WILD GOOSE ASSOCIATION

PROCEEDINGS

OF THE

FIFTH ANNUAL TECHNICAL SYMPOSIUM

AT THE
QUALITY INN, PENTAGON CITY
WASHINGTON, D. C.
ON 27—29 OCTOBER 1976

published by

THE WILD GOOSE ASSOCIATION
4 TOWNSEND ROAD
ACTON, MASSACHUSETTS 01720
PREFACE

This is the second publication of papers of the Wild Goose Association Technical Seminar. It contains not only most of the papers presented at the symposium but many of the convention highlights as well.

The theme of the 1976 Technical Symposium was Loran-C and the Law of the Sea. Papers were selected principally which pointed up problems, and solutions of problems, associated with precise radio navigation and the Law of the Sea. Other papers were selected which presented some of the latest advances in development and application of Loran-C equipments.

The symposium was well attended and the papers presented contain a significant amount of information about the use and potentials of the Loran-C system of navigation. This Proceedings is printed so that all those who are using, procuring or designing Loran-C equipment can profit from the efforts put into the papers presented.
# TABLE OF CONTENTS

## I. PROCEEDINGS OF THE TECHNICAL SEMINAR

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>AUTOMATION OF LORAN-C CHAIN CONTROL</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>R. H. Frazier, J. T. Doherty, USCG</td>
<td></td>
</tr>
<tr>
<td>B.</td>
<td>COASTAL SURVEY IN AFRICA USING LORAN-C</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>R. Marshall, G. Macdonald, R. Bryant, Canadian Hydrographic Service</td>
<td></td>
</tr>
<tr>
<td>C.</td>
<td>LORAN-C AND THE 200 MILE LIMIT</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Bahar J. Uttam and Radha R. Gupta, The Analytic Sciences Corporation</td>
<td></td>
</tr>
<tr>
<td>D.</td>
<td>LORAN-C USER EQUIPMENT</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Fritz J. Chambers, Teledyne Systems Co.</td>
<td></td>
</tr>
<tr>
<td>E.</td>
<td>FOREST SERVICE NEEDS FOR PRECISE NAVIGATION SYSTEM FOR SPRAY AIRCRAFT</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Tony Jasumback, U.S. Forestry Service</td>
<td></td>
</tr>
<tr>
<td>F.</td>
<td>LORAN-C CONCEPTUAL ANALYSIS</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>C.W. Mosher, M. Abrams, J.C. Murdock, N.Y. State Dept. of Motor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vehicles; W.L. Polhemus &amp; F. H. Raab, Polhemus Navigation Sciences</td>
<td></td>
</tr>
<tr>
<td>G.</td>
<td>FLIGHT TESTING A LOW COST AIRBORNE LORAN-C NAVIGATION SYSTEM</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>CDR R. H. Cassis, Jr., USCG</td>
<td></td>
</tr>
</tbody>
</table>

## II. HIGHLIGHTS OF THE FIFTH ANNUAL CONVENTION

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>LUNCHEON SPEAKER: CDR William B. Mohin, USCG</td>
<td>44</td>
</tr>
<tr>
<td>B.</td>
<td>PRESENTATION OF AWARDS</td>
<td>46-49</td>
</tr>
<tr>
<td>C.</td>
<td>SPECIAL MEDAL OF MERIT AWARD</td>
<td>50</td>
</tr>
<tr>
<td>D.</td>
<td>MS. WILD GOOSE</td>
<td>52</td>
</tr>
<tr>
<td>E.</td>
<td>BANQUET SPEAKER: CAPT Glenn F. Young, USCG</td>
<td>53</td>
</tr>
</tbody>
</table>

## III. CANDID CAMERA PERSPECTIVE

<table>
<thead>
<tr>
<th>Page</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>55-57</td>
<td></td>
</tr>
</tbody>
</table>
I. PROCEEDINGS OF THE TECHNICAL SEMINAR
AUTOMATION OF LORAN-C CHAIN CONTROL

R. H. Frazier
J. T. Doherty
U. S. Coast Guard

Abstract - This paper is a discussion of the design requirements, constraints, and interfacing problems encountered in the development of the Inverse Remote Control Interface (ICR) for use in automating LORAN-C chain control. Chain control is the process of (1) measurement of chain cycle and timing errors, (2) processing those measurements to determine biases, trends and required corrections; and (3) the decisions to make corrections and communicating commands to the transmitting stations.

Currently, the Coast Guard uses LORAN-C monitor receivers for measurement, a Calculator Assisted LORAN-C Controller (CALOC) for processing measurements, and a watchstander for decision making and communicating messages to the transmitting stations.

Presently, the Coast Guard uses LORAN-C monitor receivers for measurement, a Calculator Assisted LORAN-C Controller (CALOC) for processing measurements, and a watchstander for decision making and communicating messages. ICR is a microprocessor based decision making and communicating controller that is being developed and could replace many watchstander duties and ultimately permit fully automated LORAN-C chain operations.

I. BACKGROUND

Over the last several years, the Coast Guard has successfully improved the Loran-C System with the Loran-C Replacement Equipment (LRE) at transmitting stations and Calculator Assisted Loran-C Controller (CALOC) at the control stations. These improvements have several goals of which one is to permit an unwatched mode of operation at secondary transmitting stations, thereby reducing the manning level at a Loran-C station. The LRE added the capability to order changes to the precise phase timing of a transmitting station from a remote location via the Remote Control Interface (RCI). Therefore, an entire Loran-C chain could be controlled directly from a centrally located control station.

Recently a CALOC system was added to the East Coast Loran-C control station in order to relieve a watchstander of many tedious and routine tasks. The CALOC system consists of a programmable desk top calculator, X-Y plotter, and monitor receiver data interface. The CALOC system receives data from the monitor receiver data interface and the calculator keyboard as input. Output from the CALOC system consists of recommendations for timing changes and data records on the calculator printer. The CALOC system performs three major tasks: Time Difference (TD) control recommendations; abnormality detection; and record keeping. The TD control function of CALOC is handled by a sophisticated and adaptive mathematical algorithm which recommends controls, i.e., Local Phase Adjusts (LPAs), in order to keep the TD as close as possible to its control number, to assure long term zero TD bias, and to keep the magnitude and number of adjustments to a minimum.

After the CALOC System was installed the control "feedback loop" was bridged by a human watchstander who would decide whether a CALOC recommendation was warranted. If the change is desired, the watchstander implements the adjustment by typing a coded message on a system teletype loop to the transmitting station's RCI. The RCI then provides the needed adjustment to the station's timing equipment.

Figure 1 shows the overall monitoring systems as planned for the West Coast/Gulf of Alaska Loran-C chains. In other chain configurations the AUSTRON 5000 Receiver and 6019 Information Switch may be replaced by another monitoring receiver. The CALOC Data Interface is capable of formatting signals from four baselines with two monitors per baseline. It accepts receiver data in analog or digital form and supplies time of day information to the CALOC program. Control stations without an ICR utilize a watchstander to communicate between the CALOC program and the RCI at the transmitting stations. The RCI is a hardware device located at a transmitting station for the purpose of remotely controlling some transmitting station equipment. The RCI is capable of implementing the following commands: inserting LPAs; starting and stopping blink; and calling the watchstander.

The authors, officers in the U. S. Coast Guard, were attached to the U. S. Coast Guard Electronics Engineering Center, Wildwood, New Jersey, during the work described. The opinions expressed are those of the authors and do not represent the official policy of the United States Coast Guard.
II. INTRODUCTION

The Inverse Remote Control Interface (ICR) is a microprocessor based system that is designed to supplement CALOC and further relieve the watchstander of many routine and tedious tasks. The ICR does not replace the watchstander on a control station; instead, it merely supplements a watchstander's duties and allows him to focus on more important tasks.

The ICR is designed to perform three major tasks: automatic code conversion between the CALOC System and transmitting station equipment (RCI), transmission of the converted codes with error checking on retransmission of the code, and collection of all CALOC and RCI system controls on one centrally located control panel.

Automatic Code Conversion: The CALOC System is structured to make recommendations to the watchstander whenever an LPA is needed at a transmitting station. The code conversion that was previously performed by a watchstander is now performed automatically by the ICR. Therefore, the ASCII (7 level code) characters received from CALOC can be converted into Baudot (5 level code) characters and formatted into an RCI message. The code conversion program also allows the ASCII code to be converted into a bit pattern so that information may be displayed on a front panel.

Code Transmission: The ICR is designed to function in two modes: semiautomatic and automatic. In the semiautomatic modes, CALOC recommendations are displayed on the front panel of the ICR. The watchstander will then exercise a “GO-NO-GO” decision and may either execute or cancel the recommendation. When the ICR is placed in the automatic mode, the CALOC recommendations are executed immediately after they are recommended without watchstander intervention. In either case the formatted code is transmitted to the RCI over the system teletype loop. After the RCI receives and verifies the transmitted code, it retransmits the code to the ICR for error checking. The ICR then examines the retransmitted code for errors, and if no errors are found, the message is executed. Codes are then transmitted from ICR to CALOC, in order that CALOC may maintain its record keeping function.

Central Control Panel: The ICR incorporates all control points of the CALOC and RCI equipments in the front panel. This control panel allows a watchstander to execute LPAs without recommendation from CALOC and without manually typing the coded RCI message on a teletype. The watchstander will merely push a series of three switches to execute an LPA. In this mode, messages are automatically sent to CALOC for CALOC’s record keeping function. In previous systems a watchstander was also required to type coded messages on the keyboard of the calculator when abnormal conditions occurred. Now the ICR front panel allows the watchstander to send information directly to CALOC by pushing several buttons. The front panel of the ICR will eliminate the unnecessary watchstander movement and time in the control room by collecting all system controls in one location.

III. HARDWARE DESIGN CONSIDERATIONS

The input and output constraints for the ICR are summarized in Figure 2. The three inputs consist of recommendations from CALOC, front panel commands, and RCI retransmission for error checking. Similarly, the outputs are messages for CALOC, RCI messages, and front panel displays.

After examining the functions and the large number of messages that were possible in the ICR, it was determined that a random logic design would involve many printed circuit boards. In order to save a great amount of hardware and in order to give the system as much flexibility as possible, a microprocessor system approach was chosen. The microprocessor approach allows for software changes to be made while the hardware remains fixed.
The ICR is designed around the Coast Guard Bus System (CGBUS) which was formulated several months before the ICR design commenced. The CGBUS is a set of 26 lines that tie each bus member together. The bus may be divided into three distinct segments: the address bus, the control bus, and the data bus. Each module or peripheral that exists on the CGBUS monitors the address bus and control bus to determine when it is addressed and whether a transfer of data will be in receive or transmit mode. The CGBUS is controlled by a Bus Controller Module (BUSCON), and the BUSCON’s responsibility is to translate microprocessor signals into CGBUS signals for system operation. Figure 3 shows the ICR system structure with a CGBUS implementation. The great advantage of a bus system is the fact that many standard modules may be designed to be bus compatible and generally used as units in many other systems. The CGBUS system allows for two or three teleprinters to be driven from separate modules, each with different bus addresses in the same system. The ICR hardware may be more thoroughly viewed by examining each module shown in Figure 3.

**CPU:** The CPU module is the "heart" of the ICR and is composed of an 8080A microprocessor. The CPU module is equipped with several microprocessor support circuits, Programmable Read Only Memory (PROM), and Random Access Memory (RAM). The high density packaging technology of today allows for 4 K bytes of ultraviolet erasable PROM, and 1 K bytes of static RAM to be located on the CPU module. Additional memory may be housed in external memory modules, but additional memory modules are not needed for the operating program of the ICR. The PROM is used to store the operating program of the ICR, and this program remains fixed in PROM after removal of the power supply. The RAM is used for temporary storage of variables and for the microprocessor system stack.

**BUSCON:** The Bus Controller acts as a supervisor over the input and output operations on the CGBUS. The main function of the BUSCON is to reformat microprocessor control signals into CGBUS control signals. The BUSCON is designed to use the Memory Mapped Input-Output techniques due to their great flexibility. These techniques referred to as Memory Mapped I/O treat input and output peripherals on the CGBUS as memory locations, and data words that are moved to an I/O device are simply transferred to "memory". This technique allows the programmer to use very many programming instructions when dealing with I/O instead of the two instructions that are normally available with the basic type of I/O structure.

**TTYBC and PATTY:** The Teletype Bus Compati­ble (TTYBC) and Passive Teletype (PATTY) Modules provide the necessary interface to the system’s teletype loop. The TTYBC is capable of programmable baud rates and is also capable of handling 5 and 7 level codes with various parity and stop bit arrangements. The module may be programmed to accept and transmit with current loop or RS-232 format. When used in a CGBUS environment, the TTYBC may operate in an interrupt mode where it interrupts the microprocessor when data is ready to be transferred, or in a polling mode where the microprocessor polls the TTYBC to determine whether a character is ready to be transferred.

In the ICR design the TTYBC is programmed to operate with current loop and the five level Baudot code. The TTYBC has also been programmed to operate in a polling mode for ICR operation.

The PATTY module is used to convert 20, 40 or 60 mA current loop signals into a 5 volt switching signal, and this conversion is accomplished in an area that is isolated from the backplane of the chassis. Therefore, a potential noise source is removed from other internal circuits.

**CAPRI:** The Calculator Interface (CAPRI) module serves as a large buffer between the CGBUS and the CALOC program. The module is designed to have 32 character First-In-First Out (FIFO) Memories in both read and write transfer directions. The FIFO approach allows characters to be entered at a high rate of speed and removed at a rate of speed suited to the reading device. This technique also allows for one device to transfer characters to the FIFO and proceed with other tasks before the reading device removes the characters from the FIFO. The CAPRI module also contains a read and write eight bit status latch which may be used to formulate a "handshake" type of data transfer between the two devices. The reading device
would always read the status word to determine whether the writing device had information to pass. Upon receipt of an affirmative pattern, the reading device knows that the writing device had placed characters in the FIFO Memory. The reading device will then read the characters.

**FROPAN** : The Front Panel (FROPAN) module is merely an interface between a series of front panel switches (used for input) and front panel lights (used for output). Although the front panel switches and lights are contained within the same enclosure, they should be thought as two separate entities. After a switch is pushed on the front panel, the FROPAN module encodes the switch and interrupts the microprocessor. The microprocessor, in turn, accepts the character, and if it is a valid character, writes a bit pattern to the FROPAN module enabling the light. This cycle happens so quickly that it appears instantaneously after the switch is pushed. The rules for enabling or disabling lights on the front panel are contained in software, and the module's flexibility allows it to be used in other systems.

**CHARFET** : The Character Fetch (CHARFET) Module is used for programming an ICR for an installation. There are several variables between stations where ICR will be installed, and the CHARFET Module will provide information; such as, baseline code letters, number of baselines present, etc. The module will allow ICR to reload variable information after a power failure or a reset command bypassing manual loading of these variables.

IV. SOFTWARE DESIGN

Before describing some of the software modules that were designed for this application, the development system will be outlined. The main component in the development system was the Intel Intellec B/Mod 80 Microcomputer. This microcomputer contains an 8080A microprocessor and associated circuits with PROM and RAM. The development system is an important tool for the software engineer as it allows for programs to be tested in RAM before they are implemented in PROM. For the ICR system, several of the Intellec signals were different from those that would originate in the CPU module. Therefore, it was necessary to build an Intellec Interface module which would make the Intellec appear as the normal CPU module. This arrangement increased the flexibility of software design and troubleshooting in the ICR.

Another important aid in the development system was the assembly language cross assembler that is available through a timesharing service. Although editing and assembling of programs can be performed within the microcomputer itself, the facility and speed of timesharing made the programming many orders of magnitude easier.

