ABSTRACT

The Coast Guard is extending the Continental United States (CONUS) LORAN-C coverage as part of the Federal Aviation Administration project to incorporate LORAN-C into the National Airspace System. The increased coverage will expand the number of airports approved for LORAN-C non-precision instrument approaches and enable direct Instrumental Flight Rules (IFR) routing by suitably equipped aircraft in and through the mid-continent region of the United States. The project will involve construction of a new LORAN-C chain which will be linked to the existing CONUS chains. In addition to the aviation benefits, the Mid-Continent LORAN-C Expansion will broaden the availability of LORAN-C positioning to a growing number of terrestrial users such as resource management, emergency response and fleet management.

WHY LORAN-C NOW?

Why LORAN-C expansion in the age of the Global Positioning System (GPS)? The answer lies with almost forty-thousand aircraft owners who have purchased LORAN-C receivers for their aircraft. It also lies with organizations such as the National Association of State Aviation Officials (NASAO) and the Aircraft Owners’ and Pilots’ Association (APOA) which have worked with the Federal Aviation Administration (FAA) to develop a program to implement use of LORAN-C for non-precision approaches. These new aviation users of LORAN-C are now able to fly direct routes between destinations receiving a continuous update of range and bearing to their destination and true course and speed over ground. Receiver manufacturers are seeking to gain competitive advantages by offering more navigation and technical features such as pre-programmed airport coordinates and cross-chain operations. Under the FAA’s Pilot Monitor Program, LORAN-C monitors have been installed and approach procedures developed at eight airports in Massachusetts, Oregon, Texas, Ohio, Vermont and Florida. The first FAA-certified, LORAN-C non-precision approach took place in Bedford, MA on November 4, 1985. This Pilot Monitor Program will provide experience for both the FAA and aircraft users in establishing LORAN-C as a navigation aid for non-precision approaches throughout the United States.

Direct routing and non-precision approaches are capabilities that GPS promises to bring to the aviation community. LORAN-C is doing it now and at a price that is affordable to the civil aviator. From an aviation viewpoint, there is a glaring weakness in the LORAN-C coverage over the Continental United States (CONUS). LORAN-C was installed in the United States to provide maritime coverage to the Coastal Confluence Zone (CCZ) and Great Lakes. As can be seen in Figure 1, a gap in coverage exists in the mid-western region — the mid-continent gap.

Under the leadership of Administrator Donald Engen, the FAA has taken an advocacy role for incorporating LORAN-C into the National Airspace System including closure of the mid-continent gap. The Coast Guard has agreed to assist the
FAA to provide LORAN-C to civil airborne users. A formal Memorandum of Agreement (MOA) between the FAA and Coast Guard was signed on June 2, 1986. A Coast Guard project team has been assembled to design and construct the LORAN-C stations necessary to complete coverage from coast-to-coast and border-to-border. A FAA Cost/Benefits Study [1] identifies two primary economic benefits from the expansion of LORAN-C and installation of airport LORAN-C monitors. They are direct IFR routing and non-precision approaches at airports without standard instrument approach procedures. The study estimates that air taxis and business-related general aviation on established routes will be the first to benefit from IFR direct routing. Widespread random IFR direct routing will need to wait until the air traffic control system is upgraded. Meanwhile, direct Visual Flight Rules (VFR) routing is being widely used today. The study also estimates that over three-thousand airports without standard instrument approach procedures are candidates for LORAN-C approaches. The FAA projects that LORAN-C approaches can be approved at a rate of three-hundred per year.

**CHAIN CONFIGURATION CONSIDERATIONS**

At the time of this writing, the LORAN-C transmitting station configuration design to close the mid-continent gap is incomplete. Also shown in Figure 1 is a preliminary configuration of two new chains — North Central United States (NOCUS) and South Central United States (SOCUS). Four new transmitting stations are coupled to the existing West Coast, Gulf Coast, Great Lakes, and Canadian West Coast Chains. Remote monitor receivers used to control the new stations will be collocated with existing FAA VOR/DME facilities. The new transmitting stations will be remotely operated from the existing control station in Middletown, CA, which will also monitor and control the timing of the two chains. The two new chains will be integrated into the existing Coast Guard LORAN-C operations and support structures.

