DOT/FAA/CT-81/191

Test Loran-C in Mountainous Areas

Lorraine Rzonca

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Project Plan

U.S. Department of Transportation
Federal Aviation Administration
Technical Center
Atlantic City Airport, N.J. 08405

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1. OBJECTIVES.

The overall goal of this project is to determine the suitability of long range navigation (Loran)-C for airborne area navigation (RNAV) operations in mountainous areas. Operational performance of three types of production airborne Loran-C equipment will be evaluated. Approximately 120 flight data hours will be taken onboard fixed-wing aircraft flying en route within transition and terminal areas, and during nonprecision approaches to several airports located in mountainous terrain. Areas of investigation will include:

a. Accuracy (with respect to a special ground-based distance measuring equipment (DME) reference system and compared to criteria stated in Advisory Circular (AC) 90-45A for flight technical error, airborne equipment error, and total system error).

b. Effective signal coverage (as measured by each different model of Loran-C navigator).

c. Operational suitability (pilot workload, Loran-C set responsiveness during typical air traffic control (ATC) maneuvers).

2. BACKGROUND.

The Loran-C System has been used for navigation and for specialized military air operations since the late 1950's. However, serious application to civil air navigation is a relatively recent phenomenon. Technological advances which decrease Loran-C equipment costs and the commissioning of several new Loran-C chains in the late 1970's and 1980 have stimulated interest in the potential of Loran-C as a navigational aid (NAVAID) for general aviation. Since the Loran-C low frequency (100 kilohertz (kHz)) provides stable ground-wave propagation and coverage that is not limited by line-of-sight between transmitter and receiver, Loran-C is a likely candidate for aircraft RNAV at airports located in mountainous terrain. This project will provide data required by the Federal Aviation Administration (FAA) in support of a 1982 decision to recommend the civil radio navigation system mix of the future.

Early test flights under the current project included approximately 19 data hours (en route) in Alaska in June 1978 (Technical Center letter report NA-79-6-LR, February 1979); approximately 10 data hours (en route and nonprecision approaches) in Vermont, New York, and Virginia in October/November 1979 (Technical Center letter report NA-70-14-LR, February 1979); and 14 data hours (en route and nonprecision approaches) in Vermont between September 1979 and March 1980 (Technical Center report FAA-CT-81-22, April 1981).

3. RELATED DOCUMENTATION/PROJECTS.

During the summer of 1979, Champlain Technology Industries (CTI) conducted nonprecision approaches at several mountainous airports in the Western U.S.A. (report No. FAA-RD-80-28, March 1980).

Beginning in the summer of 1979, the Transportation Systems Center (TSC) has been conducting flight tests (200 flight hours planned) and collecting Loran-C ground monitor data (over a 2-year period) within the State of Vermont (report No. DOT/TSC/TSPA-80-21, November 1980, "Preliminary Results of Loran-C Flight Testing in the State of Vermont").

In the flight tests mentioned above and for tests conducted by the FAA Technical Center, accuracy statistics of the Loran-C navigation equipment are compared with the criteria set forth in AC 90-45A for 2-D RNAV systems (table 1).

TABLE 1. ACCURACY CRITERIA FOR 2-D RNAV SYSTEMS

Based upon FAA AC 90-45A, existing airborne Loran-C equipment can meet the FAA accuracy requirements if error budgets (95 percent confidence) satisfy the following criteria:

Total System Error	Crosstrack (nmi)	Along-Track (nmi)
En Route	2.5	1.5
Terminal	1.5	1.1
Approach	0.6 (3,600 ft)	0.3 (1,800 ft)

Airborne Equipment Error	Crosstrack (nmi)	Along-Track (nmi)
En Route	1.5	1.5
Terminal	1.12	1.10
Approach	0.33	0.30

Flight Technical Error	Crosstrack (nmi)	Along-Track (nmi)
En Route	2.0	0
Terminal	1.0	0
Approach	0.5	0

4. SYSTEM/EQUIPMENT DESCRIPTION.

The Loran-C equipment to be used for these tests includes a Teledyne TDL-711, a Teledyne TDL-424, and an ONI-7000 (manufactured by Austron Navigation, Incorporated). All these units are production receivers available for public purchase. Operating characteristics and physical data for each set are included in tables 2 through 4 (TDL-711 in table 2, TDL-424 in table 3, and ONI-7000 in table 4).

A functional diagram of a typical airborne Loran-C System is given in figure 1. As indicated, received Loran-C signals are processed under software control to produce the two basic time differences, denoted TDA and TDB; a coordinate converter changes time differences into latitude/longitude. The latitude/longitude can be corrected for propagation anomalies by a feature called "area calibration" which forces the Loran-C displayed position coordinates to coincide with known surveyed coordinates. Other navigation data are obtained by specific software routines and are presented to the pilot either by digital displays or by an analog course deviation indicator (CDI).

Although the basic operation of a Loran-C navigator conforms to that described above, several differences manifest themselves in the operational features provided by each manufacturer. Significant differences among the three Loran-C receivers include waypoint storage space, waypoint sequencing, Loran-C chain/triad selection, Loran-C secondary changes, and notch filters. Table 5 lists the major operational differences among TDL-711, TDL-424, and ONI-7000.

5. TESTING AND DATA COLLECTION.

The phase of Loran-C flight testing covered by this project plan will include en route, terminal maneuvers, and nonprecision approaches to five airports located in mountainous terrain. Preplanned routings will be flown in a Convair CV-580 equipped with the Loran-C navigation systems to be used during this test. Provision will be made to install one of the Loran-C sets in the overhead center panel of the cockpit, with the CDI installed in the front panel so that the pilot can fly the designated Loran-C flight profiles. The other Loran-C sets, installed in a rack in the passenger compartment of the CV-580, will be operated by the project engineer. Airborne Loran-C data and position information from the ground-truth system (multi-DME tracker) will be recorded once every second on magnetic tape by the data collection system Aircraft Tracking and Data System (ATADS). ATADS is described later in the section entitled "Instrumentation and Facilities." The ONI-7000 (or other) Loran-C System will require in-house design and construction of an interface to the ATADS.

Testing will focus on the following parameters:

a. Accuracy:

1. Comparison with AC 90-45A criteria.

2. Primary versus alternate triad operation.

TABLE 2. TDL-711 LORAN-C MICRONAVIGATOR CHARACTERISTICS

Navigation System	
Mode	Great Circle
Grid Reference (operator selected)	Latitude/Longitude (0.1 min) Time Difference (0.1 μs)
North Reference	True or Magnetic
Waypoints	9 (nonvolatile)
Display Resolution	
Distance/Bearing-to-Waypoint	0.1 nmi/1°
Estimated Time En Route/Groundspeed	0.1 min/1 kn
Crosstrack Distance/Desired Track	0.01 nmi/1°
Track-Angle Error/Ground Track	1°/1°
Offset (input)/Magnetic	0.01 nmi/1°
Variation (input) (repeatable accuracy)	Better than 0.1 nmi
Left/Right Steering to CDI	1.25 nmi full scale
Loran-C Data	
Area of Operation	Two Loran-C Triads
General	Exceeds RTCA DO-159
	Type III Requirements
Acquisition	Automatic
Velocity Envelope (unaided)	0 to 950 kn
Master Independent	Automatic
Environmental	
Operating Temperature	-55° to 55°C
Altitude (unpressurized)	20,000 ft
Power	18 to 32 Vdc, less than 40 W
Physical	
Receiver Computer Unit	7.62 x 7.50 x 12.58 in. 11.0 lb.
Control Display Unit	4.50 x 5.75 x 6.50 in. 4.5 lb.
Antenna	16.5 x 2.5 x 10.0 in. 0.5 lb.

TABLE 3. TDL-424 LORAN-C CHARACTERISTICS

Navigation System	
Mode - Long Range	Great Circle
- Short Range (less than 10 nmi)	Flat Earth
Grid Reference (operator selected)	Latitude/Longitude (0.01 min) Time Difference (10 ns)
North Reference	True or Magnetic
Waypoints (manual or automatic)	9
Display Resolution	
Range/Bearing	0.1 nmi/1.0°
Ground Track/Groundspeed	1.0°/1.0 kn
Desired Track/Track-Angle Error	1.0°/0.1°
Time-to-Waypoint/Distance Crosstrack	0.1 min/0.01 nmi
Left/Right Steering to CDI	1/2 nmi full scale
Overall Accuracy	50 to 700 ft
Loran Data	
Loran Chains	11 Permanent 1 Temporary
Stations Tracked	5
General Performance	Exceeds DO-159 Type III Reqs.
Acquisition	Automatic
Minimum Signal-to-Noise Ratio	Acquisition - 14 dB Tracking - 26 dB
Velocity Envelope (unaided)	0 to 1600 fps
Master Independent	Automatic
Environmental	
Operating Temperature/Altitude	DO-160 (B-1)
Power	28 Vdc; 3 amps max.
Reliability	1,000 hr MTBF
Physical	
Receiver Computer Display Unit	9.0 x 5.75 x 6.5 in. 9.0 lb.
Antenna Coupler	4.2 x 3.75 x 7.0 in. 20 lb.
Antenna	2.0 x 3.0 x 15.0 in. 1.5 lb.