With a little more RAM memory and a floppy disk, the assembly of programs with the microcomputer probably would have been completed as quickly and efficiently as with the timesharing service.

The system software can probably be best described by examining the program modules shown in Figure 4. The program is composed of several conversion modules, and these conversions have been implemented in "table-lookup" fashion. The remainder of the software is overhead to determine which codes are valid, and special procedure to be followed in system operation.

![Diagram of system software](image)

The main program of the ICR is the Real Time Operating System (RTOS) and only exits the RTOS loop if a request for service occurs. During the RTOS the ICR polls the CAPRI module to determine whether CALOC has information to pass. If the CALOC system does have information to pass, the ICR exists to a service routine and performs the required task. If front panel commands are entered, they are handled with interrupts, and after a CALOC execute or RCI execute switch is decoded the program branches to the appropriate service routine. Several other routines are handled during the RTOS, and these include system tests which insure that all peripherals are functioning properly.

In discussing the software design of the ICR, the software changes to the CALOC operating program should be noted. In previously installed CALOC systems the operator was required to stop the calculator at a designated position in the program in order to enter information. With the addition of the ICR, the operator is no longer required to stop the CALOC program. The CALOC program reads status information from the CAPRI FIFO, and upon receipt of a particular pattern, the CALOC program will branch to decoding routine and receive the information from the ICR. The information is then decoded and program control is transferred to the appropriate servicing section before control is returned to the RTOS. When the CALOC desires to transfer information to the ICR, the process is...
basically reversed. Each routine in CALOC that made recommendations to the operator was modified to write these recommendations to the status word and FIFO of the CAPRI module.

The elegance of a software system cannot be overemphasized for this application. After all hardware had been designed and tested, the ICR Program could be designed as extensively as desired. Changes or errors in the design could be made quickly and without much difficulty.

V. SYSTEM TESTING

The system design was initially divided into two sections: hardware and software. Due to the availability of the timesharing facilities and microcomputer development system, the software could be developed without hardware and many of the input/output routines could be simulated. As the hardware was developed, simple software routines were written to ensure proper hardware operation.

The hardware and software were combined following the final testing of all hardware modules. As soon as software routines were written to replace the input/output simulations, the system began performing as expected. Several software errors were discovered in this stage through the usage of software breakpoints and singlestepping capabilities in the microcomputer. After the necessary functions were tested, several refinements and options were added in the software with no hardware modification. Final test procedures will close the loop by testing the ICR with the RCI and remainder of the LRE. These tests will be initially conducted in a laboratory environment, and then, in a field test on an operational Loran-C chain. This field test will be run for several months before production ICRs are manufactured.

VI. BUILT IN TEST EQUIPMENT (BITE)

As mentioned earlier, a software approach in this design allows for a great deal of flexibility in system modifications. The software approach also allows for additional functions to be added as they are needed. After the ICR program is implemented, several test routines can be added to the software to aid a technician in isolating problems on a module level. After a problem is isolated, the module is replaced without much lost time.

As all of the BITE routines are not completed, the required amount of memory for these routines is unknown. If additional memory is needed, however, it will be an easy task to add an external memory module for this purpose.

VII. SUMMARY

The ICR is still in its preproduction development stage, and the operational and long term evaluation lies ahead. However, the manner in which the ICR was designed will allow for extensive software modifications to be made if they are needed.

By implementing the ICR in a microprocessor, the savings in hardware is at least a factor of two or three times. The hardware modules that have been designed for the ICR are general purpose modules and may be used in other systems if needed.

The ICR does not replace the watchstander at the Control Station; it merely supplements the watchstander in the performance of his normal duties and relieves him of many minor tasks.

VIII. ACKNOWLEDGMENTS

Although the development and design of the ICR has involved many persons from its initial stages, two men have contributed a great deal to the development of the ICR. We would like to acknowledge the contributions of Ronald HUNTER for his large effort in the software development and Royce JACOB for his efforts in hardware development.

IX. REFERENCES


Coastal Survey in Africa Using Loran-C

R. Marshall
G. Macdonald
R. Bryant
Canadian Hydrographic Service

Abstract - Loran-C signals from a pair of Accufix stations provided position data aboard the Canadian Survey Ship BAFFIN while surveying the continental margin of Senegal early in 1976. The signals were processed in rho-rho mode by an Austron 5000 receiver interfaced to a Magnavox integrated navigation system. Loran-C and ship's gyro compass were used to derive speed and heading to dead reckon the ship between satellite fixes (NNSS - transit). Survey operations continued 24 hours per day for a period of 50 days at ranges from the stations up to 650 km.

This paper deals with the contract raised to provide the Loran-C signals and the logistics of commissioning, operating and maintaining the Accufix chain within the constraints imposed by a short duration survey in a foreign water with short lead time. The history of the project is reviewed briefly, the objectives of the survey outlined, and operations aboard ship are described. Data comparing Loran-C derived positions with satellite navigation are presented and the methods used to improve the quality of position data through post analysis are presented.

The two hundred mile limit poses a challenge to the marine surveyor. This paper demonstrates the applicability of the Accufix system as a tool to accomplish his task.

I. INTRODUCTION

Part III of the informal single negotiating text of the Third Conference on the Law of the Sea proposes that states "... shall promote the development of the marine scientific and technological capacity of developing states ..., in consonance with their economics and needs, with regard to the exploration, exploitation, conservation and management of marine resources ..., with a view to accelerating the social and economical development of developing states ....

In order to achieve the above mentioned objectives, states shall endeavour to:

(a) establish programs of technical co-operation for the effective transfer of all kinds of marine technology to developing states

(b) undertake projects ..., and other forms of bilateral ... co-operation".

In discussions before and during the Third Conference on the Law of the Sea held in Geneva in March and April, 1975, the Senegalese delegates pointed out to the Canadians that they, like many third world countries, did not possess the resources or experience necessary to allow them to establish the extent and resources of their continental shelf. In the light of the discussions on the development and transfer of technology in committee three of the conference, the Canadian delegation suggested that this might be a suitable foreign aid project.

A formal agreement was eventually signed by the Canadian International Development Agency (CIDA) and the governments of Senegal and Gambia by which CIDA would pay the costs of the Canadian Hydrographic Service and the Atlantic Geoscience Centre to send CSS BAFFIN to carry out a multi-parameter survey of the continental shelves and margins of those countries. This would include gathering bathymetry, gravity and magnetic field data along with observations of the extent of hydrocarbon pollution. High resolution seismic profiling would also be carried out on the continental shelf to assist the Centre de Recherches Oceanographique de Thiaroye (CROT) in Senegal with the interpretation of their studies of the surficial geology of the continental shelf. Senegal and Gambia were invited to name staff to assist in and be trained in the various data gathering and analysis programs on board BAFFIN. Subsequently, the main responsibility for planning and carrying out the survey, was given by the Dominion Hydrographer to the Hydrography Division, Central Region, based at the Canada Centre for Inland Waters, Burlington, Ontario. BAFFIN, one of our major hydrographic vessels, based at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia, was officially assigned to the project.

Meetings were held with representatives from various Canadian government departments and agencies, and on October 1, 1975, the specific objectives of the survey were spelled out and the necessary financial arrangements were made.

II. POSITIONING SYSTEM

Once we knew we had a ship to carry out the survey, our major concern was how to accurately position her on a continuous basis at distances of up to 650 km offshore. Central Region possessed a Magnavox Integrated Navigation System with Doppler Sonar, which we had used successfully in Hudson Bay during the summer of 1975. However, the depths off Senegal, down to 5000 metres, greatly exceeded the
useful range of our sonar. Our Decca Lambda chain could not give us the 200 metre accuracies required 24 hours a day at the extremes of the survey area.

In our continual search for optimum positioning of our survey vessels, our Hydrographic Development Section had previously studied the Accufix Loran-C system. We felt that a mini Loran-C chain, set up in rho-rho mode with stations in the extreme north and south of Senegal, integrated into our navigation system would provide the best possible positioning for this area.

As the Canadian Hydrographic Service did not possess such a chain, we thought it advantageous to contract private industry to operate a Loran-C chain for us on a leased basis. Accordingly, our Hydrographic Development Officer drew up contract specifications for "The Experimental Use of a Position Fixing System in Support of Scientific Data Collection". These specifications were turned over to our Department of Supply and Services on October 22nd. They set up a bidders' conference for November 21st and a closing date for tenders on December 1st.

In early November, Rick Bryant, Hydrographic Development Officer, John O'Shea from our Headquarters' Training Staff, and Bob Marshall, went to Senegal to select sites for the antennas, transmitters and monitor. We also wanted to discuss various aspects of the survey, particularly the training of local personnel, with Senegalese government officials.

To obtain the best possible fix geometry over the survey area, we wanted stations as far apart as possible, but because of political considerations, within the boundaries of Senegal. We located potential transmitter sites near St. Louis and Diemering, 430 km apart, and a monitor site in Dakar. As 100 m towers were required to get the necessary range, special permission to erect them was arranged with the Senegalese Government. The Canadian Embassy in Dakar promised to give us all possible assistance, especially in getting speedy customs clearance for the equipment which would be brought into the country. The Senegalese Navy offered us berthing space for BAFFIN at their base in Dakar.

We returned to Canada and at the bidders' conference on November 21st, we briefed six (6) potential suppliers on our site selection and the conditions they could expect to find in Senegal. On December 12th, we entered into a contract with ComDev Marine of Ottawa, who proposed to supply and maintain a Megapulse Accufix Loran-C survey positioning system in conjunction with Megapulse Inc. of Bedford, Massachusetts.

The contractor had just under two months to acquire, pre-test and ship the equipment, erect two 100 m towers, install and shake down the chain and establish initial calibration data. All this, plus celebrate Christmas and New Year's, have endless immunization shots, get acclimatized, learn how to haggle with Customs Officials, and establish domestic facilities. Presumably, any extra time was spent swimming in the surf, sight-seeing and checking out the night life in Dakar. It is a credit to ComDev Marine, Megapulse, Leblanc and Royle (the tower subcontractor) and the Canadian Embassy in Dakar that all this was accomplished. A hydrographer was in Senegal during this period acting as liaison between the contractor and Senegalese officials.

We had hoped to have the chain operating for one week prior to the arrival of the ship. This hope was dashed however, when the antenna assembly shipped from Dakar to Diemering took two weeks to arrive on site. As it was, the chain was up one day before the departure of BAFFIN to begin survey operations on February 11th.

The tight survey schedule left little room for down time and, in an effort to maintain continuous operation, spares of all modules were kept at each site and the stations were manned 24 hours per day. Power was provided by two diesel generators used alternately. The contractor provided two technicians at each transmitter site, a chain supervisor based in Dakar and Scott Hinick of Megapulse, who provided engineering support on installation and general system trouble-shooting.

A communications network, using S.S.B., was established between Master, secondary, monitor and ship. Maintenance activity was co-ordinated by the chain supervisor who tried to schedule outages to coincide with "on station" work by BAFFIN.
The first week of operation was plagued with system failures that could have been avoided if more time for shakedown had been available. Almost daily outages resulted in the system availability reaching only 83%. However, after the first six (6) days, chain availability exceeded 98% with two down time periods of one hour each scheduled to correspond with "on station" activity by the ship. March availability exceeded 99.5% with only one outage not corresponding to on station work.

Chain G.R.I. and timing was established by a cesium standard at the master station. Timing of the secondary was regulated either by a timing receiver locked to the master transmission or by a cesium standard with timing adjustments introduced to maintain the time difference observed at monitor within 50 nanoseconds. During the first half of the operation, timing was maintained by cesium at night and receiver by day when the S/N ratio was good. Later, complete reliance on the cesium standard was adopted with three regular timing adjustments per day that totalled 90 nanoseconds.

III. SURVEY SUMMARY

BAFFIN began a previously planned refit on November 12, 1975, which was due for completion on January 16, 1976. Because we anticipated leaving Halifax for Senegal on January 26th, we had to begin installing our survey equipment, including computers, gravimeter, echo sounders, portable laboratories and satellite navigation system while the ship was still in the hands of the shipyard. In spite of this, we were able to leave on schedule. The voyage to Senegal lasted until February 8th and was used as a shakedown cruise during which all our equipment and systems were tested. Bathymetry, magnetics and gravity data were collected on a continuous basis; daily oil tows were made and a 40 cu. in. air gun was towed over the Mid-Atlantic Ridge. A mooring with 2 current meters and 1 tide gauge was laid in 50 m of water, 55 km south of Dakar prior to our docking in the Senegalese capital.

After a two day stop in Dakar, we began the survey on February 11th. BAFFIN steamed on pre-arranged lines collecting bathymetry, magnetics and gravity on a continuous basis. An oceanographic station was occupied on a daily basis. Wildlife observations were made during daylight hours; weather observations were recorded every 6 hours and the results transmitted by radio to Dakar. This program, interrupted by a visit to Dakar from March 5-8th, continued until March 18th. From the 18th to the 28th, we towed a Huntec high resolution deep seismic system over the near shore area. The current meter mooring was recovered on March 27th. After a further two day stop in Dakar, we sailed for Halifax. On route, we spent 2 days running seismic lines over drill site number 13 on the Mid-Atlantic Ridge.

IV. NAVIGATION

From Halifax until we were near the Azores, we used the satellite navigation system with inputs from the East Coast Loranz-C chain and the North Atlantic chain. After we were out of range of the N.A. chain, we used SatNav with gyro and manual speed inputs.

When BAFFIN left Dakar on February 11th to begin the offshore survey, our complete navigation system was on line. However, for the first few days, we had some difficulty maintaining lock on the Loran signal, due to excessive atmospheric noise levels at night, especially between 2300 and 0400 hours. When we temporarily lost the signal, as we did on some occasions, we reverted to manual speed input. After a few days, we were able to make some tuning and operating adjustments to our receiver and, until the end of the survey, the SatNav/Loran-C combination worked exceptionally well. We found that by tracking on the fifth cycle and using a high J (averaging) value on the Austron 5000 receiver, we were able to maintain lock throughout the survey area, even at the extreme range of 720 km from the secondary station and 770 km from master.

The satellite navigation system, Loran receiver, gravimeter and magnetometer readouts and echo sounder
recorders were located in BAFFIN's plotting room immediately above and abaft the wheelhouse. This arrangement enabled one hydrographer, on normal sea watch, to monitor all equipment and con the ship along pre-determined tracks.

Ship's position, time, depths and Loran readings were automatically logged on mag. tape, displayed on a CRT and on a printout from a teletype terminal.

A CRT showing latitude, longitude, depth, course to steer, distance off line, distance to go, etc., was located in the wheelhouse and kept the officer of the watch informed on the progress of the ship along the survey line. The helmsman used information displayed on the CRT to keep the ship on line. A similar display was set up in the seismic lab. Voice communication between plotting room, wheelhouse, seismic lab. and oceanographic lab. was continuously available. The officer of the watch could instantly over-ride the survey navigation system when required for the safety of the ship.

During the return trip from Dakar to Halifax, we tracked the Loran-C signal to a distance of 1100 km from the most distant station before the chain was taken off the air. We picked up the signal from Cape Race of the East Coast chain south of the Azores, but it was not until Mid-Atlantic that we were able to use the East Coast chain on a continuous basis.

V. POSITIONING WITH THE INTEGRATED NAVIGATION SYSTEM

In conventional applications, Loran-C lines of position generated by the Austron 5000 are subjected to a computation that derives the ship's position based on the exact location of the transmitter, measured time delay, predicted clock drift, predicted propagation factors and measured initial synchronization errors. If calibration is precise and careful records of clock drift are maintained, chains with repeatability in the order of 50 metres yield positions with errors in the order of 180 metres subject to geometric dilution.

