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# TEST PLAN FOR THE RELIABILITY AND MAINTAINABILITY EVALUATION OF THE BASIC WIDE MICROWAVE LANDING SYSTEM AT WALLOPS ISLAND, VIRGINIA

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## TEST PLAN

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Prepared for

## U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION
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Washington, D. C. 20590

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# INTRODUCTION

## PURPOSE.

The Microwave Landing System (MLS) Basic-Wide System at Wallops Island, Virginia, will be evaluated to determine the operational subsystem and system mean times between failures (MTBF) and mean times to repair (MTTR). Failure rates will be calculated. The calculated values will be compared with the contractor's predicted values. Reliability and maintainability weak points or problem areas will be determined.

## BACKGROUND.

A reliability and maintainability work statement plan was forwarded to the Landing Systems Branch, ARD-320, by the Reliability and Maintainability Engineering Section, ACT-152, in February 1980. It offered ACT-152 reliability expertise to ARD-320 in the joint National Aeronautics and Space Administration (NASA)/ Federal Aviation Administration (FAA) evaluation program on the MLS Basic-Wide System installed at Wallops Island, Virginia. ARD-320 responded favorably to ACT-152 by letter memorandum in March 1980. This reliability and maintainability evaluation will be documented and its results, conclusions, and recommendations will be included in a final report.

## RELATED DOCUMENTATION/PROJECTS.

The equipment is being tested to the specifications in FAA-ER-700-01 and subsequent amendments. The equipment was delivered to NASA by Bendix Communications Division, Baltimore, Maryland, under contract DOT-FA78WA-4180. The MLS Evaluation is a joint effort between NASA and the FAA and is being accomplished through a NASA and FAA Memorandum of Understanding, DOT-FA79WAI-086. This Reliability and Maintainability Evaluation was created by memorandum between ACT-152 and ARD-320 during February and March, 1980.

The following preliminary technical manuals and operations and maintenance instructions on Basic Wide Equipment were delivered by the contractor to ARD-320 in April 1980:

1. Antenna Subsystem (TI 6830.1), Vol. 1, March 1980
2. Ground Subsystem (TI 6830.2), Vol. 1, March 1980
3. Ground Electronics Subsystem (TI 6830.3), Vol. 1, March 1980

A related project: "Test and Evaluation Basic-Wide MLS (NASA)," project number 075-725-480, is in progress at the FAA Technical Center.

# SYSTEM DESCRIPTION

## EQUIPMENT CONFIGURATION.

This MLS system consists of three subsystems: elevation (EL), azimuth (AZ), and distance measuring equipment (DME). This system site configuration is shown in figure 1.

