Loran Recapitalization Project (LRP)

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ABSTRACT

Loran "upgrade and modernization" efforts began in 1997 at the U.S. Coast Guard Loran Support Unit following the signing of a Federal Aviation Administration (FAA)/U.S. Coast Guard (USCG) Interagency Agreement. The Loran Recapitalization Project (LRP) effort will modernize the Loran-C radionavigation infrastructure in order to preserve operations as a transition system through at least 2008. In the future, the goal may be to reduce or completely eliminate personnel at the Loran Transmitting Stations, greatly reduce all required equipment maintenance, and eventually outsource all maintenance, operations, training, and depot repair of the entire Loran System if deemed necessary for continuance.

This paper will present the LRP mission and goals, in addition to the engineering design and status of all major LRP sub-tasks. The focus will be on the "North American Loran-C System of the Future."

BACKGROUND

The United States Coast Guard has a long history of involvement in establishing and maintaining the Aids to Navigation (AtoN) infrastructure of the United States. Technological advances and Congressional language in the 20^{th} Century expanded the Coast Guard's role in providing AtoN to include radio navigation aids. The most robust and reliable of the Coast Guard's radio navigation systems has been, and continues to be, the Loran-C Navigation System. The ascendancy and pervasiveness of the Global Positioning System (GPS) and its augmentations hastened the decision to terminate other radio navigation systems, including Loran-C. The decision has been re-evaluated based largely on recent instances of GPS jamming and interference, user support and Congressional budget programming.

In 1996, Congress directed the Department of Transportation (DoT), in cooperation with the Department of Commerce, to submit a plan defining the future use of and funding for operations, maintenance, and upgrades of the Loran-C system. To assist with this task, DoT contracted with Booz-Allen & Hamilton (BAH) to conduct an independent assessment of the proposed phase-out of Loran-C and to provide suggested transition and funding alternatives for continuing and upgrading the system. The BAH study identified strong user support for the continuation of Loran-C beyond the originally scheduled phase-out date of December 31, 2000. The 1999 Federal Radionavigation Plan (FRP) allows for the short-term operation of Loran-C while the U.S. government evaluates the long-term need for the system.

Starting in Fiscal Year (FY) 1997, Congress, via the FAA, provided funding to the Coast Guard to modernize and upgrade the North American Loran-C System. Between FY 1997 and FY 1999, more that $10.2M was transferred to the Coast Guard to execute 21 Loran modernization and upgrade projects. Additional funding provided in FY00 formed the foundation for the $122M Loran Recapitalization Project. The brunt of the planning and execution of these projects has been borne by the Loran Support Unit (LSU) located in Wildwood, NJ.

WHY RECAPITALIZE THE LORAN-C SYSTEM?

This project will modernize the Loran-C radionavigation infrastructure in order to preserve operations as a transition system through at least 2008. In the future, the goal may be to reduce or completely eliminate personnel at the Loran Transmitting Stations, greatly reduce all required equipment maintenance, and eventually outsource all maintenance, operations, and depot repair of the entire Loran System if deemed necessary for continuance. System performance and safety of the Loran System cannot be sustained without initiating major modernization efforts.

The 11 U.S. operated 1960's era, labor intensive, vacuum tube transmitters constitute the highest risk factor. The vacuum tube transmitters are particularly problematic, both to quality of operations and to the safety of servicing personnel. Vacuum tube transmitters effect approximately 80% of the Loran coverage in the continental United States and all of the Loran coverage in Alaska. The failure of a tube transmitter at any one of several tube type Loran Stations would have a significant effect on Loran coverage. For example, loss of the tube transmitter at Dana, IN would eliminate coverage for the entire Midwest and a large portion of the Atlantic seaboard for the duration of that failure. Failure of the tube transmitter at Fallon, NV would have a similar effect on West Coast coverage. Loss of St. Paul or Tok, AK would eliminate coverage in the Northern Pacific and Gulf of Alaska, respectively. Several of these particular tube transmitters are already experiencing insidious problems and our support personnel are putting in tremendous extra hours to keep these pieces of equipment working.

