# FAA TECHNICAL CENTER
# LETTER REPORT



## GULF OF MEXICO LORAN-C MONITOR TEST PLAN

by

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# GULF OF MEXICO LORAN-C MONITOR TEST PLAN

## INTRODUCTION

The project outlined in this test plan is designed to investigate the stability of LORAN-C signals in the Gulf of Mexico. The project was created in response to the needs of offshore helicopter operators whose requirement for remote IFR navigation and non-precision approaches may be met by LORAN-C. The effects of rapidly changing atmospheric conditions will be investigated as they affect signal stability and derived position information.

## OBJECTIVES

The purpose of this evaluation is to measure long term and short term stability and availability of the LORAN-C signal in the Gulf of Mexico. This information will be used to support a decision on use of LORAN-C for non-precision approach guidance to oil rig platforms under various conditions and operational constraints. Specifically, the project will:

1. Collect and analyze data on the long term and short term stability of LORAN-C signals from the GRI-7980 chain.

2. Observe and quantify the effects of local atmospheric activity, including electrical and other significant meterological events, on signal quality.

## BACKGROUND

Helicopter operations have recently experienced rapid growth within the continental United States, Alaska, offshore and remote mountainous areas. With advances in helicopter technology and avionics, more aircraft are becoming capable of instrument flight rules (IFR) all weather-operations. These abilities often exceed the capability of conventional line-of-sight navigation and landing aids to meet flight requirements in remote areas. The industry is, therefore, looking toward other types of navigation systems that provide accurate position information and are not line-of-sight limited. The most popular system of this type in recent years has been LORAN-C.

LORAN-C is a passive, pulsed, low frequency (100 kilohertz) hyperbolic radionavigation system that uses synchronized signals from three or more transmitting stations to determine position. Coverage of an area is provided by a group of three to six transmitting stations, called a chain. Chains are distinguidhed by their group repetition interval (GRI), which is the period of the chain transmission sequence. Receiver position is determined by measuring time differences (TDs) between arrival of the designated master signal and a secondary signal (Figure 1) to define a line of position (LOP). The intersection of two or more LOPs is receiver position. Signal reception, which affects position determination accuracy, depends upon transmitted power from each station and upon receiver characteristics. Variations in ground conductivity affect signal propagation, while contributions from atmosperic and man-made noise degrade signal reception.

LORAN-C has been approved in and around parts of the Gulf of Mexico for enroute IFR operations. But an increasing demand for IFR operations still exists to serve the needs of commercial oil and gas exploration and production operations. The next logical step in the use of LORAN-C in the aviation field will be as a non-precision approach aid. This particular project is part of the research, development and evaluation program the FAA is conducting to investigate the use of LORAN-C for non-precision aproaches. The Gulf of Mexico LORAN-C monitor system has been jointly funded by the FAA's Program Engineering and Maintenance Service and the United States Coast Guard (USCG).

## SYSTEM EQUIPMENT

Project equipment will be deployed to form a remote automated data gathering network. At the hub of the network will be a Digital Equipment Corporation LSI-11 microcomputer located in the Houston Air Route Traffic Control Center (ARTCC). Data will be delivered from distributed LORAN-C receivers via existing offshore communications channels and onshore telephone circuits. Inputs from the lightning positioning and tracking system presently deployed (and described below) will also be accepted and recorded with Loran data. A block diagram of the system apears in figure 2.

### Northstar 7000 LORAN-C Receiver

The Northstar 7000 LORAN-C receiver is a marine unit manufactured by Digital Marine Electronics Corporation. It consists of a model 7003 mainframe and a model 7600 control head, with an antenna and antenna coupler unit. The receiver is a commercially available unit intended for marine application. It receives and tracks up to five LORAN-C stations in one chain, while displaying position and course guidance information. The receiver measures TD's and produces a latitude/ longitude (lat/lon) solution. It also allows entry of area navigation (RNAV) waypoints defined in either lat/lon or TD's. Other functions are available from the control head to monitor receiver parameters. A serial data stream output allows the parameters in table 1 to be recorded from the receiver.

The receiver is intended for marine use and is configured to receive TDs' which are expected to vary relatively slowly. Tracking loop time constants in marine receivers are relatively large (2 to 5 seconds) to filter short term variations, while time constants in airborne receivers must be relatively short because of higher vehicle velocities. Because the tracking loop time constant of this receiver (approximately 2 seconds) is less than the maximum data rate available, and because it will be operated at a fixed site, the unit provides the required capabilities in its standard configuration.