By comparison, at the time of the Senegal Survey, the location of the transmitters was only known to within 500 metres. No calibration or initial synchronization was made, and no effort was made to rate clock drift. Instead, satellite navigation fixes were used to establish the ship's position, and Loran-C range "changes" were used to derive the relative motion of the ship between fixes, acting in a similar manner to a doppler sonar providing velocity information to a dead reckoning computer program. The derived Loran-C velocity data provided accurate dead reckoning navigation, and improved the quality of the satellite fixes by providing accurate speed and heading data during the fix.

Clock drift and station location uncertainty resulted in errors in the dead reckoning that showed up at the time of the next satellite pass. The real time navigation program applied this correction and, as a result, a discontinuity (the update) appears in position data at each satellite fix. These updates were removed in a subsequent position processing program that also improved the accuracy of the D.R. positions based on the update value.

VI. POSITION ADJUSTMENTS

At the time of the satellite fix, the amount of the update can be computed. It is the difference between the dead reckoned position and the satellite position for the same instant.

\[
\text{Update (lat.)} = \text{lat. (dead reckoned)} - \text{lat. (satellite)}
\]

\[
\text{Update (long.)} = \text{long. (dead reckoned)} - \text{long. (satellite)}
\]

A portion of this update can be applied to each recorded D.R. position, as a proportion of the distance travelled since the last satellite fix.

\[
\text{lat. (corrected)} = \text{lat. (dead reckoned)} + \text{update (lat.)} \cdot \frac{D}{D + d}
\]

\[
\text{long. (corrected)} = \text{long. (dead reckoned)} + \text{update (long.)} \cdot \frac{D}{D + d}
\]

where \(d\) is the distance travelled from the last satellite fix to the present D.R. position, and \(D\) is the total distance travelled between satellite fixes.

The corrected positions were stored on magnetic tape along with the other survey parameters. This data was used to produce the bathymetry plot.

VII. POSITION ACCURACY

A large update is an indication that velocity information supplied to the integrated system is incorrect. Since it could also indicate a bad satellite fix, only those satellite fixes which passed the fix acceptance criteria were used to derive the figures in the following discussion.

By comparing the amount of the update to the normal error in the satellite fix (60 metres), an indication of the accuracy of the Accufix as a velocity sensor becomes evident. For this comparison, the survey area was divided in two: a short range (near shore) area extending 300 kilometres off the coast of Senegal and a long range area extending from 300 kilometres to 600 kilometres off shore.

In the near shore area, the median update per hour was 42 metres. This indicates that after one hour of dead reckoning the computed position of the vessel differs from the actual position (as determined from satellite) by 42 metres. Since the total error can be attributed to the satellite fix, the accuracy of the Accufix at short ranges was better than the system to which it was referenced. Updates as small as 3 metres per hour and as large as
152 metres per hour were observed. Survey accuracy was further improved by using the position adjustment techniques previously described.

In the offshore area, the median update of 95 metres per hour is larger than the error observed at the shorter range. The smallest update observed was 9 metres, while the largest update was 201 metres. After position adjustments had been made, the accuracy fell well within the required limits of ±200 metres. The deterioration of accuracy with an increase in range can be solely attributed to the Accufix derived velocity. A median error in O.R. of 67 m would yield a median update of 90 metres. Although this is not a precise measure of the accuracy of the Loran-C, it is a good estimate of its repeatability.

The update figures quoted are 'per hour'. Satellite fixes, however, occur at irregular intervals throughout the day. The interval between good fixes could vary from 20 minutes to 4 hours. In Senegal, the average interval between updates was 1 hour and 56 minutes.

Satellite fixes, however, occur at irregular intervals throughout the day. The interval between good fixes could vary from 20 minutes to 4 hours. In Senegal, the average interval between updates was 1 hour and 56 minutes.
returned to A.O.L. for analysis at the end of the cruise.

A comprehensive report with maps was prepared for inclusion in the final report to be handed over to the Senegalese Government later in 1976.

XI. WILDLIFE OBSERVATIONS

From January 26th to March 6, 1976, a representative from the Canadian Wildlife Service carried out a series of observations from BAFFIN. This allowed the quantitative mapping of sea birds, flying fish and dolphin distributions throughout the survey area. A chart of the surface temperature was prepared and the biological distributions were interpreted in terms of the various temperature zones. The importance of the offshore upwelling system to sea birds and other animals was investigated. Surface tows were made for oil particles and plankton samples were frozen for laboratory analysis.

A full report on these investigations was prepared for inclusion in the final data report for Senegal.

XII. CONCLUSIONS

The Loran-C mini chain used in Senegal proved to be a reliable, flexible positioning tool.

Accuracies of better than ±200 metres were maintained on a 24 hour basis over a survey area which extended 600 km offshore.

REFERENCES

LORAN-C AND THE 200-MILE LIMIT
by
Bahar J. Uttam and Radha R. Gupta
The Analytic Sciences Corporation
Reading, Massachusetts 01867

I. INTRODUCTION

In 1976, The Fishery Conservation and Management Act became law. This law places the responsibility on the National Marine Fisheries Service (NMFS) and the U.S. Coast Guard (USCG) for enforcing Federal conservation and territorial fishing laws and treaties over a 2.2 million square mile area. The U.S. fishery conservation zone adjoins the territorial sea (the 3-mile limit); its outer boundary is 200 nm from the coast. The exclusive authority of this law takes effect on March 1, 1977. The need for enactment of this law is demonstrated by Charles L. Philbrook, Special Agent in Gloucester, Massachusetts, regional office of NMFS, who was reminiscing of the first appearance of foreign fishing vessels off the Atlantic Coast in the summer of 1961. He states (Ref. 1), "They said the Soviets were out there fishing with 'ocean liners' and that was the first we knew about it. Those Boston fishermen were amazed - they had never seen any fishing vessels that large." The 200-mile bill gives the opportunity to the U.S. to protect the stock and to increase the amount of fish available to the U.S. fishermen. Foreign fishing is not closed out but is limited to those resources available beyond the capability of the U.S. fleet.

An obvious problem in the enforcement of such a law is the definition of the 200-mile limit. The question posed is "How well can the 200-mile limit be defined?" In this paper, an attempt is made to define the 200-mile limit using the Loran-C navigation system.

II. LORAN-C NAVIGATION SYSTEM

Loran-C is a radionavigation system operated by the U.S. Coast Guard (USCG). Currently, there is one Loran-C chain which provides coverage in the U.S. east coast. On 1 January 1977, with the availability of three Loran-C chains on the west coast, total coverage on the west coast including Alaska will be available. Implementation of a Loran-C chain in the Gulf of Mexico has been proposed for January 1, 1978, thus providing total coastal confluence coverage. The Loran-C coverage available on the east coast and west coast is shown in Figs. 1 and 2, and the transmitting station locations in Tables 1 and 2. The operation of the Loran-C system is not discussed in this paper; this information can be found in Ref. 2.

The issues discussed in this paper are:
- Availability of Loran-C signals at the 200-mile limit.

Fig. 1 U.S. East Coast Loran-C Coverage Area

Fig. 2 U.S. West Coast Loran-C Coverage Area

TABLE 1

<table>
<thead>
<tr>
<th>Station</th>
<th>Coordinates Latitude &amp; Longitude</th>
<th>Station Function</th>
<th>Coding Delay &amp; Baseline Length</th>
<th>Radiated Peak Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carolina</td>
<td>34°03'45.90N 77°54'48.78W</td>
<td>Master</td>
<td>700 kW</td>
<td></td>
</tr>
<tr>
<td>Beach, NC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jupiter</td>
<td>27°01'48.42N 80°06'53.52W</td>
<td>W Secondary</td>
<td>300 kW 2695.5 µs</td>
<td></td>
</tr>
<tr>
<td>Florida</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cape Race</td>
<td>46°46'32.09N 53°10'38.10W</td>
<td>X Secondary</td>
<td>1.9 MW 8398.85 µs</td>
<td></td>
</tr>
<tr>
<td>Newfoundland</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nantucket</td>
<td>41°15'11.84N 09°58'38.09W</td>
<td>Y Secondary</td>
<td>300 kW</td>
<td></td>
</tr>
<tr>
<td>Massachusetts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 2

<table>
<thead>
<tr>
<th>Station</th>
<th>Coordinates Latitude &amp; Longitude</th>
<th>Station Function</th>
<th>Coding Delay &amp; Baseline Length</th>
<th>Radiated Peak Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fallon</td>
<td>36°33'06.39N 118°49'56.20W</td>
<td>Master</td>
<td>400 kW</td>
<td></td>
</tr>
<tr>
<td>Nevada</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>George</td>
<td>47°03'41.50N 119°44'39.38W</td>
<td>W Secondary</td>
<td>2.0 MW 2796.50 µs</td>
<td></td>
</tr>
<tr>
<td>Washington</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middletown</td>
<td>36°46'54.70N 122°59'44.30W</td>
<td>X Secondary</td>
<td>400 kW</td>
<td></td>
</tr>
<tr>
<td>California</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Searchlight</td>
<td>36°19'18.11N 114°48'17.35W</td>
<td>Y Secondary</td>
<td>1.0 MW 1867.25 µs</td>
<td></td>
</tr>
<tr>
<td>Nevada</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Position accuracy attainable at the limit.

Prior to any analysis addressing these two issues, certain ground rules have to be established, which are discussed below.

Use of Loran-C in the Hyperbolic Mode

It is assumed that in defining the
200-mile limit, Loran-C is operated in the hyperbolic mode. This assumption is realistic since a majority of fishing vessels are likely to be equipped with a receiver that operates only in the hyperbolic mode. The direct-ranging or p-p receivers are significantly more expensive. It is therefore recommended that the 200-mile limit be defined using the hyperbolic mode, so that the user be able to relate to the common mode of operation.

U.S. East Coast and West Coast Loran-C Chains

In order to simplify the analysis, signal availability and accuracy are addressed using only the U.S. East Coast and U.S. West Coast chains. The West Canadian and Gulf of Alaska chains are not included. The effect of the simplification restricts the definition of the 200-mile limit considered herein to be between the Mexican and Canadian borders.

Additional Secondary Phase Factor (ASF) Corrections

The accuracy of Loran-C is primarily dependent on the ability to compensate for the Loran-C signal propagation phase delay over land paths. The compensation for a delay over a land path in excess of the delay encountered over an all sea-water path is referred to as an ASF correction. The compensation for phase delay over a sea-water path is the Secondary Phase Factor correction. The ASF corrections are a function of ground conductivity and distance between transmitter and receiver.

The U.S. West Coast Loran-C chain transmitters are located at sites that are at large distances from the coastline (unlike the U.S. East Coast chain transmitters, M.W., Y, which are on the coastline). As a result, ASF corrections become an important factor in addressing Loran-C accuracy.

Figure 3 illustrates ASF correction curves, based on classical theory (Ref. 3), for various values of conductivity. Millington's method (Ref. 4) is used to compute ASF corrections for mixed conductivity paths.

These ASF corrections are generally not readily available to a user, therefore the accuracy in defining the 200-mile limit on the West Coast is based on both with and without the application of ASF corrections.

Signal-to-Noise Ratio (SNR) Criterion

Loran-C signal availability is based on a SNR criterion. The criterion chosen in this study is that SNR be greater than 1:3 for noise values not exceeded 5% of the time throughout the year. Most modern receivers can operate with a SNR of 1:3.

Signal strength is evaluated using the curves shown in Fig. 4 and are described in Ref. 2. These curves illustrate the electric field strength (dB above 1μV/m) of Loran-C signals as a function of transmitter-to-receiver distance, parametric in ground conductivity, c. These curves are derived for transmitter peak radiated power of 400 kw. Signal strength values for radiated power other than 400 kw are obtained by appropriately modifying the values obtained from the curves by the specific value of transmitter power. For mixed conductivity paths, Millington's method is used to obtain values of signal strength. Noise statistics are obtained from CCIR tables (Ref. 5).

Fig. 3 Loran-C Signal Phase Behavior

Fig. 4 Loran-C Signal Amplitude Behavior

POSITION ACCURACY

A Loran-C position fix is defined by the intersection of two hyperbolic LOPs (lines of constant time differences). The crossing angle of the LOPs influences fix accuracy for a given time difference error. Position error due to a given time difference error increases as the crossing angle decreases. To account for this geometric effect, Loran-C position errors are related to time difference errors by a factor called Geometric Dilution of Precision (GDOP). GDOP is a measure of the sensitivity of Loran-C position fix accuracy to errors in Loran-C time difference measurements. It is a function of the geometry of the receiver location relative to the Loran-C transmitters.
If Loran-C system errors, in time difference coordinates (which are independent of receiver location) can be specified, then with the knowledge of GDOP, position accuracy can be evaluated.

**LORAN-C SYSTEM ERRORS**

In order to evaluate the accuracy with which the 200-mile limit can be defined, Loran-C system errors in time difference coordinates (µs) are required. An attempt, based on Ref. 6, is made to quantify these errors. The major errors in Loran-C are

- Groundwave propagation anomaly - \(a_{pa}\)
- Master/secondary synchronization error - \(a_{ss}\)
- User measurement error - \(a_{me}\)
- User prediction error - \(a_{pe}\)

and the typical magnitudes of these errors are listed in Table 3.

### TABLE 3

**TYPICAL LORAN-C SYSTEM ERRORS**

<table>
<thead>
<tr>
<th>ERROR</th>
<th>TYPICAL VALUE(µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a_{pa})</td>
<td>0.2</td>
</tr>
<tr>
<td>(a_{ss})</td>
<td>0.05</td>
</tr>
<tr>
<td>(a_{me})</td>
<td>0.1</td>
</tr>
<tr>
<td>(a_{pe})</td>
<td>0.1 (sea water)</td>
</tr>
<tr>
<td></td>
<td>0.5 (land)</td>
</tr>
</tbody>
</table>

The groundwave propagation anomaly refers to the variability in the propagation velocity. This includes weather and other temporal effects on the propagation velocity.

The secondary station synchronization error is the error in the synchronization between master and secondary station transmissions. This error is bounded by the monitoring activities of the chain service area monitors.

The user measurement error refers to the uncertainty in the measurement of Loran-C time differences due to the characteristics of the user's receiving set.

The prediction error refers to the uncertainty in the user's geodetic position by virtue of the limitation of the prediction model and the uncertainty in the propagation velocity of signal transmission from transmitter to receiver.

### 200-MILE LIMIT DEFINITION ACCURACY

In attempting to obtain a 200-mile limit definition, the following questions were posed:

- Can the Loran-C signal be received with adequate SNR?
- What is the best transmitter pair combination?
- Given the SNR is adequate, what is the magnitude of position errors?

The first question is answered using the SNR computation techniques described earlier. Except in a limited region off the coast of Florida, Loran-C signals can be received within the 200-mile limit with a SNR of 1:3 or better.

The second question is answered by computing GDOP at grid points along the 200-mile limit contour for all possible transmitter pairs and selecting the pair that yields a minimum GDOP and maximum SNR. The best transmitter pairs for the various regions are shown in Table 4. This question is irrelevant in the east coast since only three transmitters are available.

### TABLE 4

**IDEAL TRANSMITTER PAIRS - WEST COAST CHAIN**

<table>
<thead>
<tr>
<th>LATITUDE (deg)</th>
<th>STATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 - 35</td>
<td>M, X, Y</td>
</tr>
<tr>
<td>36 - 40</td>
<td>M, W, Y</td>
</tr>
<tr>
<td>41 - 47</td>
<td>M, W, X</td>
</tr>
</tbody>
</table>

The third question - the accuracy in defining the 200-mile limit - is based on a value of Loran-C system error of 0.2µs in the east coast and 0.6 µs in the west coast. The lower value is chosen for the east coast as there are no land paths. The accuracy (\(e\) ft) with which the 200-mile limit can be defined along the east coast and west coast is presented in Tables 5 and 6, respectively. (The west coast results are generated for the two cases - with and without application of ASF corrections).

