technical note technical note

OCLC: 11896720

FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER LIBRARY
ATLANTIC CITY INT'L AIRPORT, NJ 08405

# Canadian Loran C Stability Test Plan

FEB 22 1985
TECHNICAL CENTER LIBRARY
ATLANTIC CITY, N.J. 08405

Thomas Wisser

February 1985

DOT/FAA/CT-TN84/51

Document is on file at the Technical Center Library, Atlantic City Airport, N.J. 08405

U.S. Department of Transportation
**Federal Aviation Administration**

Technical Center
Atlantic City Airport, N.J. 08405

FAA TECHNICAL CENTER LIBRARY NJ
DOT/FAA/CT-TN84/51 c1
Federal Avia/Canadian Loran C stability
00008981

## NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the object of this report.

**Technical Report Documentation Page**

| | | |
|---|---|---|
| 1. Report No. DOT/FAA/CT-TN84/51 | 2. Government Accession No. | 3. Recipient's Catalog No. |
| 4. Title and Subtitle CANADIAN LORAN C STABILITY TEST PLAN | | 5. Report Date February 1985 |
| | | 6. Performing Organization Code ACT-140 |
| 7. Author(s) Thomas Wisser | | 8. Performing Organization Report No. DOT/FAA/CT-TN84/51 |
| 9. Performing Organization Name and Address Federal Aviation Administration Technical Center Atlantic City Airport, New Jersey 08405 | | 10. Work Unit No. (TRAIS) |
| | | 11. Contract or Grant No. T07-02E |
| 12. Sponsoring Agency Name and Address Federal Aviation Administration Program Engineering and Maintenance Service Washington, D.C. 20590 | | 13. Type of Report and Period Covered Technical Note December 1984 |
| | | 14. Sponsoring Agency Code |
| 15. Supplementary Notes | | |

16. Abstract

This test plan describes a series of test flights scheduled to take place in the summer and winter of 1985 and 1986 over those areas of Canada covered by Loran C. These tests will investigate the effects of seasonal variations in the Loran C grid on area calibration data.

| | | | |
|---|---|---|---|
| 17. Key Words Loran C Nonprecision Approach | 18. Distribution Statement Document is on file at the Technical Center Library, Atlantic City Airport, New Jersey 08405 | | |
| 19. Security Classif. (of this report) Unclassified | 20. Security Classif. (of this page) Unclassified | 21. No. of Pages 19 | 22. Price |

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

TABLE OF CONTENTS


| | Page |
|---|---|
| EXECUTIVE SUMMARY | v |
| INTRODUCTION | 1 |
| Purpose | 1 |
| Background | 1 |
| RELATED DOCUMENTS | 2 |
| EQUIPMENT | 2 |
| Loran C Receivers | 2 |
| Aircraft Tracking and Data System | 2 |
| Airborne Data Collection System | 4 |
| Error Budget | 4 |
| DATA COLLECTION | 4 |
| DATA ANALYSIS | 9 |
| COORDINATION - AREAS OF RESPONSIBILITY | 11 |
| SCHEDULE | 11 |

## LIST OF ILLUSTRATIONS


| Figure | | Page |
|---|---|---|
| 1 | Data Collection System | 5 |
| 2 | Flight Profile | 10 |


## LIST OF TABLES


| Table | | Page |
|---|---|---|
| 1 | Loran C Receiver Manufacturer Specifications | 3 |
| 2 | Loran C Digital Output Data | 6 |
| 3 | Remaining Digital Data to be Recorded | 7 |
| 4 | Summary of AC 90-45A Accuracy Requirements | 8 |

## EXECUTIVE SUMMARY

This test plan describes a series of test flights to be conducted in cooperation with the Canadian Ministry of Transport. The test flights are scheduled to take place in the summer and winter of 1985 and 1986 over those areas of Canadian airspace covered by Loran C. These tests will investigate the effects of seasonal variations in the Loran C grid on area calibration data and will provide a first cut area calibration over large parts of Canada with varying conductivity. Variations in signal-to- noise-ratio (SNR) will also be investigated. This effort parallels the Federal Aviation Administration's (FAA's) "Loran C Stability" program being conducted in the continental United States. The technical input provided by this program will be used by the Canadian Ministry of Transport to determine coverage and future potential of Loran C in Canadian airspace.

