, "Microwave Landing System Signal Format and System Level Functional Requirements."

BACKGROUND

The system installed on runway 21 will be used by Aeromech Airlines in conjunction with runway 18 at Washington National Airport to gain operational experience in visual flight rule (VFR) conditions and to collect operational data for the Federal Aviation Administration Service Test and Evaluation Program (STEP). At the same time Ransome Airlines will be collecting similar data flying between runway 33 at Washington National and runway 17 at Philadelphia International Airport.

RELATED DOCUMENTATION/PROJECTS

- a. MLS Engineering Flight Test Results, Washington National Airport, Automation Industries, Inc., VITRO Laboratories Division, Contract DOT-FA78WA-4210, September 1980.
- b. Microwave Landing System Service Test and Evaluation Program (STEP), November 1981 update.
- c. Microwave Landing System Signal Format and System Level Functional Requirements, Department of Transportation, Federal Aviation Administration Engineering Requirement, Report No. FAA-ER-700-8C (including Change 2, April 23, 1981).
- d. NAFEC Range Instrumentation Systems - Federal Aviation Administration Technical Center, Report No. FAA-NA-79-32, February 1980.

SYSTEM DESCRIPTION

The Hazeltine SCMLS consists of an azimuth (Az) system and an elevation (El) system. The Az system gives proportional horizontal guidance to $\pm 10^\circ$ about the phase center of the antenna. From 10° to 40° on each side, there is a full fly left or fly right signal to direct the aircraft to the proportional guidance area. The El system gives proportional vertical guidance from 1° to 15° above the phase center of the antenna.

The azimuth antenna is installed 303 feet to the right (pilot's left) of runway centerline, 2850 feet from runway threshold. This location is about halfway down the runway. It is collocated with the commissioned ILS localizer that services runway 21 and is positioned about 15 feet behind the localizer array with the Az phase center 10 feet above the ground. The Az antenna is aligned so the 0° Az angle overlays the localizer centerline which is canted to intercept the runway centerline extended approximately 11,000 feet from threshold. The El antenna is 880 feet from threshold and 250 feet to the right (pilot's left) of centerline. It is positioned 140 feet in front of the commissioned sideband reference glide slope and is collocated for a 3.0° glide path. A diagram of the runway 21 installation is shown in Figure 1.

DATA COLLECTION

Data collection will be accomplished using the Technical Center's Convair 580 aircraft (N-49) and laser tracker. Two types of MLS receiver output data, digital and analog, will be collected. The digital data will be recorded on a Kennedy 9832, 9-track digital tape recorder. This data will be time merged (post-flight) with ground tracker data to obtain raw error data (MLS angle minus