### TABLE 5

**200-MILE DEFINITION ACCURACY - EAST COAST**

<table>
<thead>
<tr>
<th>LATITUDE (deg)</th>
<th>ACCURACY (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 - 28</td>
<td>1500 &lt; (e) &lt; 3000</td>
</tr>
<tr>
<td>27 - 40</td>
<td>(e) &lt; 1500</td>
</tr>
<tr>
<td>41</td>
<td>1500 &lt; (e) &lt; 3000</td>
</tr>
<tr>
<td>42</td>
<td>(e) &gt; 5600</td>
</tr>
</tbody>
</table>

*POOR SNR ALSO.*
DISCUSSION OF RESULTS

The 200-mile limit can be defined on the east coast with an accuracy of better than 0.5 nm everywhere except in the 42° latitude region. In the definition of the 200-mile limit in the west coast, if ASF compensation is applied, the errors are less than 0.75 nm except in the 47° latitude region. The errors are approximately 1 nm if ASF compensations are not applied.

Both these sets of results must be qualified. For example, the plans for calibration of the U.S. West Coast chain include use of at-sea calibration data which has not been previously done. This technique of calibration would reduce the prediction error. However, the methodology presented herein is a means of obtaining a preliminary definition of the 200-mile limit.

This paper has addressed an important issue - the definition of the 200-mile fishery conservation zone. Enforcement laws and policies are formidable. Many questions arise in attempting to define such laws and policies. An attempt is made here to address the accuracy that can be achieved if Loran-C is used to define the zone boundary. Whether this accuracy provided by Loran-C is sufficient cannot be answered; it is an issue that will eventually be answered by the appropriate enforcement agency.

ACKNOWLEDGMENTS

The authors acknowledge the assistance provided by Dr. Joseph F. Kasper who was instrumental in defining the concepts used in this paper. Also Susan H. Joudrey who assisted in all the computer programming effort required for this study.

REFERENCES


Loran-C User Equipment, Airborne and Shipborne Navigation and Position Reporting Equipment

F. J. Chambers
Teledyne Systems Company

Abstract - Loran-C provides a capable and efficient solution to many positioning and navigation applications. This paper briefly describes the family of MOS/LSI, microprocessor based equipment in production at Teledyne Systems Company. Specifically described are

(1) TDL-701 Microlocator
(2) TDL-708 Marine Microlocator
(3) Loran Route Verification System
(4) Precision Guidance System
(5) TDL-424 Loran Navigation System

This family of equipment is designed to operate in land mobile, waterborne and airborne applications.

I. BASIC LORAN SENSOR

Teledyne Systems Company has developed a microprocessor based Loran sensor that requires a minimum of circuitry while increasing the number of functions and performance over past generations of equipment. The basic sensor receives an input signal from an antenna and outputs measured time differences to an operator display or navigation computer automatically, only requiring regulated power supply voltages. Figure 1 shows the form factor of the basic Loran sensor as used in the TDL-424 Navigator. This photograph emphasizes the extremely small size that is possible due to the minimum amount of circuitry required.

The module on the left side is the RF circuitry packaged in hybrids. This circuitry provides three hardlimited channels to the adjacent module, the Digital Processor. The three channels include two TRF channels and one envelope deriver channel used for cycle selection. The Digital Processor consists primarily of custom CMOS/LSI and a microprocessor. The processor performs all the functions of signal acquisition, phase tracking and output of time differences under control of integral 6K of read-only-memory.

The major characteristics of the Loran sensor include:

(1) Operates on Master and four Secondaries simultaneously

II. EQUIPMENT DESCRIPTION

1. TDL-701 Microlocator
The TDL-701 Microlocator is a low cost, fully automatic unit designed specifically for mobile receiver applications requiring low power consumption and high performance; see Figure 2. The Microlocator contains the basic sensor described above, configured to operate on either of two stored Loran triads, selectable by a switch at the rear of the unit. The only controls on the front of the unit is the on-off switch and a display hold push-button. One half inch gas-discharge displays present both time difference simultaneously. Stored triads can be changed at the maintenance facility.
This unit was designed for any limited area aircraft, marine or land vehicle application. The operator may record or use the position readings or the audio tone burst may be sent through any voice channel transmitter to a base station for position monitoring of the vehicle.

**TDL-701 physical characteristics include:**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>2.5 x 9.25 x 11.4 inches</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>5.7 pounds</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>12 vdc</td>
</tr>
<tr>
<td></td>
<td>110 vac (optional)</td>
</tr>
<tr>
<td></td>
<td>25 watts</td>
</tr>
</tbody>
</table>

---

Figure 2. TDL-701 Microlocator

2. **TDL-708 Marine Microlocator**

This is the low-cost receiver bought in quantity by the U.S. Coast Guard. This unit differs from the TDL-701 in that a lower chassis is added to provide for manual selection of GRI, secondary coding delays and built-in test. Figure 3 shows the TDL-708 unit. Figures 4 and 5 show the simple construction and ease of maintenance, since all modules plug in from the rear of the chassis. In Figure 4, the RF circuitry is the top module on the left, and the power supply is on the right. The Digital Processor is a single large board underneath. Figure 5 shows the upper part of the chassis standing upright on the displays and the lower chassis laying flat. The Digital Processor is in the upper chassis, and the circuitry which decodes the manual switches and provides the built-in-test is in the lower chassis. The RF circuitry and digital processor are identical to the basic Loran sensor described above, except no hybrids are used.

The built-in-test function is mechanized by generating a simulated Loran signal, including a master and two secondaries at set time differences, in the lower chassis and injecting this into the RF circuitry when the switch is in the TEST position. An end to end test of the unit is accomplished when the correct time differences have been acquired by the receiver, taking about 20 seconds.

---

Physical characteristics of the 708 are identical to the 701 except the height is 4.5 inches instead of 2.5.

Figure 3. TDL-708 Marine Microlocator

Figure 4. Rear View, Marine Microlocator

Figure 5. Digital Processor and Lower Chassis, TDL-708

3. **Loran Route Verification System (LRV)**

The Teledyne Route Verifier is a fully automatic Loran receiving and recording system.
designed for continuous monitoring of Loran position coordinate data. Once recorded, this data can provide a permanent record of the vehicle's route history for later reconstruction and post analysis or verification. This portable, briefcase sized unit, needs only to be connected to an antenna and power source (unless optional battery pack is included) to operate. It will automatically generate digital tone data messages which include time difference position data, vehicle identity number, time and date information and record this data at a selected rate on the audio cassette tape recorder. The system may be used on any surface vehicle or aircraft operating in a Loran coverage area to accurately plot its movements for many subsequent analysis or test purposes.

The LRU unit (Figure 6) contains a Microlocator receiver, cassette recorder, battery pack (4 hours operation), time of day clock and audio data decoder. The primary features include:

1. Records up to four time differences and day and date
2. Records external FSK data link and internal day/date at a selectable rate
3. Displays prerecorded data in the play-back mode
4. Microlocator displays 4 TD's
5. Outputs prerecorded data over 16 bit parallel computer interface
6. Size - 6.5 x 14 x 18 inches
7. Weight - 35 pounds
8. Power - 28 watts minimum, 47 watts maximum (displays on)

Figure 6. Loran Route Verification Unit

4. Loran Precision Guidance System (PGS)

The PGS was developed as an R&D tool to evaluate the use of Loran C as a method for navigating large vessels through restricted waterways and channels when other navigation aids are not available. This system has been demonstrated on the St Marys River out of Sault St. Marie, Michigan.

The system is depicted in Figure 7. The cabinet on the right contains a Microlocator receiver, an HP2108 Computer, Flexible Disc Unit and the Graphics Interface Unit. A Minidata station is shown on the right side of the table and a Real Time CRT graphical display is on the left.

The computer provides all navigation functions and drives the graphical displays. Position and navigation is done in latitude/longitude, being derived by a Kalman Filter that uses 3 LOP's and vessel heading simultaneously. Waypoint steering is provided with pre-stored waypoints the length of the channel. Navigation parameters computed and displayed on the Minidata station and graphical display include cross-track speed, along-track speed, cross-track distance, distance to waypoint and time to turn. The keyboard of the Minidata station provides the controls to operate the system and change operating parameters. The graphical CRT displays vessel position super-imposed on a pre-stored background showing channel edges, prominent geographic objects and navigational aids such as bells, buoys and range markers.

Figure 8 shows a CRT display just east of Sault St. Marie. The display is 10 inches on a side and the scale factor shown here is 5 inches per mile. The vessel is depicted making a turn near the center of the display; the vessel is 600 feet long and 50 feet wide. Navigation information is in the upper right. When the vessel reaches the edge of the map, the display is automatically updated to the next section of the river. The channel boundaries and channel centerline, shorelines and buoys and bells are shown on the display.

The operator may change the scale factor or select North up or Track go, as well as modify other parameters of the graphics. Position data collected on the St Marys River so far has indicated an average system accuracy of 10 to 20 feet, with maximum error of 50 feet.

5. TDL-424 Loran Navigator

The TDL-424 Loran Navigator is a compact area navigation system contained in a standard panel mounting unit. The unit contains the Loran sensor described at the beginning of the paper and a 16 bit digital computer to compute the navigation functions. Figure 9 shows this unit with the course deviation indicator along side.

The TDL-424 stores the parameters for 8 Loran chains and the operator need only select the chain rate. The unit navigates to 10 waypoints,
III. SUMMARY

In describing this broad product line, the intent is to emphasize the ease and efficiency by which Loran-C can effectively solve position and navigation problems. This capability is the result of the Loran-C systems ability to provide very accurate position at all elevation and altitudes and in all weather, combined with recent advances in technology.

Figure 7. Loran Precision Guidance System

Figure 8. PGS Graphic Displays

which may be entered in Latitude/Longitude or Time Differences. The unit displays all the common navigation functions, including the left-right needle. The unit provides automatic navigation of Search Pattern operations and Master independent operation. The audio tone burst data linking capability is also provided by this unit.

Figure 9. TDL-424 Loran Navigator
Forest Service Needs for a Precision Navigation System for Spray Aircraft

By
TONY NASUMBACK
USDA Forest Service
Equipment Development Center
Missoula, Montana

Abstract - In aerial spraying one of the primary requirements is to disseminate the insecticide uniformly over the target area. To assist the pilot of the spray aircraft in this task some type of navigation system is necessary.

I. INTRODUCTION

In aerial spraying of the National Forests for insect control one of the primary requirements is to disseminate the desired dosage of insecticide uniformly over the target area. In general this is accomplished by swathing, a swath being the width of coverage at the required dosage, on the target, produced by one pass of the spray aircraft. Each aircraft generally has a well-defined or accepted swath width, which is determined by field testing. This swath width is dependent on many factors but of concern here is only the type and size of aircraft. A small helicopter such as the Bell 47 series generally has a swath width around 60 feet. The bigger helicopter such as the Bell 205 around 200 feet, the DC-3 (C-47) about 500 feet and the DC-4 (C-54) approximately 1,200 feet. It is up to the pilot of the respective spray aircraft to assure that each swath is so spaced that no skips and/or oversprays exists between consecutive swaths. Skips reduce the effectiveness of the application, overspraying waste insecticide and both in the long run are costly.

Maintaining the swath spacing between consecutive flight paths in rugged forested terrain is a formidable task for the pilot. Generally the flight path is a zigzag type course rather than a straight line. This is caused by the need to fly relatively close to the tops of the trees, approximately 50 to 150 feet, which in turn requires flying pretty much to the shape or contour of the terrain with its many irregularities. The flight path then becomes a series of turns in the horizontal plane, each succeeding flight path must be parallel to the previous one and at the specified swath spacing to insure uniform dissemination of the insecticide. Thus, the pilot must remember where each turn was made on the previous flight, hopefully by remembering some terrain feature from that flight, and from these he must obtain the proper swath spacing. Also, at the same time he must pick up new terrain guiding points to be remembered and used as guides for the next swath. Therefore, the accuracy of the application depends solely on the pilot, his experience and familiarity all contribute to the accuracy of the application. However, even the most experienced and adept pilot cannot remember all these turning points swath after swath, therefore some type guidance system is necessary to assist the pilot if uniform application is to be achieved.

At present the price per acre for the insecticide alone runs approximately $2 to $4 per acre depending on size of project and type insecticide. If through the use of a precise navigation system the insecticide can be more uniformly applied over the target area, than is presently being done with no guidance system just pilot guesses, possibly the amount of insecticide applied could be reduced by 10 percent or more. Which would be a considerable saving in dollars and lessen the impact on the environment, and be better all around.

II. TYPE AIRCRAFT

At present there are a variety of aircraft involved in forest spraying from old World War II bombers to super constellations and modern helicopters. In the northeast where the acreages to be sprayed are large (approximately 3,000,000 acres sprayed in 1976) and generally on gentle terrain the larger fixed wing airplanes such as the C-54, PV2, Constellation and TBMs have been used with the smaller fixed wing aircraft and helicopter treating the smaller area and the highly sensitive areas. In the west where the acreages are generally smaller (approximately 400,000 acres sprayed in 1976) and the terrain more rugged, helicopters are used. These vary from the smaller ships such as the Bell 47G on the smaller acreages to the larger ships such as the Bell 205 on the larger acreages, some companies have outfitted even the bigger cargo type helicopters with spray equipment. Also C-47's and TBMs have been used but the present trend in the west seems to be helicopters. This is probably due to need to fly 50 to 150 feet above the trees in rugged terrain where maneuvering agility is a must.

III. EQUIPMENT REQUIREMENTS

Due to the variety of aircraft used in the spraying operation 1) fixed wing and helicopter, 2) large and small, 3) single engine and multi-engine 4) single pilot and pilot/copilot combination, the navigation system will have to be unique to accommodate them all.

1. It should be light weight and small in bulk so it will fit into the small as well as the larger aircraft without penalizing payload.

2. Easy installation and removal from the various types of aircraft, large and small, helicopter and fixed wing. This will allow the system to be used on several projects with different type aircraft.

3. Equipment should be capable of being located and tied down anywhere in the aircraft, as some of the smaller and older aircraft do not have adequate instrument racks.

4. Equipment operating format should follow that of a conventional navigation system so that elaborate pilot training on the equipment operation is not required.
5. Signal output indicating course deviation should be capable of driving several different type indicating devices. On the smaller aircraft the standard Right-Left indicator would be adequate or possibly a heads up type display. On the larger aircraft where a pilot and copilot are available a XY plotter may be more advantageous where required course changer can be seen on the chart and anticipated, plus the right-left indicator.

6. With so many different type aircraft used, with different acceptable swath widths from 50 to 1,200 feet the navigation equipment should provide for selection of a variety of offsets between parallel flight paths or swaths. Also there are occasions where several aircraft may fly in echelon with a resulting swath width of 2,000 or more feet.

7. Equipment should be capable of operating at a variety of air speeds. The smaller helicopter spray at about 50 mph and the larger ones around 90 mph, while the fixed wing vary from about 100 to 200 mph.

8. The length of spray run (flight path) can vary up to approximately 10 miles on some of the larger projects. In the West most of the spray runs would probably be less than 3 miles in length.

9. Systems should be capable of operating anywhere in the continental U.S., in the most rugged terrain any time of the day.

10. An additional feature that would be desirable would be a date link to a ground controller, where the controller could monitor a display, in real time, of the spraying operation and detect any skips. Thus if the controller spotted any skips caused by, too wide a swath, etc., he could direct the pilot on how to spray the skipped or missed area.