Each of these receivers will be characterized before deployment using the USCG Loran simulator in Wildwood, NJ. Parameters of interest include TD measurement errors, sensitivity and signal input range, accuracy of measured SNR and performance under in-band interference conditions. A separate report describing test procedures and results of characterizations performed before and after the one-year test period will be published.

The Lightning Positioning and Tracking System (LPATS) is presently deployed in the Gulf of Mexico and operated by the FAA to monitor and report lightning activity in offshore regions of the Gulf. The system is capable of distinguishing between intra-cloud and ground discharges. It identifies and retains data on the part of the return stroke that is within 100 feet of the ground (or water). Crossed orthogonal loop antennas resolve bearing to the lightning flash. Azimuth and intensity of each flash are then quantified and transmitted to a central analyzer. These data are time-tagged at the central processor and position of the flash in lat/lon is computed, based on reports from several remote detectors. These data are then sent to Houston Center via land line to be recorded with LORAN data. The four receivers presently are located at Michoud, Louisiana; Lafayette Airport, Louisiana; Ship Shoal 198 (N28.6, W91.3); and East Cameron 281 (N28.4, W93.0). The system provides coverage of a 15,000 square mile area, up to 150 miles offshore from a line between Lafayette and New Orleans. Data to be collected from this system are listed in Table 2.

Data from the LPATS and each Loran will be output in RS-232 format and modulated by an RFL Industries series 68 modem for transmission on phone line or microwave channel. At Houston Center these data will be demodulated for computer input.

The LSI-11 microcomputer used as the central processor has space for 36K of read only memory, 4K of core, a four-channel DZ-11J interface for RS-232 input, system terminal, asynchronous port, real-time battery backed-up clock and a custom tape controller. Data from each of the three Lorans and the LPATS enter through one of the DZ channels and are processed according to the program in ROM. Data are displayed on the terminal and recorded on a Kennedy 9800 9-track tape drive. Also, the screen image is transmitted via a UDS-103J modem connected to the asynchronous port, and is available to a dial-up terminal for remote monitoring. The battery backed up clock provides data and time of day for data logging and keeps time accurately through power outages.

Equipment Preparation

Equipment for this project consists mostly of items supplied directly by the manufacturer or equipment already in use. The latter category includes the LPATS and a full duplex microwave/telephone link from each rig to the Houston Center. Standard equipment includes the three Northstar 7000 receivers and the LSI-11 microcomputer, which will require some preparation before integration into the system. Much of the preparation will involve development of software to perform the interface and data recording tasks. While little or no hardware modification is anticipated, the LORAN receivers will undergo acceptance tests and calibration on a US Coast Guard LORAN-C Simulator. These tests will determine the characteristics of receiver operation under standard laboratory conditions.

## DATA COLLECTION

The LORAN-C data collection effort will consist of deploying and monitoring three LORAN-C receivers at selected sites in the Gulf of Mexico. LORAN-C receiver parameters output by each unit will be relayed by microwave link to the central computer in the Houston Center, which will process and record these data. A simplifed block diagram appears in Figure 2. Atmospheric data from the LPATS will also be recorded for correlation of LORAN performance to lightning activity. Sites were selected to provice coverage of the major part of the Gulf while remaining in coverage of the existing LPATS. Cooperating oil companies are providing space on their rigs for placement of the LORAN receivers. The relative locations of monitor and LPATS sites are shown in Figure 3.

The recording method used was selected to provide statistical correctness, but avoid producing an unmanageable amount of data. The plan will be incorporated into data collection software at Houston Center which will selectively accept the incoming asynchronous data. The basis for validity of the process lies in statistical and sampling theory and previous characterization of Loran performance.

Loran data will be recorded at the maximum rate of approximately once every three seconds from each receiver for a ten minute interval each hour. The position of this ten minute period in the hour will vary randomly so as to avoid introduction of any bias that may be part of longer-period variations. During the rest of each hour data will be recorded by exception only, when unusual or rapidly changing data are being measured. The limits established to determine exception will be based on previous testing of Loran performance. LPATS data will be recorded asynchronously, each time the system senses and resolves the position of a lightning strike.

The 95% confidence interval established by this recording method will be within 0.02 microseconds for each time difference measurement, based on a one-sigma error of .1 s (worst case, based on measured errors of .05 s or less) for each ten minute sampling period (see reference 1). Based on previous observations that no component of Loran TD variations has an hourly periodicity, Nyquist sampling theory determines that the sampling method is valid for observation of diurnal and seasonal variations, and will still allow observation of shorter term (approximately 10 second) variations during the ten minute period each hour.