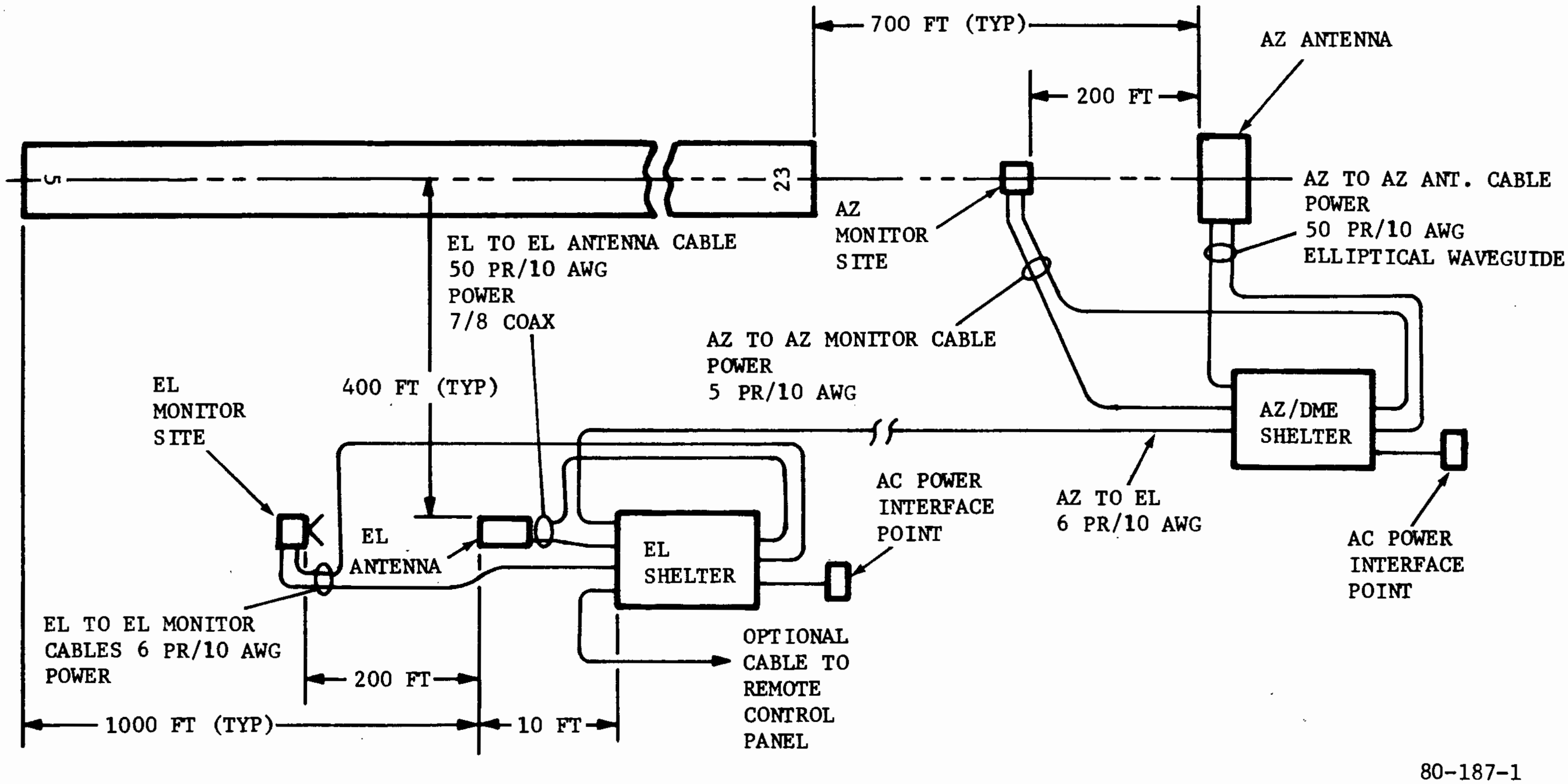


FIGURE 1. BASIC WIDE SYSTEM CONFIGURATION

The EL subsystem consists of a transmitting antenna, a monitoring antenna, and an EL shelter. The EL transmitting antenna is located 813 feet back from threshold; it is offset 400 feet from the runway centerline. The EL monitoring antenna location is 200 feet in front of the EL transmitting antenna; the EL shelter is located 15 feet to the side of the EL transmitting antenna.

The AZ subsystem also consists of a transmitting antenna, a monitoring antenna, and a shelter. The AZ transmitting antenna is located 1,283 feet beyond the runway stop-end on its extended centerline. The AZ monitoring antenna location is 200 feet in front of the antenna at an angle of -16 degrees. The AZ shelter is located to the side of the AZ transmitting antenna.

The DME subsystem is located in the AZ shelter and its antenna is attached to the AZ shelter. This subsystem does not have a monitoring antenna.

The remote control equipment is typically located in the air traffic control (ATC) tower and controls the overall system. It contains visual system status indicators.

Voice communications between the AZ and EL shelters is provided through an interphone system.

## EQUIPMENT SIGNALS LIMITS OF OPERATION.

The MLS EL and AZ subsystems use the time division multiplexed (TDM), time-reference-scanning-beam (TRSB) technique. The EL subsystem provides vertical proportional angular guidance to the aircraft from -1.0 degree to +20 degrees referenced to the EL transmitting antenna phase center. Out-of-coverage indication (OCI) is given between +20 and +40 degrees. The signal coverage is up to 20,000 feet altitude, out to a range of 20 nautical miles (nmi), and horizontally ±60 degrees from the EL transmitting antenna phase center.

The AZ subsystem provides horizontal proportional angular guidance to the aircraft, ±60 degrees, referenced to the AZ transmitting antenna phase center. OCI is given in all the outside of ±60 degrees. The signal coverage is up to +20 degrees in the vertical plane, to 20,000 feet altitude, and a range of 20 nmi.