Many experienced Loran personnel are also reaching retirement age or transferring out of the Loran field. This decreasing knowledge base increases the risk to personnel and to system operations. The age of components making up the Loran System has placed an ever-increasing workload on Coast Guard personnel. In the past 41 months, the Loran system has required an unprecedented 128 technical assists by LSU alone to avoid unusable time. These assists resulted in 20 Crisis Contingency Projects and 41 Engineering Change Proposals/Orders.

CURRENT STATUS

The $122M LRP effort has been designated as a Coast Guard non-major systems acquisition. On November 8, 1999 a project staff consisting of ten new positions was approved, with the majority of the positions located at the Loran Support Unit. LSU also has four contract personnel onboard with more than 100 years of combined Loran experience to provide invaluable technical assistance.

As a result of an Interagency Agreement between the USCG and FAA, LSU has been recapitalizing Loran since 1997. Every project completed has been a stepping-stone for Loran recapitalization. Since funding will be coming to the Coast Guard in yearly distributions and could be stopped at any time, the LRP effort will be treated the same way as all of our projects, only on a larger scale. In order to keep the scope of the LRP initiative manageable, the LSU has broken up the project into several smaller sub-projects.

The LRP initiative will modernize the U.S. Loran System to meet present and future radionavigation requirements while leveraging technology and funds to optimize operations, support, and training, and reduce the total cost of ownership. What exactly does this mean? A complete replacement and/or upgrade of all electronics systems at all 29 Loran Transmitting Stations (LORSTAs), 29 Primary Chain Monitor Set (PCMS) Sites, and 4 Control Stations (CONSTAs) located throughout North America. This includes:

Completed:

- Replacement of all PCMS equipment. **[Completed in FY00]**
- Installation of the Automatic Blink System. **[Completed in FY00]**
- Installation of Command & Control wireless Backup Communications. **[Completed in FY00]**
- Installation of the Loran Consolidated Control System (LCCS) throughout North America. **[Completed in FY99]**

Underway:

- Tube-Type Transmitter (TTX) replacement at 14 locations (includes LSU & Loran Training School).
- Possible replacement and/or Service Life Extension of all Solid State Transmitters (SSX) at 17 locations.
- New/refurbished buildings at all sites receiving replacement transmitters.
- Tower replacement/modernization at selected sites.
- Replacement of all Loran Timing and Frequency Equipment (TFE), including new cesium beam oscillators, integrated Automatic Blink System (ABS), and Universal Time Coordinated (UTC) synchronization functionality.
- Installation of the new Remote Automated Integrated Loran (RAIL) command and control equipment.
- Installation of new Uninterruptable Power Supply (UPS) systems; one for the Operations Room equipment and one for the transmitter system.
- Replacement of all Loran Casualty Control receivers.
- Major upgrades and improvements to the Loran Consolidated Control System (LCCS).
- Enhancements to the capabilities of the Loran System.
- Improvements with the availability, continuity, integrity, and accuracy of the Loran System.

MAJOR MODERNIZATION INITIATIVES: "BEFORE" & "AFTER"

The North American Loran-C system can be looked at as a system with three major components, each with its own suite of equipment. The first component is the Loran Station (LORSTA), which consists of the timing and transmitting equipment needed to transmit the Loran signal to the user. The second component is the Primary Chain Monitor Set (PCMS) site, which consists of monitoring equipment necessary to ensure the Loran signal seen by the user is within published tolerances. The third component is the Control Station, which consists of command and control equipment that is operated 24x7 and remotely connects to the LORSTA equipment and PCMS equipment for a Loran chain. Figure 1 shows the location of all North American Loran Stations and Control Stations. The sections that follow provide a snapshot of what Loran was "BEFORE" and what Loran will be "AFTER" completion of major LRP efforts.

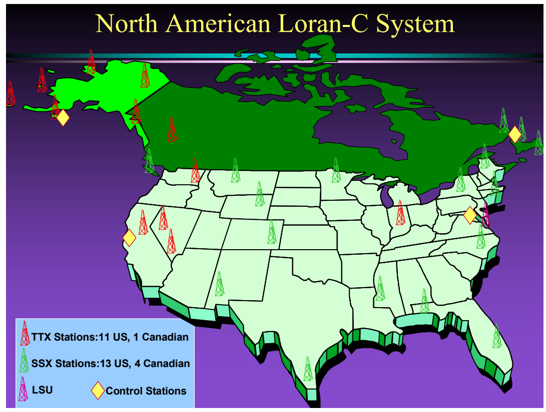

Figure 1: The North American Loran-C System

Control Stations - BEFORE

Prior to 1997, there were six North American Control Stations; four in the U.S. and two in Canada. Control Stations of the past required many personnel (85 in the U.S. alone), formal training, a large facility footprint, and consisted of four labor-intensive, standalone systems. Figure 2 depicts a typical Control Station prior to 1997.

