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Loran Aviation Monitor Shakedown and Integration Test Plan

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May 1988

DOT/FAA/CT-TN88/6

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U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City International Airport, N.J. 08405

technical note technical note

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/CT-TN88/6		

4. Title and Subtitle	5. Report Date
LORAN AVIATION MONITOR SHAKEDOWN AND INTEGRATION TEST PLAN	May 1988
	6. Performing Organization Code ACT-140
7. Author(s) Norman Beauregard and Robert H. Erikson	8. Performing Organization Report No. DOT/FAA/CT-TN88/6
9. Performing Organization Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City International Airport, N.J. 08405	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. T0702N
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Program Engineering Service Washington, D.C. 20590	13. Type of Report and Period Covered Technical Note January 1988
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This plan will provide the necessary guidelines for the integration test and shakedown evaluation of the Loran C monitor and Remote Maintenance Monitoring System (RMMS) interface. The results of these tests will provide verification that this system is ready for full operation as part of the National Airspace System (NAS).

17. Key Words	18. Distribution Statement
Loran C VOR	Document is on file at the Technical Center Library, Atlantic City International Airport, N.J. 08405

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	16	

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

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EXECUTIVE SUMMARY

This test plan describes a series of tests that will be conducted to investigate the performance of first article Loran C monitor. The results of these tests will provide verification that this system is ready for full operation as part of the National Airspace System (NAS).

1. INTRODUCTION.

The Federal Aviation Administration (FAA) and other segments of the aviation community are becoming increasingly aware of the potential of Loran C navigation for en route flight and, more recently, for nonprecision approach operations. As part of an overall response to user's requirements, the FAA is planning to implement a network of approximately 100 Loran C monitors within the United States. These monitors are designed to provide current status of the Loran C stations for use by the aviation community. This information is necessary for conducting consistently reliable Loran C nonprecision approaches. For economic and logistical reasons the Loran C monitors will be collocated at existing very high frequency omnidirectional radio range and tactical air navigation aid (VORTAC) sites.

1.1 PURPOSE.

This plan will provide the necessary guidelines for the integration test and shakedown evaluation of the Loran C monitor and Remote Maintenance Monitoring System (RMMS) interface. The results of these tests will provide verification that this system is ready for full operation as part of the National Airspace System (NAS).

1.2 SCOPE.

In accordance with ADL test terms and definitions (NAS-MD-110) the integration testing will be conducted by the FAA against the 13th production delivery of the Loran C monitor to the FAA. The Loran C monitor will be installed at the FAA Technical Center and tested in two phases. Phase one will consist of installing the Loran C monitor in the experimental VORTAC facility (building 196) and evaluating the Loran C aviation monitor.

The RMMS will not be evaluated in the first phase. The evaluation will consist of both flight and ground tests. Of prime concern is the effect of the VORTAC on the Loran C monitor and vice versa. Phase two testing will consist of installing a new facility computer processor unit (FCPU) in the experimental VOR (building 196), installation of the Remote Maintenance Monitor Facility (RMMF), and evaluation of these communications channels. The Loran monitor data will be routed through the FCPU to the RMMF where all control and command functions will be checked.

1.3 REFERENCE DOCUMENTS.

a. FAA-E-2762, Loran C Monitor Specifications.

b. Order 6860, System Implementation.

c. FCPU/Loran Monitor Interface Design.

2. SYSTEM DESCRIPTION.

2.1 LORAN C AVIATION MONITOR.

2.1.1 General.

The Loran C monitor receives Loran C signals from a single triad of transmitters and compares measured values with preset limits. In the event observed parameters exceed specified limits, an alarm signal shall be sent to the remote monitoring subsystem (RMS) to advise FAA maintenance and air traffic personnel. Parameters monitored are time differences (TD's), signal-to-noise ratios (SNR's), envelope-to-cycle differences (ECD's), and blink for the selected triad.