The DME subsystem operates independently and provides distance information from the aircraft to the DME antenna throughout the AZ and El proportional coverage area.

## SUBSYSTEM OPERATION.

The AZ subsystem consists of a phased-array approach antenna, an electronics shelter that has sector antennas, and a DME transponder (shown in figure 2). The AZ subsystem electronic timing and control circuits (which produce all the clock and control signals) cause all signals radiated from the AZ shelter to synchronize within the TDM format. The radio frequency (RF) waveforms are generated by a C-band exciter, phase and amplitude modulators. A traveling wave tube amplifier, with an integral power supply, provides a 20-watt output at the sites operating frequency. The antenna select switch is controlled in time synchronization with the RF signal. The signal is routed to the correct antenna on the AZ shelter. The order of antenna selections is as follows: (1) the forward ident antenna, (2) the scanning beam antenna which radiates the RF in the to-fro scan, and (3) the OCI antennas (right to left) which radiate the out-of-coverage indicator pulses.

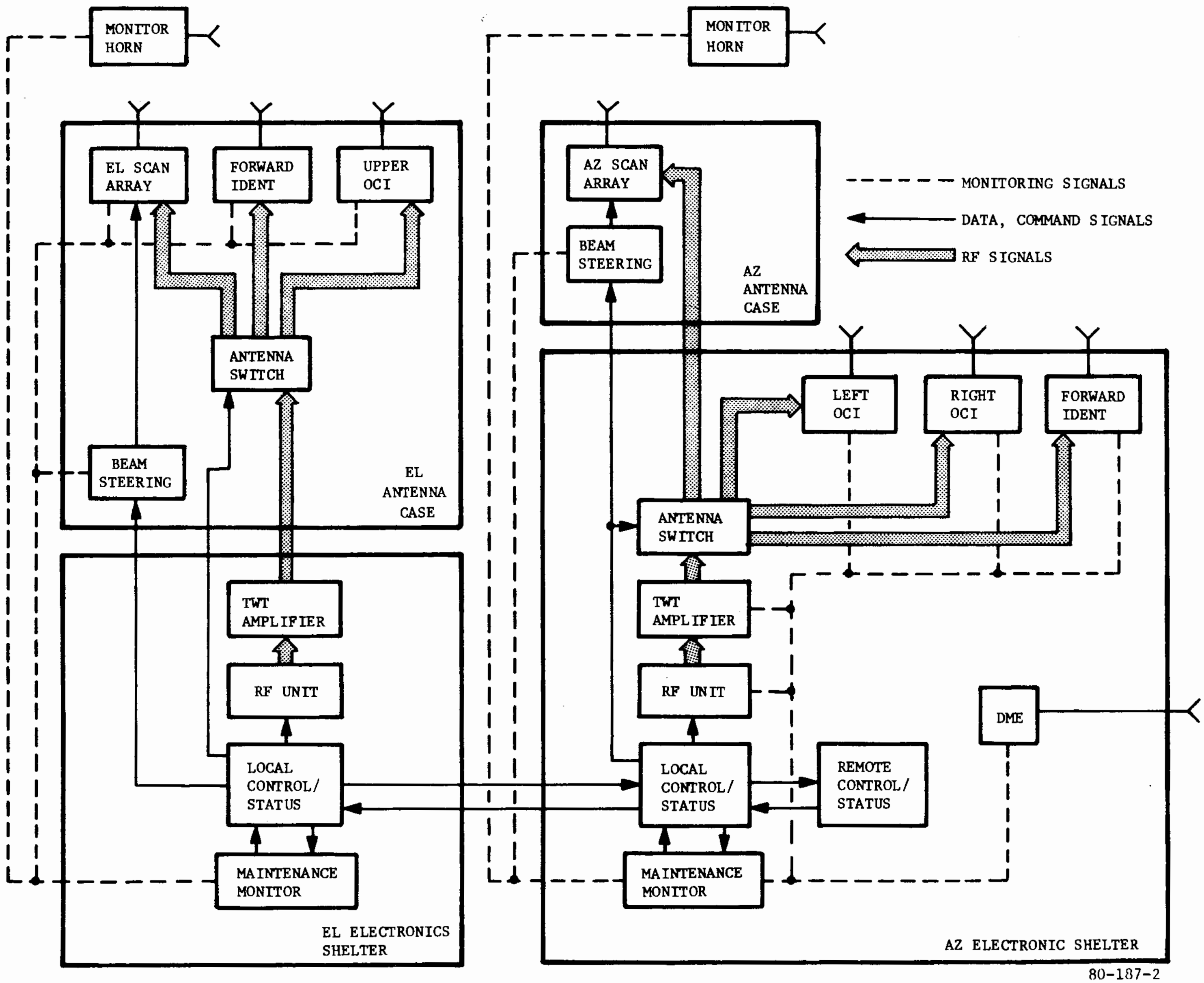


FIGURE 2. BASIC WIDE SYSTEM BLOCK DIAGRAM

The scanning beam antenna has an array of 116 slotted waveguide radiating elements that are fed by a strip-line power divider. Phase shifters are connected to each of the slotted waveguide radiating elements. The elements are controlled by an ordering of digital control words in the scan interval which causes the phase gradient across the array to rotate about the array center. A narrow fan beam is produced that is steered ±60 degrees through the AZ proportional guidance coverage sector. The ordering of control words for the phase shifters is produced in the beam steering unit. The linear scanning rate is 20,000 degrees per second.

Site radiated signal monitoring is built in. Both executive (system has failed), and maintenance (system is functioning within its specified limits) states are monitored. The executive state monitoring checks the critical system parameters and initiate executive action of automatic subsystem shutdown when a parameter does not fall within a predetermined tolerance. Maintenance monitors sense component and line replaceable unit (LRU) performance as opposed to final system performance. Maintenance monitor thresholds are set close enough to nominal values that subsystem degradation is normally detected before an executive fault occurs. Consequently, scheduled maintenance and corrective maintenance can be taken to minimize unscheduled system shutdowns. If a maintenance monitor exceeds its limit by a large margin, executive action limits will be exceeded so that a subsystem shutdown and a maintenance alert occur.