11. The accuracy of the navigation system in terms of the offset distance between consecutive parallel flight paths should be the best possible. However, human error involving how accurate the pilot can fly this indicated course is also a factor. Most times the pilot simply guesstimates this offset distance, in fact even where the last flight path was. Anything to reduce this guess work would help.

We would envision a navigation system that on each flight path would record the spray aircrafts position every second or so, and for the next consecutive flight compute the desired offset from the recorded position from the previous flight and provide navigation information to the pilot on how to fly a course parallel to that previous flight.

IV. CONCLUSIONS

This report briefly covers our spray aircraft navigation requirements in rugged terrain. It appears we have more problems than solutions, however I believe the technical expertise and equipment is available to solve the problem.
LORAN-C CONCEPTUAL ANALYSIS

C. W. Mosher
M. Abrams
J. C. Murdoch

New York State Traffic Records Project

W. L. Polhemus
F. H. Raab

Polhemus Navigation Sciences, Inc., a Subsidiary of The Austin Company

ABSTRACT - The terrestrial applications of LORAN-C were investigated by the New York State Traffic Records Project under contract with the U.S. Department of Transportation. Operational, technical, economic and social factors were all considered in evaluating data obtained from the interviews conducted with representatives of State and local government and of private industry. Technical consultative services were provided by Polhemus Navigation Sciences, Inc., whose staff accompanied the study team on many of the potential user interviews.

Three broad categories of applications were identified:

(i) Automatic Vehicle Monitoring - i.e., the monitoring in real-time of the locations of police vehicles to determine the nearest vehicle to the scene of the emergency.

(ii) Automatic Vehicle Location or Dispatch - i.e., the sending of an emergency vehicle to a LORAN-C determined location.

(iii) Site Registration - i.e., the determination and registration of the location of traffic accidents or violations.

The accuracy requirements of these application categories range from 15.2 to 152.4 meters.

INTRODUCTION

The feasibility of using radio based technology to identify site locations has been under study. In the basic conception, it was envisioned that an investigating officer at an accident site would transmit a signal which would be picked up by receiver/transmitters which would trigger a return signal to him indicating his exact location, probably in the form of coordinate values appearing on a digital display. These values would then be made a part of the submitted accident report.

The U.S. Department of Transportation (DOT) has been interested in identifying viable land position location applications for LORAN-C. DOT's awareness of the existence of these land applications, and particularly those which are economically viable, could assist it in justifying expansion of the LORAN-C system.

These mutual interests culminated in a study entitled, Conceptual Analysis and Feasibility Demonstration Plan.

Under contract to DOT, the study team has had the task of determining whether LORAN-C can technically, operationally and economically satisfy the requirements, and in particular the traffic safety require-ments, for precision position identification in New York State, and if so, how.

Examples of the type of applications that LORAN-C should be able to meet are expressed in the Highway Safety Program Standards. Among these are:

- Accurate identification of Accident Locations... to within one-tenth of a mile in rural areas and to within 100 feet in urban areas.
- Highway Geometrics and Surface Condition Inventories - For more exact location fixing of terminal points of road segments, highway geometric references, and landmarks.
- Emergency Medical Services - For more effective dispatch and allocation of resources.
- Selective Enforcement - An ongoing analysis of... locations will aid in objective selection of enforcement measures among several alternatives: stationing a patrolman at specific locations - during certain hours,...

STUDY APPROACH

From the outset care was taken to ensure that the user representatives' conception of their site location requirements and of the capabilities of LORAN-C be as objective as possible. Each question was formulated so that those interviewed were unhampered by their lack of knowledge and experience regarding LORAN-C.

Letters were sent to a broad range of potential users. From the replies, a representative list of those to be interviewed was established. Concurrent with these activities, detailed engineering inquiries were being made to establish technological capabilities of LORAN-C equipment, equipment requirements and the ability of available equipment to meet them. The latest advances in receiver technology were studied, as were the present and planned LORAN-C signal characteristics of New York State.

APPLICATIONS

Discussions were held with approximately 70 people from 40 agencies, encompassing State and local government, as well as various agencies within the private sector.

The efforts to ascertain the applications that might feasibly use LORAN-C were first directed towards trying to determine the precise position needs of each user group. Then, after ascertaining those needs, a determination was made of those which could be satisfied using LORAN-C.

Based upon the interviews, a set of definitive applications has been developed as well as additional applications which appear feasible based on information obtained elsewhere and on the training and experience of the members of the Study Team.

The identified applications fall into three (3) general classes, two of which group themselves under the general system "Automatic Vehicle Location" (AVL). They are Automatic Vehicle Monitoring (AVM) and Dispatch. The third classification is termed Site Registration which does not require a communication link as do the AVL modes.
A. Automatic Vehicle Monitoring (AVM) - AVM can be defined as a system for locating vehicles, persons or shipments, instantaneously and automatically.

Automatic Vehicle Monitoring, in the Study Team’s definition, also refers to Automatic Person Monitoring (APM) and therefore implies that the system must be portable to enable a user to leave his vehicle and still be located. Typical users of an AVM system capability are police and public transit operations.

Police: The personnel of many police agencies stated that there was a need to have an Automatic Vehicle Monitoring capability.

Supervisory police officers wish to know automatically the location of their men in the field in order to determine personnel proximity to an event or they might want to know the location of the officer on patrol for purely supervisory purposes.

Therefore, an AVM capability could be used for basically two purposes in police operations. The first would involve situations where a policeman might need help, but did not have the time or the basis for accurately identifying and transmitting his location. As a result of pressing a button either in his vehicle or on a device on his person, a policeman could call for help, have his location picked up at the central monitoring place, and have assistance immediately dispatched to him.

The second purpose is primarily one of supervision and dispatch, and the need for the supervisory field officers to know where the men on patrol are. The safety value of such a system should be strongly emphasized to the policeman in the field. The increased effectiveness of the police officer and of his agency should be firmly stressed from the beginning.

Transit: Managers of transit operations called "demand responsive" or "dial-a-ride" systems indicated that a need for AVM exists. Even where two-way radio systems presently exist, the AVM ability to instantly know the location of each vehicle would serve to improve operations, both in the form of a more immediate response to consumer demands and in reducing the mileage. Urban Mass Transportation Administration (UMTA) personnel reported that there is also an interest in AVM “fixed route” bus operations. The interest of UMTA in AVM systems is substantiated by the fixed-route busing AVM systems test conducted in Philadelphia during 1976. These tests evaluated total AVM systems.

Several other potential applications were noted; these are included as an aid to the reader in appreciating the scope of the possible uses of LORAN-C and not as specifically identified economically feasible applications resulting from interviews conducted by the Study Team. Among them are: (a) tracking of shipments of extraordinary value or hazard such as bank shipments or nuclear fuels; (b) tracking of vehicles aircraft and boats in the course of law enforcement activities; (c) control and monitoring of snow removal equipment; and (d) monitoring school buses, and permitting semi-automatic input to bus routing computer programs.

B. Dispatch - Dispatch is defined as that type of application where a person or vehicle is sent to a location determined automatically, one determined by LORAN-C and associated supporting systems (i.e., maps algorithms).

Dispatch, which has a sense of urgency or immediacy is a very common application not only for traffic accidents, but for other emergency situations; a policeman needing to identify the location of an accident in order to dispatch an ambulance, or the home owner calling the telephone operator to request fire apparatus.

Problems in effective location identification currently exist. A person reporting an incident in many instances will inadequately identify the location or will offer identification using terminology not known to the responding emergency vehicle staff. The problem of correct terminology is of real significance in rural areas where names known to local people may not be known to emergency service respondents who frequently are not intimately familiar with the locale.

It was discovered that an emergency situation telephone call made in some rural areas will be handled by an operator who may be 40 or more miles away from the location, who is unfamiliar with the area, and cannot easily describe the location to responding emergency services.

When Emergency Medical Services are operating in a LORAN-C dispatch or AVM environment, it is technically feasible for the dispatcher to so route emergency vehicles that traffic congestion is avoided as much as possible.

It was determined that at many railroad grade crossings, the railroad/highway crossing number signs used for the national inventory are missing. The present approach is to refer to the site location in relation to some landmark. They could be quickly, precisely and uniquely identified by a LORAN-C signal even on roads having reference marker systems.

Personnel reductions on the inland waterway system make feasible the use of LORAN-C to advise lock operators of the location and direction of canal traffic so that shipping is not delayed waiting for the lock attendant to arrive from another lock.

It was expressed that if all the agencies responding to emergencies (i.e., police, fire, ambulance) were to work with a common location system, greater coordination would result not only among the different types of agencies, but among the same type converging on an area from different localities.

There are other suggested uses for LORAN-C in the dispatch mode which may prove to be economically feasible, but which were not specifically identified to the Study Team during its interviews. Among these are: (a) General aviation navigation aid; (b) navigation aid for control and guidance of aircraft and ground crews engaged in forest fire control activities; (c) navigation aid for aircraft engaged in areal activities such as crop spraying or dusting operations; (d) navigation between mountain ranges where there is no VOR/DME signal; and (e) precision river navigation.

C. Site Registration - Site Registration is defined as the determination of a geographic location which has significance and is to be recorded for reasons of documentation. In accidents or at crime scenes where there may not be a need to dispatch more personnel to the site, there remains a need to register the site location. The policeman who records the
location of an accident site could use a LORAN-C identity rather than writing the narrative and other information such as reference markers as is now done.

Highway inventory files generally use a route number and accumulated mileage (called mile points) from zero point for identification of segments of highway. A problem arises whenever a construction change shortens or lengthens a route, since the mile points for that route must be adjusted, which often can be a cumbersome procedure.

With a LORAN-C capability, it would be possible to identify the end points of the segments in terms of LORAN-C coordinates. Thus, construction changes would not affect any segments or records, except those directly connected with the construction. The coordinate would be obtained easily without use of maps or charts in the field, although it is likely that the coordinates would have to be converted later to some more traditional identification form. It should be noted that this application was not specifically endorsed by the persons interviewed.

The suggestion has been made that a LORAN-C receiver coupled to a small tape recorder could be used to build a highway inventory file in the field by means of keying-in coded information, such as a change in the number of traffic lanes. This would automatically be associated with the LORAN-C location of the vehicle.

With a LORAN-C capability, it would be possible to identify segments of appreciably smaller size and locate points along a highway without a dependence on the presence of any of the traditional delineators.

In addition, there are location needs on the part of others not associated with highway safety. For example, recreation facility authorities frequently identify the presence of underwater hazards in inland waters using marker buoys. However, before the buoy is in place, if it has been disturbed, field personnel have difficulty going back to the site of the underwater obstacle, unless there is an available landmark by which they can orient themselves. LORAN-C could provide the necessary capability regardless of operational circumstances.

Environmental conservation agencies also have many applications requiring an improved site registration capability. Many sites are off-highway and are often located in areas lacking any effective landmarks which enable the user to refer to, and in some cases return to, a point previously identified using LORAN-C. Some of these are:

- forest stream point discharge locations
- forest preserve excavation sites
- oil and gas well identification
- other forest preserve permit identification
- deer crossing locations
- deer yard area locations
- pure waters monitoring
- forest burn area locations
- wet-lands mapping
- marine shellfish hatching site locations
- underwater obstacle locations and
- search and rescue referencing

Private utilities (i.e., gas, electric, telephone) somewhat disagree as to the usefulness of LORAN-C; however, there was a general consensus that a common system available to all utilities would lessen service disruptions.

Many of the applications considered for LORAN-C such as the determination of the location of arrests, automobile accidents, highway inventory and planning surveys and emergency medical service would benefit from the existence of a common location language such as LORAN-C. Events and locations heretofore unrelated or compared only with some difficulty could be readily compared.

Many potential applications for LORAN-C in the site registration category were ascertained by the Study Team during the course of the study, although not specifically cited in the interviews. Since the economic feasibility of the following applications was neither sought nor determined, lack of confirmation of their utility in practice must be recognized. Some of these applications are:

1. Conducting of field surveys such as those required by timber cruisers, geologists, wildlife managers and others; (2) Analysis by jurisdiction of geocoded data; (3) Identification of land use boundaries in relation to new or existing highways for highway planning; (4) Location of emergency vehicles during flood relief; (5) Crime Victimization Surveys: Periodic surveys of crime and crime victims as conducted by Law Enforcement Assistance Administration and aligned with Census Bureau Surveys; (6) Forest Insect and Disease Control: Insect infestation mapping, location and relocation of sample trees for insect spray assessment; (7) Aggregation and tabulation of Census data for geographic combinations required by users; and (8) Tracking of weather balloons to upgrade data of upper-air system.

**FACTORS TO CONSIDER**

It was determined that merely identifying applications for LORAN-C would not be sufficient, but that several factors warranted consideration. These factors fall into four main categories which are: operational, technological, economic and social.

A. Operational Factors - These are classified into three groupings: functional, performance and informational.

- **Functional Characteristics** requirements are those which pertain to gatherers of data; what, why and how data is gathered, the operational environment, the relation to other systems, the periods of performance and maintenance and other such factors as weight, size and power source which affect equipment portability.

- **Performance Characteristics** requirements consider the accuracy, repeatability, reliability and signal availability aspects of the identified user needs.

- **Informational Characteristics** requirements are those necessary to achieve the desired output formats and interface requirements of the position data, and include consideration of operator equipment and cartographic and interface requirements.

B. **Technological Factors** - This category encompasses the technical features relevant to determining the capability of LORAN-C to meet the position identification criteria. Consideration is given to signal availability, strength, and inherent accuracy. The characteristics of the receiver, including design,
size and power requirements, and the nature and flow of the position information to be retransmitted (i.e., time differences or coordinates), are also considered in this area.

C. Economic Factors - This area describes cost considerations that must be recognized. Where possible, the cost associated with using present technology versus a proposed LORAN-C technology are discussed.

D. Social Factors - There are also social considerations or social benefits which warrant consideration.

OPERATIONAL FACTORS

Within each of the general use categories, described in the preceding section of this report, functional, performance and informational characteristics requirements are addressed.

A. Automatic Vehicle Monitoring (AVM) - It is envisioned that a LORAN-C receiver, installed in each police vehicle, would be linked to the vehicle's two-way radio or to the patrolman's walkie-talkie to become an AVM transceiver. The signal received by the transceiver would be relayed to a dispatch and control center where the officer on duty could note the location. It is expected that the return signal should have the ability to carry at least 48 kilometers and on limited occasions over 64 kilometers.

The manner in which the location data is displayed to the officer in the vehicle is of great importance, and the additional training requirement which may be placed on police agencies by LORAN-C implementation must be minimal. One agency stated that six hours of training time per officer was the maximum it could support. Other agencies were not as specific in their remarks, but they too expressed the need for ease of operation from the police officer's point-of-view. If the system is complex and difficult to operate, training costs will increase. Perhaps even more importantly, the officer will take time away from his principal duties if it is difficult for him to determine his location. This would be in direct contradiction to one of the anticipated benefits of the application of LORAN-C on police work. A goal, of course, is to lessen the officer's workload and yet provide him with a working tool not previously available.

There are two trends within the police services community which should be noted, because they both impact police Automatic Vehicle Monitoring operations. One is the increasing amount of equipment being installed in police vehicles for a variety of uses and the second is the continued reduction in police vehicle size as automobile manufacturers respond to the increased concern for and awareness of the need for energy conservation. Both of these factors must be kept in mind.

Transit usage, for both "dial-a-ride" or "fixed route" operations, would not require portability; however, the LORAN-C receiver should be able to work in conjunction with a two-way radio on the bus. Current operations in New York State are limited to the suburbs and merely provide a link-up to urban fixed route operations. The areas covered are quite limited in scope and serve communities of less than 26 square kilometers.

