INVESTIGATION OF AIR TRANSPORT TECHNOLOGY AT

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 1983

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SUMMARY OF RESEARCH

Runway Approach Guidance Using Loran-C

1.0   Introduction

     For 1983, research activity in the NASA Joint University Program for Air Trans-
portation Technology has concentrated on several topics connected with investigating
the use of Loran-C for flying "pseudo-precision" approaches to runways at low density
general aviation airports. These topics have arisen in preparation for a flight test
demonstration of approaches to be flown at Hanscom airport in Bedford, Mass. The
goal of this research has evolved to determining the limitations in providing both
centerline and altitude guidance for runways in good Loran-C signal coverage. The
high data rate (10 per second) and good "repeatable" accuracy (60 feet, 1σ) of
Loran-C indicate that it will be possible to provide the pilot with a continuous,
cross pointer display of guidance information similar to that provided by ILS/MLS,
at least when good signal-noise ratios and good geometry from Loran-C LOP's (Lines
of Position) exist at the airport.

     The research goals are to demonstrate approach guidance of higher quality than
prior demonstrations of where L-NAV approaches to the airport in the direction of the
runway have been flown. The intention here is to provide performance more similar to
ILS/MLS, and to determine the degradation of guidance performance as geometrical and
signal-noise factors degrade. With the advent of very low cost, high performance
Loran-C receivers for general aviation to approach guidance for use in enroute area-
navigation, it is timely to explore this application, since the results may have
pertinence to decisions on deploying MLS/ILS in the NAS (National Airspace System)
and the future role of GPS (Global Positioning System) for general aviation.

2.0   Description of the Concept

     The basis for the concept lies in the remarkable stability of points located in
Loran-C TD (Time Difference) coordinates over extended periods of time. Prior work
by students in this program (see ref. 1) noted that the repeatable accuracy over
long periods of time was a few hundred feet, and over a short duration perhaps
60 feet. This leads one to try to use this short term repeatable accuracy and the
high position rate of Loran-C by establishing a local tangent plane coordinate frame,
centered on the touchdown point. The location of the origin of this coordinate frame
can be described in Loran-C TD values which are published and perhaps updated by the
pilot at the time of initiating the Loran-C approach. A simpler conversion of Loran
TD's can be made into the local tangent plane coordinate frame at high data rates, and
is independent of the errors in modelling the Earth's reference ellipsoid and varia-
tions in signal propagation velocity, thereby avoiding some of the major sources of
Loran-C error for enroute flying.

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The Loran-C receiver can provide data at a rate of roughly 10 times per second on cross-track and along-track position and position rate. This can be suitably filtered, and combined with heading rate data in a microprocessor before generating signals for the autopilot or pilot display. Since distance to touchdown is known, the nominal glide slope altitude can be determined very accurately. This can be displayed separately, or combined with signals from an encoding altimeter to display the current altitude deviation to the pilot. Both cross-track and altitude deviation signals can be displayed electronically.

3.0   The Loran-C Approach Guidance Display

A special display has been designed and constructed which uses a microprocessor to interpret data from the Loran-C receiver and drive bar-graph and seven-segment LED's display units. The Loran-C receiver (Micrologic ML-3000) has been especially modified to transmit filtered data on TD and TD rate once per second via a RS232 link, and the filter constants of the receiver can be set by the experimenter.

Figure 1 shows the current layout of the front panel of the Loran-C Approach Guidance Display in its present configuration. The top bar-graph LED display will show right-left cross track deviations from the runway centerline. The bottom LED will be used to show cross-track velocity. The seven-segment LED displays on the right side of the display will give numerical readout of range to touchdown and glide slope altitude. The microprocessor program for the display has been written and tested for a current version which uses only Loran-C data. Later developments will accommodate data from heading rate gyros and the encoding altimeter, and display glide path deviation.

There are several alternate display options which have been considered. The original P-POD CRT display developed under this grant was abandoned in favor of the new display of figure 1. A digitally driven, electro-mechanical round display has also been constructed and will be flown to test its operation. In January 1983, Norry Dogan, an undergraduate at MIT, visited Langley Research Center for 1 week to work with Langley personnel on constructing the display of figure 1.