Figure 2: Control Station - BEFORE

Control Stations - AFTER

There are now four North American Control Stations: Alexandria, VA; Petaluma, CA; Kodiak, AK; and St. Anthony, Newfoundland. Starting in 1997, all Control Station Equipment started being phased out by the Loran Consolidated Control System (LCCS). The LCCS is a computer-based system that provides remote command and control of the Loran-C system. The computer consists of an HP9000/J210 series workstation running the HP-UX 10.10 UNIX operating system. The LCCS application was developed in house with contractors and LSU personnel, "blue-suiters" and civil service alike, working side by side. It is written in C++ and uses the Informix Database Engine for data storage. LSU personnel are solely responsible for the maintenance and upgrades to the LCCS application, the UNIX system administrator functions and the Informix database administrator functions. In December 1998, the last Control Station (Kodiak) switched to the LCCS. The U.S. Coast Guard alone is now saving over $1.46M/year in combined billet and support savings as a result of LCCS deployment. Figure 3 shows a typical LCCS control suite. One suite controls two Loran-C chains. [1]

The U.S. Coast Guard is now contemplating the further consolidation of U.S. Control Stations. Fewer stations will produce additional personnel, support, and training savings.

LCCS software is also being modified to include automatic control features, trend analysis reports, and a diverse list of enhancements to improve LCCS functionality. LSU is also working with the U.S. Coast Guard Academy on an upgrade of the current LCCS Time Difference Controller (TDC). A Proportional Integral Derivative (PID) controller and Kalman filter controller will be tested and compared with the current LCCS TDC controller.

Figure 3: Control Station - AFTER

PCMS Sites - BEFORE

Austron 5000 Loran-C receivers and 1960's vintage PDP-8 computers, until recently, were used to monitor and control the broadcast of all Loran-C signals in North America. The 1970s vintage Austron 5000 was large, power-hungry, required use of hand-wound notch filters, a 35' whip antenna with large ground plane, and was difficult to support. The 1960s vintage PDP-8 octal computer with 16K of onboard memory and 0.8MhZ processing speed…need I say more? Figure 4 shows a typical PCMS equipment suite prior to FY00.


Figure 4: PCMS Site - BEFORE

PCMS Sites - AFTER

Since there were no commercially available replacement Loran monitor receivers that met the U.S. Coast Guard requirement to replace the Austron 5000/PDP-8 equipment, a Small Business Innovative Research (SBIR) contract with Locus, Inc. was used to design a new Loran receiver. The Locus LRS-IIID receiver is the outcome of that contract. In FY00 the Locus LRS-IIID receiver replaced the Austron 5000, PDP-8 octal computer, antenna system, and notch filters at all 29 PCMS sites located throughout North America. In addition, new equipment racks were provided and the Elgar 102 Uniterruptable Power Supplies (UPS) were replaced with a Clary DT800R UPS. There are many benefits realized with the new PCMS equipment, including:

- Reliability and availability have increased due to the increase in Mean Time Between Failure (MTBF) with this new technology.
- There has been a significant improvement in performance. The Locus LRS-IIID receiver is a multi-chain receiver that uses a patented linear averaging digital filter, which significantly reduces the cross rate interference (a major source of noise in Loran signals). The Locus LRS-IIID receiver provides additional data information and remote control capabilities, such as, automatic notch filters, remote spectrum scans, and a primary power loss alarm.
- The annual maintenance, support and training costs have decreased. The former PCMS equipment required a local technician be familiar with individual circuit boards and with programming the PDP-8 using dip switches. With the new PCMS equipment, the Lowest Repairable Unit (LRU) is the receiver itself. This dramatically simplifies the maintenance and troubleshooting required by the local technician. In addition, the need for lengthy formal PCMS training has been eliminated. Figure 5 shows the replacement PCMS equipment.