The DME transponder in the AZ shelter is controlled and monitored by the proportional guidance electronics. This transponder transmits and receives at L-band frequencies through the DME antenna with a ±60 degree forward coverage.

The EL subsystem is basically identical to the AZ subsystem as to equipment grouping and functional operation (figure 2). However, only two sector antennas are required. The EL subsystem is slaved to the AZ subsystem for synchronization of the EL subsystem transmissions within the MLS system TDM format.

## DATA COLLECTION

Data collection will consist of logging any event or situation which is different from the normal energized and operational status of the equipment. Such events include: shutdown of any equipment unit, preventive maintenance (when shutdown of equipment unit is involved), hardware failures, engineering changes, and changes in system configuration.

### FAILURE AND MAINTENANCE REPORTING ITEMS.

Failure and maintenance data, as well as changes in operational status, will be entered on a standard log form. A proposed Facility Maintenance Log Form, FAA Form, 6030-1 (figure 3), is presented at the end of this test plan. This shall include a complete and comprehensive history of every hardware failure, regardless of whether or not such failure resulted in a degradation of system performance. The failure history shall include the following:

1. Date and time of any hardware failure or other type occurrence.

2. Brief description of hardware failure or other type occurrence.

F— 1386602

| FACILITY MAINTENANCE LOG | STATION | |
|---|---|---|
| | SUBJECT OF LOG | MONTH AND YEAR |

| DATE | TIME (24 HOURS) | CODE | REMARKS | INI-TIALS |
|---|---|---|---|---|
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| DATE | SIGNATURE OF SECTOR MANAGER/DESIGNEE | DATE | SIGNATURE OF MAINTENANCE TECHNICIAN |
|---|---|---|---|
| | | | |

**FAA Form 6030-1** (10-70) FORMERLY FAA FORM 406C

☆ U.S. GOVERNMENT PRINTING OFFICE: 1972—460-288

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FIGURE 3. FACILITY MAINTENANCE LOG

3. Symptoms of failure or other type occurrence.

4. Effect of failure or other occurrence on subsystem and system operation.

5. Location of failure or other occurrence (including subsystem, unit, drawer, and slot number).

6. Name of corrective maintenance diagnostics or procedures used.

7. Actual troubleshooting and repair time for restoration to normal operation (hours and minutes).

8. Date and time hardware failure or other occurrence is corrected.

9. Name, location, and serial number of failed part(s).

10. Disposition of failed part (replaced, repaired, discarded, returned to manufacturer, etc.).

11. If failed part or item is repaired off-line, report the off-line repair time and give name and location of defective part or unit.