During that week, a display case was built, printed circuit boards were designed by Langley personnel from a pin diagram of the display circuit supplied by MIT, and some software problems were solved. The printed boards were subsequently manufactured at Langley Research Center. They replace the wire wrapped board built at MIT.

Finally, a flat panel, bit mapped LCD display (3-1/2" by 7") has been purchased for general experimentation; it was planned in the next year's work to develop digital circuitry to create an approach display using this device for the next year's work.

4.0   The Fluidic Rate Gyro and Encoding Altimeter

A fluidic rate gyro originally conceived at NASA Langley Research Center has been developed further at MIT. Further modifications are planned to improve its frequency response before incorporating it in the approach guidance system. The original thermistors were modified to keep them at a constant temperature, and now they are being replaced with hot-wire elements with less thermal inertia.

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As a result of a conversation between John Einhorn, another undergraduate at MIT, and Mr. Gary Burrell, Vice President Engineering, King Radio Corp. at the June 1983 Research Progress meeting at Ohio University, MIT received a Model 5035 electrical encoding altimeter. It was to be incorporated into the approach guidance system by Einhorn in the next year.

5.0 Ground Survey of Loran-C Signals at Hanscom Field

In the period November 1983 – January 1984 the ML-3000 receiver was mounted in ground vehicles for various preliminary tests of its operations. Data were displayed and stored using an Apple II computer, and later printed out. These tests showed the short term accuracies of the receiver, and its transient response to speed changes of the ground vehicle. Typical data obtained are shown in figures 2, 3, 4, and 5 where the filter constants for a slow moving vehicle (marine) and fast moving vehicle (aircraft) are being used.

Figures 2 and 3 show the transient response of position data to accelerating the vehicle to a given speed, and then decelerating to a stop for the two filters. Figures 4 and 5 provide some data on the effect of poor SNR (Signal Noise Ratio) on the standard deviation of short term position data while stationary. Notice that the aircraft position data degrades from 0.07 μsec (69 feet) at good SNR to values around 0.2 μsec (196 feet) when SNR is -20 dB. If the ship filter constants are used, the heavy slow filter greatly improves these short term standard deviations to values of 0.02 μsec (20 feet) at good SNR and 0.08 μsec (80 feet) at poor SNR. Further experimentation is planned on these data which will include information on TD rates output by the receiver. The data gathering programs have been written for the Apple Computer, including a Fast Fourier Transform coding which will provide information on the spectral distribution of those error signals.

In January, a preliminary ground survey of the Loran-C signal grid around Hanscom field was carried out to discover any anomalies, and to measure the TD gradients from the Caribou-Seneca and Nantucket-Seneca LOP's. Touchdown points for all runways were surveyed, as well as a variety of points around the periphery of the airport. Figure 6 shows the location of the test points around the airfield, as well as the Loran-measured position. The Airport Reference Point was chosen as the Loran reference point, and its TD's adjusted to obtain a zero mean error for all 21 points surveyed. From these data, it was discovered that anomalies of several hundred feet could exist at hangars, amongst trees, and on sloping ground. This suggests more effort be expended in surveying the airport, and that a balloon platform should be constructed to raise the Loran-C antenna off the ground surface to see if these surface anomalies disappear, and to explore the final approach airspace along the glide slope.

In general, a good Loran-C grid exists at Hanscom field, and the measured and calculated TD gradients show excellent agreement. For Seneca-Caribou, the measured gradient was 161.5 m/μsec, compared to the theoretical (v = 1) 162.6 m/μsec for Hanscom. For Seneca-Nantucket, the measured gradient was 177.5 m/μsec compared to the theoretical 180.4. Since the 99% confidence interval for the sample is ±6 m/μsec, this difference is not statistically significant. These survey points are to be extended (fig. 6).