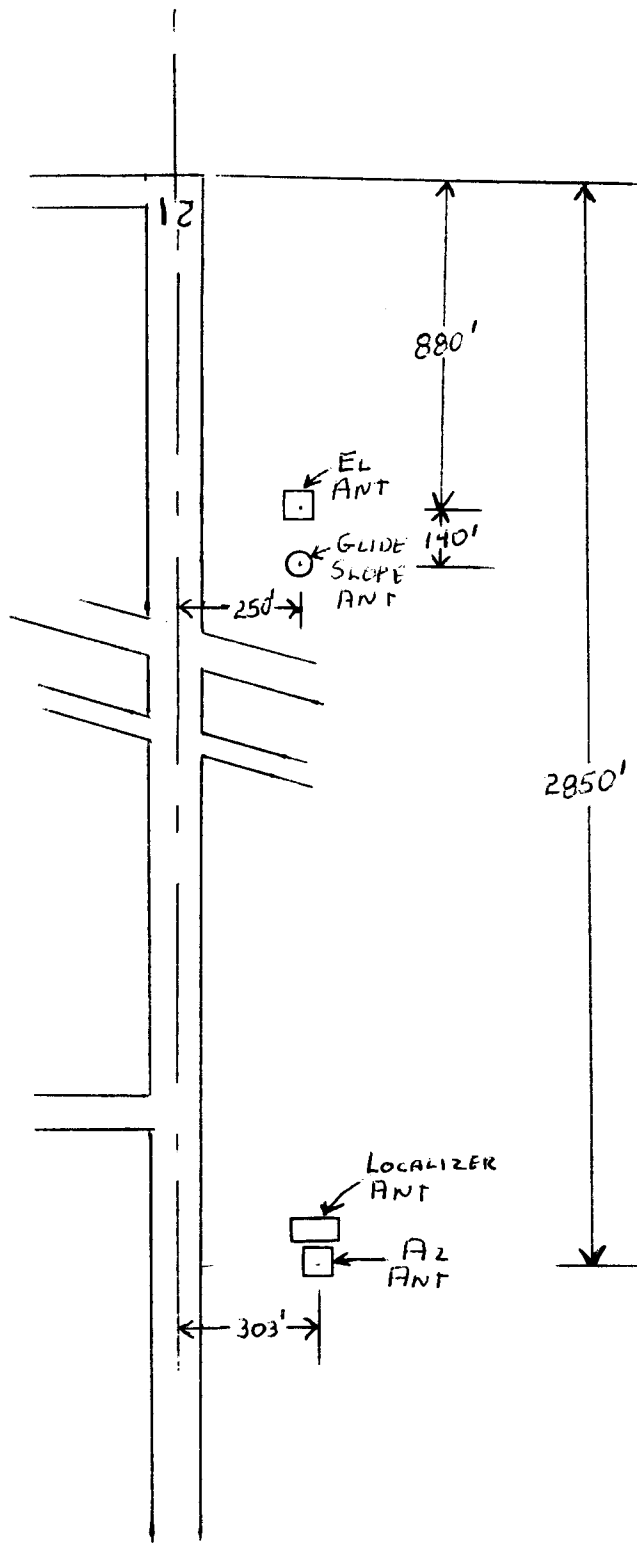


FIGURE 1 - CKB RUNWAY 21 SITING CONFIGURATION

tracker angle) which, after filtering and processing, will result in path following error (PFE) and control motion noise (CMN) plots. A Brush 481, 8-channel, strip-chart recorder, will be used to record the analog data. The analog data is used primarily to determine where the analog warning flags appear and to determine if there is any signal radiated in the out-of-coverage regions. The analog outputs, course deviation indicator (CDI) and warning flags, are normally displayed to the pilot on a Flight Director System. A diagram showing the airborne data collection system is shown in Figure 2. Table 1 is a listing of the recorded digital and analog parameters.

Since the ILS and MLS ground sites are colocated for 3.0° approaches, the ILS glide course deviation indication, both glide slope and localizer, will be recorded during the 3.0° approaches. The analog ILS signals and the MLS analog signals will be on different recorders and we will attempt to match recorder sensitivities and speed for ease of visual comparison.

Three types of data collection profiles will be flown: (a) constant altitude, in-bound radials, which check all elevation angles at one azimuth angle; (2) constant altitude, partial orbits, which check all azimuth angles within the coverage sector at one elevation angle; and (c) approaches which check the system as it will be used operationally. Appendix 1 includes a description and diagram of the proposed data collection runs. Runs 1 through 12 will require two good data runs each; runs 13 through 15 will require four good data runs each, runs 16 through 19 will only require one good data run.