2.1.2 Basic Characteristics.

The Loran aviation monitor was specified using a "top-down" approach. Existing hardware modules were used to the extent possible to reduce design risk and enhance reliability. The system also has remote maintenance monitoring (RMM) which will diagnose failures down to the lowest replaceable unit (LRU). This design concept will not require maintenance visits more frequently than once every 2,190 hours (quarterly) and will permit remote certification from a central maintenance facility. The projected mean time between failure (MTBF) is 10,000 hours. The Loran monitor maintenance concept is compatible with the quarterly maintenance schedule currently in effect for the VOR system.

There are three levels of security for accessing monitor functions, either from the monitor front panel or via the VOR FCPU. The monitor equipment, except for the antenna coupler and antenna, are mounted in a standard 19 inch equipment rack. The equipment rack will be located in a VOR facility and will interface with the VOR FCPU through an RS-232 port. The FCPU will receive all operational, control, and status data from the Loran monitor and forward it to the appropriate Flight Service Station (FSS) over existing dedicated communication lines. The Loran monitor consists of six discrete elements: (a) antenna and coupler, (b) Loran receiver, (c) Loran processor, (d) remote monitoring subsystem, (e) signal generator, and (f) power supply.

Each element will be discussed in the following paragraphs, and is illustrated in figure 1, Functional Diagram of Loran Monitor.

a. Loran Antenna and Coupler. The receiver antenna is a 3-meter whip antenna. The Loran signals are received by the antenna, inserted into the coupler, and passed to the receiver via a cable.

b. Loran Receiver. The Loran receiver receives low-frequency (100 kilohertz (kHz)) signals from the antenna/coupler and processes the signals to calculate the TD's, SNR's, loss of signal, signal blink, and ECD. These data are then provided as an output to the Loran processor.

c. Loran Processor. The Loran processor receives digital data on signal parameters from the receiver. The values of these parameters are then compared to predetermined standard values for that location. If all values fall within the allowable limits, the processor outputs a positive indication to the RMS board. If one or more values fall outside of the allowable limits, the processor delivers an out-of-tolerance alarm indication to the RMS.