6.0 Computer Simulation of Loran-C Approach Flying

Finally, a computer simulation of approach flights to Hanscom has been initiated to allow more detailed exploration of the effects of all these parameters on expected approach guidance. With the knowledge of the signal geometry, the statistical Loran data output by the receiver over space and time, it will be possible to explore the effects of crosswind, the mixing of heading rate and altitude signals, etc., and to repeat many simulated approaches to see the average statistical performance of the guidance system and display.

Reference

1. Natarajan, K., Use of Loran C for General Aviation Aircraft Navigation, 2/1981, MIT Flight Transportation Laboratory (FTL) Report 81-2.
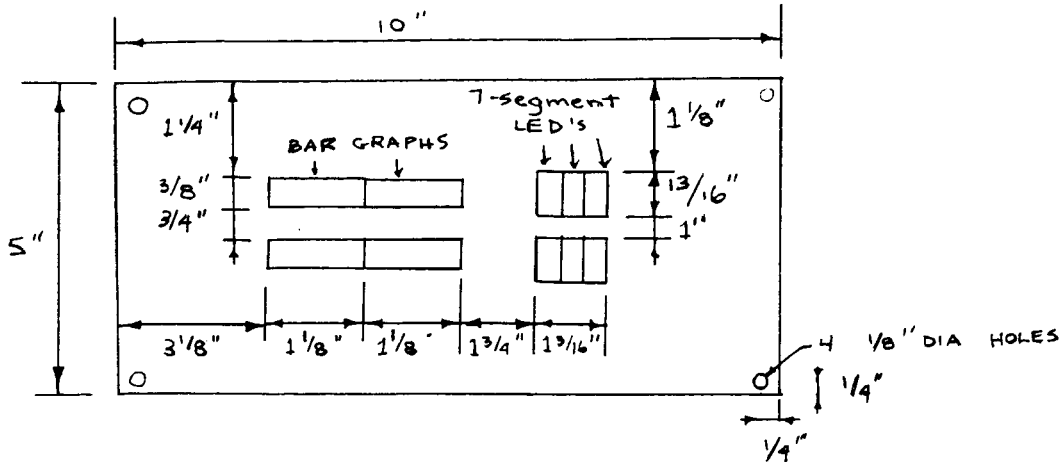
(NOT TO SCALE)

Figure 1. Loran-C approach guidance display.

$\omega_n \approx 0.1$ rad/sec, $\zeta \approx 0.7$
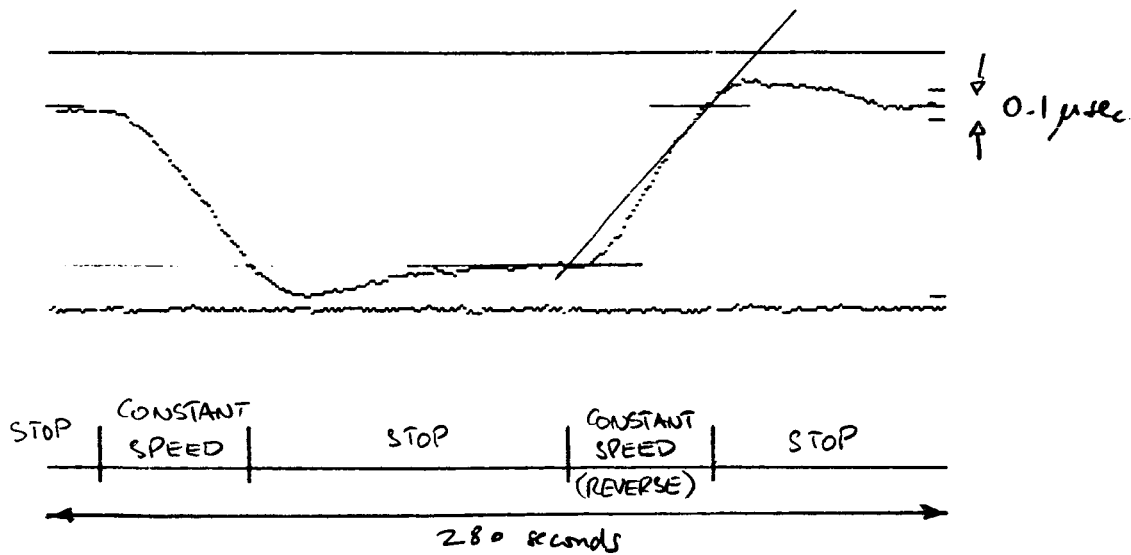
Figure 2. Transient response of marine filter.