In designing the chain configuration to close the mid-continent gap, designers have taken the aviation user into primary consideration. A general definition of coverage is the area where the system meets the navigation requirements of the typical user equipped with a standard receiver. In generating coverage diagrams for marine use, the Coast Guard has translated the general requirement to define geometric-fix-accuracy limits and range limits [2]. The geometric-fix-accuracy is established at 1500 feet, 2 drms, based on a time-difference standard deviation of 0.1 microseconds. Predicted atmospheric noise and estimated LORAN-C signal strength based on transmitted power and conductivity profiles are combined to obtain expected 1:3 signal-to-noise (SNR) range limits. The lesser of the two limits is used to generate coverage diagrams. The coverage diagrams also assume the user's receiver operates in the hyperbolic mode using a single chain. For aviation use, additional factors come into consideration such as enroute vs. non-precision approach navigation. Radio Technical Commission for Aeronautics Special Committee 137, LORAN-C RNAV Minimum Operating Performance Standards, and Special Committee 158, Airborne LORAN-C Receiving Equipment, are dealing with these issues. The NOCUS and SOCUS chains are being designed to provide enroute coverage through the mid-continent area and emphasize coverage in areas where non-precision approach capabilities are most needed, e.g., areas with frequent periods of poor visibility.

![Figure 1. Mid-Continent LORAN-C Gap](image-url)
AVIATION LORAN-C ISSUES

The extension of LORAN-C from a marine radionavigation system to recognition and exploitation as an aviation aid-to-navigation will cause overall navigation system changes both within the Coast Guard and the FAA. Issues to be dealt with include integrity, momentary off-airs and the Notice-to-Airmen System.

Integrity

Integrity is the ability of the aviator to detect a system abnormality or a warning that the navigation system is not operating within tolerances. The capability to warn a pilot that a LORAN-C base-line (master-secondary pair) is out-of-tolerance during a non-precision approach is of particular concern to the FAA. The Coast Guard procedure is to blink a tracking pattern during the first 2 pulses of a secondary pulse group, when the system is out-of-tolerance. Both RTCA Special Committees 137 and 158 are attempting to resolve the SNR that a receiver can detect blink within the ten-second time period specified for a non-precision approach. A FAA sponsored project under the Coast Guard/FAA MOA will investigate alternatives to the current blink procedure to improve the detection ability of airborne LORAN-C equipment. The Coast Guard must also remain sensitive to the effect of any change in LORAN-C system operating procedures on the marine user community. Obviously meeting the concerns of both the aviation and marine communities will make the jobs of our Loran Chain Managers more difficult.

Momentary Off-Airs

Another area of discussion between the FAA and Coast Guard are very short station off-airs, termed "momentaries". These "momentary" off-airs occur when transmitters are switched at a tube type transmitting station, or when a transmitter overloads for a number of reasons; e.g., a power surge. Off-air periods of less than sixty-seCONDS are not used in the calculation of station availability, since they have negligible effect on marine receivers. However there is concern that an error of several miles could be introduced in an airborne receiver. All LORAN-C receivers have circuitry implemented either in hardware or software to identify a track point, nominally the third cycle, on the transmitted LORAN-C pulse of each station tracked. Errors in this circuitry will result in time-difference errors in multiples of ten microseconds. In general, after a receiver verifies it is tracking the correct cycle, the cycle selection circuitry is disabled. There is concern that the tracking circuit in an airborne LORAN-C receiver may slip a cycle (10 microseconds) during a momentary off-air. Such an error could go undetected by a pilot until he can identify the error with another navigation aid. The issue of momentaries will also be addressed under the Coast Guard/FAA MOA for aviation LORAN-C.

Notice-to-Airmen (NOTAM)

The Notice-to-Airmen (NOTAM) System will also undergo change as LORAN-C is incorporated into the National Airspace System. A nonscheduled or scheduled off-air period for a LORAN-C transmitting station can affect a large area. For example, the area along the West Coast from San Francisco, CA, to Seattle, WA, would be without LORAN-C coverage if the secondary station at George, WA is off-air. The FAA will be linked into the existing Coast Guard notification system. The FAA will in-turn distribute information through the NOTAM system and develop a publication that will enable pilots to determine the impact of a station off-air. Comments or objections to a scheduled off-air will be considered by the appropriate Coast Guard LORAN-C Chain Manager. All reasonable efforts are made to accommodate users to minimize the impact of a scheduled off-air. However, it may not be possible to satisfy all objections and the resulting schedule may appear to favor one user group. One factor that will also enter to off-air scheduling is the cost to government to re-schedule the maintenance.