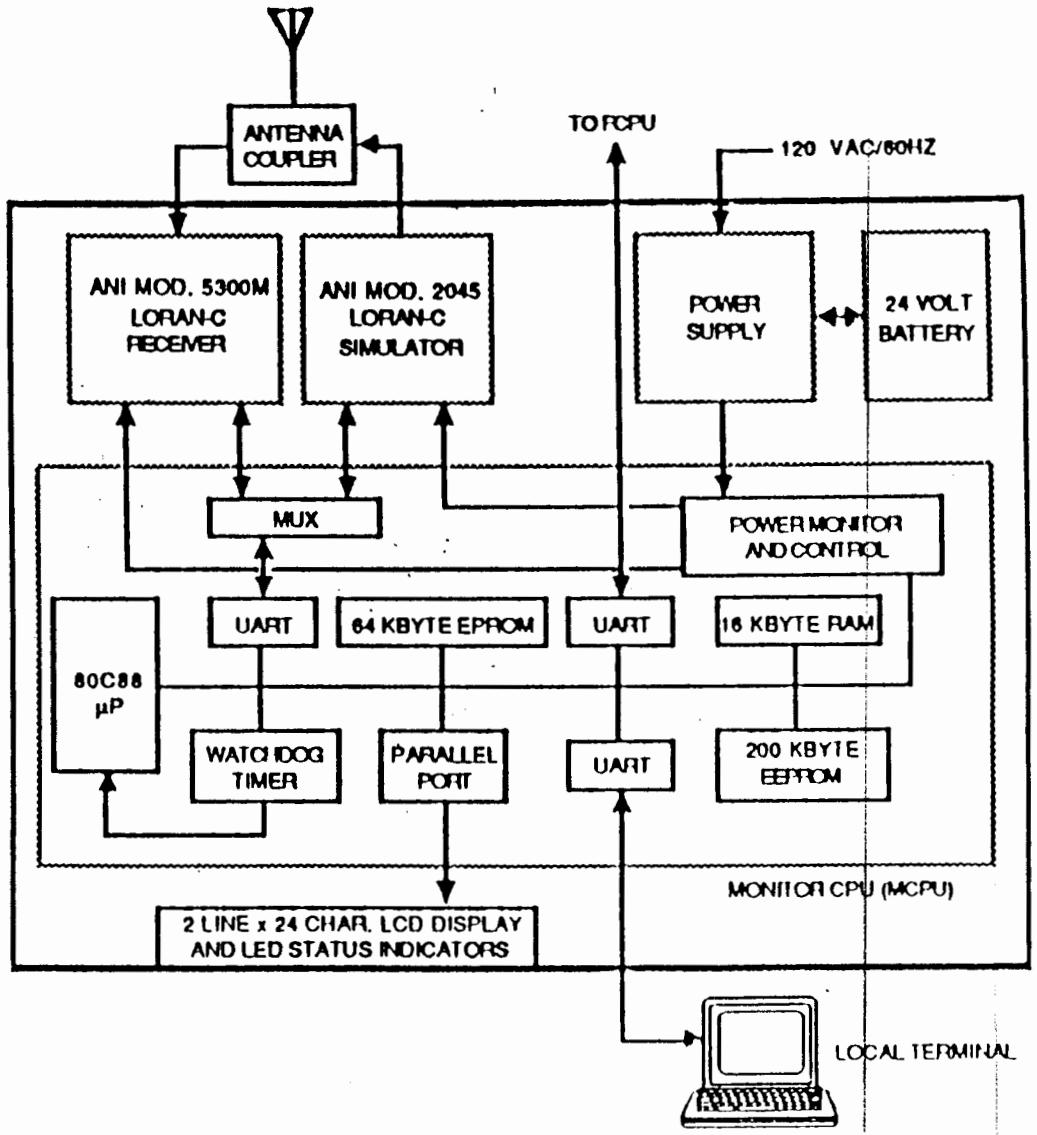

FIGURE 1. **FAA LORAN-C** MONITOR BLOCK DIAGRAM

d. RMMS. The RMMS receives data from the Loran processor and provides an output to the FCPU or to memory. Status data are routed through an EIA RS-232C port to the FCPU in the VOR. Signal parameter data are averaged and stored in nonvolatile memory. Upon request from the FCPU, this signal quality history will be sent to the FCPU and then to a central data collection point. These data will be used to create a historical data base and to validate the mathematical model used to predict calibration values published with approach procedures. Data are also collected on the time and cause of all alarm conditions.

e. Signal Generator. The signal generator is capable of simulating various Loran signals on command. The generator signals can be set for a specific Group Repetition Interval (GRI), SNR, TD's (normal and fault), ECD, and blink signal. The antenna signal will be switched, on command, via the RMS or via a local maintenance terminal connected through the front panel port; one of the preset signal conditions from the generator will then be inserted at the input to the antenna coupler.

f. Power Supply. The monitor operates from a single-phase, two-wire plus ground 120 volt, 60 hertz (Hz) power source.

2.1.3 External Interfaces.

The Loran monitor interfaces with the FCPU in the VOR via an RS-232C interface on the back panel of the Loran monitor. Data transfer is serial at a 1200 bit per second rate. The Loran monitor can be accessed from the RMC-F and the input/output terminal (IOT) of the VOR system through this interface. Data can be accessed from these terminals and remote verification can be accomplished by activating the signal generator.

The FCPU will monitor the status of the Loran monitor. When the Loran monitor goes into alarm, an interrupt will be sent to the FCPU which will remove the "Loran" portion of the VOR voice identification message (if that function is in use). The FCPU currently controls the speech signals that are broadcast by a VOR, including the voice identification function.

There is a second EIA RS-232C port on the front panel of the monitor for access by technicians at the VOR facility, or at the depot maintenance facility.

2.1.4 Maintenance Concept.

The Loran monitor will be supported by two levels of maintenance: site and depot. During the first year of operation, the depot level maintenance will be performed by the Loran monitor contractor; on-site maintenance will be performed by Airway Facilities (AF) personnel. The status output of the Loran monitor will be monitored by the VOR FCPU. After receipt of an alarm from the FCPU and remote fault analysis, an AF technician will be dispatched to the VOR facility to repair the fault causing the condition. The technician will accomplish the repair and then return with the faulty line replaceable unit. After return to the work center, the technician will send the faulty unit to the depot for disposition.

