GLEN E. BAER and JOSEPH G. WALL

# COAST GUARD PRECISION NAVIGATION PROGRAMS USING LORAN-C

This article is an overview of recent U.S. Coast Guard programs that use Loran-C for precision navigation in restricted waters. The Coast Guard's interest in a number of these programs was to prove the concept of precision navigation with Loran-C and thereby stimulate the commercial sector to produce such units—a result that is just beginning to happen.

## BACKGROUND

The Coast Guard has a continuing interest in precision navigation equipment using Loran-C, which enables a mariner to travel safely through restricted or treacherous waters in all weather conditions.

The use of Loran-C for precision navigation and guidance is basically a two-step process: data (signal) measurement and data transformation. For the first step, three or more Loran transmitters and a suitable receiver provide the raw data for determining a position fix. However, navigation with the raw data is awkward because the lines of position are hyperbolic microseconds of difference in signal arrival time. Manually reducing these data to obtain a position fix (when Loran charts are available) negates much of the true potential of Loran-C, especially its speed and accuracy. This is the reason for the second step, which consists of using a mathematical processor to transform the raw data into a form useful for navigation and plotting.

As an outgrowth of work performed for the U.S. Air Force on a Loran Assist Device (LAD) in 1967, the Coast Guard requested APL's assistance in the development of a civilian version of LAD, which was designated the Coast Guard Loran Assist Device (COGLAD).[1]

COGLAD was developed around an SPN-45 transceiver and an HP 9100B programmable calculator. Two systems were successfully tested by the Coast Guard on Lake Huron in 1970. In late 1975, one of the COGLAD systems was modified for use in testing a special four-station Loran-C minichain established by the Coast Guard to provide an all-weather, year-round navigation capability on the 65-mile-long St. Mary's River. The river, located in northern Michigan near Sault Ste. Marie, connects Lake Superior and Lake Huron and is the only water shipping route connecting Lake Superior with the rest of the Great Lakes and the St. Lawrence Seaway. It is traversed by ore carriers up to 1000 feet long and 105 feet wide and has channels as narrow as 300 feet. Being able to safely extend the number of days that the river is navigable is extremely important to the area's economy. The

**GLOSSARY OF ACRONYMS**

AAPS—Automated Aids to Navigation Positioning System
COGLAD—Coast Guard Loran Assist Device
LAD—Loran Assist Device
PILOT—Precision Intracoastal Loran Translocation
PLAD—Portable Loran Assist Device

tests, conducted during January through July 1976, demonstrated that navigation accuracy could be achieved,[2] but the Coast Guard felt that the COGLAD system was too costly to go into production. No further testing of the system was done.

After several years of experimenting with the mini-Loran-C chain, the Coast Guard returned to APL in late 1978 with a request for the design of an integrated Precision Intercoastal Loran Translocator (PILOT) that would be low in cost (i.e., less than $20,000) if mass produced.[3] In addition to that requirement, the design objective was to demonstrate that the Loran-C capability for repeatability (i.e., returning to presurveyed points) could be used successfully in piloting in harbors and rivers without significantly increasing the work load of bridge personnel.[4]

To minimize development and production costs, a commercially available microprogrammable graphics terminal (HP 2649A) was selected as the nucleus of the PILOT system. The Loran-C receiver currently used with the system is an unmodified commercial item. New software was developed, including sophisticated data-filtering and transformation techniques.[5,6] During the successful trials of the PILOT system in 1981, the Coast Guard requested that APL develop a Portable Loran Assist Device (PLAD) that could be used by U.S. pilots to navigate vessels through restricted waters, capitalizing on the Loran-C system's repeatability and using the sophisticated software developed for PILOT. Four units were developed, two servicing the Delaware Pilots Association and two supporting navigation on the St. Lawrence Seaway.

The problem of precision placement of aids to navigation (e.g., buoys) was not solved by the previously described systems. The Coast Guard requested APL in 1983 to develop an Automated Aids to Navigation Positioning System (AAPS). Testing of the equipment being developed in this program began in October 1984.[7]

## The COGLAD Program

COGLAD initially was composed of five system elements (Fig. 1): an HP 9100B calculator, an interface unit, a printer, an X-Y plotter, and an SPN-45 Loran receiver with a receiver control unit.[1,8] The interface unit was developed to connect electrically the output of the receiver to the calculator, to provide high speed digital filtering, and to display position and velocity information. An HP 9125A plotter was used to plot the ship's course on standard navigation charts, and an HP 9120A printer was used for data logging.