TABLE 4. ONI-7000 LORAN-C NAVIGATOR CHARACTERISTICS

<u>Navigation System</u>	
Area of Operation	All Existing Loran-C Chains World-Wide
Mode	Great Circle
Grid Reference (operator selected)	Latitude/Longitude (0.01 min) Time Difference (0.01 μs)
North Reference	True or Automatic Magnetic Correction
Waypoints	200 (Nonvolatile)
Display Resolution	
Distance/Bearing-to-Waypoint	0.1 nmi En Route or 0.01 Approach/1°
Estimated Time En Route/Groundspeed	0.1 min/1 kn
Crosstrack Distance/Desired Track	0.01 nmi/1°
Track Angle Error/Ground Track	1°/1°
Offset (input)/Magnetic Variation (input)	0.01 nmi/1°
Repeatable Accuracy	Typically Better than 0.1 nmi
Left/Right Steering to CDI	5 nmi En Route/2.5 nmi Approach
<u>Physical</u>	
Receiver Computer Unit	7.62 x 7.50 x 12.58 in. 13.1 lb
Control Display Unit	4.50 x 5.75 x 6.50 in. 5.0 lb.
Antenna	6.25 x 3.50 x 14.50 in. 1.5 lb.

TABLE 5. OPERATIONAL DIFFERENCES AMONG TDL-711, TDL-424, AND ONI-7000

Feature	TDL-711	TDL-424	ONI-7000
Waypoint storage	9 waypoints	9 waypoints	200 waypoints
Waypoint sequencing	Manual with leg change advisory	Optional: manual or automatic change	Optional: manual or automatic
Chain/triad selection	2 preprogrammed triads (PROM-CHIP) or 16 triad option (preprogrammed)	11 chains with all secondaries preprogrammed; 1 extra chain may be entered manually	All existing Loran-C chains worldwide; automatic selects best stations for navigation
Secondary change	Automatic (if chosen secondary is lost during navigation)	Manual with automatic (based on SNR, GDOP, and crossing angles)	Automatic (based on SNR, GDOP, and crossing angles)
Chain change	Manual	Manual with automatic advisory	Automatic
Master independence	Yes (if 3 secondaries being tracked and master lost during navigation)	Yes (if 3 secondaries being tracked and master not acquired during search or lost during navigation)	Yes (searches for and acquires all stations available, then selects best for navigation)
Notch filters	2, manual tuning	6, manual tuning	3, automatic tuning; 3, manual

3. Repeatable versus predicted latitude/longitude.

4. Transmitter near-field effects and geometric dilolution of precision (GDOP). (The Loran-C position fix is obtained by the intersection of two hyperbolic lines-of-position (LOP's.) GDOP is a measure of the sensitivity of position fix accuracy to the errors in Loran-C time difference (TD) measurements. GDOP is usually measured in feet/microseconds and is a function of both the spreading of the hyperbolic lines and the crossing angle between LOP's.

5. Seasonal effects.

6. Effect of area calibration.

b. Signal coverage:

1. Actual versus predicted.

2. Possible losses due to interfering frequencies.

3. Variation due to seasonal changes.

c. Operational suitability:

1. Pilot workload, blunder errors.

2. System responsiveness during ATC maneuvers.

d. Data to be recorded from each Loran-C set includes:

1. Present position in latitude/longitude.

2. Loran-C time differences (microseconds) for secondary stations.

3. Loran-C triad in use.

4. Track status of master and secondaries.

5. Blink status of master and secondaries (ON-OFF transmissions of individual pulses according to a specified code indicate unusable signals from the station).

6. Enveloping status and envelope numbers for master and secondaries (status of signal processing within receiver; defines particular mode from search to track mode).

7. Signal-to-noise ratios (SNR) for master and secondaries.

8. Desired track, actual track, distance and bearing to next waypoint, ground speed, and crosstrack deviation.

9. Scale factor for CDI.

10. Control display unit (CDU) switch status: identifies switch position, time difference or latitude/longitude mode, and test mode.

A comprehensive test matrix has been devised (as shown in figure 2) to obtain the data required prior to the 1982 decision. An estimated 120 flight data hours have been allocated to en route terminal and approach phases at five designated test sites. The following are details of the preliminary tests at the FAA Technical Center and the flight tests in the field.

5.1 PRELIMINARY TESTS.

The ATADS was fabricated by the Sierra Nevada Corporation under a Systems Research and Development Service (SRDS) contract. Acceptance tests of this system, to document its accuracy, are to be performed under another project at the FAA Technical Center using the Nike-Hercules tracking radar as a reference system. A separate test plan for the ATADS test will be prepared. The system is expected to provide aircraft position within 200 feet circular error of position (CEP) when 6 or more (up to 10) commissioned DME's are received, and within 50 feet CEP when 4 or more specially modified (fast rise time pulses) portable DME's are received. A block diagram of ATADS appears in figure 3.

Familiarization tests for the project team will be required, both on the ground and in the air. Included will be deployment of portable DME's for ATADS; accurate surveys of DME locations, using a JMR-3 satellite surveyor; pilot familiarization with Loran-C operation (TDL-711 and TDL-424); project engineer and technician familiarization with operation of ATADS airborne subsystem, TDL-711, TDL-424, and ONI-7000. Familiarization flights in the CV-580 at the FAA Technical Center will include 20 approaches to runway 13. The first two approaches will follow a general aviation pattern with base leg 1 1/2 nautical miles (nmi) long and final approach 1/2 nmi long. The pilot will operate the TDL-424 on the 9960 XY triad (Seneca-Nantucket-Carolina Beach) with "area calibration" applied prior to flight, waypoint latitude/longitude for the start/end of the base leg and the center of the runway will be interpolated from geological survey charts, and waypoint sequencing will be automatic.

For the remaining 18 approaches, the pilot will operate the TDL-711. The pilot will be hooded and follow the special Loran-C approach plate shown in figure 4. The familiarization test matrix is included in table 6. The two Loran-C sets in the project rack will be initialized with the same waypoints and same triads as the pilot's Loran-C set.

Loran-C data will be digitally recorded on ATADS. All area calibrations will be performed at a preselected surveyed point on the airport, at which time Loran-C TD's and latitude/longitude will be noted for all three Loran-C sets. Values of TD's for approach waypoints will be measured at these points by a TDL-424.

5.2 FLIGHT TESTS IN MOUNTAINOUS REGIONS.

Flight tests will be conducted at five airports: Rutland, Vermount (RUT), New River Valley, Virginia (PSK), Bishop, California (BIH), Lake Tahoe, California (TVL), and Grand Junction, Colorado (GJT). Special Loran-C approach plates for these airports are included in figures 5 through 9. Position reference will be provided by portable DME's deployed in the vicinity of the airport (four to six DME's) and any commissioned DME's within range. The test matrix applicable to each airport is included in table 6. Loran-C data, aircraft altitude (barometric), reference position, and time will be recorded on ATADS. Flights will be made under visual flight rules (VFR) conditions; the pilot will use either the TDL-711 or TDL-424 as primary guidance and will simulate IFR conditions by wearing a hood. The project engineer or technician will activate an "event" button on the ATADS when the pilot starts/ends a turning maneuver.

TABLE 6. TEST MATRIX FOR NONPRECISION APPROACHES

1. Range tests at ACY: Nike-Hercules range tracking:

	9960 XY Primary Triad	9960 WX Alternate Triad	8970 WX Other Chain
L/L Waypoints	4 area cal. 2 no area cal.	2 area cal. 2 no area cal.	2 area cal. 2 no area cal.
TD Waypoints	2 no area cal.	2 no area cal.	2 no area cal.

2. Field Tests: ATADS position reference:

	Primary Triad	Alternate Triad	Other Chain
L/L Waypoints	3 area cal. 3 no area cal.	3 area cal. 3 no area cal.	3 area cal. 3 no area cal.
TD Waypoints	3 no area cal.	3 no area cal.	3 no area cal.