# INTRODUCTION

## PURPOSE.

The purpose of these tests is to investigate seasonal time difference (TD) variations in the Loran C grid over Canada. Technical input will be provided and will be used by the Canadian Ministry of Transportation to assess the existing and future potential of Loran C in Canadian airspace.

## BACKGROUND.

Loran C is a pulsed, low frequency 100 kilohertz (kHz), hyperbolic navigation system. Loran C receivers measure signals from a master station and at least two secondaries as TD's, which are used to derive a geodetic position. Loran C's ground wave signals provide coverage at low altitudes and in remote regions.

The major source of error in Loran C is uncertainty in the propagation velocity of the ground wave signal, which is, in part, caused by changes in the conductivity of the earth's surface. These variations in conductivity are related to the index of refraction, atmospheric pressure, temperature, and humidity along the signal paths. Loran C receivers convert TD's into geodetic position using various signal propagation models, ranging from a simple baseline model which uses standard atmosphere and all seawater path, to the highly complex, five-level Defense Mapping Agency (DMA) conductivity map based on Millington's method. Conductivity changes affect the stability of the Loran grid and the receiver's coordinate conversion calculation. The difference between the actual signal velocity and the velocity used by the receiver's propagation model can lead to position errors that are unacceptable for nonprecision approaches.

Loran C grid instability consists of short term instability intervals, i.e., periods less than 10 hours, and a long term, or seasonal instability intervals, with a period of 1 year. Short term instability is principally noise and equipment related, and is considered negligible for the 5-minute period necessary for a nonprecision approach (see document No. 1 under "Related Documents").

Grid stability is not uniform throughout the Loran C coverage area. Stability is controlled to 0.1 microsecond at the System Area Monitor (SAM), and increases in proportion to the Double Range Difference (DRD) from the SAM. Position errors are due to instability and, therefore, are dependent on location, the Loran C chain in use, and triad geometry.

The effects of grid bias on aircraft position may be reduced by the use of a more complex propagation model or by area calibration of the receiver. Area calibration consists of updating the receiver's position at a known location, i.e., a surveyed point, allowing the receiver to compute an offset to apply to subsequent position calculations. Corrections are valid for a given area around the calibration point. Area calibration can be used in order to meet the requirements of Federal Aviation Administration (FAA) Advisory Circular (AC) 90-45A for nonprecision approaches in certain areas. For some areas, a

single calibration over the entire year may suffice. In other areas, the position errors due to grid instability may necessitate a periodic update of area calibration.

## RELATED DOCUMENTS


1. De Palma, Leon M. and Creamer, Paul M., Loran C Grid Calibation Requirements for Aircraft Nonprecision Approach, DOT/FAA/RD-81/65.

2. Naimo, Matthew, Aircraft Tracking and Data System (ATADS) Position Accuracy, FAA Technical Center, Report DOT/FAA/CT-TN83/35, December 1983.

3. Specification of the Transmitted Loran Signal," U.S. Coast Guard Report, COMDTINST M16562.4, July 1981.

4. Approval of Area Navigation Systems for use in the U.S National Airspace System, FAA Advisory Circular 90-45A, February 21, 1975.

5. Federal Radionavigation Plan, DOD-4650.4-P-I to IV, DOT-TSC-RSPA-81-12-I to IV March 1982.

6. Minimum Performance Standards - Airborne Loran A and Loran C Receiving Equipment, Radio Technical Commission for Aeronautics (RTCA), Document Number DO-159, October 17, 1975.

7. Erikson, Robert, Loran C Nonprecision Approach Test Plan (Fixed Wing), FAA Technical Center, Report DOT/FAA/CT-TN83/21.

8. Lorge, Frank, Loran C Nonprecision Approaches in the Northeast Corridor, FAA Technical Center, Report DOT/FAA/CT-82/76, October 1982.