Police usage performance demands vary depending on whether the environment is rural or urban. In rural areas, the State Police and other local police report that they must have repeatable accuracy requirements of 61 meters to 161 meters and relative accuracy requirements of 61 meters.

In urban areas, police have indicated a need for 30.5 meters repeatable and relative accuracy, with a probability of achievement of 95 percent (i.e., 95 percent of all measurements shall not deviate more than 30.5 meters from the true locations).

In rural areas, police vehicles will be interrogated while standing still or while cruising at speeds of up to 89 kilometers per hour. However, there could be instances when the speeds might reach 161 kilometers per hour. In urban areas, cruising speeds rarely exceed 50 kilometers per hour, with occasional instances of speeds approaching 97 kilometers per hour.

It is the Study Team's judgement, that while the relative accuracy requirements as stated are reasonable, a repeatable accuracy capability of 61 meters is quite sufficient for police AVM purposes in rural surroundings.

The AVM retransmission signal should always be available on command either by the policeman in the field or the officer at the monitor center. The informational requirements of AVM are somewhat more demanding than the other use classifications. In an AVM operation, more than two-way transmission must exist. The LORAN-C signal picked up by the receiver at the event site must be transmitted in turn to some central control or monitoring point. At that center, some form of reference is required to relate the time differences (or other coordinates) to locations expressed in common reference terminology (i.e., street names). Typical devices could be display maps, computer printouts or a cathode-ray tube (CRT) display.

To convert the time differences to usable terminology such as street names, algorithms must be used to first reduce the time differentials to some other coordinate system, for instance, latitude/longitude. That coordinate system could be in a standard geographic base file, such as the Bureau of the Census Geographic Base File/Dual Independent Map Encoding (GBF/DIME) system. Presently, the GBF/DIME system development is limited to the Standard Metropolitan Statistical Areas (SMSA's) within each state; however, some states have expanded these files into rural areas. These types of files are often referred to as "computerized maps", and can in turn relate several standard coordinate systems to street names.

In normal operation, obtaining a LORAN-C reading should require no adjustment or dial turning by the person. It is recognized that it is possible to operate an AVM system with no display of location in the vehicle; however, this would restrict the value of LORAN-C equipment for use in other modes, and therefore, a "blind" system is unlikely to gain favor except for transit operations. Displays, of course, should be capable of being read in varied light conditions, and positioned so that they can be read while driving the vehicle.

The bus driver should not be required to convert the LORAN-C coordinate values of his present location or the location to which he is being dispatched since present "dial-a-bus" operations often have a digital
readout capability tied to a "real-time" computer system which provides the driver with locations identified by street name and addresses. This appears to be quite efficient. The dispatcher, however, will require a means to convert the return LORAN-C signal to a location so that he can then properly relate to the location of a person requesting the bus by interacting with a stored geographic base file. This entire operation should be done automatically by computer, and would involve some modification to the existing "real-time" computer system already in use by bus systems. The selection of which bus to dispatch to a location could be done manually by reference to paper or computer stored maps, or automatically by having a computer select the closest available bus.

B. Dispatch (or AVL) - It is obvious that everyone who has an AVM capability also has a Dispatch capability. There exists a large group of additional users who fall into the dispatch category. Fire, ambulance, automobile tow trucks, utility and highway maintenance vehicles would typify those users who would be dispatched to an event by "homing-in" on a LORAN-C location.

Naturally, there would be two classes of users; those desiring help, and those responding to the call. The first might require a LORAN-C receiver in order to reference the site, but this would not be necessary if it were a fixed location, such as a building whose LORAN-C identity were known beforehand. The latter condition may be difficult and therefore, undesirable since in most emergency type situations, the responder to "that location" would require that the LORAN-C identity they are homing-in on had been established under the same conditions. The second class of user, the responding emergency service, would by necessity, require a receiver with a form of display discernible in the field so that it can "home" on the emergency location.

The operational environment would be all-weather, all seasonal, and desirable be available 24 hours a day, 365 days a year. The need for portability would be on an exception basis since in most instances, if a respondent is within a few hundred feet of the off-highway site, the nature of the event or other people at the site could direct the emergency vehicle to the specific location.

The police officer is often the first professional to get to an accident scene. He would transmit the location of the accident to the emergency medical service, possibly to fire fighting personnel and if required, to a towing service in the vicinity. In some cases, the accident will have been reported by a passerby and in such cases, aid from various agencies may already be on the way. Since each dispatcher can identify the location of the accident in a manner which is understandable and useable by all personnel involved if LORAN-C is being used, no time is lost in reaching the scene. If there is more than one dispatcher, the common location language of LORAN-C makes consolidation of dispatching functions possible.

As in the AVM mode, the repeatability requirement varies from the rural to the urban situation. In rural areas, fire and ambulance authorities indicate a rendezvous need of 76 meters while in urban areas a 15.2 meters to 30.5 meters capability is necessary. All police dispatch needs are expressed as 30.5 meters. It is the judgement of the Study team that whether the event is for police, fire or ambulance services, repeatability on the order of 61 meters to 76 meters would be quite acceptable. In urban areas, and in particular congested areas, greater resolution is necessary with a level of repeatability on the order of 40 meters being reasonable.

The person requesting aid would need a receiver with a digital readout, daylight or dark adapted, requiring no, or a very minimum, adjustment of dials. Some "operating improperly" signal should be built into the receiver display.

The unit responding to that request for aid would require a device that could home-in-on a location. Presumably, it would be powered by the vehicle's power source, would require fresh readings allowing for speeds up to 97 kilometers per hour in urban areas, and 121 kilometers per hour in rural areas. The display characters should be large enough to permit a driver to scan it while driving the vehicle. It may be necessary to supplement the device with maps in the beginning to narrow down reference areas to mile squares in rural areas. However, the need for this supplemental aid should disappear as the users become accustomed to using LORAN-C coordinate values.

It is envisioned that up-to-date maps of the quality of the U.S. Geological Survey series with LORAN-C coordinate values overlayed on them could be used.

C. Site Registration - This mode of LORAN-C utility for land position identification has potentially the greatest number and variety of uses, and at the same time is the simplest in system concept. As indicated, there are a great number of site registration uses ranging from those where the police record the location of a traffic accident, traffic violation or criminal event to those for conservation purposes.

Since there is no great sense of "urgency" in any of the site registration activities cited, the user can take advantage of the averaging quality of typical LORAN-C receivers resulting in more reliable position fixes. Stopping at a place for greater than 10 seconds will improve the accuracy of a fix by about a 2 to 1 ratio.

In the traditional police work, the receivers would desirably be operated at any time in a 24 hour day, 365 days a year; however, in most of the conservation monitoring work, such as point discharge, deer yards, and shellfish line demarcation, the need would be seasonal and limited to daylight hours. In police work, all forms of weather would be encountered.

The receiver units would, by necessity, have to be portable and need a rechargeable battery.

In site registration applications, repeatable accuracy has greater importance than relative accuracy. Rendezvous in the immediate sense is not of consequence in these applications. In traffic accident site registration, the State Police indicated that they could manage with a tenth mile accuracy while local police indicated that in rural areas for the same purposes they would require a repeatable accuracy of 30.5 meters. In urban and suburban areas, the same police indicated a need for 30.5 meters repeatable accuracy.

In highway surveillance studies and physical inventories, segment end points and other points are identified and using mile points expressed in hundreds of miles, or 16 meters.
For search and rescue work, forest fire sighting, and most emergency service registration, 30.5 meters repeatable accuracy is necessary while for most other environmental applications, a need for 15.2 meters or better repeatable accuracy was indicated. The identification of deer crossings, deer yard demarcation, stream pollution point verification, permit verification, underwater obstacle delineation and shellfish line demarcation were presented as requiring this accuracy.

These latter accuracy needs appear to be somewhat too demanding, and it is the Study Team's considered opinion that in areas where traditional physical landmarks are presently nonexistent, those people involved in off-highway positioning applications would use LORAN-C even if it did not fully meet the stated accuracy requirements.

The site registration receivers would require a digital readout capable of being read during daylight or dark, and preferably requiring a minimum number of characters to facilitate the work related to data gathering. At the central office, the LORAN-C data could be inputted to the base file and used directly; that is, summaries could be created using these identities as the summary key, however, it is envisioned that for many applications, it will be necessary to convert from the LORAN-C time difference values to conventional coordinate values (i.e., latitude and longitude), and then to standard location names such as streets and avenues. This would require computer interface containing conversion algorithms and stored geographic base files.

TECHNICAL ASPECTS

The objective of this section is to attempt to assess the capabilities of LORAN-C for terrestrial applications. While marine and airborne capabilities of LORAN-C are well known, terrestrial use will be subject to some special problems not encountered in other applications. This study considers both the future capabilities (when the new East Coast main chains are fully implemented) and present capabilities (for demonstration/test in the 1976-1977 time period). Attention is directed to the New York State area, although results are expected to be more generally applicable.

System Performance Assessment

A. Ideal System Performance - At present, the U.S. East Coast chain includes a master station at Carolina Beach, North Carolina, and slaves at Jupiter, Florida; Dana, Indiana; Nantucket, Massachusetts; and Cape Race, New Found land. Coverage of the State of New York is provided best by the Carolina Beach/Dana and the Carolina Beach/Nantucket lines of position. Signals from Jupiter and Cape Race will be weaker and will have a poorer geometry; and hence do not produce as accurate a position as do the other signals.

In the 1977 to 1980 period, new stations at Caribou, Maine; Seneca, New York; International Falls, Minnesota; Malone, Florida; and other locations will be activated to complete planned coverage of the coastal confluence zone. The Seneca and Caribou stations, in addition to the Carolina Beach, Dana and Nantucket stations, are of primary interest to users in the State of New York because of their adequate signal-to-noise ratios. The new system of stations will be broken into several chains.

According to present plans, Seneca will be a master station, with Caribou, Nantucket, and Carolina Beach as slaves. Dana will become a master with International Falls, Seneca and Malone as slaves. The present master-slave relationships will be discontinued.

Coverage of the eastern portion of the State of New York will be provided by the Seneca/Caribou, Seneca Nantucket, and/or Seneca/Carolina Beach lines-of-position. Unfortunately, coverage of the western portion of the state is somewhat more complicated. The strength of the signals from the International Falls station will be low, hence the Dana/International Falls line-of-position will not provide high accuracy. The same is true for the Dana/Malone line-of-position.

If the chains are implemented as presently planned, this difficulty can be overcome by the use of chain positioning. The Dana/Seneca line-of-position should be quite accurate in the western portion of the state. While Dana and Carolina Beach will have different group repetition rates, their signals will still be quite adequate. Since the group repetition rates are locked to the same frequency standard, it is possible for a suitably programmed receiver to produce the equivalent of a time difference, and hence a line-of-position, from this pair of stations. The combination of the Dana/Seneca line-of-position and the Dana/Carolina Beach cross-chain line-of-position can thus provide the needed coverage of Western New York State. The receiver may use whichever set of signals gives the accurate position. Equipment used in limited geographic areas can be pre-set. Equipment used in broad geographic areas should have an automatic selection capability.

Both Western New York and the Great Lakes area will experience this difficulty if the presently planned chain structure is implemented. For this reason, the Coast Guard has recently proposed to change the structure of double rating Dana to the Seneca chain. In this configuration Dana will operate as a Master of its chain, but will also transmit as a slave to Seneca. This technique would improve accuracy in the western portion of New York, eliminating any need for cross-chain capability in the receiver.

The ideal or unperturbed system accuracy must now be evaluated. An unperturbed environment is one which is free from ground conductivity variations and propagation effects such as those due to weather fronts. As such, there are four quantities which affect the accuracy capabilities of the system; atmospheric noise, receiver resolution, transmitter control, and crossing angle (geometric dilution of position).

B. Terrestrial Effects - Terrestrial users of LORAN-C equipment are subject to a number of perturbations which seldom affect either marine or airborne users. These effects include fine structure changes in conductivity, interference from carrier communications systems, high rise canyons, and power line influences. It is these effects, rather than atmospheric noise levels, which will ultimately limit the predictable accuracy of LORAN-C in terrestrial use. Some of these effects may be partially overcome by suitable operational procedures.
1. Calibration

Inspection of FCC charts for New York State shows that conductivity ranges from 0.5 to 15.0 millimho/meter. These variations cause changes in signal strength, envelope-to-cycle differences, and phase velocity. While the first two are not expected to be great enough to cause serious impairment of operations, the third directly affects predictable accuracy. Changes in the time-of-arrival of up to a microsecond are possible at ranges of 1000 kilometers. Fortunately, these effects are essentially stable and therefore can be removed through calibration of "one-time" differential corrections. Techniques for implementation of such calibrations have recently been investigated.

2. Fine Conductivity Changes

Local conductivity can vary over ranges from 0.1 millimho/meter to infinity. The causes of these changes are numerous, and include such things as the steel in the road, bridges, nearby railroads, buildings, power and telephone lines, and metal light posts. The effects of these fine conductivity changes are evidently a fine grid warpage. Adequate statistical data on this effect is not available, except for a few specialized cases.

In principle, it is possible to store these fine variations in a computer memory and use these data to remove the degradations of the predictable or geographic accuracy. For example, in the case of a roadway, one could store the major grid perturbations caused by such things as bridges and overpasses. In cases where only the distance along the road is needed, the components of the error transverse to the road can be disregarded. However, it would probably be impractical to correct for all of the errors caused by guard rails, lamp poles, and iron in the road because of the magnitude of the storage requirements.

3. Continuous Wave Interference

Continuous wave interference (CWI) to LORAN-C reception refers to the effects of other signals, both in the 90 and 110 kHz bands and immediately adjacent to it. In aeronautical and marine operations, these signals are attributable to long range communications transmitters. While in Europe and Asia, CW stations may operate in the LORAN-C bands, interference in the Americas is limited to out-of-band signals such as NSS in Annapolis on 88 kHz. Since the magnitude and frequency of such interference in a given area is essentially fixed, the interference can be removed by simple notch filters.

Terrestrial users will be subjected to occasional interference from carrier communications systems. Such systems employ signals in the 30 to 300 kHz range, and reception of such signals is confined to a relatively small area surrounding the lines which carry them. Many terrestrial users of LORAN-C will undoubtedly operate near power, telephone and railroad lines and will therefore occasionally encounter an interfering signal. The solution to this problem lies in the FCC regulations pertaining to unlicensed communications signals. Since unlicensed operations are allowed only on a noninterfering basis, they must change frequency in the case of serious interference of a user of LORAN-C. Such frequency changes are relatively simple to make and should not adversely affect the user of the carrier communications.

4. High Rise Clusters

Clusters of high rise buildings can cause severe problems to the terrestrial user of LORAN-C. Fortunately, these effects are confined to a relatively small region within most cities. Experience shows that such building clusters must typically be at least twenty stories high to produce these severe effects.

The effects include reduction of signal strength, increase in noise levels, and general distortion of the signal (both ECD and time-of-arrival). In principle (although not in practice), the signal-to-noise ratio problem could be solved by increasing transmitter power. However, the signal distortion problem remains, negating most of the possible benefits of increased power. These distortions generally must be treated as uncorrectable changes in the signal and grid pattern since they are quite severe and abrupt.

A solution to this problem is to install augmentors or some other form of LORAN-C compatible sign post in the areas where problems occur.Basically, an augmentor is a low power transmitter which produces a simulation of the LORAN-C signal which would be received at the augmentor's location if there were no perturbing effects. A nearby receiver recognizes the augmentor signal as a legitimate signal and therefore displays an appropriate position.

5. Power Lines

Many terrestrial users of LORAN-C will operate in the vicinity of power and telephone lines. While definitive data is scarce, there may have been many observations of changes in the measured time differences as large as several microseconds in the vicinity of some lines. While this effect only occurs in a few places, it can be quite severe when it does. As in the case of the fine grid structure and the high rise effects, the power line effect must be considered largely unmeasurable because of its abrupt nature.