DATA REDUCTION AND ANALYSIS

Two parameters, PFE and CMN, are of prime importance when measuring the system's performance. PFE includes the steady state bias and cyclical error components of low enough frequency for the aircraft to physically track and

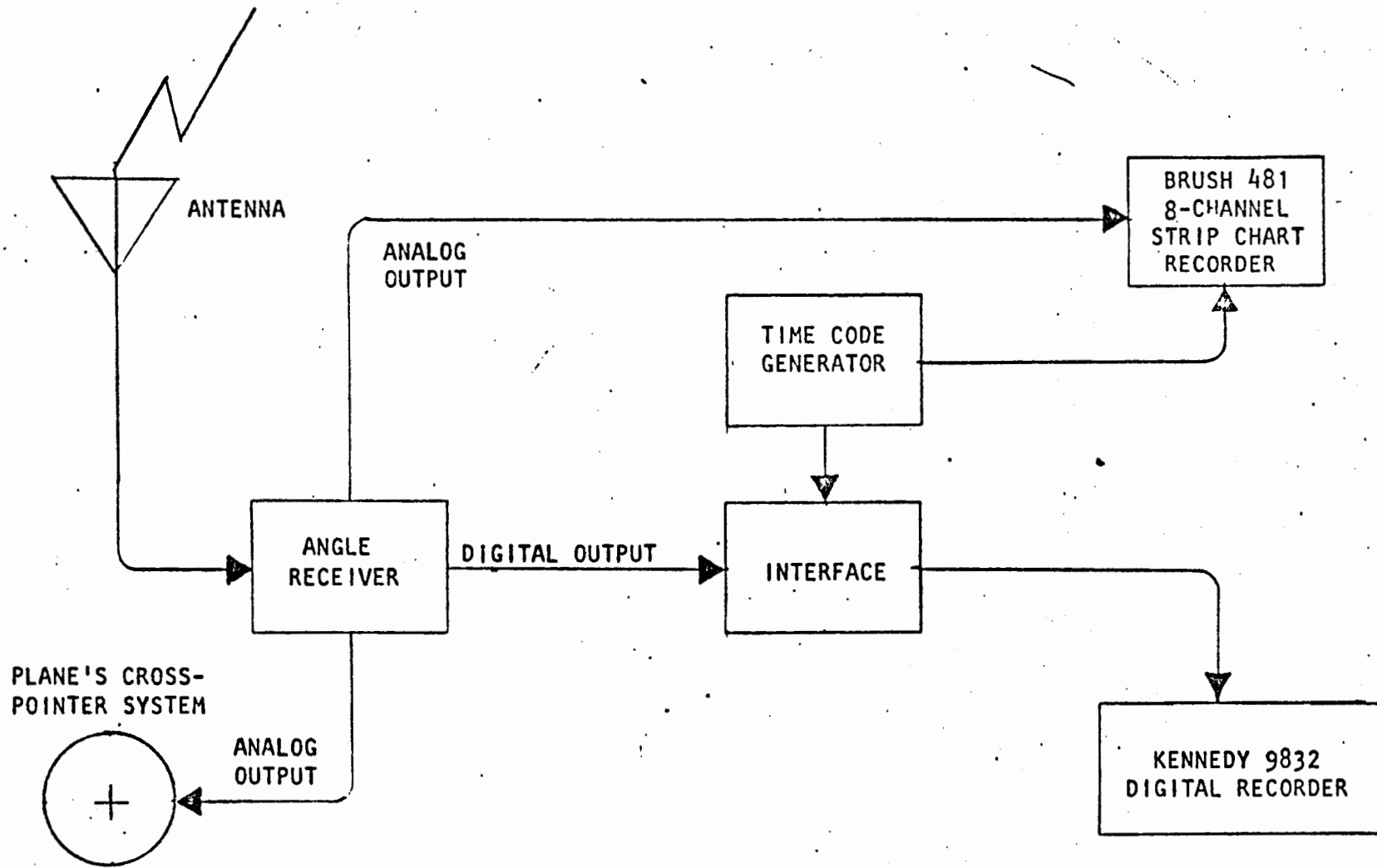


Figure 2. Airborne Data Collection System

TABLE 1 - AIRBORNE DATA RECORDED IN N-49

<u>DIGITAL</u>	<u>ANALOG</u>
Receiver 1 Az Angle	<u>Brush Recorder</u>
Receiver 1 Az Frame Flag	Receiver 1 Az Crosspointer
Receiver 1 Az System Flag	Receiver 1 Az Flag
Receiver 1 EL Angle	Receiver 1 EL Crosspointer
Receiver 1 EL Frame Flag	Receiver 1 EL Flag
Receiver 1 EL System Flag	Receiver 2 Az Crosspointer
Receiver 2 Az Angle	Receiver 2 Az Flag
Receiver 2 Az Frame Flag	Receiver 2 EL Crosspointer
Receiver 2 Az System Flag	Receiver 2 EL Flag
Receiver 2 EL Angle	Time IRIG-B (Slow Code)
Receiver 2 EL Frame Flag	<u>Century Recorder</u>
Receiver 2 EL System Flag	Localizer Crosspointer
Time (IRIG-B)	Localizer Flag
VOR Angle	Glide Slope Crosspointer
	Glide Slope Flag
	Marker Beacon AGC

have a measurable effect in terms of deviations from the desired track. The transfer function of the low-pass filter used to extract this error from the data is:

$$H(S) = W_n^2 / (S^2 + 2W_n S + W_n^2)$$

where $W_n = 0.78$ radians/second for Az and $W_n = 2.34$ radians/second for El.

CMN encompasses errors that are generally of a frequency too high for the aircraft to physically track but low enough for the control system to respond to. This results in rapid, small amplitude control surface wheel and column motions and is undesirable because it diminishes flight crew confidence by presenting them with a "shaky stick". The transfer function of the highpass filter used to extract CMN from the data is:

$$H(S) = S/S+W_1$$