9. Fox, Daniel P., Loran C Stability Test, FAA Technical Center, Report DOT/FAA/CT-TN84/11.


## EQUIPMENT

### LORAN C RECEIVERS.

The following Loran C airborne receivers will be used for these tests: Teledyne TDL-711, Micrologic ML-4000, Texas Instruments TI-9100, and two Advanced Navigation ANI-7000 units. All units are production models, available for public purchase. Each of the receivers exhibits different operating characteristics. Table 1 provides a list of the important Loran C receiver features.

### AIRCRAFT TRACKING AND DATA SYSTEM.

The Aircraft Tracking and Data System (ATADS) will be used as the reference for aircraft position (see document No. 2 under Related Documents). The aircraft's position is determined by using multiple distance measurement (DME) ranges from several ground stations. The airborne system consists of a modified airborne

TABLE 1. LORAN C RECEIVER MANUFACTURE SPECIFICATIONS

| Parameter | Teledyne TLD-711 | Micrologic ML-4000 | Manufacturer Model Advanced Navigation Inc. ANI-7000 | Texas Instruments TI-9100 |
|---|---|---|---|---|
| Area of Operation | 16 triads | All existing chains | All existing chains | All existing chains |
| Receiver Type | | | | |
| No. of Chains Simultaneously Tracked | 1 | 1 | 4 | 1 |
| Chain/Station Selection Tracked | 3 | 6 | 8 | 5 |
| a. Auto/Manual | Manual | Automatic | Automatic | Automatic |
| b. Method | | Geometry | Shortest Range | Geometry |
| Acquisition | Automatic | Automatic | Automatic | Automatic |
| Notch Filters | | | | |
| a. Numbers | 2 | 4 | 3 | |
| b. Method Set | Manual | Manual | Automatic | Manual |
| Minimum SNR for Operation | | | | |
| a. Acquisition | -10 dB | --- | -12 dB | --- |
| b. Track | -16 dB | -17 dB | -18 dB | --- |
| Maximum Signal Imbalance | 60 dB | --- | 60 dB | --- |
| Position Fix | | | | |
| a. No. of chains (if >1 cross-chain) | 1 | 1 | 4 max | 1 |
| b. No. of stations | 3 | 3 | 8 max | 3 |
| Loran C GRID | Hyperbolic | Hyperbolic | Hyperbolic | Hyperbolic |
| Master Independence | | | | |
| a. Acquisition | no | no | * | no |
| b. Track | yes | no | yes | yes |
| North Reference (operator selectable) | Mag/True | | Mag/True | Mag |
| Grid Reference | | | | |
| a. Lat/Long | yes | yes | yes | yes |
| b. TD | yes | yes | yes | yes |
| Coordinate Conversion | | | | |
| a. Model | Seawater | ** | Based on Millington's Method | ** |
| | | | Map | |
| Area Calibration | yes | yes | no | yes |
| Dedicated TRIAD | yes | yes | yes | yes |
| Maximum Velocity (unaided) | 950 | 1000 | 600 | 565 |

Note:

* Requires peak energy of the master.
** Single optimized value which gives best results for both land and sea.

DME interrogator unit and a microprocessor unit. The station channeling, station acquisition, and range tracking are controlled by the microprocessor. The normal sequencing rate of this cycler tracker is 10 stations per second. The ATADS will be configured to function in a free scan mode, whereby the stations are selected by signal strength, and sequential scanning is employed.

AIRBORNE DATA COLLECTION SYSTEM.

A Norden militarized PDP 11/34M computer will be used to collect the data. The data will be recorded on a Miltope 9-track tape recorder. A Technical Center designed aircraft systems coupler (ASC) is used to interface the equipment to the PDP 11/34M. Figure 1 is a block diagram of the system. Selected engineering data will be computed and printed on a line printer both in-flight and post-flight. This will serve as an in-flight equipment monitor and an assurance of data integrity. The Loran C parameters to be recorded are listed in table 2; the additional parameters to be recorded from various aircraft systems are listed in table 3.

ERROR BUDGET.