Now that a new multi-chain or "all in view" monitor receiver is installed in the field, the sky's the limit when it comes to controlling the North American Loran System. Currently, primary Loran control in the U.S. and Canada is based on far-field information obtained from two PCMS sites; a Primary "Alpha-1" site and a secondary "Alpha 2" site. With a receiver which can now track up to 11 Loran chains simultaneously installed, the LCCS TDC algorithm could be provided with many more inputs. More inputs equate to better timing stability of the transmitted Loran signals, which equates to better accuracy and repeatability. The U.S. Coast Guard is also investigating Time of Transmission (ToT) control and changing operations to allow master-independent navigation; i.e., not blinking all secondary stations in a Loran chain when the master station is out of tolerance or off-air.

Figure 5: PCMS Site - AFTER

Loran Stations - BEFORE

1960-1965 vintage Tube Type Transmitters (TTX) and 1976-1990 vintage Solid State Transmitters (SSX) are currently operating in the North American Loran System. 12 TTX and 17 SSX stations make up the inventory. 1970-1985 vintage timing and command and control equipment provides the critical timing and control signals to and from the transmitter system. The following Loran Station discussions will be divided into the Operations Room (timing/command & control equipment) and the transmitter system. Figure 6 shows typical Operations Room, TTX, and SSX equipment.