NOTE: If area calibration is not needed for a particular triad, then those three approaches will be deleted.

3. Triads To Be Tested:

Site	Primary Triad	Alternate Triad	Other Chain
Rutland, Vt.	9960 WX	9960 XY	
New River Valley, Va.	9960 YZ	9960 XY	8970 WX
Bishop, Calif.	9940 XY	9940 WX	
Lake Tahoe, Calif.	9940 XY	9940 WX	
Grand Junction, Colo.	9940 WY		

Total number of approaches = 90

Airports have been chosen to demonstrate Loran-C operation in: (1) locations where high terrain surrounds the airport (RUT, PSK, and BIH); (2) boundary areas for signal coverage (GJT); and (3) areas which include transmitter near-field effects (TVL). Use of primary and alternate triads will indicate effects of GDOP. The effectiveness of area calibration in compensating for propagation anomalies will be examined. En route flights in the vicinity of each site will include approximately 3 hours at 6,000 feet above ground level (AGL) along existing airways: a 1-hour flight with primary triad, area calibration; a 1-hour flight with primary triad, no area calibration; and a 1-hour flight with alternate triad, no area calibration.

The flight route between test sites in the Eastern and Western United States is shown in figure 10. En route flights will include triad and chain switches in flight, operation in close proximity to a Loran-C transmitter, signal reacquisition during flight, and effect of detuning the notch filters (if adjustable). Of special interest is the area in the Midwestern United States which currently lacks sufficient Loran-C coverage. The location where coverage ends when outbound from a Loran-C chain and where coverage begins when inbound to the next chain will be noted for each Loran-C set. Based on manufacturer claims, the ONI-7000 is expected to provide Loran-C navigation even in the Midwestern coverage gap; consequently, en route patterns along existing airways will be flown in the vicinity of Pierre, South Dakota, and Albuquerque, New Mexico, to demonstrate capability within the coverage gap.

6. DATA REDUCTION AND ANALYSIS.

ATADS provides for in-flight quick-look data which indicates that the DME tracker and Loran-C Systems are operating properly and being recorded. Provision for track plots and time history plots of Loran-C data compared to the position reference system is included in the ATADS software package to determine whether any data flights need to be repeated. This data reduction would be performed in the field after the day's flights had been completed. Formal data reduction will be done on the ground-based data reduction subsystem of ATADS, although this capability will not be available until 2 months after delivery of the airborne ATADS package. Formal data reduction will include accuracy statistics for comparison with AC 90-45A, scatter plots, and data listings (e.g., date, time, Loran-C triad, altitude, DME's tracked, latitude/longitude, Loran-C signal-to-noise ratio, time differences, signal status information, ground speed, distance to go, and cross-track distance). Prior to delivery of the ground-based data reduction subsystem, data will be processed through the Range, Programming and Analysis Branch.

Casette tapes from ATADS will contain multiple DME ranges, Loran-C data, inertial navigation system (INS) data, and time. A Kalman filter designed by the Systems Test and Evaluation Division will be applied to the multiple DME ranges to produce the ATADS reference position. This filtered ATADS position will be merged with the Loran-C data and Nike-Hercules radar tracking position (when tests are conducted at the FAA Technical Center) and recorded on 9-track tape. The Range, Programming and Analysis Branch will unpack the 9-track tape and produce preliminary data listings and track plots for data editing purposes. The Loran-C project engineer will edit and specify the data to be used for accuracy statistics. Crosstrack and along-track errors, flight technical errors, and northing/easting errors will be computed for each nonprecision approach and en route segment. Accuracy of Loran-C will be based upon the Nike-Hercules radar position. Track plots, scatter plots, and point-by-point error listings will be produced for specific flight segments as requested by the Loran-C project engineer. Computer programs already exist to handle similar data generated during Vermont Loran-C tests so that only minor revisions are required to handle the ATADS output.

The accuracy statistics will be computed for each nonprecision approach, for each straight line segment of an en route flight, and for the total en route flight. Values will show effects of area calibration, primary and alternate triads, latitude/longitude and time difference waypoints, and whether AC 90-45A criteria can be met. Instances of triad switching and chain switching will be examined to determine any position discontinuities at the switch, and the length of time that valid navigation capability is lost. Flights near Loran-C transmitters, near baseline extensions, or with an interfering signal present should provide information on differences in response among the three Loran-C equipments. Seasonal effects will be derived by comparison of summer and winter tests at RUT and PSK. Comments on pilot workload will be obtained from the project pilots, and blunder errors (type and frequency) will be noted.

7. INSTRUMENTATION AND FACILITIES.

Loran-C data collection, recording, and analysis will be provided by ATADS (delivery date June 30, 1981, by the Sierra Nevada Corporation under an SRDS contract).

Range tests at the FAA Technical Center will require the Nike-Hercules radar and the Honeywell 66/60 large-scale computer for data processing.

The JMR-3 satellite surveyor from the Range Engineering Section will be required for accurate surveying of the portable DME's installed at field sites.

8. COORDINATION AND AREAS OF RESPONSIBILITY.

Nonprecision approaches to the five selected airports will require coordination with airport operators since portable DME's will have to be installed and surveyed in the vicinity of the airport. Sites for portable DME's may be on private property; this will require prior coordination with property owners, possibly through the appropriate FAA Regional Office.

ACT-100B.2: Make prior arrangements for permission to install portable DME's at the test sites, install DME's and survey the sites, conduct flight tests, and analyze data and report results.

ACT-650: Install ATADS rack, Loran-C set for pilot operation, and required antennas in CV-580.

ACT-750: Process FAA Technical Center range test data and limited amount of Loran-C data (prior to delivery of ATADS ground-based data reduction subsystem in August 1981), revise existing programs to accommodate ATADS data.

ACT-754: Provide JMR-3 satellite surveyor.

ACT-753: Provide Nike-Hercules radar tracking.

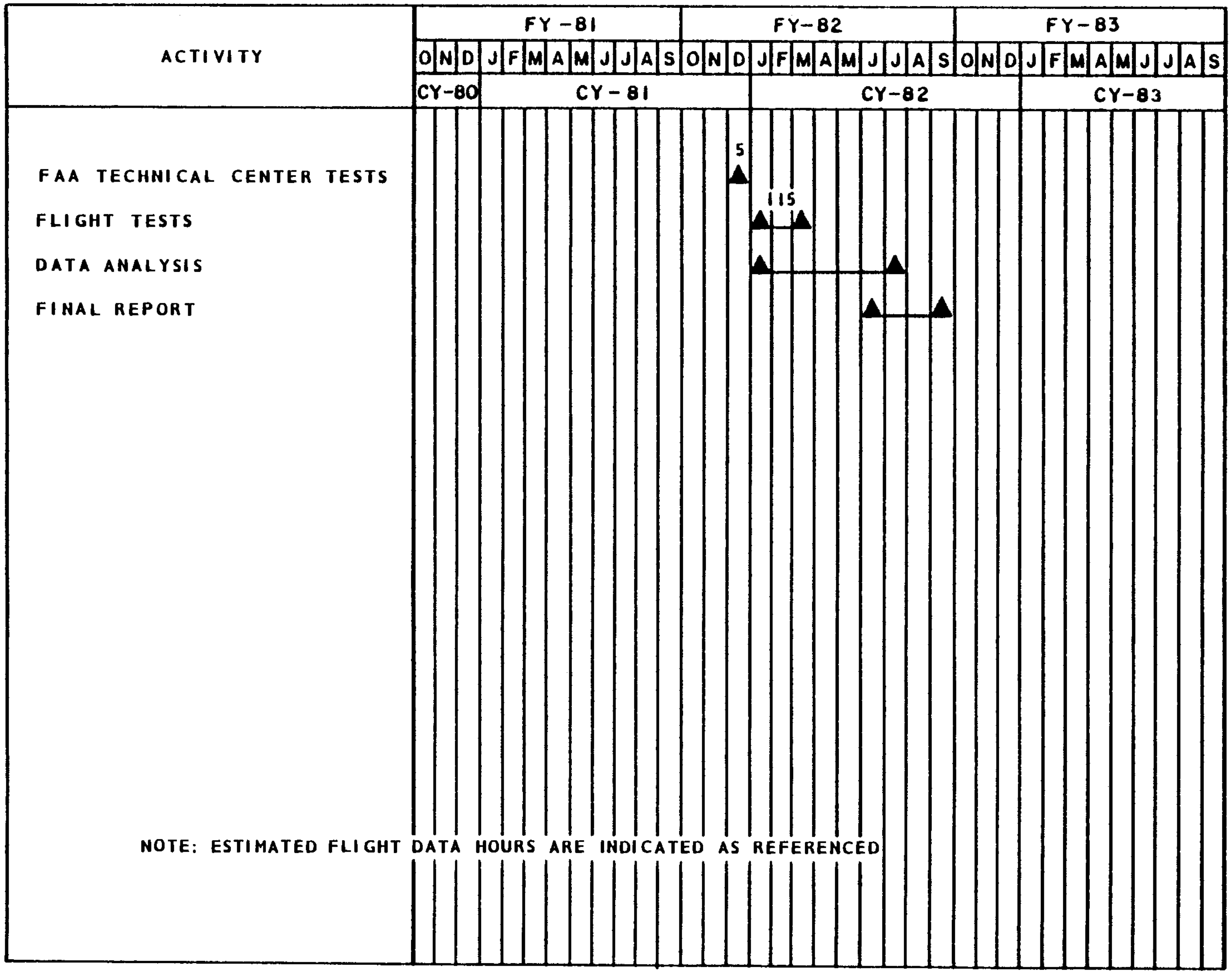
ACT-640: Provide aircraft (CV-580, N-49) and flight crew.