Following a Loran monitor maintenance failure, the alarm indicator at the Remote Maintenance and Control Unit remote maintenance console (RMC-F) will be

extinguished only after restoration of the Loran monitor. For signal tolerance alarms, a selectable provision will permit automatic restoration to normal operation when all preset parameters have been met. For maintenance alarms, restoration of service will require verification by an AF technician.

2.1.5 Software Philosophy.

The Loran monitor is microprocessor controlled. The VOR FCPU serves as the interface between a local or remote operator and the Loran monitor. In addition, an input/output terminal can be connected via an EIA RS-232C port directly to the Loran processor by a local operator. The Loran processor issues maintenance and system out of tolerance alarms when critical parameters are out of tolerance. The controlling microprocessor for the Loran processor is the Intel 80C88.

Detailed flow charts or program design language, a program listing in the C language, and program design specification are to be provided for all Loran monitor software. Reprogramming of the firmware will be controlled on a system basis with the FAA depot providing the reprogrammed read only memory devices when required.

2.2 VOR.

The experimental VORTAC Facility located in building 196 is described herein. The FA-9969 VOR is a completely solid-state system providing identification and azimuth navigation information to aircraft. A ground transmitter radiates continuous wave signals on 1 of 40 channels between 108 and 112 megahertz (MHz) or 1 of 120 channels between 112 and 118 MHz. The assigned VOR frequency for the facility is 111.65 MHz; the tactical air navigation (TACAN) channel is 53Y. An antenna with a cardioid shaped radiation pattern is rotated 30 times per second to generate a radiated 30-Hz amplitude modulated (AM) signal with a phase angle proportional to the aircraft bearing from north. A 30-Hz frequency modulated (FM) reference signal is also radiated omnidirectionally on a 9960 Hz subcarrier. The airborne receiver determines bearing as a function of phase difference between the detected FM and AM 30-Hz signals.

The VOR monitor utilizes a microcomputer design and, in conjunction with ground check equipment, performs all VOR monitoring functions. If a discrepancy occurs in the monitored parameters, the monitor shuts down the VOR transmitter. The VOR monitor unit is redundant, containing two identical and independent monitors. During executive monitoring, 1 of 16 antennas (typically at 90 or 270 radial in a conventional VOR station) is selected and designated by the monitor as the executive antenna. For these tests the number 1 monitor and the 270 radial antenna will be used. The radio frequency (RF) signal from the executive antenna is routed to the RF level detector which provides an RF level output that is proportional to the VOR carrier and is routed to the VOR monitor.

2.3 EXTENDED AREA INSTRUMENTATION RADAR (EAIR).

The model 661 EAIR is a precision C-band instrumentation radar system designed to measure, record, and display aircraft coordinates in slant range, azimuth, and elevation angles. Maximum tracking distance of the EAIR is 100 nautical mile (nmi) primary (skin) mode, 190 nmi in secondary (beacon) mode, while minimum tracking distance is 1 nmi. Digital output data consisting of time, slant range, azimuth angle, and elevation angle are recorded on magnetic tape. Analog

horizontal position and altitude are recorded real-time on a 30-inch plotter. The azimuth (Az) and elevation (El) accuracy is 0.2 milliradian (0.011°).

3. ORGANIZATIONAL ROLES.

3.1 GENERAL.

APS-400 has overall responsibility for the Loran C monitor program. The contractor is responsible for the installation of the shakedown system and will be available for maintenance while the test is underway.

3.2 TEST DIRECTION.

Program management will be supplied by APS-420. This branch is responsible for test schedule adherence and can authorize test procedure additions and deviations.

3.3 TEST OPERATION.

ACT-140 will be the test director, act as operator, and perform the test procedures. ACT-140 will also be responsible for making any corrections necessary to maintain the continuity of the test.

3.4 TEST RECORDER.

ACT-140 will maintain a log of tests actually performed, results of those tests, and deviations or additions to the planned procedures. Results of tests will be published in a Technical Note.