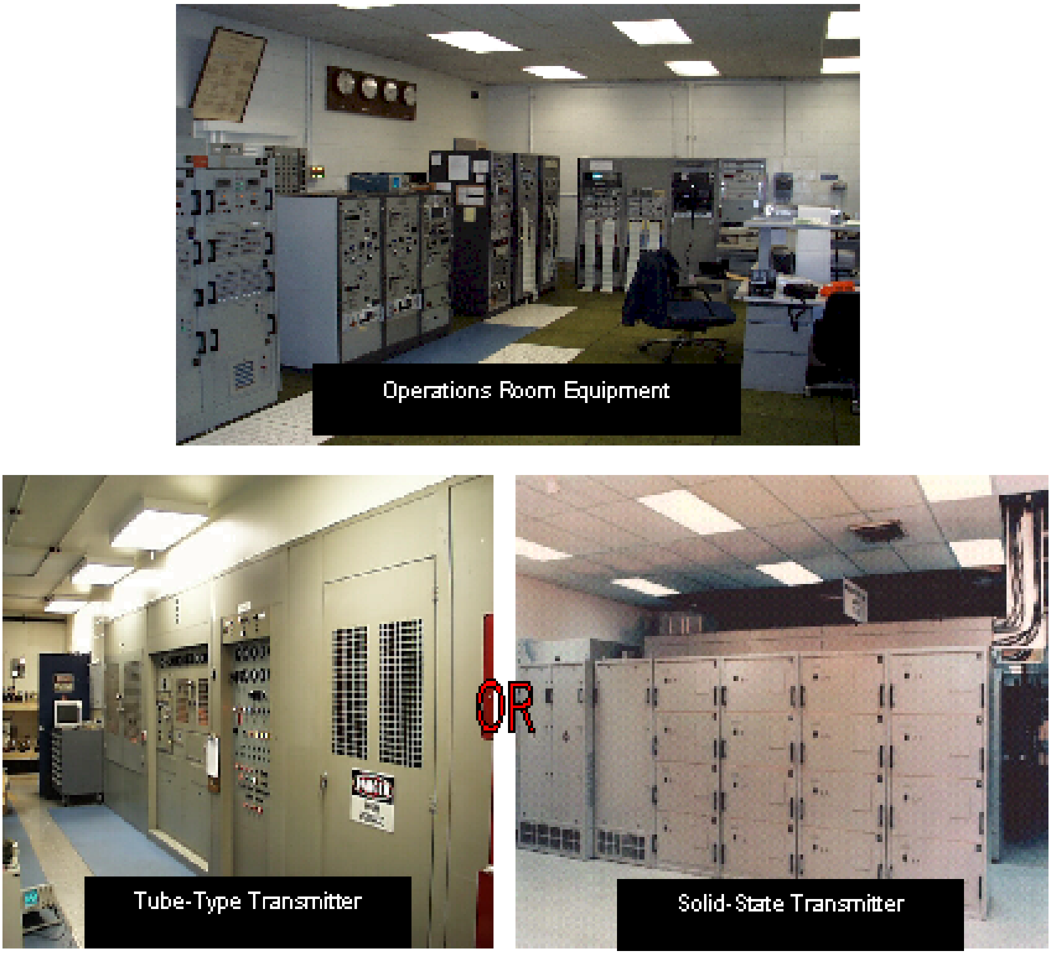

Figure 6: Operations Room, TTX, and SSX Equipment

<u>Loran Stations (Operations Room) - AFTER</u>

Numerous multi-year projects have been started within the last year at LSU to modernize the LORSTA component of the Loran-C system. In FY00 LSU began the replacement of the HP 5061A cesium beam oscillators with new state-of-the-art HP 5071A oscillators. These new oscillators, considered the “heartbeat” of the Loran system, provide a nine percent improvement to the inherent repeatability of Loran. Typical drift rates are on the order of seven nanoseconds per day versus approximately 200 nanoseconds per day with the older technology. To date, 80% of all North American LORSTAs are operating with the new oscillators. In addition, Time of Transmission Monitor (TTM) equipment has been installed at ten of eleven Master LORSTAs as a tool to better synchronize Loran to Universal Time Coordinated (UTC). Figure 7 shows newly installed LORSTA oscillators and TTM equipment.

Figure 7: New Cesium Beam Oscillators and TTM Equipment (LORSTA Havre, MT)

LSU completed the installation of the Automatic Blink System (ABS) in FY00. ABS provides a signal integrity indication to Loran-C receivers. Signal integrity involves notifying the user through either "blinking" a secondary LORSTA or taking a master LORSTA "off air". ABS will provide user notification of Time Difference (TD) signal aberrations in less than two seconds. This is especially important to aviation users because of their speed of travel. Figure 8 shows the ABS unit installed in a LORSTA Timer Rack [2].

Figure 8: Automatic Blink System

Work is well underway prototyping the Remote Automated Integrated Loran (RAIL) System. RAIL is currently being Field Tested at LORSTA Jupiter, FL; LORSTA George, WA; and LORSTA Seneca, NY. The RAIL system is a computer-based system that provides remote (via LCCS) and local command and control of LORSTA equipment. The RAIL computer consists of a 550 MHz Pentium III processor with various cards installed that provide analog/digital conversions, time interval counter functions, and that expand the number of RS-232 ports to 16. The operating system is Windows NT Version 4.0 and the RAIL software is written in Visual C++ with Roguewave Tools and Lab Windows/CVI Version 5.0 [3].

The RAIL system is being designed to integrate the various equipment installed at a LORSTA and automate as many functions as possible. By default, RAIL becomes the local command and control system for the LORSTA and the remote interface for LCCS. Here are some of the items being designed into the RAIL system:

- Replace the current Teletype communications system.
- Provide digital charts (replaces up to 14 mechanical, chart recorders).
- Replace the Local Site Operating Set (LSOS) Time Interval Counter.
- Interface with the recently installed Automatic Blink System.
- Interface with the Time of Transmission Monitor.
- Interface with the new Cesium Beam Oscillators.
- Interface with the new Locus Casualty Control receiver.
- Interface with and then replace the LSOS computer.

Examples of the prototype RAIL Graphical User Interface are shown in Figures 9 and 10. The RAIL Home Screen provides a complete picture of the current status of the LORSTA equipment. This screen contains all the data and alarms that must be monitored. A user can navigate to other screens that provide additional details [3].