where $W_1 = 0.3$ radians/second for Az and $W_1 = 0.5$ radians/second for El.

The CMN and PFE specifications, including system error and degradation allowances, are shown in Figure 3 for Az and in Figure 4 for El. These two figures were developed from the accuracy specifications contained in FAA-ER-700-08C, including Change 2, paragraphs 3.2.6.1 and 3.2.6.2. The results will be presented on two types of plots; rectangular and polar. Rectangular plots obtained from ACT-750 (CALCOMP plotter) will show the PFE and CMN in degrees on the Y-axis plotted against distance or azimuth angles from the azimuth antenna phase center on the X-axis. Polar plots (reduced manually) will show where the analog flag is on and off as a function of azimuth angles. The tolerances, as detailed in Figures 3 and 4, will be applied by ACT-100B.4 personnel to the CMN and PFE plots. The error plots will then be analyzed according to the criteria in FAA-ER-700-08C to determine whether or not the system is in or out of tolerance. Out of tolerance conditions will be investigated as to the

ERROR COMPONENT	SYSTEM ERROR (FT) (1)	DEGRADATION ALLOWANCES		
		WITH DISTANCE	WITH AZIMUTH ANGLE	WITH ELEVATION ANGLE
PATH FOLLOWING ERROR (PFE)	20	2:1 in angle from the reference datum to 20 nmi	1.5:1 in angle from the reference datum to <u>+40°</u>	None to 9° 2:1 in angle from 9° to 20°
CONTROL MOTION NOISE (CMN)	10.5 (3)	1.3:1 in angle from the reference datum to 10 nmi (2)	1.3:1 in angle from the reference datum to <u>+40°</u>	NONE

NOTES:

Specifications are per FAA-ER-700-08C, Change #2 (dated 4/23/81).

1. At approach reference datum defined as the point on the minimum glide path at threshold. For systems with collocated Az and El use 5000 feet distance to the approach reference datum.
2. The CMN is unspecified beyond 10 nmi
3. Maximum CMN at the reference datum is 0.1°.