Ideally, in order to keep the errors introduced by the measurement system itself to less than 1 percent, the measurement system should be at least 10 times as accurate as the system under test. ATADS en route accuracy using standard International Civil Aviation Organization (ICAO) beacons was determined to be 0.078 nautical miles (nmi), 2 distance root mean squared (drms) (see document No. 2 under Related Documents).

AC 90-45A defines the minimum accuracy specifications for navigation systems. These are listed in table 4. ATADS meets these requirements for en route operation. The AC 90-45A nonprecision approach crosstrack or along track minimum criteria are specified as 0.3 nmi, 2 sigma. The ATADS accuracy is approximately 3.8 times more accurate than the minimum criteria. When compared to AC 90-45A nonprecision approach criteria, the error introduced by using the ICAO beacons is less than 10 percent. This will not permit conclusions as to the exact TD corrections to meet AC 90-45A for nonprecision approaches. However, it will permit establishing trend lines for seasonal variations and approximations for TD corrections.

## DATA COLLECTION

The Loran C receivers will be configured in wide open, i.e., automatic mode, except the TDL 711 which will use the primary triad of the current chain. The data collection system will sample and record the Loran C data and aircraft parameters every 10 seconds. The only exception to this will be barometric altitude from the air data computer and the ATADS DME beacons, which will be recorded every second. This faster sampling rate for altitude and DME beacons is needed to provide continuous reference position data.

In-flight printouts will be generated every 30 seconds. Time, Inertial Navigation System (INS) position, very high frequency omnidirectional radio range (VOR) bearings, and the differences in position between the INS and the respective Loran C receivers will be displayed to the user. ATADS DME ranges