Many hypotheses have been advanced to explain this phenomenon, including changes in conductivity, reflections, Beverage antenna effect, strong noise fields, Shadowing, and strong 60Hz fields. It is the consultant's opinion that the lines can act as Beverage antennas when they are aligned radially with a LORAN-C transmitter. In this hypothesis, near-field re-radiation from the 100 kHz current induced in the line produces a distortion in the signals received within 30.5 meters of the line, resulting in the observed errors. This hypothesis should be tested during the field demonstration.

Unfortunately, there is no data to quantify either how often these effects occur or how long they may be. Also, none of the explanations of this phenomenon has been developed to the point where it can be advanced to the status of theory. Further work in each area is definitely warranted.

Some possibilities for overcoming the effects do exist, however. A dead reckoning system or an inertial system can be used to detect abrupt changes in time differences which occur when a
moving vehicle approaches a region of large signal distortion. It may also be possible to steer a null in the reception pattern of an antenna so as to minimize the interference.

C. Receivers - LORAN-C receivers for land use may be fabricated in many forms to fit many diverse applications. The essential and optional characteristics of these receivers are enumerated below:

1. Functional Elements

All receivers must have an antenna, coupler, tracking loops, and a display. Useful options include a calculator for coordinate conversion and an interface for communication through a two-way radio system.

Antenna and Coupler: Reception of LORAN-C signals can be accomplished by a short whip antenna not unlike a standard automotive radio antenna. A coupler must be installed nearby. Included in the coupler are the preamplifier and CWI filters, which must be able to reject signals known to occur in the part of the country in which the unit will be used. Adjustment would be done at the factory or by a technician, and would not involve the user.

Tracking Loops: Acquisition and measurement for the LORAN-C signal is accomplished by the acquisition & tracking loops. For fully-automatic operation, it may be necessary to track several stations simultaneously, rather than the minimum of one master and two slaves. It is essential for use by operators who are expected to have no knowledge of LORAN-C that all acquisition and measurement functions are completely automatic.

Display: The type of display will have to be selected to fit each class of user. In its simplest form, it could be a digital readout of the time difference measurements. Warning indicators for receiver or signal malfunction should be included. More sophisticated displays could take the form of X-Y plotters or computer stored maps which would automatically place and display the signal location on a map of the area of operation. Recommendations relative to the type of display and information content form a complex problem which requires further analysis.

Computer: Some land-based users have indicated that they will require automatic conversion of the LORAN-C time differences into another system of coordinates such as UTM (Universal Transverse Mercator), latitude and longitude, or even link-node designators. This operation will require the inclusion of a computing calculator chip (costing about $30) to a system with a small programming memory, depending on the needs of the user.

Interface: Some users have indicated that they desire an automatic location reporting capability. The interface unit could provide this capability by converting the LORAN-C into voice frequency data signals upon operator or automatic command. An option required by some users will be the capability of receiving a "real-time" differential correction through the two-way radio.

2. Specific Requirements

Since each category of users will have different needs, no single set of technical requirements will fit all users. The following should therefore be regarded as generally applicable design guidelines, rather than hard requirements.

Basic Requirements of a receiver

a. 60 second initial acquisition time
b. 60 second integration/update time
c. 50 nanosecond measurement accuracy (standard deviation)
d. Automatic tracks of master and two slaves
e. Display receiver's location in Universal Transverse Mercator (UTM) or other suitable coordinates.
f. Acquire signal automatically.
g. Recognize "blink" and low SNR and give warning to operator.
h. Provides TD's and/or UTM as digital output upon operator command.
i. Provide 5 CWI filters (may vary with location).
j. Provide presetable GRI and TD.
k. Operate from -45°C to 43°C.
l. Operate from 12 Volt Source. Portable unit should have capability of 4-6 hours of operations from battery.
m. Weight, including battery; 3.6 kilograms (portable unit).
n. Capable of under-dash or in-trunk installation (vehicular).

Optional Requirements of a Receiver

o. 10 to 20 nanosecond measurement accuracy (standard deviation).
p. Warning of ECD discrepancy.
q. Track additional secondary stations.
r. Capable of cross-chain measurements.
s. Velocity-sensitive tracking loops or capability of selectable integration times.
u. Automatic selection of best TD's to use.
v. Automatic noting or cancellation of CWI.

D. Differential Corrections

1. Capabilities and Use

The extreme accuracy indicated by some terrestrial users could make the use of differential corrections desirable. Differential corrections can be made by first positioning the receiver at a known, permanent and accurately surveyed location. A LORAN-C receiver of the same quality as used in the field could be used for this purpose. In most cases existing communication networks would be sufficient to convey the information. Differential corrections may then be made by one of several techniques. (1) in one technique, the fixed receiver simply calculates its position and its measurements to the nearby receiver. The receiver then calculates the expected signals at the monitor's location and produces its own correction. In either technique, both spatial and temporal variations in the LORAN-C signal are removed. No effort on the part of the user is required, other than possibly to push a button to initiate the process. A differential LORAN-C experiment produced a two-sigma (95%) accuracy of 11.6 meters.
The timing synchronization control of a LORAN-C chain is accomplished by a monitor station. When a monitor/control station observes a discrepancy in the signals it receives, it (automatically) issues instructions to the transmitters to correct the discrepancy. Presently, control of the U.S. East Coast chain is vested in a monitor station in Bermuda (except for the Dana station, which is controlled from Eglin AFB). Control of the expanded LORAN-C chains serving the Coastal Confluence Zone (CCZ) will be vested in a system of monitors located in or near the CCZ. It is probable that an average of the measurements from two monitor stations will be used to control a given chain.

While this method of control provides a highly accurate positioning in the vicinity of the monitor, it allows for some variations in the other areas. In particular, inland terrestrial users may not be located in the regions where the control will be most effective. Most changes from "ideal" are due to changes in terrain conductivity and therefore, relatively fixed, and can be corrected by one-time monitoring of calibration. However, changes as large as 500 nanoseconds have been observed coincident with the passage of weather fronts and other smaller variations can occur with phenomena such as ice coverage of the ground. Correction of such changes can only be accomplished by instantaneous differential corrections.

A further advantage of using differential correction is that it leaves the user independent of any control imposed on the chains. Variations in the received signal can be so corrected, and the user may continue to make accurate position measurements with transmitters that are of marginal performance. Also possible future changes in transmitter control will not affect the user, since he will automatically correct for them.

2. Implementation

An obvious means of implementing differential LORAN-C corrections is that used by virtually every AVM system. A receiver is installed at the control point and its readings are used to determine the LORAN-C "coordinates" of that known location. This approach could be used by any user who desired to do so, but requires each to install his own monitor receiver within communications range of his portable/mobile receivers.

If a large number of users could benefit from differential correction capability, a system of monitor systems common to all users would be justified. The Delaware River experiments showed no measurable degradation of performance of the corrections within 111 kilometers of a monitor station. Based on these results it appears feasible to use the corrections at distances up to 161 kilometers from the monitor receiver. The State of New York thus could be supported adequately with a system of three or four monitor stations, if needed, at a cost of $50,000 per station. Such stations would probably employ three receivers with a "majority-vote" system for detecting failure of any one receiver.

If differential monitor stations are installed for the benefit of a multitude of diverse users, a means of distributing the data must be devised. The data consists of the locations of the monitors and the significant (changeable) digits of their time difference measurements, and must be updated every five to ten minutes. This relatively low data rate can be sustained by a number of communication channels. One possibility is dedicated land lines to the user's communications system. Another is distribution by a dedicated low frequency station in the vicinity of each monitor. Similarly, data could be transmitted through subcarrier modulation applied to a non-directional navigation beacon near the monitor. Another possibility is the use of the many suggested types of modulation of the LORAN-C signal itself. In any of these techniques, the cost and complexity of the additions to the user equipment would be minimal.

ECONOMIC FACTORS

Management doctrine dictates that while possible, present operations should be directly compared with operating models of proposed systems to most properly evaluate the economic impact of proposed changes. Where economic data regarding present system development, capital demands and maintenance requirements were available, system to system comparisons were made. Many applications, however, do not lend themselves to such a ready and direct comparison; those applications, for example, which have no present comparator because without LORAN-C the application is not economically feasible. Too, there are applications which would be so altered by the introduction of LORAN-C that comparison efforts would be awkward and not specific if not impossible.

A survey of manufacturers was made to establish the probable cost of LORAN-C receivers (Table 1). There is evidence of a significant continuing downward trend in receiver costs which has a fortunate effect upon the economics of terrestrial uses of LORAN-C.

<table>
<thead>
<tr>
<th>RECEIVER OPTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low 4,000 1,200 600 425</td>
</tr>
<tr>
<td>High 5,000 1,900 1,000 600</td>
</tr>
<tr>
<td>Coordinate Low 6,000 1,700 850 600</td>
</tr>
<tr>
<td>Conversion High 10,000 2,000 1,500 900</td>
</tr>
<tr>
<td>Including all desired Low 7,300 2,300 1,150 815</td>
</tr>
<tr>
<td>Options High 20,000 2,800 1,720 1,035</td>
</tr>
</tbody>
</table>

Other costs which were considered include those associated with retransmission of a signal from the receiver in the vehicle or on the person to a command or dispatch center and those associated with establishing the command center including systems, programming and equipment costs. Modification of existing chartographic products to include LORAN-C data was also considered.

The following are furnished as representative examples of applications upon which LORAN-C has a positive economic effect.

Automatic Vehicle Monitoring (AVM)

Within Automatic Vehicle or Personnel Monitoring are two general categories. They are:
In the latter category, based on the conservative estimate that of the time allotted for police field supervision 10 percent is spent surveilling the men on patrol. On a Statewide basis, this figure represents approximately $20,000,000 which could be otherwise allocated using a LORAN-C AVL system.

In the former category, the dollar value of reducing the time required for aid to reach the emergency scene is indeterminate and often inestimable.

Dispatch or AVL

In this mode of operation, the response time required for the ambulance to reach first the emergency scene and then the hospital would be reduced particularly in rural areas where distances are greater and location identifiers fewer. Based on New York State Departments of Health and Motor Vehicles figures, the reduced response time can be equated to a reduction in loss due to Motor Vehicle accident deaths and injuries of in excess of $4,000,000. Reduction of response time for fire fighting vehicles would also reduce losses due to fires particularly in rural areas.

Site Registration

In many states, mile point markers or reference markers are placed along highways at uniform spacing intervals. By use of the physical devices, field site locations are determined by either citing the nearest field marker as the event location, or by measuring the distance between the event and the nearest marker and describing the location as occurring at "X" feet from marker "ABCD". The manufacture, installation and maintenance of these markers are costly.

In New York State in 1973, the low bid cost for manufacture and installation was in excess of $20 per marker. Extending this unit cost figure over the entire highway network in the State (100,000 plus miles) at tenth mile intervals would come to over $20 million. This is a conservative estimate since double markers are required on divided highways. Experience on State operated highways indicate that approximately one fifth of these signs require annual replacement.

SOCIAL FACTORS

The societal benefits of LORAN-C are perhaps less easily quantified than are the operational, technical or economic factors. However, ultimately the value of LORAN-C may be confirmed by the reduction in loss of human, economic and natural resources made feasible by its use in efforts to reduce accidents, crime, loss due to fire, and misuse of the environment.

SUMMARY

The LORAN-C system of radionavigation will soon provide coverage of much of the continental United States. The planned main chains will cover New York State with signals capable of providing up to 30.5 meters at 95% level repeatable accuracy in unpe­rurbed conditions. A similar accuracy may be possible with the present chain in parts of the State.

However, many factors affect terrestrial users which do not affect airborne and marine users. These include changes in conductivity, power lines, high rise clusters and carrier communications signals. In a smaller number of areas these effects will be a slight degradation of accuracy. The statistics relating to these effects are not available and should be produced by a future testing program.

Receivers similar to those coming into being today are generally suitable for terrestrial users. Fully automatic operation is required, and most users will desire coordinate conversion. Interface with a two-way radio will also be useful to many.

Differential corrections can be used to improve the accuracy for users with stringent requirements. A user could produce his own measurements by installing a receiver at a surveyed location. Also, a system of three or four monitor receivers could provide state­wide coverage for many diverse users. Differential corrections would have the added benefits of removing any changes in transmitter control and any effects of weather fronts.

CONCLUSIONS

It has been determined that LORAN-C can technically, operationally, and economically satisfy the precise position identification requirements for selected applications in New York State.

The bases of the determination is the projected signal performance of present and future main Trans­mitter chains, an understanding of user needs, personal experiences and evaluations, and their ability to analyze and evaluate present and future equipment, including both capital and maintenance costs.

In most instances, the anticipated technological performance of the system will meet the indicated operational requirements. However, for many environment­al conservation site registration uses, the anticipated capabilities of LORAN-C will not meet the stated accuracy requirements. Nevertheless, it is believed that LORAN-C would be used since it would provide more detailed location information than the present system.

Many highway safety related application require­ments are not only met by LORAN-C but it is expected that its accuracy will exceed other present location techniques, such as field marker referencing or measurement by automobile odometer.

It is believed that a properly constituted compre­hensive demonstration would provide the background from which several of the previous answers could be more firmly founded. As with other technological advances (i.e., telephone, computer), it is strongly expected that additional applications will surface as a result of the demonstration.
Flight Testing a Low Cost Airborne Loran-C Navigation System

Cdr R. H. Cassis, Jr.
U. S. Coast Guard
Office of Research and Development

Abstract - A Loran-C Airborne Navigator for use in Coast Guard helicopters is described. Cockpit mounted, the device weighs only 12 pounds, uses LSI circuitry extensively and includes a microcomputer and a completely automatic Loran-C receiver. The navigator generates steering information relative to a trackline defined by up to nine operator entered waypoints.

The Coast Guard conducted an extensive laboratory and operational flight evaluation program. Flight testing under formal and informal conditions is described. Results to date are presented which indicate the receiver will perform satisfactorily using the Coastal Confluence Zone Loran-C system.

The U. S. Coast Guard operates 81 Sikorsky HH52 helicopters from air stations in the coastal regions of the United States and on the Great Lakes. These helicopters are frequently deployed on polar icebreakers and on high and medium endurance cutters. Standard radio navigation equipment consists of very high frequency Omnidirectional Range (VOR), Tactical Air Navigation (TACAN) and Automatic Direction Finding (AFF). When operated at low level or beyond the range of the VOR/TACAN stations, the navigation capability is severely limited. Loran-C in the coastal confluence zone and the Great Lakes could meet the needs for navigation of Coast Guard helicopters if suitable user equipment was available and installed. In February of 1974, the Coast Guard had an opportunity to participate in the development of an airborne Loran-C navigation system which appeared suitable. A contract was awarded to Teledyne Systems Company to build the system by integrating a hybrid Loran-C receiver and a digital computer developed in other programs. The system was delivered in April of 1975. This paper briefly describes the navigator and the test program to which it has been subjected.

Figure (1) is a photograph of the HH52 helicopter in which the navigator will be used. Typically, there is very little space available for additional equipment. This aircraft has limited lifting capacity and every pound of weight added for new equipment reduces its endurance and on scene lifting capacity. These two aircraft characteristics tend to minimize the dimensions and weight of the navigation system. On the other hand, the navigator must be large enough to contain all of the electronics, provide for sufficient heat dissipation and allow economical manufacturing costs. Pilot workload generally limits the attention which can be given to operating the navigation system; therefore a low density of controls is needed to permit operation with minimum error and while wearing gloves. A single package was desired to minimize production costs. The result were tradeoffs in these areas is a two box system consisting of the navigator which contains control, display, computer, and receiver functions; and an antenna coupler which also contains the Loran-C interference notch filters. The system has a total weight of less than 12 pounds. The computer, display, control unit measures 9" x 5.75" x 6" and the antenna coupler measures 4" x 4.5" x 5". Figure (2) is a photograph of the system including an optional Course Deviation Indicator.