$W_n \approx 0.4 \; rad/sec \;, \; \zeta \approx 0.7$

$0.1 \; \mu sec.$

STOP	CONSTANT SPEED	STOP	CONSTANT SPEED (REVERSE)	STOP

280 seconds
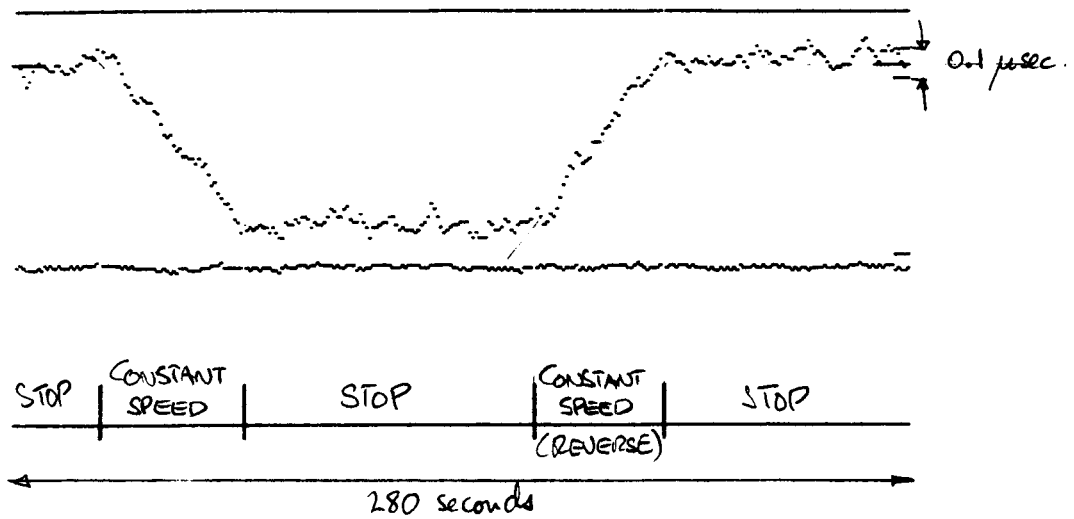
Figure 3.   Transient response of aircraft filter.

FILE: SNR5, 280 DATA POINTS
TD1, TD2, SNR2, SNR3

280 sec

TD1   +0.1μ -0.1μ

TD2   +0.1μ -0.1μ

SNR1 dB   +4 -9

SNR2 dB   +4 -9
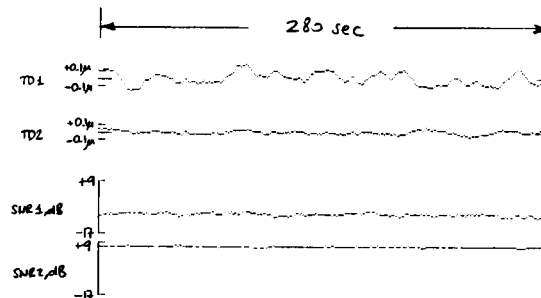
FILE: SNR5, 280 DATA POINTS
          TD1   TD2
AV: 14105.5071   25985.4919
SD: .0854119987   .0251286182
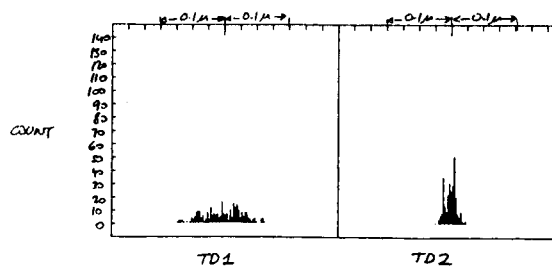AV. S/N: M-> 222 S2-> 90 S3-> 237