## LORAN-C Monitor Site Preparation

Preparation of each site to collect monitor data involves several steps. First, the position of the rig must be determined accurately. Platform lat/lon are already known. Survey data maintained by oil companies will be made available for this project.

Modem interface and microwave transmission facilities will be provided by cooperating oil companies using in-place equipment and materials supplied by the FAA. Microwave links are presently used for communications from rigs to shore, and will be leased from the oil companies for this project.

Decisions on antenna placement and receiver installation will be made by project personnel in cooperation with oil company representatives. These decisions will minimize the project's impact on daily rig activities while providing for accomplishment of project objectives.

## LORAN-C Stations to be Monitored

The LORAN-C chain which provides coverage of the Gulf is the GRI 7980 chain (Figure 4). It is comprised of a master station in Malone, FL, with secondaries in Grangeville, LA: Raymondville, TX, Jupiter, FL, and Carolina Beach, NC. Distances of rigs from each transmitter are given in Table 3.

Station geometry considerations require that lines of position intersect at an angle as close to ninety degrees as possible. Angles of thirty degrees or less will provide inaccurate solutions and should not be used. However, time difference measurements are still valid. It is expected that all stations will be available at each of the monitor.sites.

## U.S. Coast Guard LORAN-C Monitor Data

The U.S. Coast Guard monitors LORAN-C stations as part of its chain control function. Measured data is fed back to keep errors within certain boundaries. Compensation is made for timing drift between two transmitters. Automated stations also record some performance data, including station outages of more than one minute duration. These data will be gathered for correlation with LORAN performance measured by FAA receivers at times of observed station outages or signal degradation to determine whether these problems existed at transmission or were a result of passing through the transmission medium.

NOAA Weather Data

Weather data from the National Atmospheric and Oceanographic Administration (NOAA) will be gathered and utilized for weather correlation. NOAA has agreed to supply weather reports for the area, as well as satellite maps and interpretations. This will enable observation of any cause and effect relationship between weather conditions and variation of LORAN parameters. It will also aid in interpretation of the LPATS data. When available, pilot reports (PIREPS) and significant meteorological activity (SIGMETS) will also be correlated with recorded weather data. It is expected that this information will be used in a very general manner to determine types of weather in the area and loosely correlate it to Loran performance.

DATA ANALYSIS

Data analysis will be performed to characterize short and long term stability and the effect of atmospheric activity on LORAN performance. Received time differences, which include errors in transmission, propagation and receiver measurement, are more sensitive to variation than the lat/lon solution computed by the receiver. These measured TDs will, therefore, be used to determine signal transmission and propagation characteristics. The effects of receiver sensitivity and time difference measurement will be minimized by applying a correction factor based on measured receiver bias. The correction factor for each receiver will have been determined as a result of the calibration tests performed using the USCG LORAN-C simulator. Relative signal strengths (SNRs) and signal distortion (envelope-to-cycle discrepancy or ECD) will then be used to characterize system performance at various times and under various atmospheric conditions.

The first phase of the analysis will focus on stability versus time, independent of meteorological events. The minimum time interval will be ten minutes, representative of the duration of a final approach segment. The long term analysis will be conducted by determining the rate of variation of recorded parameters, expanding the time interval progressively to hourly, daily, weekly and monthly time periods. Statistics will be computed to characterize data as a mean and variance for each time interval for: time differences, ECDs, and SNR computed by the receiver. Position variations will be calculated as two-dimensional errors (2D mean and 2 drms) and the ninety-five percent confidence interval of the lat/lon solution to judge compliance of measured accuracies with FAA published requirements for non-precision approaches. Data will also be presented graphically, both as scatter plots and as time dependent variations, to better show trends in the data.

The second phase of data analysis will address short term stability of TDs and SNRs correlated to meteorological activity. This will quantify the amount of variation in measured parameters during periods of electrical activity of various durations and proximities. Also, short term variations will be correlated to atmospheric activity, including cloud cover at the receiver, transmitter, and along the propagation path which may affect the conductivity of the intervening region. Possible existence of diurnal and seasonal variations will be examined and, if present, correlated to temperature, moisture content of the air, and cloud cover. The second phase will be carried out over the duration of the test to determine the effect of various ground conductivities in the areas between transmitter and receiver. Propagation paths for different signals at each site consist of varying percentages of over-land and over-water portions, which are expected to cause constant biases in measured TDs at each site.