3.5 FACILITY.

ACT-600 will be responsible for providing project aircraft, pilots, maintenance of the VORTAC, and for approving the flight test schedule

3.6 MONITOR.

APM-150 will provide personnel to observe test results.

4. TEST METHODOLOGY.

4.1 GENERAL.

The integration and shakedown test is intended to demonstrate and verify that a field deployed Loran C monitor functions as part of the NAS. Components of this system have previously been tested and, in general, will not be individually tested again. Emphasis will be on the interoperability of the collocated Loran C monitor and the VOR system, as well as the operational functions of the Loran C monitor system as a whole. If any faults occur during testing they will be corrected, using standard maintenance procedures, if possible. Faults beyond cutting off the alternating current (ac) power supply will not be purposely introduced into the system or it's components. Specific tests will be conducted to verify that proper alarms are set and that the system shuts down when the Loran C monitor or the FCPU are made to fail. As many tests as possible will be made on the site of the Loran C monitor and remotely through the RMMS firmware at

an RMC-F. Phase two testing will be delayed until an FCPU board is available for the VOR. Phase one testing will be conducted with a terminal connected directly to the Loran C monitor to expedite testing.

4.2 CRTICIAL ISSUES.

The specific items that have critical concern are:

a. Interoperability of Loran monitor and VOR.

b. Communications between the Loran C monitor, FCPU, and RMC-F.

c. Security access to the Loran monitor.

d. Certification test of the monitor.

e. Monitoring of the Loran C signal.

f. Evaluation of field maintainability.

g. Documentation evaluation.

4.3 TEST RESULTS.

Test results will be compared to the system specifications given in FAA-E-2762 and the System Program and Implementation Plan for the Loran Aviation Monitor. Primary conclusions will be drawn as to whether the system is functionally complete enough for operation in the NAS.

4.4 DOCUMENTATION.

Documentation of the tests conducted will consist of the following:

a. A summary of the test results. This summary shall briefly outline the tests conducted and their results. The summary shall also identify any test failures.

b. Documentation shall also include the detailed test procedures used during testing.

4.5 TEST MATRIX.

Table, 1 Test Plan Matrix, lists the specification's paragraph number, Program Plan paragraph number, paragraph title, and test plan paragraph number. The table is provided as a reference guide.

5. DETAILED TEST PLAN.

5.1 TEST PROCEDURES.

5.1.1 VOR/Loran Interoperability.

Tests will be conducted to study the effect of the VOR on the Loran C aviation monitor as well as the effect of the Loran monitor on the VOR. The study will include monitoring one system for changes while the other system is cycled on and off.

TABLE 1. TEST PLAN TRACEABILITY MATRIX

Specification's Paragraph Number	Program Plan Order 6860	Paragraph Title	Test Plan Paragraph Number
	12.b	VOR/Loran Interoperability	5.1.1
3.10.6		Communications	5.1.2
3.10.4		Security	5.1.3
3.10.9		Monitor Test	5.1.4
3.8.4		Alarm Generation	5.1.5
3.11		Field Maintainability	5.1.6
	42.d	Documentation Elevation	5.1.7

To study the effect of the VOR on the Loran C monitor, Loran C data will be collected every second for a 5-minute duration with the VOR energized, and then deenergized. Six 5-minute intervals with the VOR energized, and six 5-minute intervals with the VOR deenergized will be conducted. Recordings will be taken from the Loran C monitor and comparisons made with the Loran C data for both VOR conditions. Quick look data will be obtained directly from the monitor output. Quick look data will also be recorded and statistically analyzed later. Interference effects from the VOR will be analyzed by studying the SNR's and TD's for the triad of interest (9960 MXY). Interference, if present, would be expected to appear at least on the weakest station in the triad, station Y. The Loran C RF spectrum will be monitored with a spectrum analyzer for interference between 80 to 120 kHz.

To study the effect of the Loran C aviation monitor on the VOR, the aviation monitor will be cycled on and off while recording VOR data. VOR data will include VOR monitor and ground check data. Parameters to be analyzed are: azimuth angle, 30 Hz modulation, 9960 Hz subcarrier, and field intensity. Baseline VOR monitor and ground check data recorded without the Loran C monitor installed will be compared with the data recorded with the monitor installed.