12. Preventive maintenance time (hours and minutes).

13. Other information: temperature, humidity, environmental items (lightning, rain, etc.), low power, backup power used, loss of cooling, etc.

A proposed hardware Failure Maintenance Log report sample information list is included at end of this test plan. This information, reported on a 2-week basis, shall be supplied to ACT-152 by ARD-320 where it shall be processed and analyzed as described below. The contractor's technician at the site is on duty 40 hours per week. Failures may occur during non-duty hours. These failures (time-till-technician's-next-duty hours) will not be chargeable in computing overall system operating time.

## DATA ANALYSIS

### UNIT FAILURE ANALYSIS.

From the equipment logs, each reported failure shall be analyzed to determine whether it is chargeable. The criteria for chargeability are as follows:

1. The failure is independent, that is, it did not occur as a result of a previous failure or hardware modification.

2. The failure causes a loss or degradation of performance beyond specified or acceptable limits of the equipment unit (reliability element) in which it occurred.

3. The failure requires actual maintenance effort to correct, as opposed to a transient outage which can be reset or master-cleared.

These individual failure analyses shall include: coordination with site maintenance personnel to resolve questions of chargeability, actual maintenance time expended, any other questions concerning the failure that may arise during the course of the analysis. A listing of the failures occurring in each of the unit types will be made. This listing will include a documentary on each failure, including its chargeability. Presentation of these failures by equipment unit type will aid in determining the existence of distinct or repetitive failure patterns.

UNIT-TYPE FAILURE RATES, MTBF's and MTTR's.

The failure rates, MTBF's and MTTR's for the unit types will be determined. This will be done by determining the total uptime (U), total number of chargeable failures (N), and total corrective maintenance or repair time (C) for each unit type per system. The values U and C will be expressed in terms of unit-hours.

Since an underlying exponential (constant failure rate) statistical distribution is assumed for the failure and repair rates, the following formulas will be used for each unit type.

$$\text{Failure rate } (\lambda) = \frac{N \times 10^6}{U} \text{ failures per million hours}$$

$$\text{MTBF} = U/N \text{ hours}$$
$$\text{MTTR} = C/N \text{ hours}$$

Where environmental and usage conditions permit, corresponding unit-type data within the site will be lumped to provide combined unit-type values of λ, MTBF, and MTTR for this site.

SUBSYSTEM AND SYSTEM FAILURE RATE, MTBF AND MTTR.

To compute the subsystem and overall system failure rate, MTBF and MTTR, a reliability model must be employed to determine which of the units must be operational to achieve full and complete equipment functional capability. The DME will be considered one system and the MLS AZ and EL subsystems as another system.

An overall set of values using combined failure data for the unit types will be computed. Where practical, unit-type and system failure rates will be compared with the contractors' predicted values.

Where the observed values significantly exceed the predicted values, it will be highlighted and brought to the attention of appropriate FAA offices.

## RELIABILITY REPORTS

Data reports will be issued. These reports will: (1) summarize the failures occurring to date, (2) include failure rate for each unit, (3) include system failure rate (following the development of the system reliability model), and

(4) compare observed failure rates with predicted failure rates when practical (when the observed values significantly exceed the predicted values, a note to this effect will be contained in the report).

A final report will be prepared. This report will include a description of the test effort, results, and description thereof, conclusions, and recommendations.

## INSTRUMENTATION AND FACILITIES

No special instrumentation nor any facilities are required by this effort.

## COORDINATION AND AREAS OF RESPONSIBILITY

Memorandum Agreement No. DOT-FA79WAI-086 outlines the areas of responsibility between the FAA and NASA. In the reliability and maintainability evaluation area, nothing is required of NASA.