The final step in data analysis will be to calculate position errors derived from time difference measurements. A USCG computer program has been obtained and will be used to generate lat/lon solutions using various pairs of TDs. These will then be used to derive errors from known rig position and compared to AC 90-45A accuracy requirements for non-precision approaches.

The spatial model of Loran propagation characteristics contained in the Coast Guard program will be used to observe local grid warpages, which will appear as differences between predicted and observed time differences. Variables in the model include refractive index of the atmosphere and conductivity along the propagation path. Use of the model will allow the magnitude of the effect of variations in these parameters to be quantified. Notch filter parameters (amplitude and frequency) will be used to identify interference in the Loran band. Information of this type is useful for receivers with fixed notch filters, as it may identify local sources of interference that are not widely known.

TABLE 1

LIST OF LORAN PARAMETERS TO BE RECORDED

TIME

TIME DIFFERENES OF UP TO FOUR SECONDARIES

SNRS OF ALL SECONDARIES AND MASTER

ECDS OF ALL SECONDARIES AND MASTER

ALARM CONDITIONS OF ALL STATIONS - BLINK, LOW SNR, TRACK CYCLE UNCERTAINTY

CHAIN SELECTED

NOTCH FILTER FREQUENCY AND AMPLITUDE

TABLE 2

LIST OF LPATS PARAMETERS TO BE RECORDED

TIME

LIGHTNING STRIKE NUMBER

LATITUDE OF STRIKE

LONGITUDE OF STRIKE

STATUS OF LIGHTNING SENSORS

STRIKE INTENSITY

TABLE 3

DISTANCES FROM LORAN TRANSMITTERS TO RECEIVERS (NAUTICAL MILES)

| Transmitter | BR-A70 | EC-281 | WD-152 |
|---|---|---|---|
| Malone | 594 | 420 | 277 |
| Grangeville | 312 | 165 | 142 |
| Raymondville | 137 | 300 | 448 |
| Jupiter | 836 | 663 | 511 |
| Carolina Beach | 847 | 678 | 544 |

COORDINATION AND AREAS OF RESPONSIBILITY

APM-720 - will provide program management and coordinate various program aspects with the Federal Aviation Administration Technical Center Engineering Division (ACT-100).

ACT-140 - will provide center program and project management, engineering and other technical support. ACT-140 will be responsibile for collection, reduction and analysis of data, design, fabrication, programming and installation of the data collection system in Houston Center; and writing the final report. Coordination will be accomplished between ACT-140, APM-720, APM-610, ASW, NOAA, the U.S. Coast Guard, and participating oil companies and oil support companies.

ASW - will provide space in the Houston ARTCC for data collection equipment and personnel to change data tapes and forward them to the Technical Center.

APM-610 - will provide engineering and technical support for design and installation of the offshore network, including Loran and LPATS. Coordination will be accomplished with APM-720, ACT-140, ASW and participating oil and offshore support companies.

NOAA - will provide weather charts and analysis at ACT-140 request.

USGC - will provide Loran monitor data and use of their Loran-C simulator for receiver characterization.

Oil and offshore support companies are providing space on oil rigs, leased microwave facilities and transportation of personnel and equipment to offshore rigs.

## REFERENCES

1. Natrella, M.G., Experimental Statistics, NBS Handbook 91, U.S. Department of Commerce, National Bureau of Standards, August 1, 1963.