FIGURE 3 - AZIMUTH ERROR SPECIFICATIONS

ERROR COMPONENT	SYSTEM ERROR (FT) (1)	DEGRADATION ALLOWANCES		
		WITH DISTANCE	WITH AZIMUTH ANGLE	WITH ELEVATION ANGLE (3)
PATH FOLLOWING ERROR (PFE)	2.0	0.2° maximum at 20 nmi (On the minimum glide path and 0° azimuth radial)	1.3:1 in angle from the reference datum to +40°	2:1 in angle from minimum glide path to 15° 6:1 in angle from 60% of minimum glide path to lower coverage limit. Maximum allowed is 0.8°
CONTROL MOTION NOISE (CMN)	0.75	1.3:1 in angle from the reference datum to 10 nmi (2)	1.3:1 in angle from the reference datum to +40°	2:1 in angle from minimum glide path to 15°. Maximum allowed above the reference datum is .07° 6:1 in angle from 60% of minimum glide path to lower coverage limit. Maximum allowed is 0.4°

NOTES:

Specifications are per FAA-ER-700-08C, Change #2 (dated 4/23/81)

1. At approach reference datum defined as the point on the minimum glide path at threshold.
2. The CMN is unspecified beyond 10 nmi.
3. Elevation equipment sited to provide a minimum glide path higher than 3° shall provide angular accuracies not less than those specified as if the equipment were sited for a 3° glide path.

FIGURE 4 - ELEVATION ERROR SPECIFICATIONS

cause. A data analysis summary matrix is shown in Table 2.

A sample of the computed error tolerances is shown in Figure 5. The solid lines indicate the PFE tolerances and the dashed lines indicate the CMN tolerances for the azimuth data during a 0° , constant altitude (3,000 feet) inbound radial. Similar tolerances will be calculated and applied to the other two flight profiles, partial orbits, and constant altitude radials.

In addition to the digital plots and the analog flag plots, the raw data ILS CDI readings for the 3.0° approaches will be visually compared to the MLS analog CDI recordings. Since this is raw data with no tracker corrections for aircraft deviations from on-course, a quantitative assessment of ILS signal quality (amplitude excursions) for comparison to MLS data will not be made. However, time domain measurements such as scalloping rates, may be performed for comparative purposes, as required. Plots of ILS and MLS analog CDI traces will be included in the report.

INSTRUMENTATION AND FACILITIES

No special additional instrumentation is required. The aircraft used for these flight tests, N-49, is already instrumented with the necessary receivers, recorders, and antennas. In addition, it has a laser retro-reflector installed on top of the fuselage over the cockpit for tracking purposes. The Technical Center's laser tracker will be transported to Clarksburg and deployed on the airfield. The laser tracker is a mobile facility which uses an invisible laser beam to illuminate and automatically track a retro-reflector mounted on the target aircraft. Accuracy tests performed on the laser tracker by the Technical Center indicate 2-sigma estimates of error of 0.017° in azimuth, and 0.026° in elevation, and 5.2 feet in range (at 6 nmi). The report describing the accuracy tests is listed in Section 1-3, "RELATED DOCUMENTATION," item d.