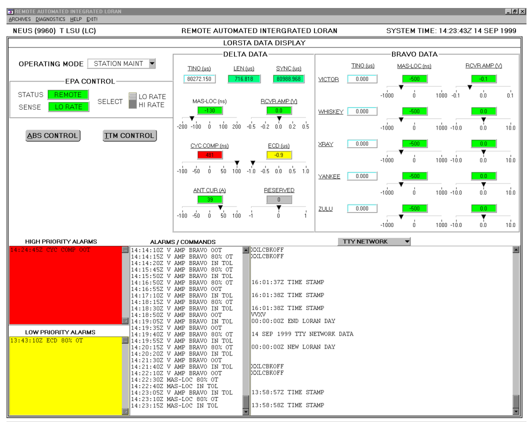

Figure 9: RAIL Home Screen

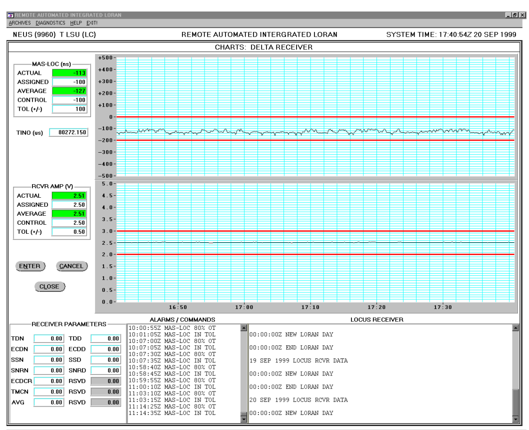

Figure 10: Example of RAIL Charts Screen

Final-form rack-mount RAIL hardware installations are starting at the U.S. SSX Stations in FY01. In conjunction with the installation of RAIL, the Austron 2000 Casualty Control receivers will be replaced with the same Locus LRS-IIID monitor receivers used at all PCMS sites. Up to 5 Austron 2000 receivers will be replaced with one Locus receiver. Figure 11 shows the Austron 2000 and Locus receivers.

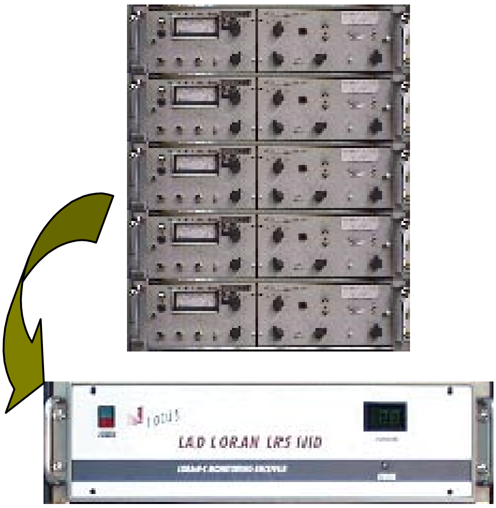

Figure 11: Austron 2000 and Locus LRS-IIID Casualty Control Receivers

Also in FY01, Operations Room UPS systems will begin to be installed at the U.S. SSX stations. In conjunction with this installation, existing backup DC power systems, associated hardware and wiring, and conversion of all electrical distribution in accordance with National Electric Code (NEC) standards will be accomplished. The Operations Room UPS systems will not only provide battery backup to all operations room equipment (including the Control Console at SSX Stations), but will provide vital line filtering functions. Figure 12 shows one UPS system. Transmitter UPS systems for selected SSX stations will also be procured and installed in FY01. The Field Test of a prototype transmitter UPS successfully ran a 32 Half Cycle Generator (HCG) SSX transmitter for 34 minutes on battery power!

Figure 12: APC UPS System

In FY01 a solicitation will be prepared to replace the aging suite of Timing and Frequency Equipment (TFE) at all North American LORSTAs. The new suite of equipment will replace the current TFE and will also include updated Automatic Blink System and Time of Transmission Monitor functionality, Loran data channel Pulse Position Modulation (PPM) capabilities (discussed later in this paper), and provide an interface to the RAIL System. Commercial Off The Shelf (COTS) equipment with extended support warranties will be used as much as possible.

As you can see, the Loran Station Operations Room is in the process of being completely replaced. What will the new Operations Room look like? Figure 13 shows what the new equipment may look like.

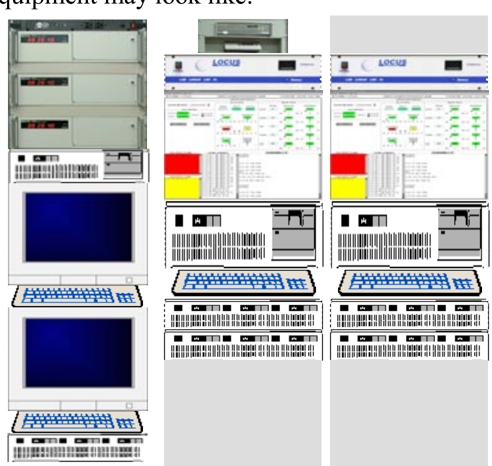

Figure 13: New TFE and RAIL Systems - Operations Room of the Future!