The initial system was modified to meet the specific needs of navigating the St. Mary's River. The Hewlett Packard computing equipment was expanded with the addition of an extended memory unit (Figs. 2 and 3). The software was completely rewritten with such expanded capabilities as dead reckoning, continuous navigation throughout the entire river, log compensation, and storage of way-point information. The system presented a current position fix to the user every 6.5 seconds.

The COGLAD equipment proved that precision navigation of the St. Mary's River was possible. Figure 4 is a comparison of COGLAD position data versus Autotape data. (Autotape is a short-range, high-precision positioning system used for position verification. Because of the line-of-sight position requirements, it is not suitable for long-range navigation.) The plot was prepared by the Coast Guard R&D Center at Groton, Conn., using data taken jointly by APL and Coast Guard personnel. The difference in cross-track position (i.e., distance left or right of the center of the channel) measured by the two systems typically is much less than 15 feet. The Coast Guard design goal for the entire system was to determine cross-track position with an error within $\pm 25$ feet 95% of the time. The track plot in Fig. 4 shows that the goal was achieved with a comfortable margin.

## THE PILOT PROGRAM

The primary objective of the PILOT program was to use the technology of the COGLAD program to produce a system that could be built for less than $20,000 and that would provide repeatable Loran-C navigation. The equipment complement was to be kept to a minimum because the whole system was to be installed on the bridge of a vessel.[9]

PILOT was first tested in the fall of 1979 on the St. Mary's River. Eight units were built by APL for use on American and Canadian Coast Guard ships and commercial ore-carrying vessels. Units are still being used by the Coast Guard in research and development programs.[10]
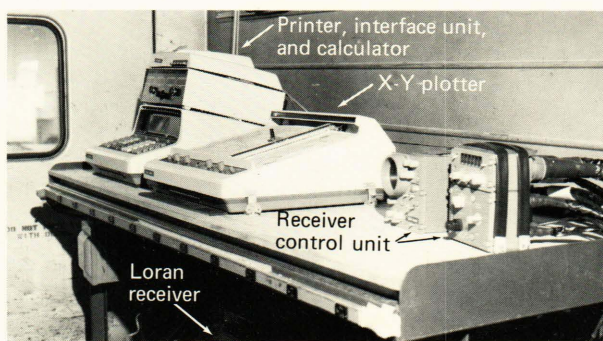


Figure 1 — The initial COGLAD system installed in a van. This system was used for testing prior to installation on Coast Guard vessels.
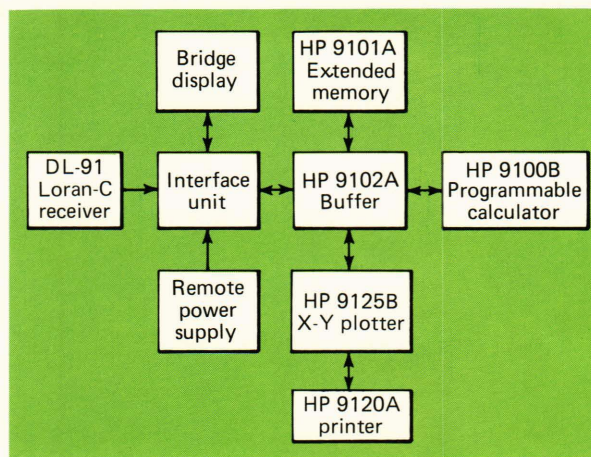


Figure 2 — Block diagram of COGLAD II. The nucleus of the COGLAD II system is a Hewlett Packard 9100B calculator.
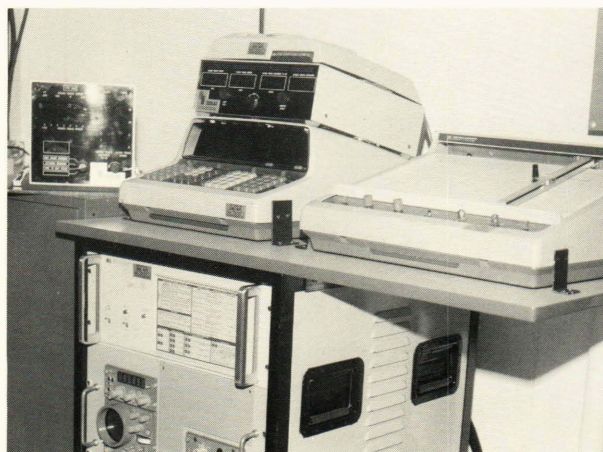


Figure 3 — The COGLAD II complement of equipment installed on a Coast Guard ice breaker on the St. Mary's River.