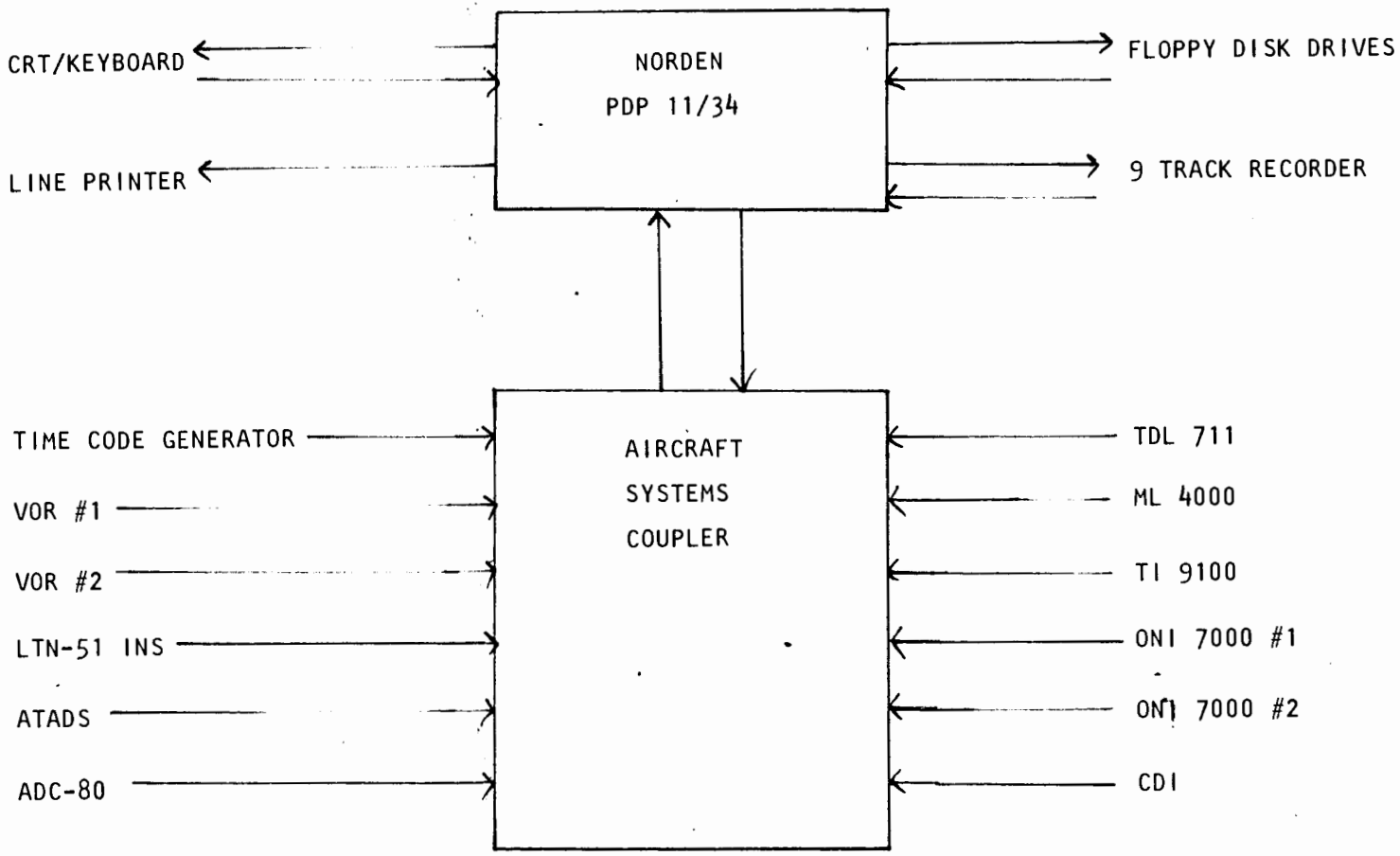


FIGURE 1. DATA COLLECTION SYSTEM

TABLE 2. LORAN C DIGITAL OUTPUT DATA

| | TDL-711 | ML-4000 | ANI-7000 | TI-9100 |
|---|---|---|---|---|
| Present Position Lat/Long | x | x | x | x |
| Station Status | M + 4 | M + 5 | x | |
| Station SNR's | M + 4 | M + 5 | 8 | |
| Time Differences | 4 | 2 | 8 TOA | |
| ECD's | M + 4 | | 8 | |
| TO Waypoint Name | | x | x | x |
| TO Waypoint Lat/Long | | x | x | x |
| Crosstrack Error | x | x | x | x |
| Ground Speed | | x | x | x |
| Distance to Go | x | x | x | x |
| Front Panel Switch Setting | | x | x | |
| En Route/Approach | | | x | |
| Annunciator Lamps | | | x | |
| Receiver Status | x | | x | x |
| Grid Reference | | | x | |
| Bearing to Waypoint | | | x | x |
| Desired Track | | | x | x |
| Estimated Time En Route | | | x | x |
| Heading | | | * | |
| True Airspeed | | | * | |
| Notch Filter Setting | | | x | |
| Secondary Phase Delay | | | x | |

Note:

*Require TAS and Mag Heading into ANI-7000, but is not used for navigation.

x = Data present in digital output.
M = Master.

TABLE 3. REMAINING DIGITAL DATA TO BE RECORDED

| | |
|---|---|
| TIME: | Hours<br>Minutes<br>Seconds |
| LTN-51 INS: | Present Position<br>Heading<br>Track Angle<br>Ground Speed |
| ADC-80: | True Airspeed<br>Altitude |
| ATADS: | Multi-DME Ranges With Time Tags |
| VOR No. 1: | Bearing |
| VOR No. 2: | Bearing |
| CDI: | Analog Course Deviation Indicator |
| INS: | Inertial navigation system. |

TABLE 4. SUMMARY OF AC 90-45A ACCURACY REQUIREMENTS

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:

| | Crosstrack | | Along Track | |
|---|---|---|---|---|
| Total System Error | (nmi) | (km) | (nmi) | (km) |
| En Route | 2.5 | 4.6 | 1.5 | 2.8 |
| Terminal | 1.5 | 2.8 | 1.1 | 2.0 |
| Approach | 0.6 | 1.1 | 0.3 | 0.6 |