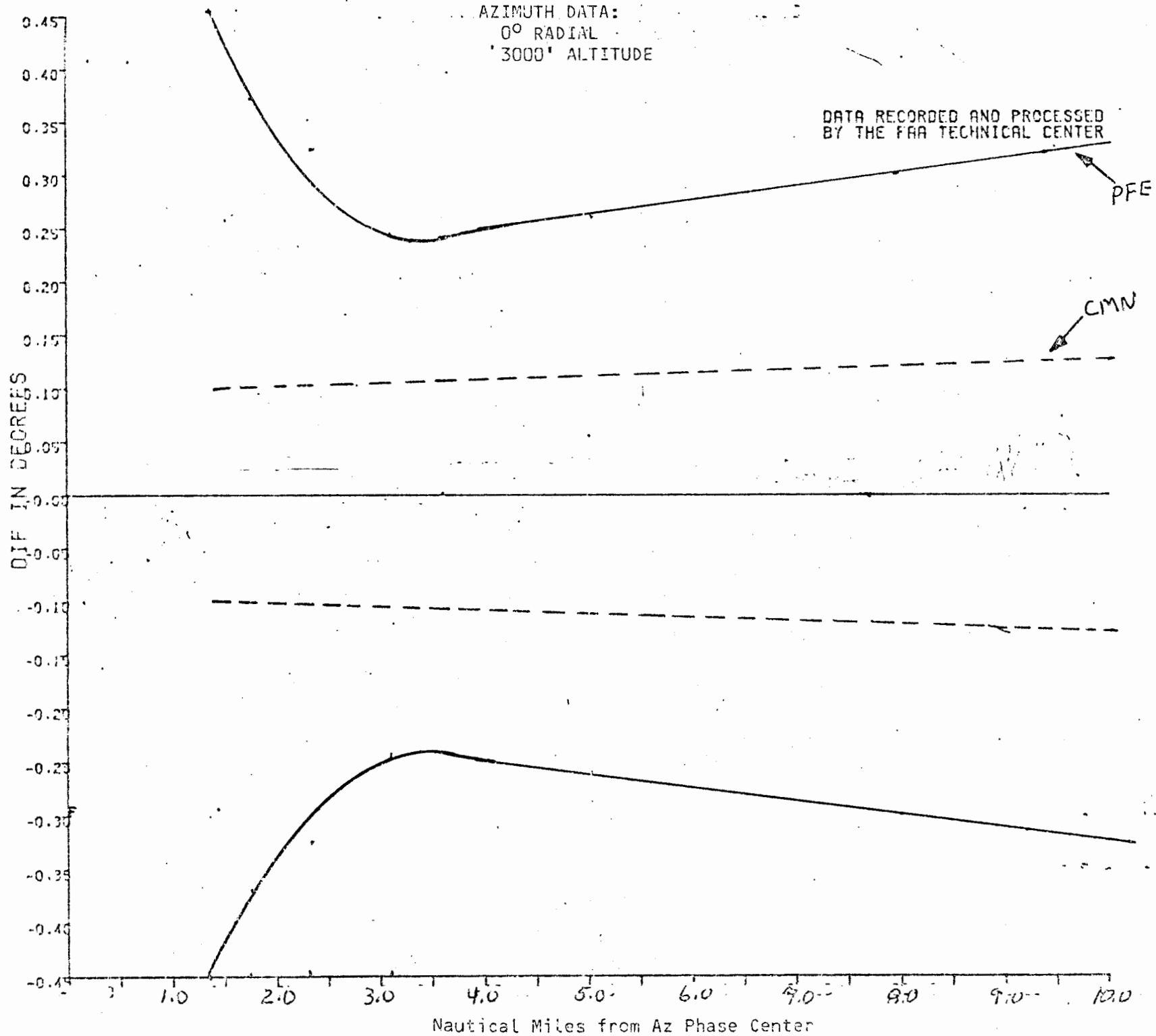


Figure 5. Azimuth Tolerances

COORDINATION AND AREAS OF RESPONSIBILITY

A meeting will be held with the Clarksburg air traffic control (ATC) personnel to determine the days, times, and conditions under which they will be able to support the MLS flight tests. After this preliminary meeting, ACT-100 personnel will handle all coordination with ATC. In addition, the following is a list of organizations at the Technical Center with their responsibilities:

