The Game Plan for Loran-C Modernization

2003 Conference of the International Loran Association, Boulder, Colorado

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Abstract

Since 1997, the Federal Aviation Administration (FAA), the U. S. Coast Guard (USCG), Academia, and Industry have established a close teaming relationship to modernize the Loran-C infrastructure and to improve the performance of the service to both timing and navigation users. As a result of this team's efforts, nearly every component of the Loran system has been redesigned, and many of the modernized components have already been installed. The a major stage of the system modernization required the new Timing and Frequency Equipment (TFE) to be integrated with the new Solid State Transmitter (nSSX), which was developed to replace the tube-type transmitters at eleven Loran stations. On August 19, 2003, members of the Loran Support Unit and the Navigation Center successfully performed the first on-air test of the entire integrated system in New Jersey. Then on October 23, 2003, a significant milestone was reached when the Loran station at George, WA, began broadcasting its operational signal from its newly installed solid-state transmitter. Now that the rollout of the modernized system is at hand, the implementation strategy had to be developed in order to properly coordinate the many aspects and organizations involved.

This paper provides the strategy, the priorities, the goals, and the anticipated effects of the recapitalization work in the future. The paper names the order in which the U. S. Loran stations are planned to receive the modernized Loran equipment. The paper also surveys other components of Loran modernization including a Differential-Loran proof of concept.

Introduction

When the U. S. Government brought the Global Positioning System (GPS) to full operational capability, nonmilitary timing and navigation users were given access to the Standard Positioning Service (SPS), which provided a global source of information for timing, positioning, and navigation applications.

Several organizations recognized the potential and the advantages of using this all-weather, global, timing and positioning service to improve the safety and efficiency of a multitude of civilian applications, including transportation by sea, land, and air. The problem was that, by itself, the SPS delivered neither the accuracy nor the integrity necessary for many civilian transportation applications. To improve upon the SPS, several organizations, including the USCG and the FAA, developed systems to provide GPS augmentation services (i.e., DGPS and WAAS) for surface and air modes of transportation. These augmentations provide services that are available in defined coverage areas.

When the U. S. Government discontinued the use of Selective Availability (SA) in May 2000, the basic SPS improved significantly, and many noncritical applications are now enabled using SPS alone. Currently, the U. S. Government is further improving the SPS by adding two more signals (for a total of three signals) for civilian uses. This improved service will be available worldwide, not only where DGPS service exists. However, the need for differential GPS services will remain for many critical applications, including safety-of-life transportation uses.

During the development of GPS augmentation services for transportation use, the U. S. Government investigated the vulnerability of the SPS to intentional and unintentional interference. In 1998, the Volpe National Transportation Systems Center began a study into the vulnerability of the national transportation infrastructure that relies upon the SPS. This study looked into the characteristics of the SPS, its susceptibility to intentional and unintentional interference, and the consequences of a loss of the SPS on timing and transportation applications. The study described several technologies and techniques available or under development that could be used to mitigate the consequences of SPS loss in timing and transportation applications. The Department of Transportation released this study to the public on September 10, 2001. One of the mitigating technologies identified was Loran-C. Loran-C was identified as having the potential to mitigate SPS-vulnerability concerns for timing users as well as civilian transportation users for all modes of travel.

The Potential of Loran-C

There is little disagreement that the safety and/or efficiency of civilian timing and transportation applications can be well served by the SPS. The need for a backup comes where the security of the application using the SPS is also of concern. Timing applications such as banking and telecommunications systems, and safety-of-life transportation applications such as maritime harbor entrance and approach and aviation nonprecision approach, have security concerns.

Loran-C has the potential of providing a backup to the SPS in the event of interference. The Loran-C service, like the SPS, is applicable to many timing applications as well as to multimodal transportation users. For the most part, the U. S. Coast Guard is currently operating the Loran-C system where there is the majority of concern over vulnerability and consequences; i.e., in the continental United States (CONUS) and Alaska.