ACT-63B: Process interim and final reports.

ACT-100D: Design interface for ONI-7000 Loran-C data to be recorded by ATADS.

Sierra-Nevada Corporation: Provide field assistance in operations of ATADS at the FAA Technical Center (1 week) and in Vermont (1 week).

9. SCHEDULE.


ACTIVITY
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-83
FAA TECHNICAL CENTER TESTS
5
FLIGHT TESTS
115
DATA ANALYSIS
FINAL REPORT
NOTE: ESTIMATED FLIGHT DATA HOURS ARE INDICATED AS REFERENCED

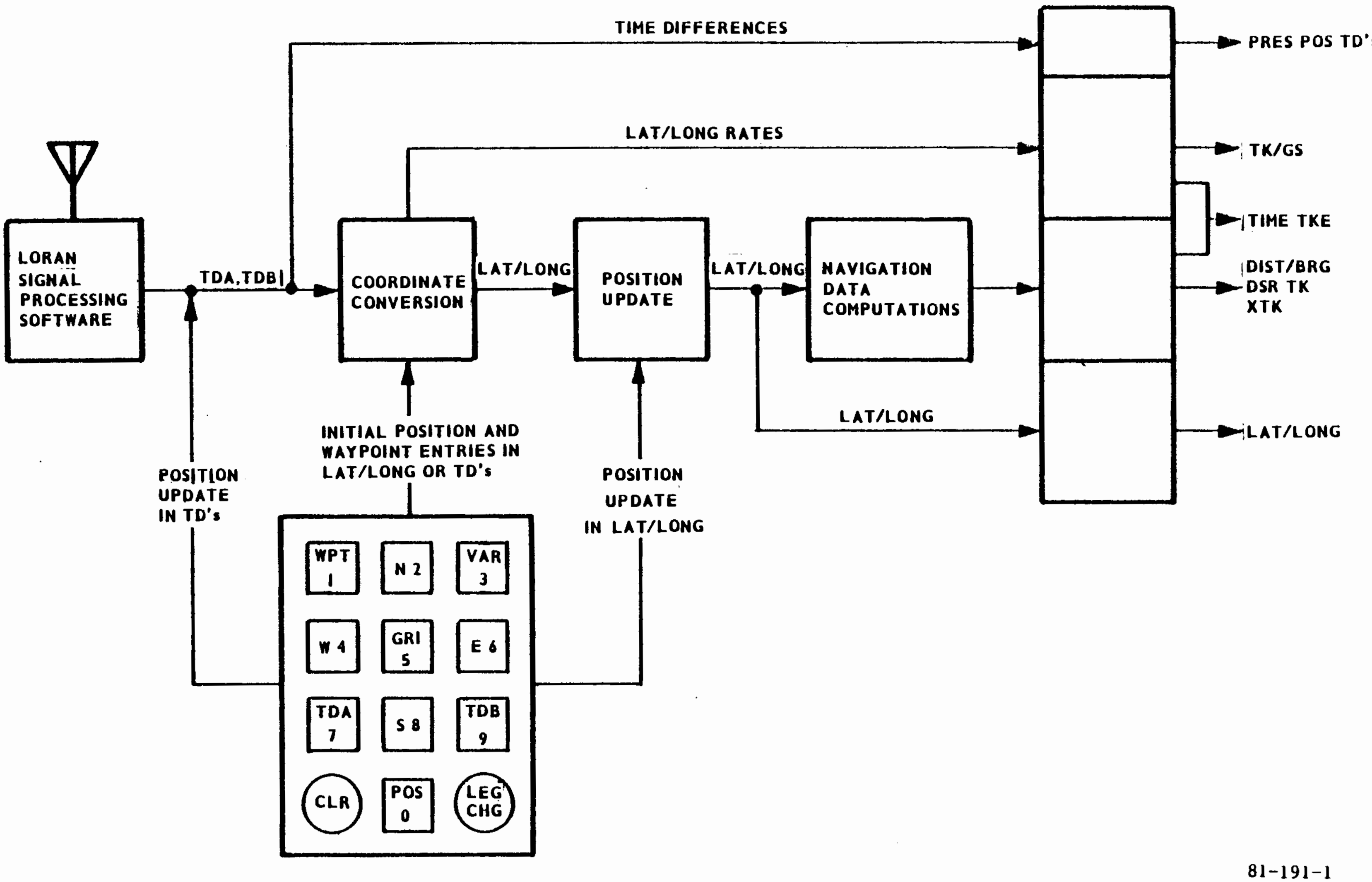
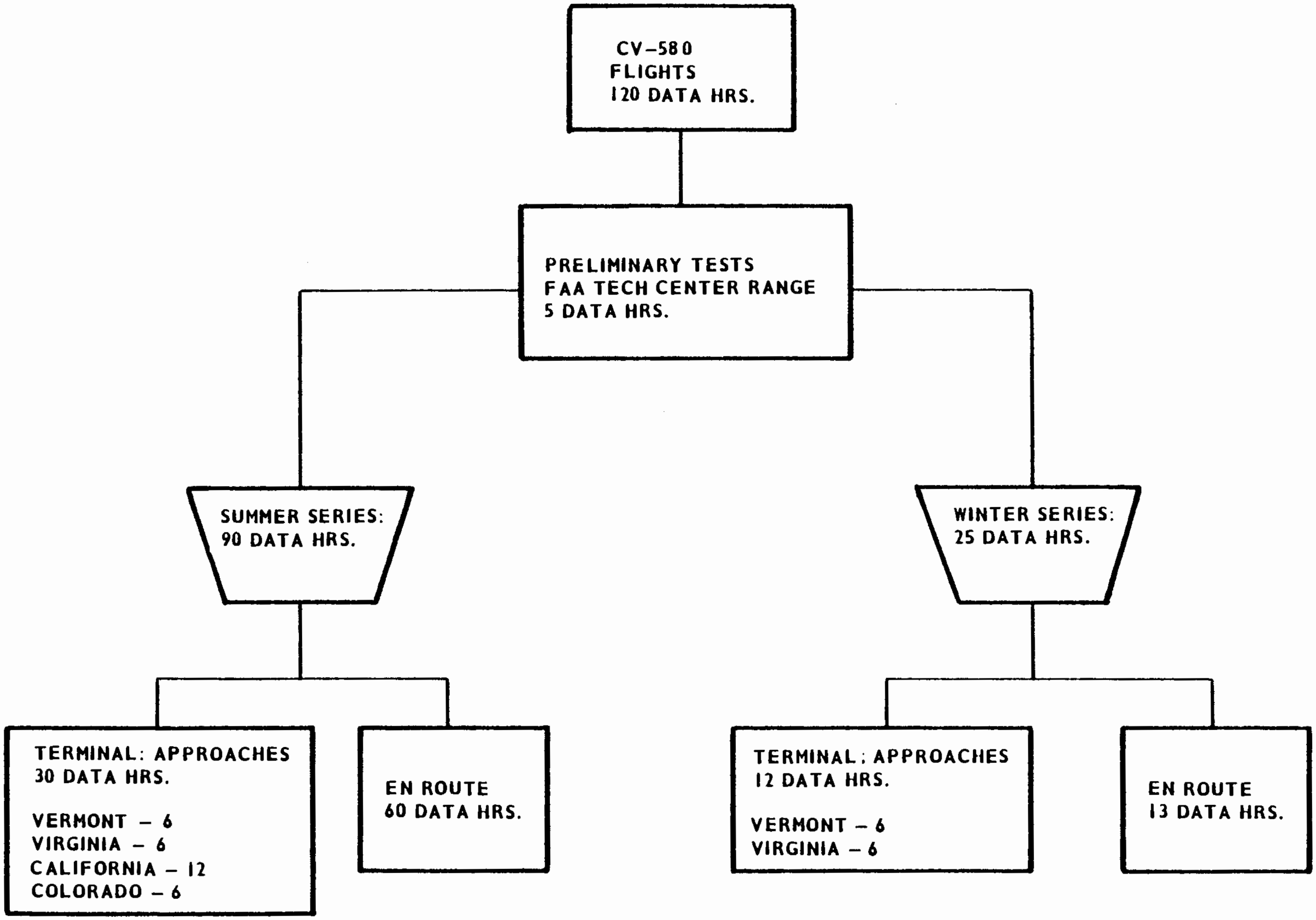