The PILOT terminal is shown in Fig. 5, and a block diagram of the system is shown in Fig. 6. Normal shipboard installation consists of the PILOT terminal, a Loran-C receiver, and a cable connection to the ship's gyro. Optional equipment includes a printer, a second

**Figure 4** — Comparison of COGLAD II data with Autotape, a known reference system. The COGLAD II cross-track position error meets the design goal within ± 25 feet 95% of the time.
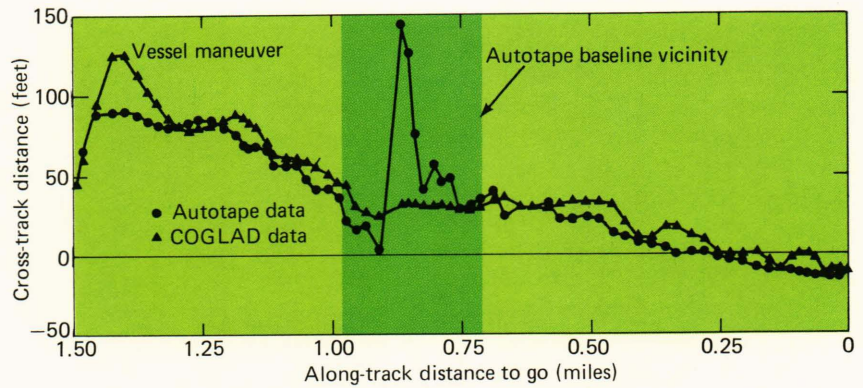


**Figure 5** — The PILOT unit developed for the Coast Guard.

Loran-C receiver, and an interface or modem for remotely entering time difference bias values.

The nucleus of the system is a microprogrammable graphics terminal. This device was selected because it has a separate graphics processor with memory, dual tape cartridge units, and an 8-bit microprocessor that can be modified and programmed as required. The basic unit was transformed into the PILOT unit by modifications that included (a) converting the microprocessor from software arithmetic to hardware arithmetic by adding an arithmetic processing unit, (b) developing an interface board to preprocess data from two Loran-C receivers, (c) developing an interface board to connect to the ship's gyro, (d) developing a time difference bias modem or box, (e) replacing the large general-purpose keyboard with a small predefined keypad, and (f) building a short base for the terminal to serve as a cable junction box.

Approximately 17,000 bytes of machine language code were developed at APL for the PILOT terminal; an additional 40,000 bytes of the code originally supplied by the terminal vendor were retained. Structured programming and assembly language were used for maximum efficiency.[11]

## THE PLAD SYSTEM

The PLAD system is a portable electronic aid for piloting vessels in harbors and rivers.[12] One memory chip in PLAD contains the Loran-C coordinates of points along shipping lanes in harbors and rivers. It can contain as many as nine routes, representing a combined total of several hundred miles of waterway. A fully automatic Loran-C receiver in the system provides the information needed for the microprocessor to compute the vessel's position and speed. Position is displayed as along-track distance (i.e., distance remaining along the present course) and cross-track dis-



**Figure 6** — Block diagram of the PILOT system. Most of the hardware shown here was purchased. However, special interfaces were designed and built by APL.
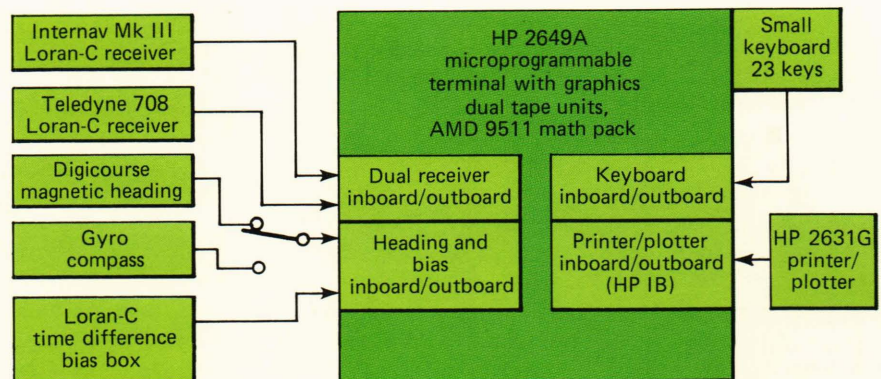
tance. Speed over the bottom is similarly computed as along-track and cross-track speed. A small, hand-held terminal with a 10-foot service cable, stored in the lid of PLAD during transit, is used to control and display the data. The antenna for the Loran-C receiver is a telescoping whip that clamps on a rail or stanchion outside the wheelhouse.