COUNT

TD1   TD2

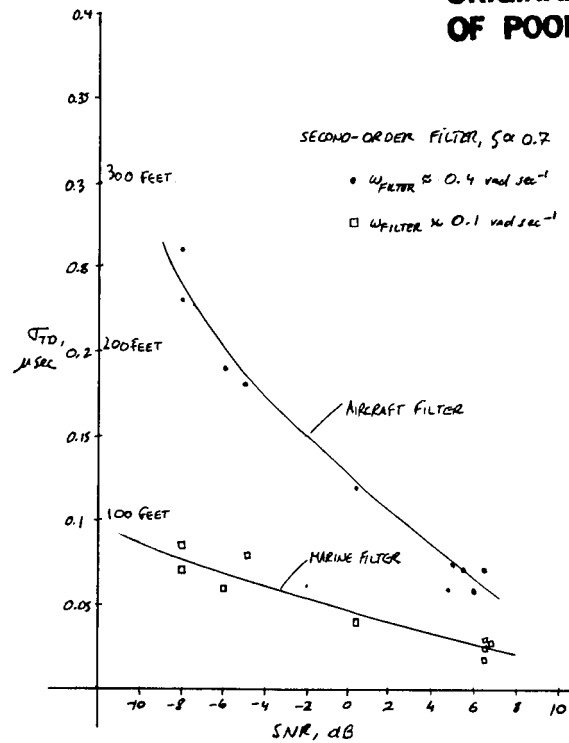Figure 4.   Effect of SNR on short-term TD variation.

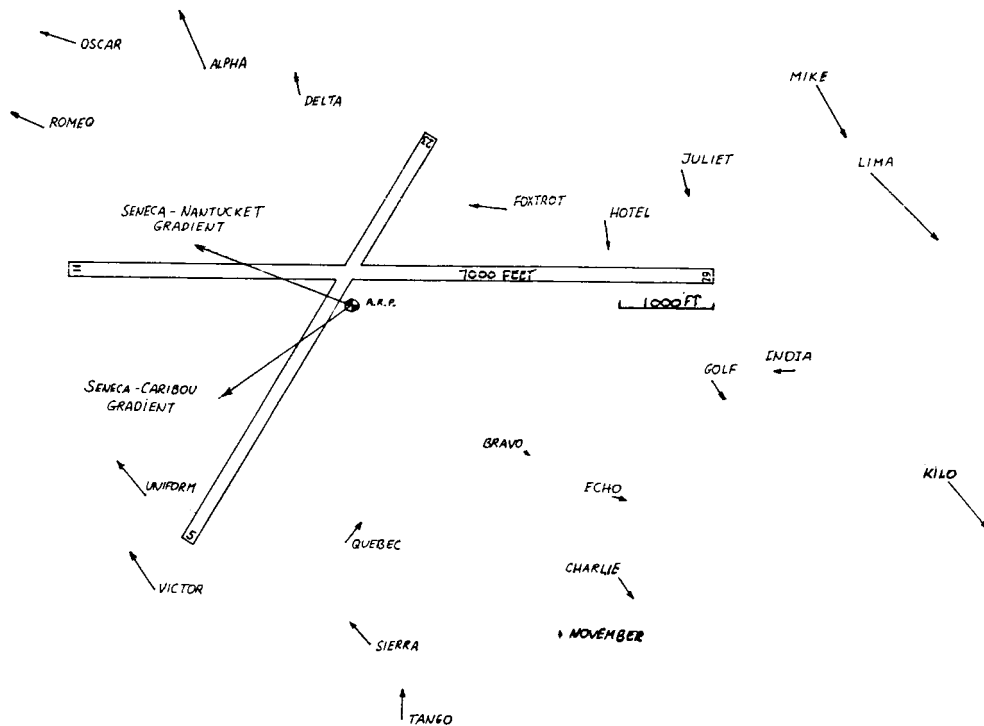Figure 5. Short-term variation in position versus SNR.

Figure 6. Loran-C survey at Hanscom Field,
residual errors in touchdown position.