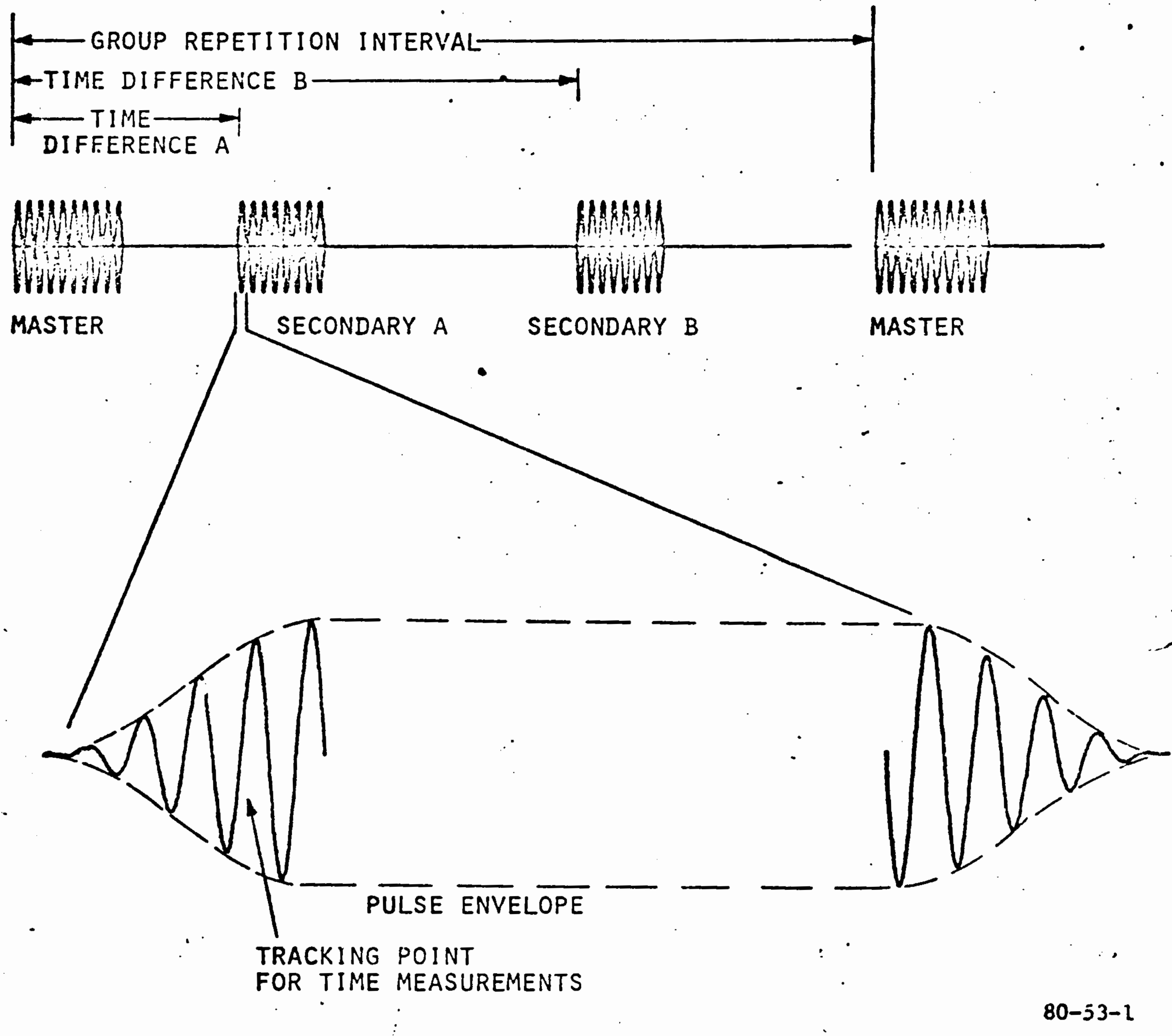


FIGURE 1. LORAN-C PULSE TRAIN

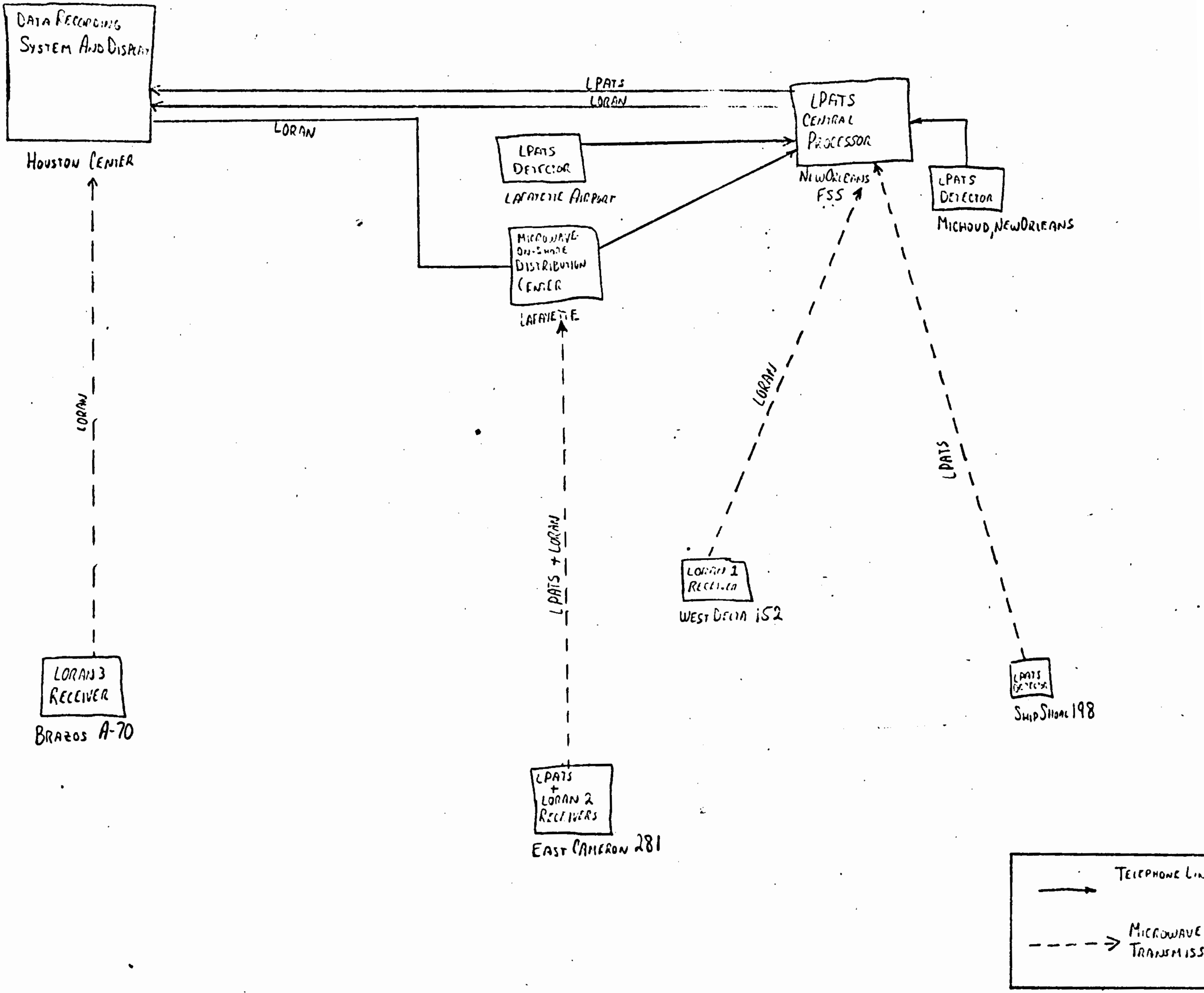