FIGURE 1. FUNCTIONAL DIAGRAM FOR TYPICAL AIRBORNE LORAN-C SYSTEM



NOTE: APPROACHES PLANNED TO FIVE AIRPORTS IN THE STATES LISTED; THEY ARE RUTLAND,VT., NEW RIVER VALLEY,VA., BISHOP,CALIF., LAKE TAHOE,CALIF., GRAND JUNCTION,COLO.

81-191-2

FIGURE 2. LORAN-C MOUNTAINOUS FLIGHT TEST MATRIX

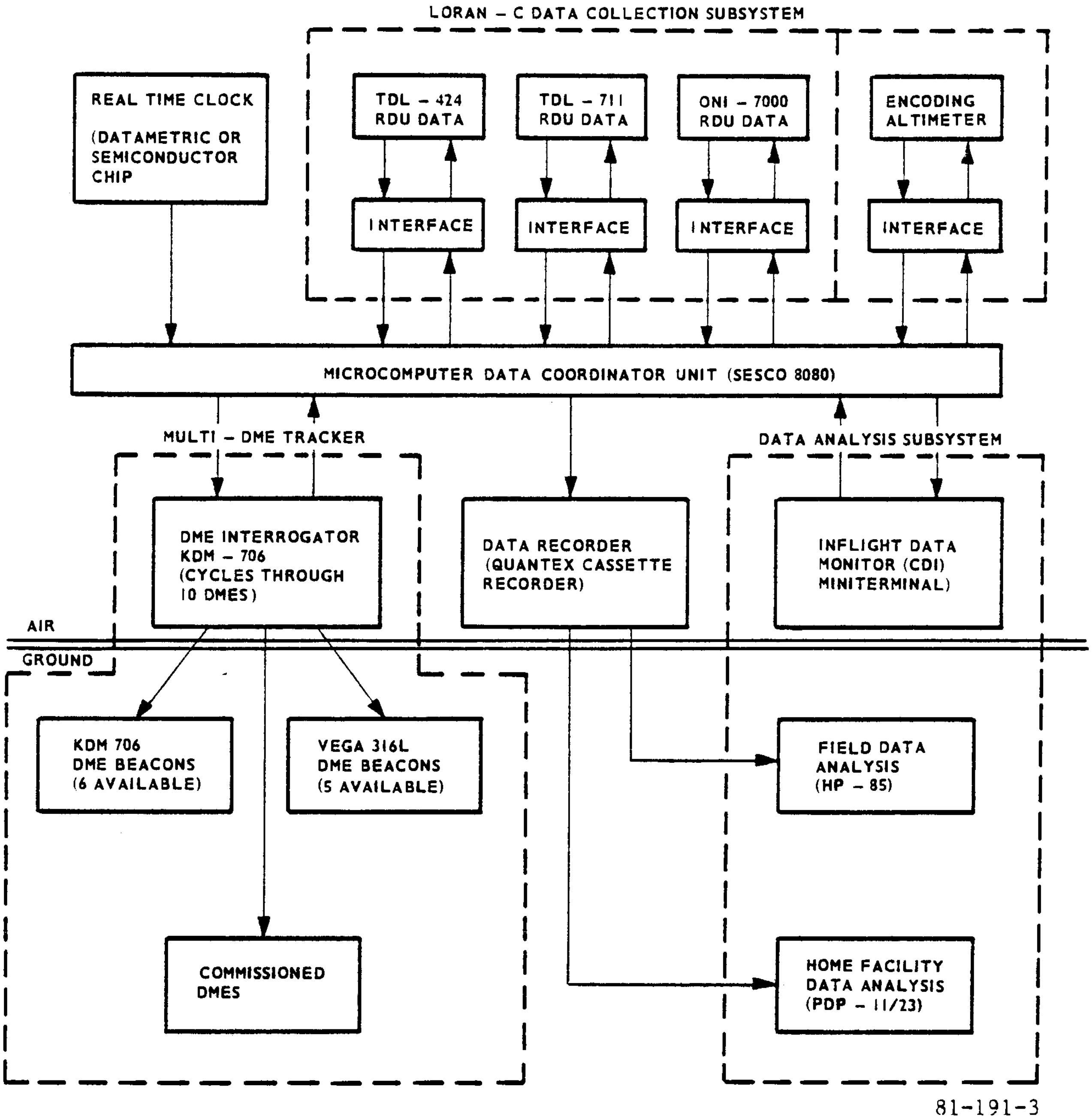
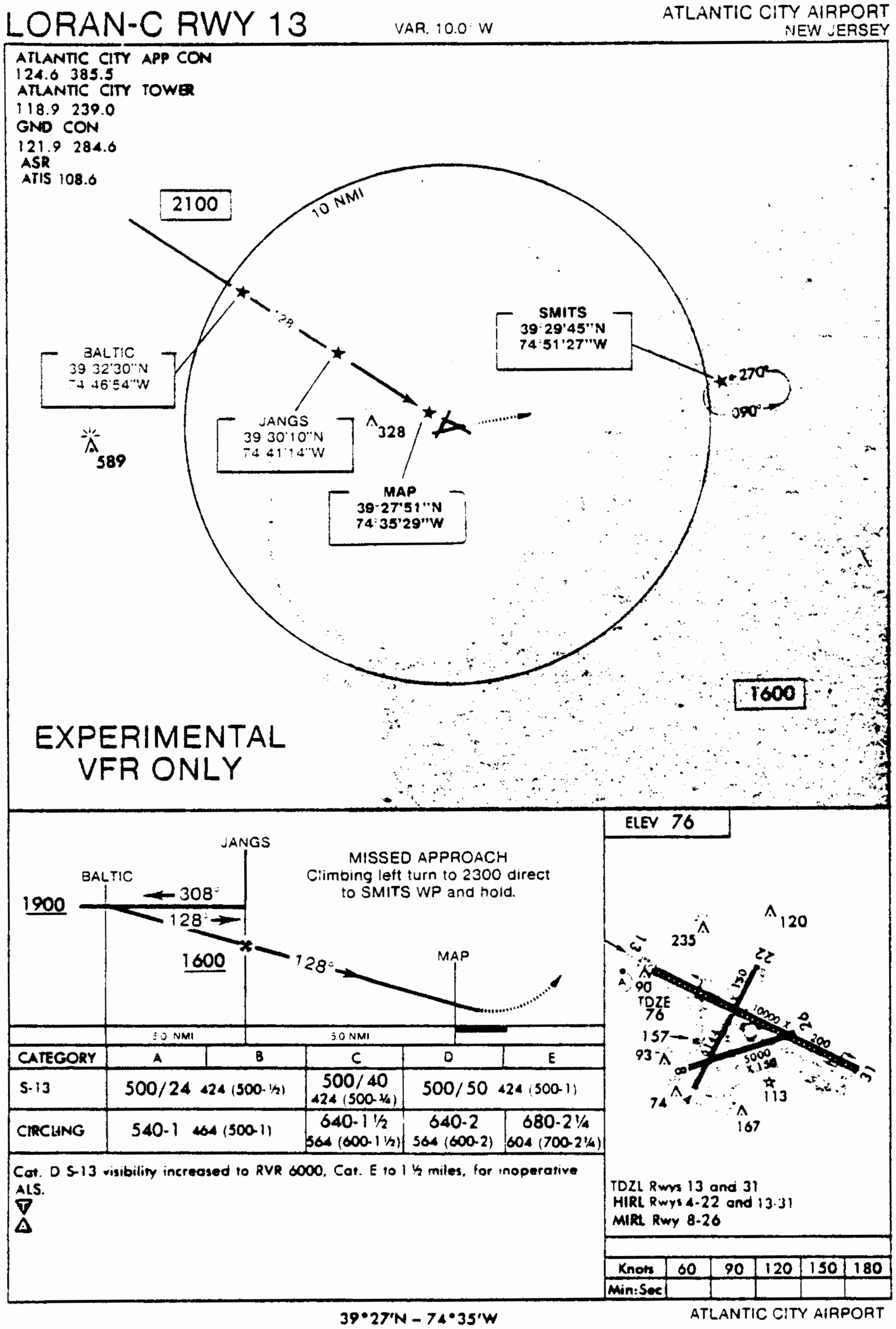