Other features available to the operator include the ability to display the time differences and status messages from the internal Loran-C receiver. Current route number, range mnemonic (i.e., section of river), and heading angle to steer can also be called to the display. To compensate for seasonal variations, PLAD has a built-in autocalibration feature to measure small variations in the Loran-C coordinates at calibration points in the operating area. These time difference variations or biases can then be entered by the operator and recalled to the hand terminal at any time.

The antenna, 75 feet of cable, the hand-held terminal, and the power cord are stored inside the lid of the PLAD unit (Fig. 7). PLAD is packaged in a splash-proof metal case about $8 \times 9 \times 16$ inches and weighs 22 pounds. Figure 8 is a system block diagram showing the major components. For use aboard foreign vessels, a plug adapter kit and a small stepdown transformer are provided.

## THE AAPS PROGRAM

The function of the AAPS program is to develop a system with PILOT features that assists in the placement of aids to navigation[5] and that is intended for use only by the Coast Guard on buoy tenders.

The block diagram of the system is shown in Fig. 9. Its heart is an HP 9836C color computer with high-resolution color graphics. As in the PILOT program, a Loran-C receiver and a cable to the ship's gyro are part of the system. The remote cathode ray tube and the digital sextants are new items that will be used in placing buoys. The graphics printer will document the location of the buoys as they are set.

AAPS hardware and software are being developed; field testing began in October 1984. Testing will occur on the East Coast aboard a Coast Guard buoy tender.

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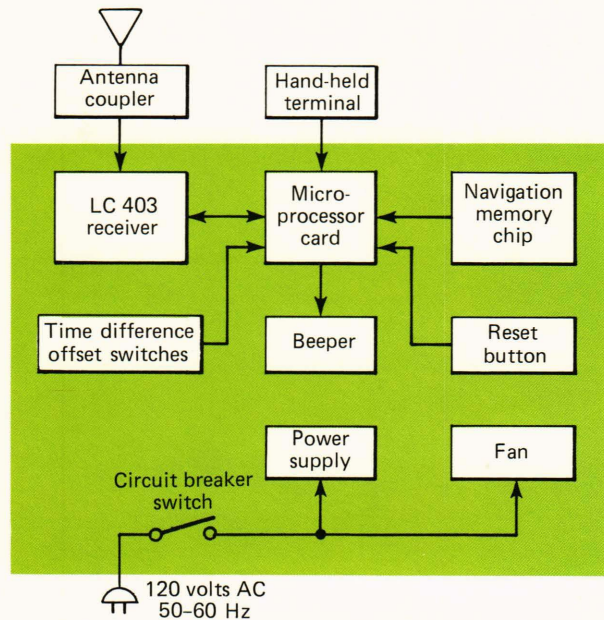
**Figure 8** — Block diagram of the PLAD system. The basic parts of the unit are the receiver, the hand-held terminal, and the processor/interface built by APL.
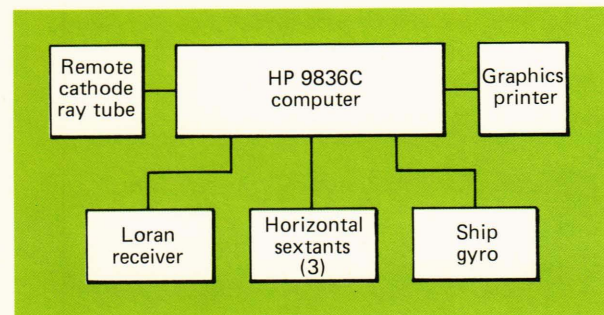


**Figure 7** — The PLAD unit, a compact version of the PILOT unit. The entire portable unit is contained in a small suitcase.



**Figure 9** — Block diagram of the AAPS system being developed for the Coast Guard. Field testing of the unit is scheduled for October 1984.

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