FIGURE 2. LORAN MONITOR SYSTEM

# LORAN MONITOR SYSTEM

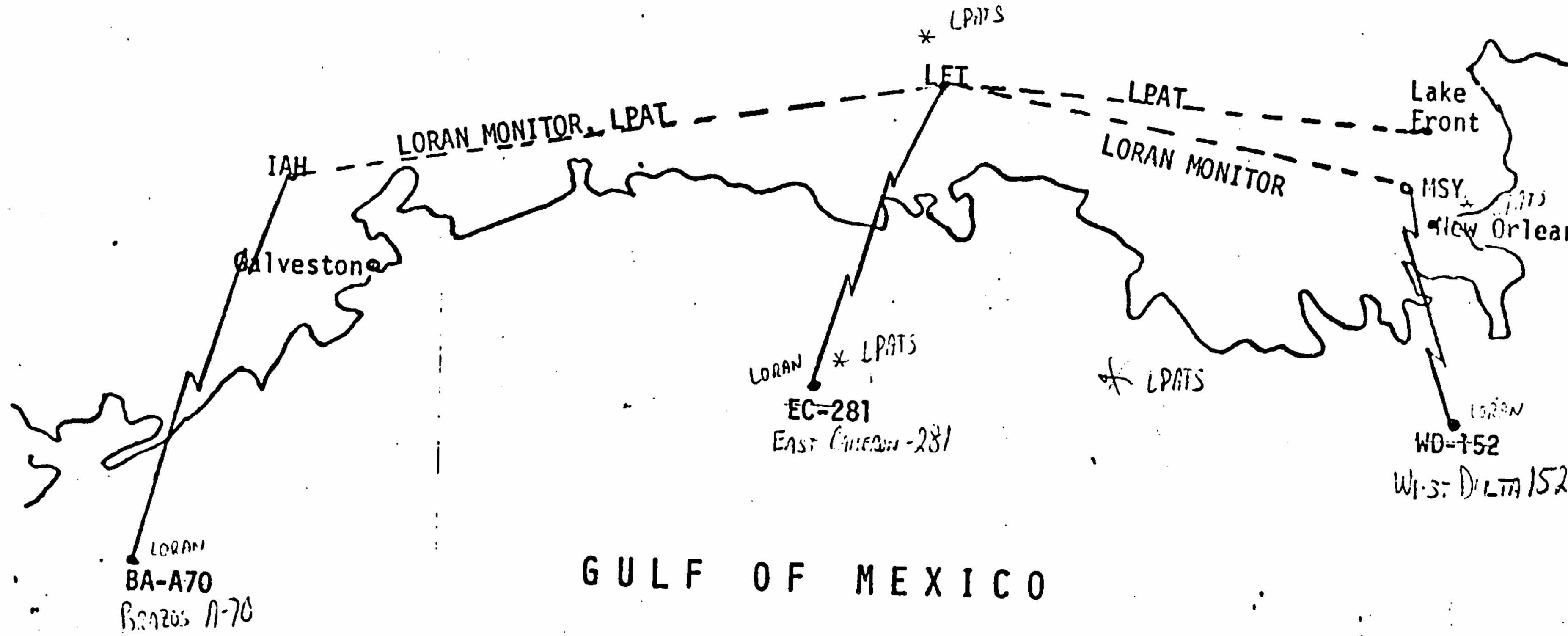