The monitor antenna will be mounted as described in the contractor's installation plan.

To verify the VOR signal in space agrees with the VOR monitor and ground checks under the various test conditions, a series of flight checks will be flown at the test VORTAC. An initial test will be flown with the VORTAC operating in its normal mode (without the Loran C monitor installed). Each flight test will be identical, consisting of one complete inbound and outbound radial of 270° (site reference valid) and one complete 15-mile orbit. All flight testing will be accomplished at an altitude of approximately 1,500 feet above sea level. Data collection will include analog recordings of the course deviation indicator (CDI) and signal strength. Bearing position reference for all flight testing will be obtained from EAIR. A second series of flight tests will be conducted with the Loran C aviation monitor installed and operating.

5.1.2 Communications.

All command and control instructions will be executed at each I/O port to check for proper operation. I/O ports will include the Loran C monitor IOT, FCPU (IOT), and RMC-F. Phase one testing will be conducted with the Loran C monitor IOT port only. Phase two testing will address all other ports.

5.1.3 Security.

Security access to the system will be tested at each I/O port. The communications tests described above will be used to check for normal access to the Loran C monitor. Attempts will be made to access the various command and control instructions using nonstandard security codes at each of the three levels of access. This test will be designed to make sure only the allowable command and control instructions for each security level may be accessed. No detailed attempts will be made to break the security codes. I/O ports will include the Loran C monitor IOT, FCPU (IOT), and RMC-F. Access to the VOR system with the required security levels for the Loran C monitor will also be evaluated.

5.1.4 Monitor Certification Test.

The monitor certification command will be issued to force the monitor into the self-test mode. Return of the test parameters will be analyzed.

5.1.5 Alarm Generation.

Alarm generation procedures will be evaluated by introducing specific Loran C signal conditions into the aviation monitor and verify the correct message is transmitted to each I/O port. An external Loran C simulator will be connected to the aviation monitor to generate each condition. The monitor will be checked in both the manual and automatic alarm cleared modes.

5.1.6 FIELD MAINTAINABILITY.

No specific tests for field maintainability will be conducted except to verify that access to all components is possible after installation in the VOR building. If any failures occur during the test period, equipment will be repaired and any problems in field maintainability noted.

5.1.7 Documentation Evaluation.

Documents supplied with the system will be reviewed for completeness and correctness. Documents to be supplied include software overview, flow diagrams and listings, user's manual, and field maintenance manual.

5.1.8 Shakedown Test.

The shakedown test will consist of operating the Loran C equipment for 336 hours (14 days). Daily readings will be taken to determine the status of the equipment. Any deviations or outages will be recorded.

5.2 ANALYSIS OF RESULTS.

5.2.1 VOR/Loran Aviation Monitor Interoperability.

Five-minute means and standard deviations of delta TD's and SNR's with the VORTAC energized and deenergized will be compared for any aberrations. The VORTAC flight test data will be examined to determine if the Loran C monitor affects the criteria established by Flight Inspection for VORTAC facilities, e.g., course roughness and scalloping, radial alignment, and bends. The flight test data with the Loran C monitor installed will be compared against the baseline data without a Loran C monitor installed.

5.2.2 Remaining Tests.

All tests to be conducted in paragraphs 5.1.2 through 5.1.7 involve a functional test. The monitor will either respond with correct information, incorrect information, or no information. Analysis of these tests will be simply a pass or fail evaluation. Results will be reported in a list form showing the test conducted and whether the monitor successfully passed the test condition or not.

5.3 DOCUMENTATION.

All tests will be documented in an FAA Technical Note.

6. SCHEDULE.

Project Plan Draft	12/87
FEI Maintainability Test at Factory	3/88
Conduct Tests Phase One	4/88
Conduct Shakedown Test	5/88
Conduct Tests Phase Two	7/88
Draft Technical Note	11/88

7. PRODUCT.

Technical Note: Shakedown Test

Technical Note: Integration Test