Loran Stations (Transmitter System) - AFTER

Not all of our efforts have been with LORSTA Operations Room modernization. For the past year, LSU and Coast Guard Headquarters procurement specialists, have been developing the solicitation for replacement transmitter systems. The primary thrust of this procurement is to replace the AN/FPN-44/45 Tube Type Transmitters at 11 USCG Loran Stations. The competitive procurement strategy, however, allows optional procurement of up to 31 transmitters. This strategy will permit the Coast Guard to take advantage of possible unexpectedly low transmitter costs, and/or budget windfalls, to upgrade the transmitters at some or all USCG and Canadian Loran Stations, as well as Coast Guard Training Center Petaluma and the LSU. State of the art transmitters at many or all Loran stations should enhance Loran Data Channel capability, equipment reliability, and remote control capability, thereby increasing the potential to un-staff all Loran stations. A copy of the transmitter replacement performance specification is available at:

www.uscg.mil/hq/lsu/webpage/LRP/xmtrspec.htm

In addition to transmitter replacements, Coast Guard Headquarters, CG Facilities Design & Construction Center Pacific, and LSU have been working together to design the Loran transmitter site of the future. Each site receiving new transmitter systems will require major facility modifications. In FY01 building designs will be completed for the first site to receive a new transmitter system and an effort will be completed to analyze and identify longevity or recapitalization issues for 24 USCG Loran-C transmitting antennae systems. Transmitter facility designs are centered around one major criterion - design the sites for unmanned operations. Figures 14 and 15 show a comparison between a typical manned LORSTA and what the unmanned Loran transmitting site of the future may look like.

Figure 14: A typical Loran Station

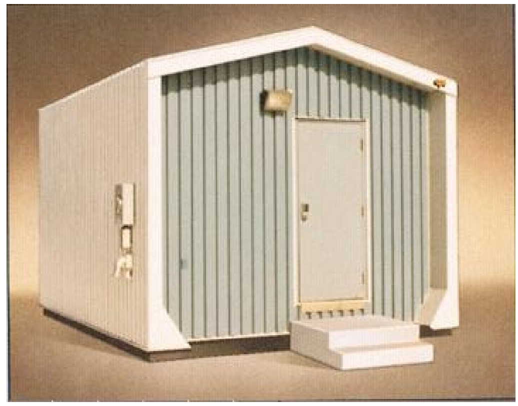

Figure 15: Possible Loran Station of the Future

A great success story in FY00 was the outcome of the Prototype Automated Loran Station (PALS) Field Test conducted at LORSTA Jupiter, FL. PALS developed and tested techniques, procedures, policies, equipment, systems, and infrastructure changes needed to reduce the operating costs of a Loran Station, as well as determining the capability of automating all routine functions. The primary goal of this project was to identify possible ways to reduce the operational costs while retaining required reliability and availability to the user.

In support of the PALS effort, several upgrades to station electronics were required. The following items were completed prior to the test:

(a) The Automatic Blink System was installed.

(b) LCCS Back-up Communications were installed.

(c) The RAIL prototype was installed.

(d) New HP 5071A cesium beam oscillators were installed.

(e) A prototype Operations Room UPS system was installed.

(f) A prototype transmitter UPS system was installed.

LORSTA Jupiter began the PALS field test on April 2, 2000. To date, the PALS field test has been a complete success. It has shown that a Loran Station with a solid state transmitter can be operated as an unmanned transmitter site, while continuing to meet the required 99.9% availability standard. The field test was originally scheduled for completion on October 31, 2000, but due to the overwhelming success, LORSTA Jupiter will continue in its present configuration with future plans to fully implement the automation in FY01. PALS Phase II expands testing of the PALS concept at additional Loran Stations in the Southeast U.S. (SEUS) Loran Chain: Loran Stations Grangeville, LA and Carolina Beach, NC. These stations will first need to receive Operations Room and Transmitter UPS systems and the RAIL System prior to the initiation of the PALS concept. Installation of this equipment into the LSU Master Configuration Baseline Equipment (MCBE) is also included with this phase of the project.