FIGURE 3. LORAN MONITOR AND LPATS DETECTOR SITES

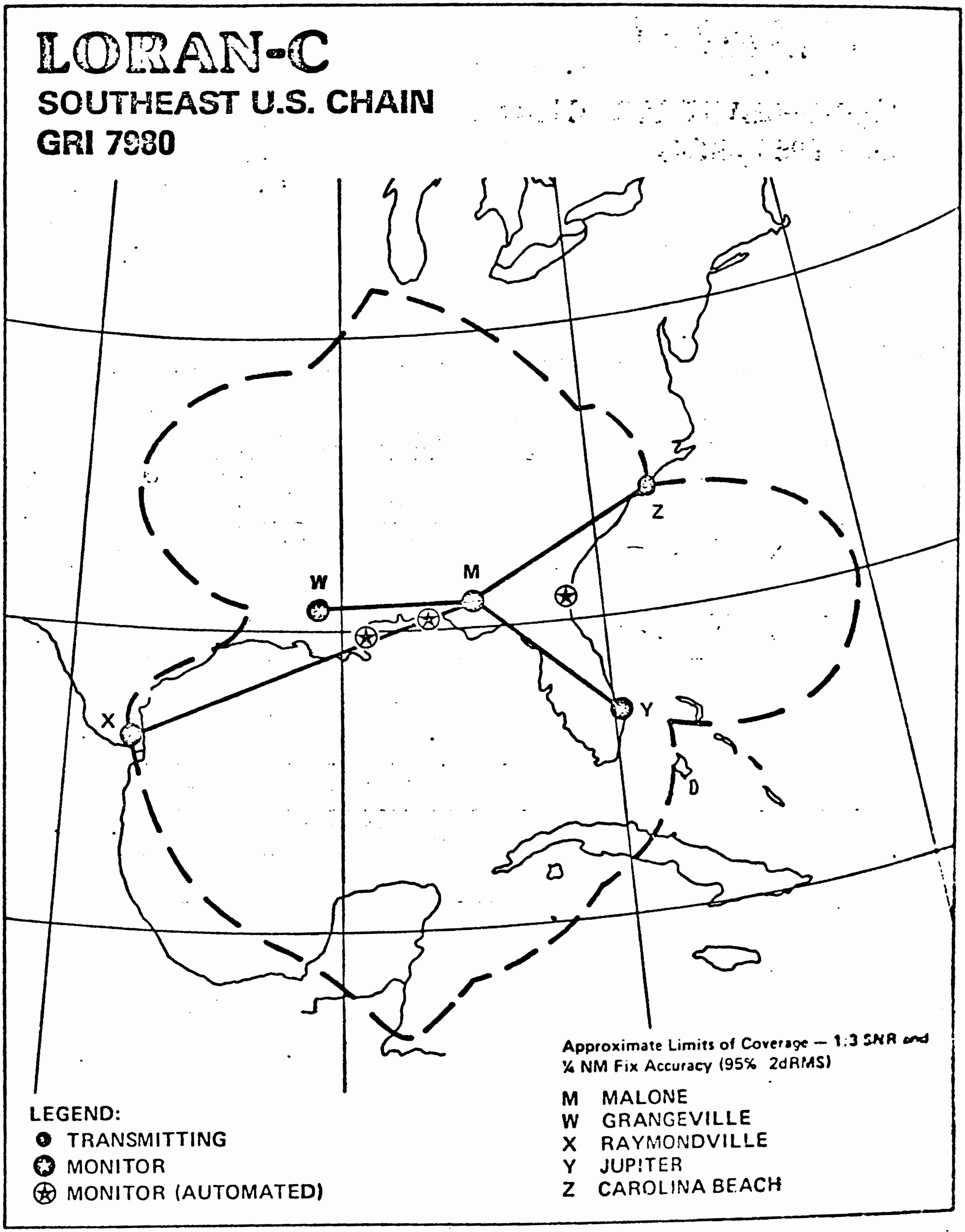