ALASKA EXPANSION

Outside of CONUS, the Coast Guard is working with the FAA to improve the LORAN-C coverage in Alaska. This will be accomplished by double rating the Port Clarence, AK Station (Northern Pacific Chain) to the Gulf of Alaska Chain. (See Figure 2.) The new TOK-Narrow Cape-Port Clarence triad may be in limited operation as early as second quarter, FY 87. In the limited operation mode, the monitor receivers at Loran Monitor Station Space Cape located in Kodiak Island will be used to control the new base-line. Additional monitor receivers in the coverage area will be added later and remoted to Kodiak, AK. Figure 2 also shows a

Figure 2.
poor coverage area in Southeast Alaska, south of Juneau. During the late 1970’s and early 1980’s plans were made to construct an additional station at Yakutat, AK to fill in the missing coverage. Unfortunately, the Coast Guard could not develop the necessary benefit/cost ratio to justify the additional station and the project was canceled.

**CANADIAN AVIATION LORAN-C**

The interest in aviation LORAN-C has spread north of the border to Canada. The Canadian Ministry of Transport is investigating the number of transmitting stations necessary to provide LORAN-C coverage to 60 degrees North Latitude. At the time of this writing, the direction that Canada will take towards expansion of LORAN-C is unclear.

**OTHER APPLICATIONS**

In 1974 LORAN-C was selected by the Department of Transportation as the navigation system to satisfy the requirements for marine navigation in the CCZ and Great Lakes. Since that time the number of marine LORAN-C users has grown to several hundred thousand; the receivers have become more automated with sophisticated navigation feature for much less cost than the basic original “low cost” receivers. Manufacturers started marketing receivers for the aviation community with such excellent results that in 1984 the FAA took an advocacy role towards integrating LORAN-C into the National Airspace System. The aviation interest and FAA recognition of LORAN-C has led to the expansion of LORAN-C coverage to close the mid-continent gap. By 1990, all 48 contiguous states will have LORAN-C coverage. What will be the effect on terrestrial transportation in the United States?

Automatic vehicle location systems is an application that is presently marketed by several manufacturers. The capability to more efficiently or effectively deploy a fleet of vehicles is attractive to businesses with large fleets of vehicles; e.g., taxis, delivery trucks, busses, etc., and emergency services such as police departments, fire departments and ambulance services. A reliable, accurate and low-cost positioning system is an integral part of any automatic vehicle location system.

During a series of user conferences sponsored by the Research and Special Project Administration and the Coast Guard, a number of applications of positioning systems were discussed. These included electronic maps for automobiles, tracking of wildlife to study feeding and migratory habits, location of forest fires to assist in fire fighting operations, identifying high- and low-yield areas on large farms, management of a large railroad system. A long-distance telephone company brought attention to the use of LORAN-C for timing and synchronization of telephone switching networks.

Will LORAN-C take on a significant role as radionavigation system for terrestrial applications? Or are potential users waiting for GPS? What will be the effect of the estimated two-year GPS delay? How intensely will manufacturers of LORAN-C equipment market their equipment? The number of current terrestrial users of LORAN-C is small. However, the total number of trucks, automobiles and trains is enormous compared to ships, boats and airplanes.

**THE FUTURE**

The LORAN-C system has achieved high reliability by the installation of redundant equipment at transmitting stations; i.e., three cesium beam oscillators, dual timers, two transmitters (tube type). As discussed previously, loss of a single station can affect a large operating area. Are there system or receiver improvements to reduce this dependence? Are low cost range/range receivers achievable? Can LORAN-C transmission be more closely synchronized with Universal Time using GPS as a timing reference? Rather than a hyperbolic solution, LORAN-C receivers could estimate pseudo-range and time. Therefore, any three stations within range and providing suitable geometry could be used for the navigation solution. Is the combination of GPS and LORAN-C a practical, synergistic navigation system for the United States? Or will GPS alone meet the navigation and positioning needs for marine, aviation and terrestrial users of position and time information?

**SUMMARY**

As a result of intense civil aviation acceptance and use of LORAN-C, the FAA has taken steps to incorporate LORAN-C into the National Airspace System. The Coast Guard has agreed to assist the FAA in this endeavor and has begun major projects to close the mid-continent gap and increase coverage in Alaska. Other projects are being initiated to improve the NOTAM system and investigate methods to modify the blink procedures and minimize the effects of momentary off-airs. The FAA has started a project to provide LORAN-C approaches at the rate of 300 per year. The Canadian aviation community and government are actively monitoring the expansion of LORAN-C in the United States and studying the costs/benefits of expanded coverage in Canada.

The expansion of LORAN-C in CONUS will also benefit terrestrial users. How big this impact will be remains to be seen. There is a tremendous potential due to the large number of potential users.

Will LORAN-C pass in obsolescence when GPS becomes operational and the GPS technology matures? Or is there a need for a terrestrial redundant system?

**REFERENCES**

1. LORAN-C for En Route and Non-Precision Approach Applications in CONUS, Benefits Analysis, ATC-85-1017 Supplement 1, November 1985.