Coast Guard helicopter operations require direct point to point navigation. Deviation from the shortest path between origin and destination reduces on-scene search time and lessens the chance of finding the person in distress or meeting other mission objectives. Area navigation (RNAV) is a method of navigation that permits aircraft operations on any desired course within the coverage of station referenced navigation signals or within the limits of self-contained system capability. The desired track is defined by specifying a point of departure, a destination and intermediate points if needed. These geographical points are called waypoints. The airborne Loran-C navigator system permits area navigation in the horizontal plane using waypoints defined in either latitude and longitude or Loran-C time difference coordinates.

The function of the navigation system can be divided into four areas: navigation, situation display, test and reporting. To place the system in operation it is only necessary for the operator to enter the desired chain, an approximate present position in latitude and longitude and the desired waypoints. Optional inputs include magnetic variation, a Loran-C position correction (for highest geodetic accuracy), particular Loran-C traid selections and non-standard or unique Loran-C or D chain information. Operator entered information is stored in memory and is not erased when the system power is secured. It is used with the description of the selected chain stored in permanent memory by the navigation system to automatically acquire all of the Loran-C signals available for the chain and to determine the optimum traid. The navigator then computes the desired track and steering signals which drive the course deviation indicator (CDI) and advisory flags. The pilot can fly the desired route segment by keeping the steering needle centered. When a waypoint is reached, the next waypoint in the sequence is selected either
Figure 1 - A USCG HH52 Helicopter ready for takeoff during night operations from a high endurance cutter.

Figure 2 - The TDL 424 Airborne Loran-C Navigator System.
The navigation function is performed continuously as long as a route segment has been selected and sufficient signals are in track. The pilot does have a need to know more information about his situation; however, therefore the system can concurrently compute and display the following parameters: the coordinates of any waypoint, present position, magnetic variation, distance and bearing to the next waypoint, speed and track over the ground, desired course, track angle error, time to next waypoint, track error, and distance and direction of any parallel track offset entered by the pilot. Waypoints can be changed by the pilot at any time. It is also possible to freeze the display using a special hold button and if the display contains a position, store that position in any waypoint location for later use. A fly direct to waypoint number "N" leg can be executed by selecting "O" and "N" as the "From" and "To" waypoints respectively.

A test function performs a constant self check of the receiver, computer, and pilot entered data. Should a condition arise that makes the navigation function invalid (e.g. loss of the Loran signal) a steady warning light is illuminated and the CDI "off" flag is lowered. If the situation does not invalidate the navigation function but is of interest to the pilot (e.g. automatic change of triad) a flashing warning light is illuminated. The pilot can use the test function to readily determine the cause of the alarm for either case. Several special operator input routines normally not required by the pilot are available in the test function. These allow the pilot to override the automatic triad selection, to read any memory location and to change any of the stored initialization data. Complete receiver performance data can also be displayed.

The fourth functional area is that of reporting. A subroutine has been written in the computer which takes information from the navigation system and provides modulating and transmitter keying signals to any air-ground communications set on the aircraft. This signal can be demodulated and displayed when received to provide remote readout of the information. The data which can be reported includes identification, present position, any data displayed by the navigation system and a pilot entered report code. Reporting can be either continuous, periodic or intermittent at the option of the pilot.

Figure (3) is a photograph of the navigator showing the layout of the hardware. The front panel is divided into a display area and a control area. Displays are of the gas discharge type and are viewable in direct sunlight. The input keyboard uses dual function keys: the first function being a description of the type of data being entered and the second function an alpha-numerical data point. Dual rotary switches are provided to select data displayed and unit functional mode.

The Loran-C receiver is a microprocessor based device which utilizes several custom designed read only memories and hybrid circuits. Acquisition and tracking of a master signal and up to four secondaries is automatic. Acquisition time is less than 100 seconds for a -10db signal to noise ratio. Tracking velocity is 1200 feet/second.

The navigation computer is contained in a hermetically sealed package which measures less than 2" x 2" x 0.2". The device is a 16 bit digital computer with an instruction execution speed of 4.9 microseconds. Memory is provided by a combination of ultra-violet erasable PMOS programmable read only memory (6144 x 16 bit words) and CMOS random access memory (768 x 16 bit words). Figure (4) is a photograph of the interior construction of the navigator.

Reference (2) provides further information about the navigation system technical details.

Early in the design phase of the project, it was apparent that the desired technical objectives would be achieved. The question of greatest interest was whether or not the system would meet the desired operational objectives of accurate navigation and reasonable pilot workload. These questions were to be answered by a test program consisting of 3 phases; informal flight tests, a laboratory evaluation and a formal flight test. The laboratory tests were cancelled after extensive testing of several versions of the receiver and the informal flight tests clearly showed adequate performance.

An initial flight took place on May 21 and 22, 1976, on board a U. S. Coast Guard HC130 based at Elizabeth City, North Carolina. The flight on May 21, consisted of a southerly leg to Tampa, Florida thence westerly to Corpus Christi, Texas. On May 22, the flight included a southerly leg to the Yucatan Peninsula thence northerly to Shreveport, Louisiana and thence easterly in the National Airspace System to Elizabeth City.

Performance was fair to good during the first day's flight. Several discrepancies were discovered as were some of the system's peculiarities. After insertion of one software change and the modification of 5 software constants, the second day's flight went much better. It was possible to consistently reacquire the signals and re-establish the aircraft position as far south as the peninsula. However, at the southerly limits, the signal to noise ratio was so low that the steering needle was too unsteady for pilot use. During the return leg to Elizabeth City, radar centerline checks were obtained which agreed with the navigator system data. Upon landing at Elizabeth City, the navigator indicated an arrival position that appeared exactly correct.
Figure 3 - Front Panel of Airborne Loran-C Navigator

Figure 4 - Interior Construction of the Navigator
Encouraged by this performance, a demonstration in the New York City area was conducted using an HH3 helicopter based at Brooklyn. This flight plan consisted of legs within the National Airspace System from Brooklyn to Atlantic City, New Jersey, to a buoy 12 miles at sea, thence to Ambrose Flight Station in New York Harbor and a return to the Air Station. The system performed very well during this flight demonstrating two planned non-precision approaches to Bader Field in Atlantic City. It was necessary for the pilot to move away from the buoy and Ambrose Tower so that they could be observed by the passengers since the navigation system placed the plane directly over them in a blind spot.

The third and most impressive portion of the informal flight tests occurred when an HH52 helicopter with the navigation system installed was deployed on U. S. Coast Guard Cutter Morgenthau (WHEC-722) during the cutter's assignment as Search and Rescue (SAR) vessel for the Bermuda to Newport leg of the tall ships race, a part of Operation Sail 1976. In addition to providing SAR coverage the ship helicopter team was used to obtain photographs of the tall ships such as the Coast Guard Academy's training barque USCGC EAGLE shown in figure (5). Morgenthau's Commanding Officer, CAPT Fern, a strong advocate of Loran-C, and his vessel regularly use the C-LAD navigation system developed for the Coast Guard by the Applied Physics Laboratory of Johns Hopkins University. For these tests, a special authorization was given to operate the helicopter to a maximum radius of 50 miles from the ship, twice the normal range, provided the Loran-C navigation system was operable.

Quantitative analysis of the data obtained could not be performed because the accuracy of the air search radar and manual plotting methods was clearly inadequate for the purpose. However, the radar plots did confirm the following conclusions: Monitoring helicopter position relative to the vessel using the data telemetry capability without the use of radar is possible to the limit of communications coverage. The helicopter can be deployed to a specific position with efficiency and with high accuracy. Intricate search patterns can be flown with high accuracy without guidance from the vessel. Rehearsal between a vessel and a helicopter using Loran-C only is possible to a few hundred feet. In addition to these operational capabilities, a great deal was learned about the human factors aspects of the navigation system design.

Formal flight tests were conducted in accordance with a detailed flight test plan developed for the Coast Guard by Champlain Technology Industries Division of Systems Control Incorporated. These tests were conducted at the FAA's NAFEC facility using an HH52 helicopter operating out of Coast Guard Air Station, Cape May. Three flight scenarios were followed: Search and Rescue (SAR), National Airspace System (NAS) and Surveillance. Six pilots were trained on the system and each pilot was scheduled to fly at least one SAR and two NAS scenarios. Three surveillance flights were scheduled. Three SAR flights using conventional navigation techniques were to be flown to act as a control. The test plan contractor furnished a flight observer who monitored pilot workload and operated the airborne data recording equipment. The Extended Area Instrumentation Radar at NAFEC which has an accuracy of ±50 feet was used to track the helicopter. Data recording equipment on board the aircraft recorded Loran position and cross track distance and range to the next waypoint to the nearest 0.01 of a nautical mile.

Flights were conducted during the periods of September and October. An interruption was caused by problems with the data recording equipment and an improperly entered software constant change. Due to other operational requirements at the air station, and the excellent repeatability and accuracy of the data obtained, one SAR flight, one conventional and two surveillance flights were cancelled. A series of non-precision approaches using the propagation anomaly correction feature was added. In general, the data acquisition phase was fairly routine.

The data is currently being analyzed by the contractor as described in the analysis portion of the test plan. The report of the analysis will be made available through the National Technical Information Service after it is delivered in March 1977. Quantitative statements of performance cannot be made prior to completion of the analysis. However, figures 6 through 8 are plots of one of the better flights for each of the SAR, NAS and non-precision-approaches. The straight dotted lines are the desired tracks, the continuous lines are the actual radar tracks and in the case of non-precision-approach flights, the total system error allowed for the segment is indicated by dashed lines on either side of the desired track. In addition to the quantitative system performance data, several design improvements to reduce pilot error potential and workload have been identified.

An agreement between the FAA and the Coast Guard to conduct a joint evaluation of Loran-C as an aid to navigation for civil aviation use has been signed. The NAFEC support of this test program is one of the projects called for in the detailed plan resulting from this agreement.

The potential of Loran-C to provide an accurate area navigation capability for aviation use has been demonstrated by the military and is well-known to the Loran-C community, in order to have this aid to navigation seriously considered for civil aviation it is necessary to provide coverage in areas where the accuracy is
Figure 5 - Coast Guard Academy Training Barque USCGC EAGLE
FIGURE 6 - RESULTS OF A COAST GUARD SEARCH AND RESCUE SCENARIO FLIGHT
**FIGURE 7 - RESULTS OF A NATIONAL AIRSPACE SYSTEM SCENARIO FLIGHT**

- **FLIGHT**: AC 90-45 A
- **PHASE**: CROSSTRACK LIMITS (NM)
  - Route: Cape May - Victor
  - Romeo - Cape May
  - Terminal:
    - Victor - Golf
    - Golf - Hotel
    - Bravo - Romeo
    - Romeo - Sierra
    - Sierra - Victor
  - Approach:
    - Hotel - India
    - India - MAP

- **Scale**
  - 0 2 4 6 8 Nautical Miles

- **Note**: Actual Actual Crosstrack (FAIR Radar) -- Impromptu Desired Track

- **3.0 nm Right Offset to Intercept Final Approach Course**

Cape May
FIGURE 8 - RESULTS OF TOW NON-PRECISION APPROACH SCENARIO FLIGHTS
needed and attractively priced user equipment which has been designed to satisfy the needs. It appears that the Coastal Confluence Zone program will provide the coverage and this navigator will partially satisfy the requirement for user equipment.

The problem of navigation of Coast Guard helicopters which often must operate out of the range of VOR/TACAN coverage and under instrument flight rules is serious. Based upon the results of the formal and informal testing described in this paper, additional units incorporating correction of the observed design deficiencies are being procured for further operational evaluation. Serious consideration is being given to fitting Coast Guard helicopters with the navigation system.

REFERENCES


II. HIGHLIGHTS OF THE FIFTH ANNUAL BANQUET
LUNCHEON SPEAKER

CDR William B. Mohin, USCG DOT LORAN-C Applications Project Manager, shown here on the right, presented a very challenging view of the almost innumerable potential LORAN-C applications within the continental U.S. all the way from urban traffic management to the needs of the forestry service.
PRESENTATION OF AWARDS
Murray Block accepting the Outstanding Service Award for his efforts as chairman of the annual golf tournament. Leo Fehlner, Awards Chairman, presents the award as Jim VanEtten looks on.

James P. VanEtten accepting the Outstanding Service Award upon completion of two terms as President. The award was presented by John Beukers, the new WGA President.
Norman C. Dickerson, Jr. accepting the Outstanding Service Award from Jim VanEtten for Claude J. Pasquier, awarded posthumously for his many contributions as Vice President, Director, Goose Gazette Editor and Awards Chairman.

Mrs. William K. Vogeler accepting the Outstanding Service Award from Jim VanEtten for her husband, awarded posthumously for his years as a loyal member and generous contributor to the technical sessions.
William F. Reveille accepting the Outstanding Service Award for his contributions as chairman of two annual conventions.

Norman C. Dickerson, Jr., accepting the Outstanding Service Award for his contributions as chairman of two technical sessions.
James A. Graydon accepting the Charter for the Southeast Chapter.
MEDAL OF MERIT AWARD
General William J. Evans accepting the Medal of Merit for General John D. Lavelle awarded for his outstanding contributions to the operational use of LORAN. The citation, which was presented to General Evans by Jim VanEtten, is reprinted on the following page.
Citation on the Occasion of the
Award of the Medal of Merit of the
Wild Goose Association to
John D. Lavelle

The Medal of Merit of the Wild Goose Association is awarded to you, General Lavelle, in recognition of your significant and long-lasting contributions to the development and fostering of loran. These contributions, which were focused on the use of Loran-C in military operations in Southeast Asia, led to systems that have been in continuous use for over seven years.

As Director of the Defense Communications Planning Group from February 1968 to August 1970, you clearly recognized the potential of Loran-C for precision guidance of aircraft and for use by ground and airborne personnel in a common grid system. You also foresaw the need for a companion calibration system that would result in guidance accuracy that approached Loran-C precision.

Without the usual lengthy research and development cycle, you boldly initiated, among other things, the development of the BALLAD and Pave Phantom guidance systems for aircraft, the development of Sentinel Lock/Loran for accurately relating the loran grid to the geodetic grid, and the development of ground systems involving the use of loran manpacks. Furthermore, your personal interest in the development of tactics and doctrine permitted timely operational use of loran.

These systems were highly successful from the beginning and several continue to be operational at the present time. These successes justified the application of existing loran equipment to Pave Nail and Pave Buff and stimulated the development of improved loran manpacks, new solid state loran transmitters and new loran guidance systems for drones, helicopters and fixed-wing aircraft. These facts attest to your foresight and the soundness of your judgment.

The Wild Goose Association believes that these contributions have had a most favorable effect on the stature of Loran-C as a precision navigation system for both military and civil applications, and for this we are forever grateful to you.

Awarded this 28th day of October 1976.

James P. VanEtten
President
MS. WILD GOOSE
The MS. WILD GOOSE honors for 1976 were bestowed on Ms. Judi Smoot of ITT's Washington office by Chairman Bill Reveille, who enjoyed every minute of it!
CAPT Glenn F. Young, the Guest Speaker at the Banquet, gave a very interesting history of the international Law of the Sea negotiations from the early beginnings to the recent United Nations Law of the Sea Conference in New York. CAPT Young of the U.S. Coast Guard is Special Assistant to the Deputy Secretary of Transportation for the Law of the Sea.
III. CANDID CAMERA PERSPECTIVE