| | Crosstrack | | Along Track | |
|---|---|---|---|---|
| Airborne Equipment Error | (nmi) | (km) | (nmi) | (km) |
| En Route | 1.5 | 2.8 | 1.5 | 2.8 |
| Terminal | 1.12 | 2.1 | 1.1 | 2.0 |
| Approach | 0.3 | 0.6 | 0.3 | 0.6 |

| | Crosstrack | | Along Track | |
|---|---|---|---|---|
| Flight Technical Error | (nmi) | (km) | (nmi) | (km) |
| En Route | 2.0 | 3.7 | 0 | 0 |
| Terminal | 1.0 | 1.9 | 0 | 0 |
| Approach | 0.5 | 0.9 | 0 | 0 |

will also be displayed at a rate dependent on the number of stations received. These printouts will serve as an in-flight equipment monitor which can detect most equipment malfunctions. They will also serve as a hard copy flight log for data reduction and analysis.

The flight profile for these tests is shown in figure 2, along with VOR's to be followed en route. The length and width of this grid was selected: (1) to encompass portions of Canada where Loran C coverage is predicted to exist, (2) to provide data for regions with various terrains and conductivity using different Loran C chains, and (3) to be completed in approximately 50 hours of flight time. The data will be collected at an altitude above 10,000 feet to facilitate multiple DME coverage for ATADS, which is a line-of-sight system. In the event DME coverage is inadequate, INS position will be used in the final analysis.

The Western segment of Canada covered by the 5990 chain will be investigated in February 1985 on a 1-day exploratory probe. The complete flight profile will be flown in the summer of 1985. The extent of the flight tests conducted in the winter of 1986 will be dependent on the results obtained in the winter of 1985 exploratory probe.

## DATA ANALYSIS

For all flights, the ATADS aircraft position will be converted to seawater model reference TD's. The ATADS position will be used to compute the great circle distance to each Loran C transmitter. TD's will then be calculated using these distances, the transmitter's nominal emission delay, and a seawater propagation delay.

For data reduction and presentation purposes, the flight profile will be divided into regions around a given set of transmitters, facilitating analysis on a chain by chain basis.

The following data will be available for analysis:

TD Bias - The difference between the measured TD and the seawater model reference TD calculated from the ATADS position.

Field Strength (FS) - The root mean square (rms) value of the signal strength at the third cycle of the Loran C pulse.

Atmospheric Noise - The rms level noise through a 30 Hertz (Hz) bandwidth (BW) filter.

Signal-to-Noise-Ratio (SNR) - These values will be used to predict the range of coverage of the given Loran C chain.

Envelope-to-Cycle Difference (ECD) - The difference is the time relationship between the phase of the radio frequency (RF) carrier and the time origin of the envelope waveform of the Loran C pulse. The ECD represents a measure of signal distortion.

FIGURE 2. FLIGHT PROFILE

## COORDINATION - AREAS OF RESPONSIBILITY

ACT-140 will provide center program and project management and other technical support available within ACT-140. ACT-140, along with the Canadian Ministry Transport, will be responsible for conducting the data flights and collecting the flight test data. The Technical Center will provide ATADS software and other software developed for the U.S. Loran C stability project to the Canadian Ministry of Transport. The Canadian Ministry of Transport will be supplied copies of the flight test data tapes by the Technical Center. The Canadian Ministry of Transport wil be responsible for rehosting the Technical Center software, reducing and analyzing the flight test data, and preparing the final report. The Technical Center will provide the Canadian Ministry of Transport liaison support within the confines of funding provided. Coordination will be accomplished between ACT-140, ACT-600, and APM-420.

ACT-600 will be responsible for providing project aircraft, pilots, maintenance, and for approving the flight test schedule. ACT-140 will be responsible for coordinating with ACT-600 for optimum aircraft scheduling and submitting a flight test schedule.

APM-420 will be responsible for subprogram management and allocation of project funding.

## SCHEDULE

| | |
|---|---|
| Test Plan Complete | 3/85 |
| Exploratory Winter Flight Tests (1 Day) | 1/85 - 2/85 (1 Day) |
| Summer Flight Tests | 7/85 - 8/85 |
| Winter Flight Tests | 1/86 - 2/86 |