ARD-320 will provide: (1) branch contact, (2) a site contact, (3) system documentation, (4) reliability documentation (reliability models, reliability predictions, reliability specifications, etc.), and (5) direction to maintenance personnel at the site to fill out the failure forms and forward them to ACT-152.

ACT-150 will provide an electronics engineer assigned as a project manager/engineer who will draw upon the resources within ACT-152 and upon other FAA Technical Center resources as required.

ACT-100E will incorporate this project into the Landing System Technical Program Document (TPD) 07-115.

## EVALUATION SCHEDULE

| | | |
|---|---|---|
| 1. | Plan concurred with by ARD-320 | 3/25/80 |
| 2. | Reliability Test Plan draft completed (with system description*) | 4/25/80 |
| 3. | Meeting with ARD-320 to discuss item 2 | 4/30/80 |
| 4. | First site visit | 5/5-5/6/80 |
| 5. | Site data collection starts | 5/12/80 |
| 6. | Reliability Test Plan completed | 6/2/80 |
| 7. | Data collection end date for first quarter | 8/1/80 |
| 8. | First data report | 8/22/80 |
| 9. | Meeting with ARD-320 to discuss item 8 | 8/27/80 |

10. System reliability model and predicted reliability values completed* 9/26/80

11. Data collection end date for second quarter 10/31/80

12. Second data report 11/14/80

13. Meeting with ARD-320 to discuss item 12 12/3/80

14. Site data collection completed 1/16/81

15. Second site visit 2/2-2/3/81

16. Final reliability report draft completed 2/20/81

17. Meeting with ARD-320 to discuss item 16 3/4/81

18. Final reliability report completed 3/16/81

*Subject to contractor delivery of appropriate documentation.

## LOG REPORTING SAMPLE INFORMATION LIST

RELEVANT TERMS:

| | |
|---|---|
| Failure | (FL) |
| Corrective maintenance | (CM) |
| Preventive maintenance | (PM) |
| Equipment powered down | (PD) |
| Engineering changes | (EC) |
| Other | (OT) |

1. DATE-TIME FL/CM/PM/PD/EC/OT BEGAN

May 12, 1980, 1:05 p.m. = 5/12/80/1305

2. FL/CM/PM/PD/EC/OT DESCRIPTION

Elevation subsystem stopped transmitting.
Smoke from TWTA power supply.

3. SYMPTOMS OF FL/CM/PM/PD/EC/OT

Elevation subsystem TWTA power supply caused a visual alert alarm and the monitor's status of BEAMERP showed it to be out of tolerance; or the pilot in an approaching aircraft notified ATC tower that the MLS elevation proportional signal was not now being received.

4. EFFECTS OF FL/CM/PM/PD/EC/OT ON SYSTEM OPERATION

Elevation subsystem proportional guidance unusable.

5. LOCATION OF FL/CM/PM/PD/EC/OT

Describe: subsystem name, rack number, drawer number, card/slot number, card or part number, card or part serial number, etc.

6. NAME OF CM/PM/OT DIAGNOSTIC OR PROCEDURES USED

Replaced elevation TWTA P.S. with another P.S. unit. Powered up elevation subsystem (nontransmitting) under local control. Checked monitoring BEAMERP and found it to be in tolerance. Notified ATC tower and put this subsystem into remote control.

7. TROUBLESHOOTING AND REPAIR TIME

18 hours and 29 minutes = 18:29

8. DATE-TIME FL/CM/PM/PD/EC/OT ENDED

May 12, 1980, 3:01 p.m. = 5/12/80/1501

9. NAME, LOCATION AND SERIAL NUMBER OF FAILED PARTS IN FL/CM/PM/PD/EC/OT

TWTA power supply, card number or part number, serial number.

10. DISPOSITION OF FAILED PART(S)

Power supply held at workbench for possible local repair. If necessary, will send to manufacturer for repair at a later time.

11. OFF-LINE REPAIR

Power supply repaired at local workbench. Found burned out power resistor R4 and capacitor C2. Replaced both components. 2 hours and 15 minutes off-line repair time.

12. DIAGNOSTIC-CM/PM/EC/OT TIME

2 hours, 48 minutes = 2:48

13. OTHER INFORMATION

Temperature, humidity
Environmental items (lightning, rain, etc.)
Low power, back up power used
Loss of cooling, transient, etc.