Loran-C and the SPS are complementary to each other; their characteristics, and therefore their strengths and weaknesses, are very different. For example, where Loran-C is affected by weather, the SPS is not. Conversely, where the SPS is a low-power system, Loran-C operates at a relatively high power. The two systems are very widely separated in the frequency spectrum,

with the SPS broadcasting in bands between 1.0 GHz and 2.0 GHz and Loran-C broadcasting around 100 kHz.
The existing Loran-C system was first made available to nonmilitary users in the mid 1970's, and has been operating ever since. Consequently, much of the Loran-C infrastructure is in need of replacement and much of the design would significantly benefit from modern technology. The Coast Guard and the FAA are working together with several other public and private organizations to modernize the Loran-C system. The modernization efforts will enable the operation of Loran-C into the future by recapitalizing virtually every aspect of the infrastructure and making several improvements along with the recapitalization.

Enhanced Loran-C

There are several initiatives associated with the development of Enhanced Loran that will result in changes in the broadcast signal, methods of control, and methods of communications with the users. We will attempt to describe some of these initiatives here for context only. While much of these changes are still under development, the Loran Evaluation Team has identified a number of significant options, and there may be value in sharing them. Please note that the information presented in this section is pre-decisional and not fully detailed. When additional options are identified, and further developed, there will come the need to document and promulgate the changes to other stakeholders. The "Specification of the Loran-C Signal" is the traditional reference document for this purpose.

Antenna Technology: The Coast Guard Academy, the FAA Technical Center, and others are investigating different antenna techniques to mitigate the effects of precipitation static and antenna orientation on the received Loran signal. This is a significant challenge and is only one aspect of the overall need to make the Loran signal less affected by weather and other limiting factors.

Blink. There is an elevated concern over the integrity of the Loran-C system. Methods are being considered to both detect and communicate the fact that the user is receiving hazardously misleading information. The traditional methods of monitoring the signal are being reevaluated (e.g., the future role of system-area monitor (SAM) sites is being examined). The traditional methods of blinking the signal (i.e., turning off the master signal or repetitively turning off and on to alert users) may be redesigned.

Communications Over the Loran Signal. Methods of using the Loran-C signal to broadcast information to enhance system accuracy and integrity are being considered. One proposed method is to add a ninth pulse to all transmissions, both masters (between the eighth and "master 9th pulse") and secondaries (following the eighth pulse), and to modulate this pulse to carry information. There are other proposed and operational methodologies also under consideration at this time.

Differential Loran. The concept of differential Loran is being revisited to improve accuracy for both navigation and timing users. Currently, the Coast Guard Loran Support Unit, Peterson Integrated Technologies, and U.S. Army Corps of Engineers (USACE) have partnered in a localized real-time feasibility test of this concept. Depending upon the results of these and other tests, and depending upon decisions made on whether the Loran-C system should be expanded to include differential Loran-C, this technique will have to be adequately described to the user segment. In addition, the methods to gather spatial and temporal corrections would also have to be adequately described. If expanded nationwide through interagency partnerships, the spatial corrections could be made available to a broad user base.

Early Skywave. The effects of early skywave on the integrity of Loran-C in the Continental U. S. are being studied. There are different options being considered to mitigate this concern. One proposal is to quicken the rise time of the pulse and/or make other signal-structure changes. Another proposal is to frequency-modulate one pulse to perform a channel-sounding technique. There may be other methodologies that are developed since investigation of this issue is still in the early stages.

Time of Transmission (TOT) Control. The new timing and frequency equipment will give the Loran-C system the option of TOT control, moving away from the traditional U.S. method of system-area monitors (SAM) for control and monitoring of a chain. Moving to TOT control would enable the use of "all-in-view" receivers no longer constrained by Loran-chain geometry. In addition, the timing community will receive much tighter control of the Loran signal to Universal Time Coordinated (UTC). On the other hand, if the role of Loran-C is elevated to that of an integrated back-up to GPS-based timing and navigation systems, Loran-C may be required to guarantee the integrity of the signal as received by the user. If this becomes the case, the role of SAM sites may need to be redefined.

Calibration of the Loran System. There may be opportunities to more tightly calibrate the Loran system using the Standard Positioning System and its augmentations. When the original system was established, the best methods to calibrate chain timing was using a "hot clock" maintained at the U. S. Naval Observatory and to fly it to each station in a chain, without knowledge of the effects of motion and temperature on the real time of the clock. This methodology is described in the 1994 Signal Specifications. In addition, antenna locations were determined by traditional survey methods. Today, the SPS is available and it may become necessary or desirable to develop a new method of Loran calibration and to recalibrate the Loran chains with respect to both timing and positioning.