FIGURE 4. LORAN-C SOUTHEAST U.S. CHAIN GRI-7980

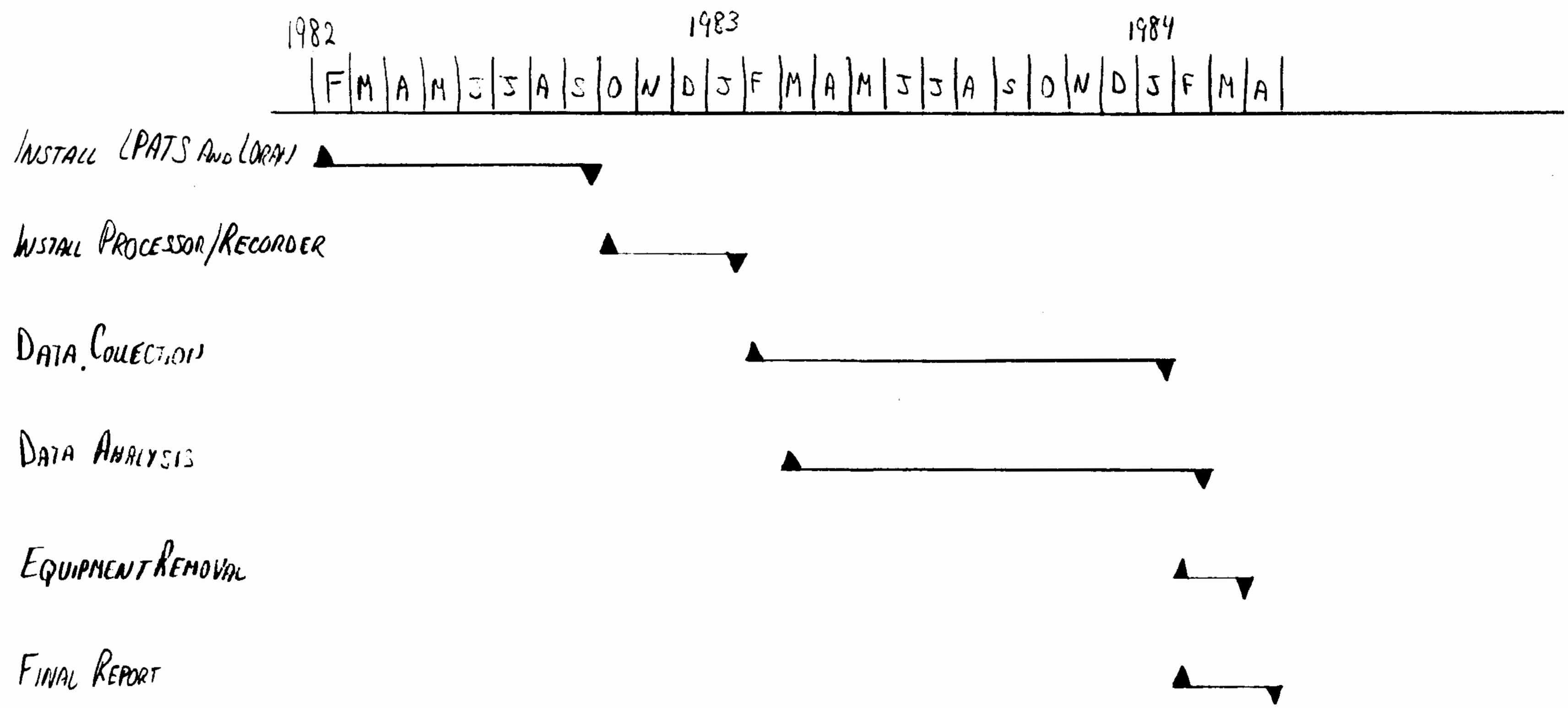


FIGURE 5. PROJECT TIME TABLE