ENHANCED LORAN-C CAPABILITIES

The FAA has been directed to assess the continued development of Loran-C. The LSU, in cooperation with Stanford University, the Coast Guard Academy, and private FAA contractors is developing an enhanced Loran Communications Capability for GPS integrity and potentially for GPS correction data that meets the FAA's Wide Area Augmentation System (WAAS) requirements. Stanford University and FAA contractors are researching and developing several different modulation schemes: Pulse Position Modulation (PPM), Intrapulse Frequency Modulation (IFM), and Supernumary (Interpulse) Modulation (SIM). As part of LSU's Timing and Frequency Equipment replacement project, a performance specification has been completed to procure a TFE suite that is capable of providing required legacy timing signals, in addition to the digital modulation information necessary for the PPM, IFM, and SIM schemes. In conjunction with contractors and Stanford University, LSU will cooperate in the evaluation of viable data formats and technology to permit the modulation and demodulation of data messages transmitted via modulation of Loran signal pulse(s). Analysis of the effects of the various modulation schemes on cycle compensation, Envelope-to-Cycle Difference (ECD), and other parameters will be conducted. Also, the effects on legacy receivers will be analyzed. Live flight tests in Alaska using the Gulf of Alaska 7960 Loran-C rate are scheduled in August 2001. In addition, the FAA and LSU will provide funds to the Coast Guard Academy to support continued development of a digital multi-chain navigation receiver. Figure 16 depicts how Loran-C may be integrated into the FAA's Wide Area Augmentation System (WAAS).

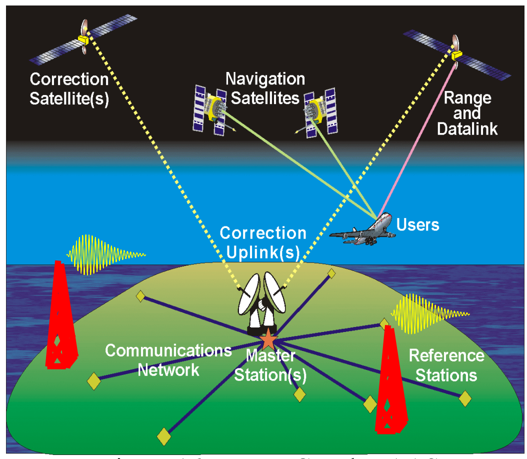

Figure 16: Loran-C and WAAS

THE LORAN-C SYSTEM OF THE FUTURE…THE SKY'S THE LIMIT!

As you have just read, the North American Loran-C System is currently undergoing a complete face-lift. The Loran Recapitalization Project is paving the way to improve the availability, continuity, integrity, and accuracy of the world's premier radionavigation system.

REFERENCES

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3. LCDR Jim Koermer, "Modernizing the Loran-C System for the New Millennium," U.S. Coast Guard Radionavigation Bulletin, Spring/Summer Issue 2000, Number 34.

BIOGRAPHY

Alan N. Arsenault is a Lieutenant Commander in the United States Coast Guard and is presently assigned as the Chief of Engineering at the Coast Guard Loran Support Unit in Wildwood, New Jersey. In addition, he is assigned as the Project Manager for the Federal Aviation Administration sponsored Loran Recapitalization Project. He has completed tours as the Executive Officer at the Loran Support Unit, as Project Manager and Assistant Branch Chief in the Loran-C Branch at the Coast Guard Electronics Engineering Center (EECEN), as Project Officer in the Electronics Technology Division at Coast Guard Headquarters, and as Operations, Communications, and Electronics Material Officer aboard the U.S. Coast Guard Cutter BRAMBLE stationed in Port Huron, Michigan. LCDR Arsenault received a BSEE degree from the U.S. Coast Guard Academy in 1988 and a MSEE degree, specializing in communications and digital signal processing, from the University of New Hampshire in 1994.

ACKNOWLEDGEMENTS

I would like to thank all of the hard working engineers and technicians, military, civilian, and contractor, for all of their hard work getting the LRP initiative off the ground. Thanks to our friends at G-SCE, G-SEC, G-ACS, G-OPN, G-WTT, FAA, NAVCEN, ELC, FD&CC Pacific, TRACEN Petaluma, CGA, MLCP, MLCA, District Seventeen, various ESUs/ESDs, all LORSTA personnel, and the Canadian Coast Guard, FY00 was a very busy and successful year.

LCDR Alan Arsenault