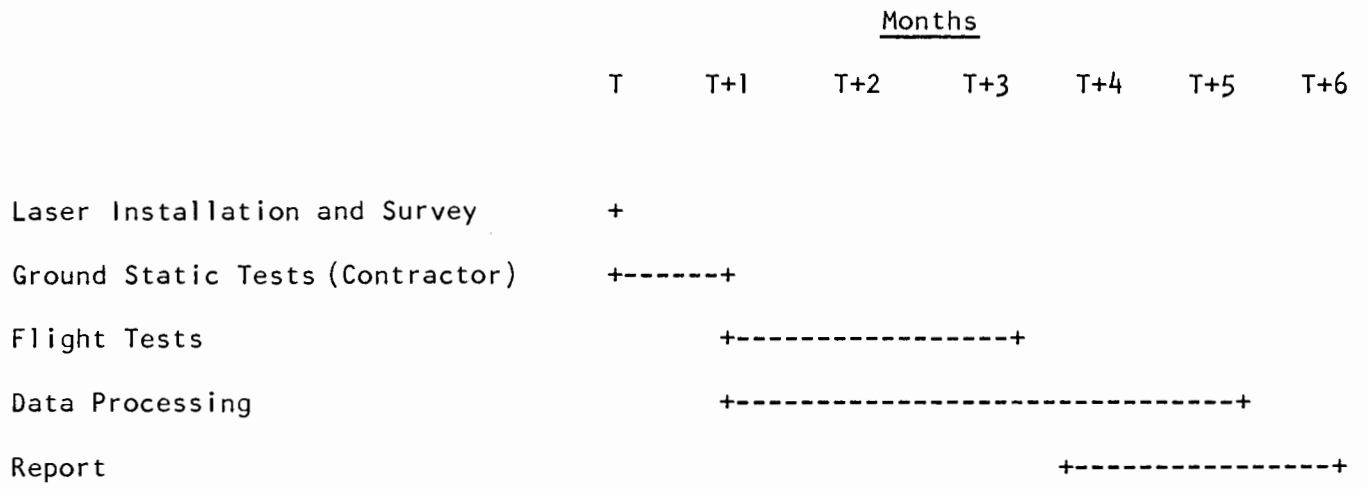
a. ACT-100B.4 will write a product plan, schedule all of the necessary Technical Center facilities, perform a site survey, and provide the necessary manpower for data collection. In addition, they will merge the filtered airborne and tracker tapes and generate the necessary listings and plots. They will also write a data report.

b. ACT-640 will supply the aircraft and pilots for flight testing.

c. ACT-750 will move, install, calibrate, and operate the laser tracker at Clarksburg. They will perform outlier and filter the tracker tapes and make them available for ACT-100B.4 for processing.

d. The MLS equipment at Clarksburg will be maintained by Hazeltine personnel throughout the tests. They will perform the ground static tests using an instrumented MLS van on loan from the Technical Center.

SCHEDULE



<u>PROFILE NO.</u>	<u>DESCRIPTION</u>
1	Radial 10° Left, 3000 feet from 12 nmi
2	Radial 5° Left, 3000 feet from 12 nmi
3	Radial 0°, 3000 feet from 12 nmi
4	Radial 5° Right, 3000 feet from 12 nmi
5	Radial 10° Right, 3000 feet from 12 nmi
6	Full Orbit 4000 feet 7 nmi from 50° Left, a full CCW orbit to 50° Right
7	Partial Orbit ± 40° CW, 7 nmi 2500 feet
8	Partial Orbit ± 40° CCW, 7 nmi 2500 feet
9	Partial Orbit ± 40° CW, 7 nmi 4000 feet
10	Partial Orbit ± 40° CCW, 7 nmi 4000 feet
11	Partial Orbit ± 40° CW, 7 nmi 5000 feet
12	Partial Orbit ± 40° CCW, 7 nmi 5000 feet
13	3.0°, Centerline Approach from 12 nmi @ 3000 feet
14	4.5°, Centerline Approach from 12 nmi @ 3000 feet
15	6.0°, Centerline Approach from 12 nmi @ 4000 feet
16	Partial Orbit ± 40° CW, 20 nmi 3000 feet
17	Partial Orbit ± 40° CCW, 20 nmi 3000 feet
18	Partial Orbit ± 40° CW, 20 nmi 20,000 feet
19	Partial Orbit ± 40° CCW, 20 nmi 20,000 feet

NOTE: All altitudes are above airport elevation (1200 feet)