FIGURE 3. BLOCK DIAGRAM OF ATADS



CATEGORY	A	B	C	D	E
S-13	500/24 424 (500-½)		500/40 424 (500-¾)	500/50 424 (500-1)	
CIRCLING	540-1 464 (500-1)		640-1½ 564 (600-1½)	640-2 564 (600-2)	680-2¼ 604 (700-2¼)

Knots	60	90	120	150	180
Min:Sec					

FIGURE 4. LORAN-C APPROACH PLATE FOR ACT, RUNWAY 13

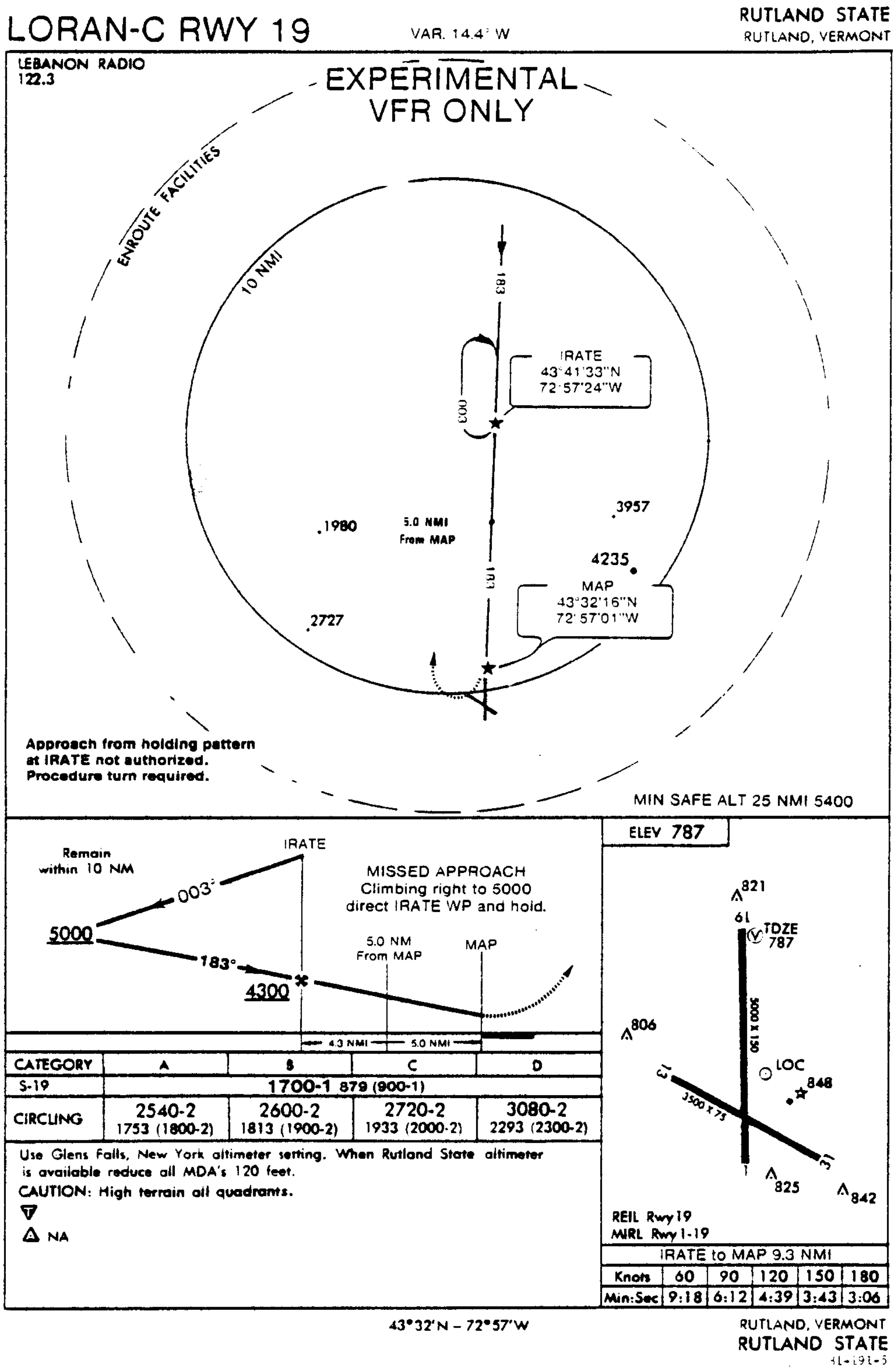


FIGURE 5. RUTLAND (VERMONT) LORAN-C APPROACH PLATE

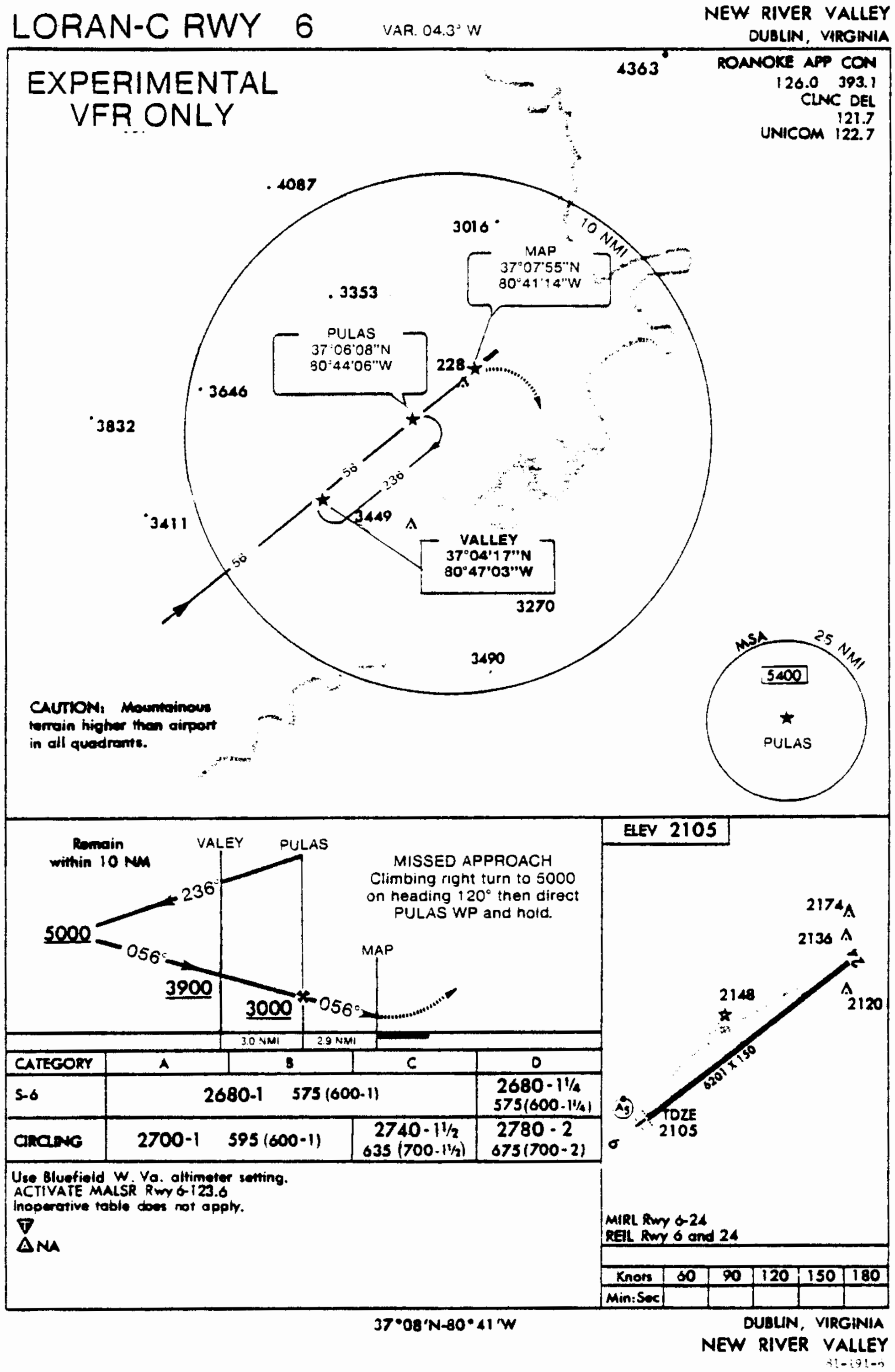


FIGURE 6. NEW RIVER VALLEY (VIRGINIA) LORAN-C APPROACH PLATE

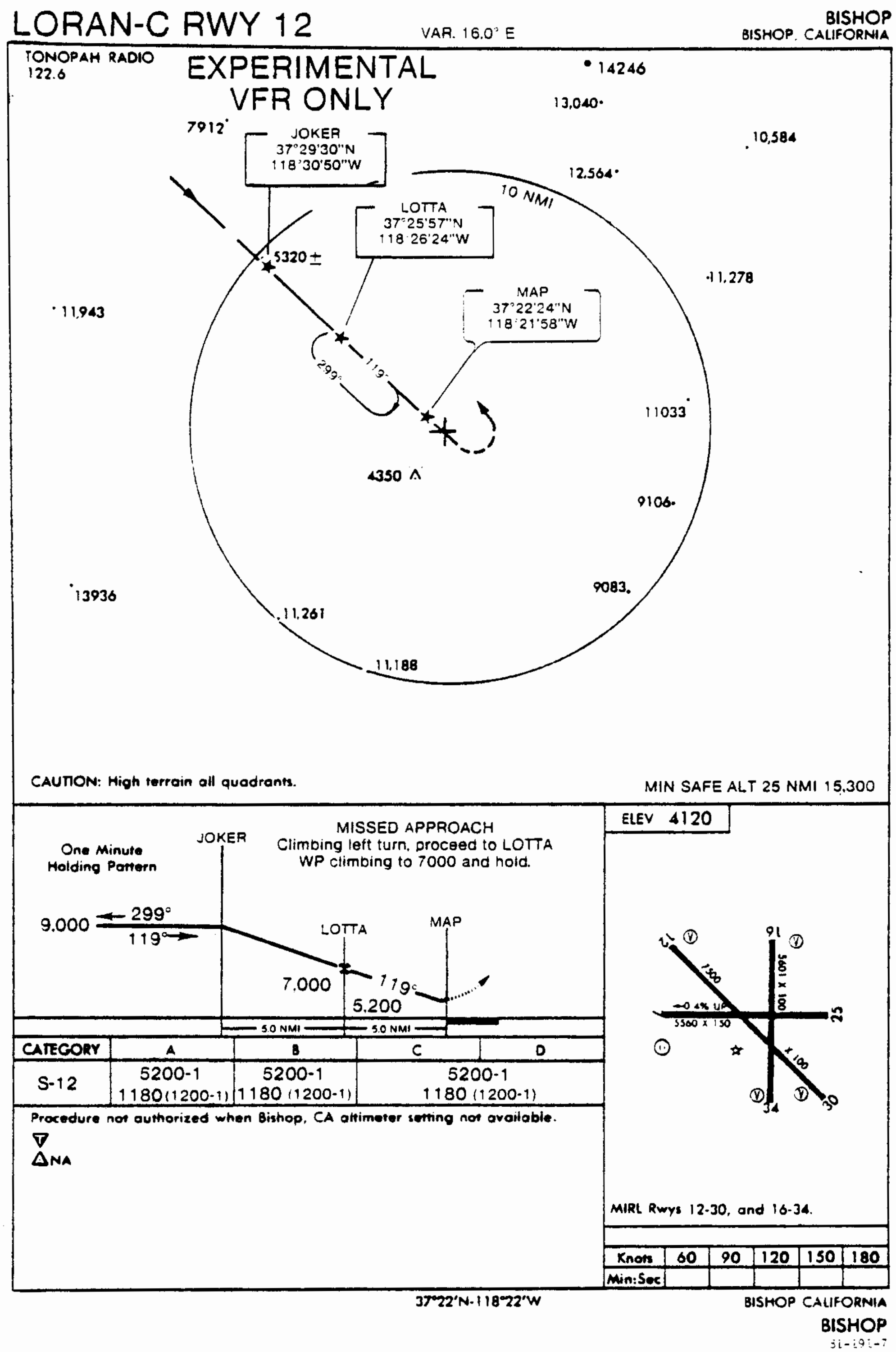
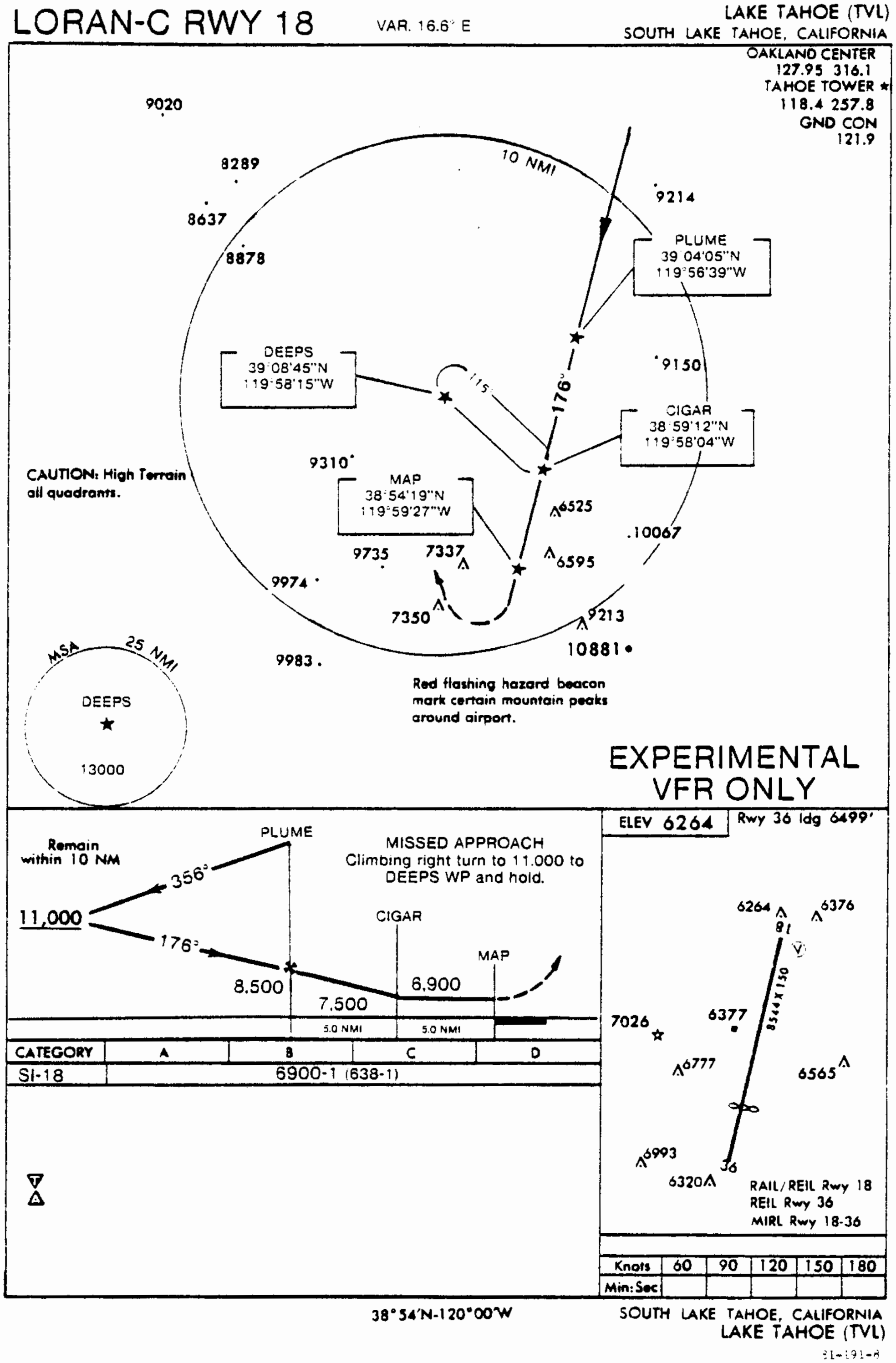


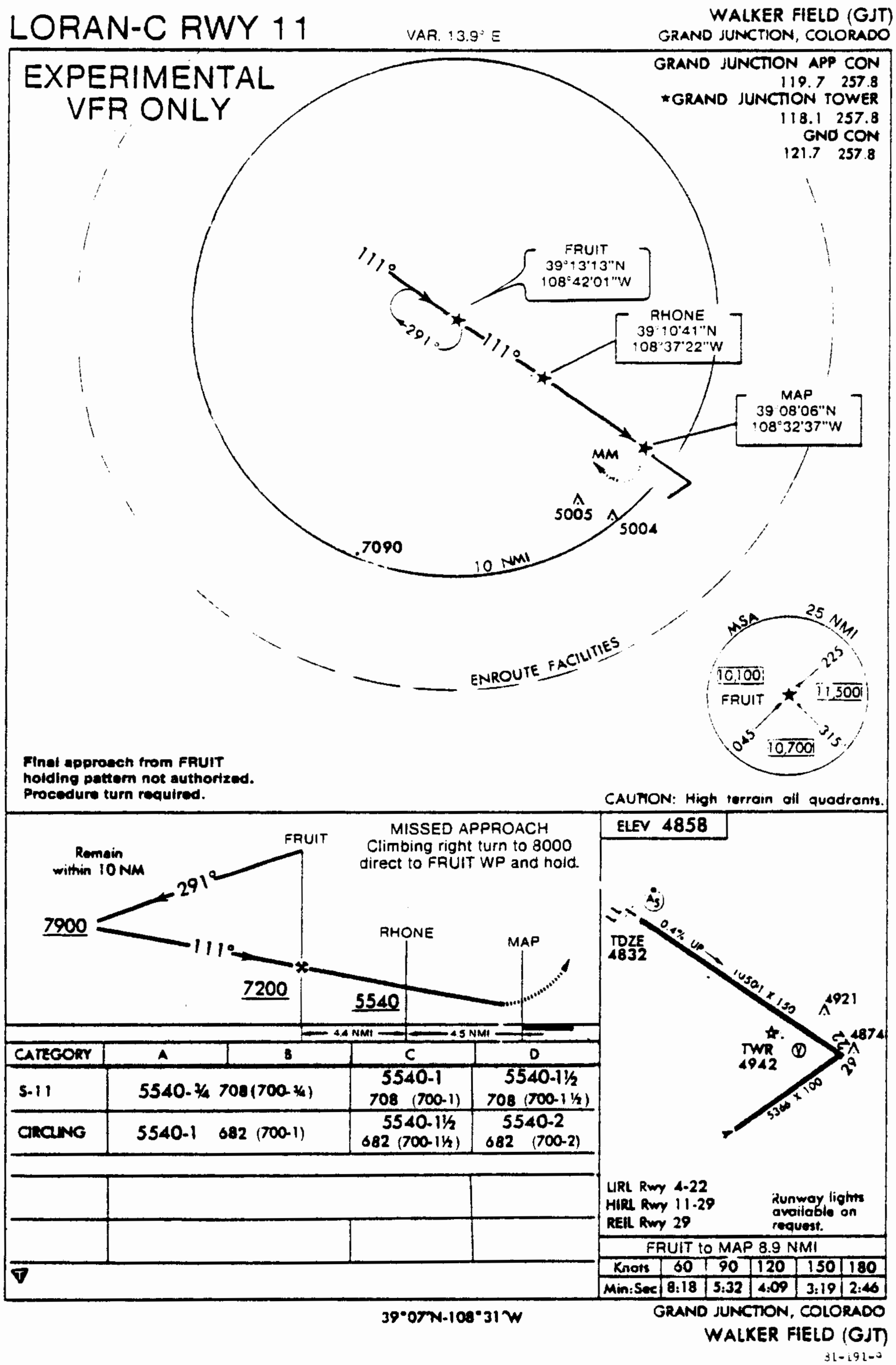
FIGURE 7. BISHOP (CALIFORNIA) LORAN-C APPROCH PLATE



CATEGORY	A	B	C	D
SI-18	6900-1 (638-1)			

Knots	60	90	120	150	180
Min:Sec					

FIGURE 8. LAKE TAHOE (CALIFORNIA) LORAN-C APPROACH PLATE



CATEGORY	A	B	C	D
S-11	5540-¾ 708 (700-¾)		5540-1 708 (700-1)	5540-1½ 708 (700-1½)
CIRCLING	5540-1 682 (700-1)		5540-1½ 682 (700-1½)	5540-2 682 (700-2)

FRUIT to MAP 8.9 NMI					
Knots	60	90	120	150	180
Min:Sec	8:18	5:32	4:09	3:19	2:46

FIGURE 9. GRAND JUNCTION (COLORADO) LORAN-C APPROACH PLATE

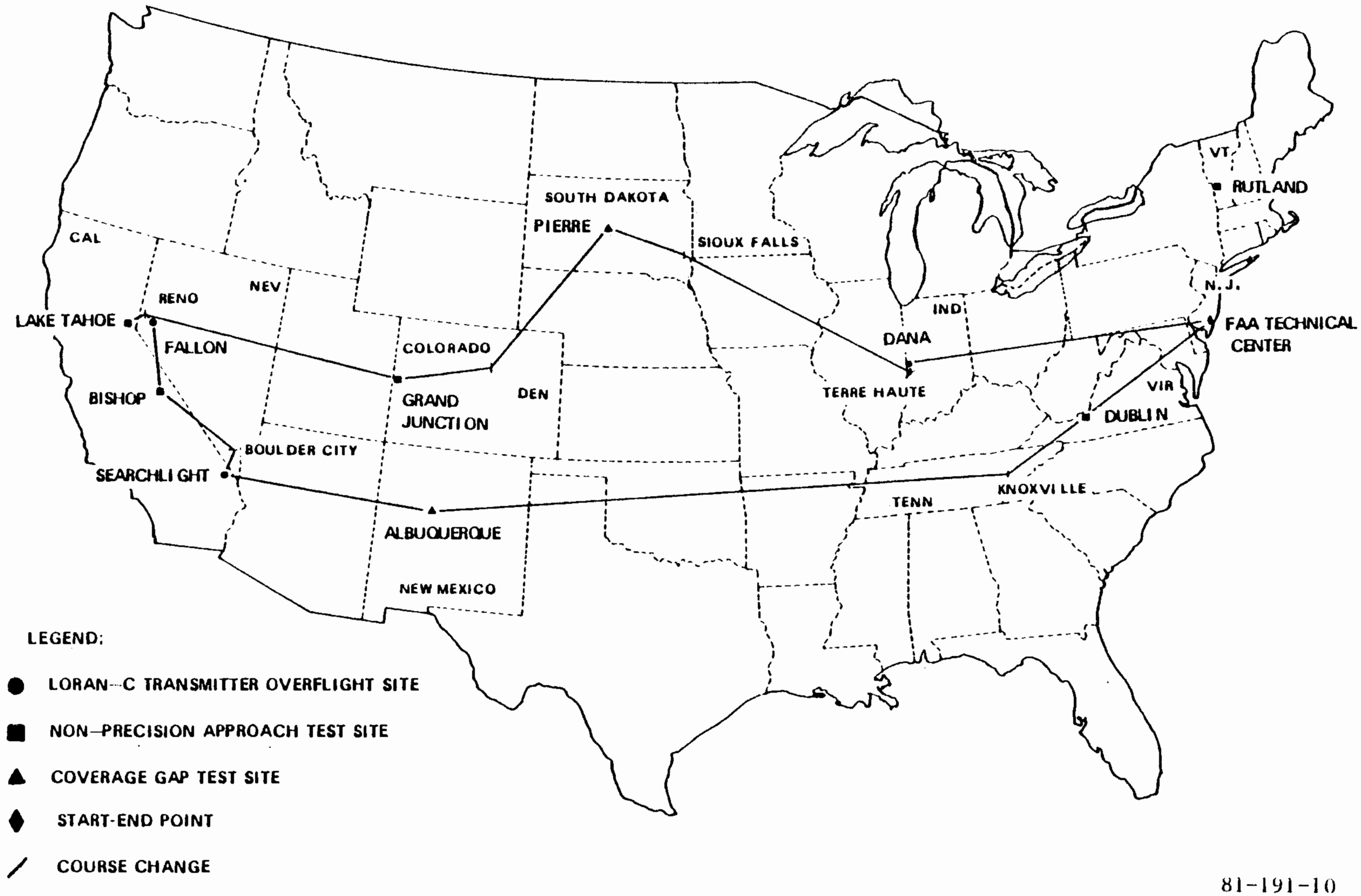


FIGURE 10. FLIGHT ROUTE, FAA TECHNICAL CENTER TO WESTERN MOUNTAINS