Loran Equipment Recapitalization: The Loran Recapitalization Project, the last Loran-modernization initiative to be surveyed in this paper, will be addressed in more detail.

Loran Recapitalization Project

Since the publication of the Loran Signal Specifications in 1994, virtually every component in the entire Loran-C system has been redesigned. At this point, we have several new sub-systems:

(1) The new solid-state transmitter (nSSX), manufactured by Megapulse, Inc., in Massachusetts to replace the vacuum-tube transmitters AN/FPN-42, 44, and 45;

(2) The new Timing and Frequency Equipment (TFE), manufactured by Timing Solutions, Inc., in Boulder, Colorado;

(3) The new control and monitoring equipment developed at the Loran Support Unit (LSU) in New Jersey and at Locus, Inc., in Madison, Wisconsin. For local monitoring and control, this equipment consists of the Remote Automated Integrated Loran (RAIL) and the Locus Receiver Timing Monitor Status System. For remote monitoring and control from the Coast Guard's Navigation Center (NAVCEN) this equipment consists of the Loran Consolidated Control System (LCCS) and the Primary Chain Monitoring Set (PCMS).

All these new sub-systems, produced by different entities in different locations, were recently integrated with each other and with existing sub-systems to work together as an overall system. Personnel from the Coast Guard's Loran Support Unit and Navigation Center first successfully tested this overall system on August 19, 2003. With this test, we needed to determine the order of conversion of the Loran stations to facilitate planning and coordination. This work will follow two separate, somewhat independent paths.

(1) <u>New-SSX Loran Station</u>: We will convert each of the eleven USCG Loran stations currently operating vacuum-tube transmitters by constructing a new transmitter building, manufacturing a new solid-state transmitter (New-SSX), installing the New-SSX in the newly constructed transmitter building, and installing the new Timing and Frequency Equipment (TFE) in the Loran station's operations room. All these stations have already received the new RAIL equipment, new cesium time standards, and several other modernized components. It is clear that converting these eleven stations will require a significant investment and the commitment of precious resources, and will require the construction of new buildings in remote locations and the manufacture of major electronics equipment. The schedule we propose is admittedly ambitious and is completely dependent upon the funding received for the project.

(2) <u>Legacy-SSX Loran Station</u>: We will convert each of the thirteen USCG Loran stations currently operating the AN/FPN-64 solid-state transmitter (referred to as the "Legacy-SSX"). These stations will be modernized by installation of the new TFE in the operations room and by interfacing this equipment to the existing transmitter. Testing of this new control equipment with the Legacy-SSX has not yet been completed. We are expecting this testing to be completed in the near future. LSU Wildwood completed the site-surveys at the Legacy-SSX stations in the Great Lakes Loran Chain.

Our Macro Schedule lays out the timeframe to modernize each of the twenty-four Loran transmitting stations that are operated by the U. S. Coast Guard, both for the New-SSX Loran stations and for the Legacy-SSX stations. We are just beginning down these paths now, and we expect both obstacles and opportunities to present themselves as we move forward. We also will have to determine the details of the modernization of the five Loran stations being operated by the Canadian government and work these decisions into the schedule. At this time, our best schedule estimates are as follows:

(1) <u>First Modernized Loran Station</u>: The first Loran station to be converted was Loran Station George, WA (U. S. West Coast 9940-W and Canadian West Coast 5990-Y). The conversion from the vacuum-tube transmitter to the New-SSX was completed on Thursday, October 23, 2003, when the station began operational broadcasts using the New-SSX.

Unfortunately, on October 29, 2003, the new electronics system suffered a major casualty and the station had to be rolled back to the vacuum-tube transmitter while the cause of the casualty is being investigated.

There are several advantages associated with choosing this station as the first one to convert. First, we gain the ability for the signal to be monitored by the National Institute of Standards and Technology (NIST) and Timing Solutions Corporation (TSC) in Colorado. Next, we gain the opportunity to involve the Canadian government in the modernization program. And finally, we gain the ability to decommission the AN/FPN-45 vacuum-tube transmitter and use its salvageable parts at other Loran stations using vacuum-tube transmitters until their future conversion to the New-SSX.

Figure 1 depicts the predicted coverage of the Lorsta George signal greater than 45 dB referenced to 1 micro-Volt/meter. [Coverage diagram is courtesy of Dr. Benjamin Peterson of Peterson Integrated Geopositioning.]

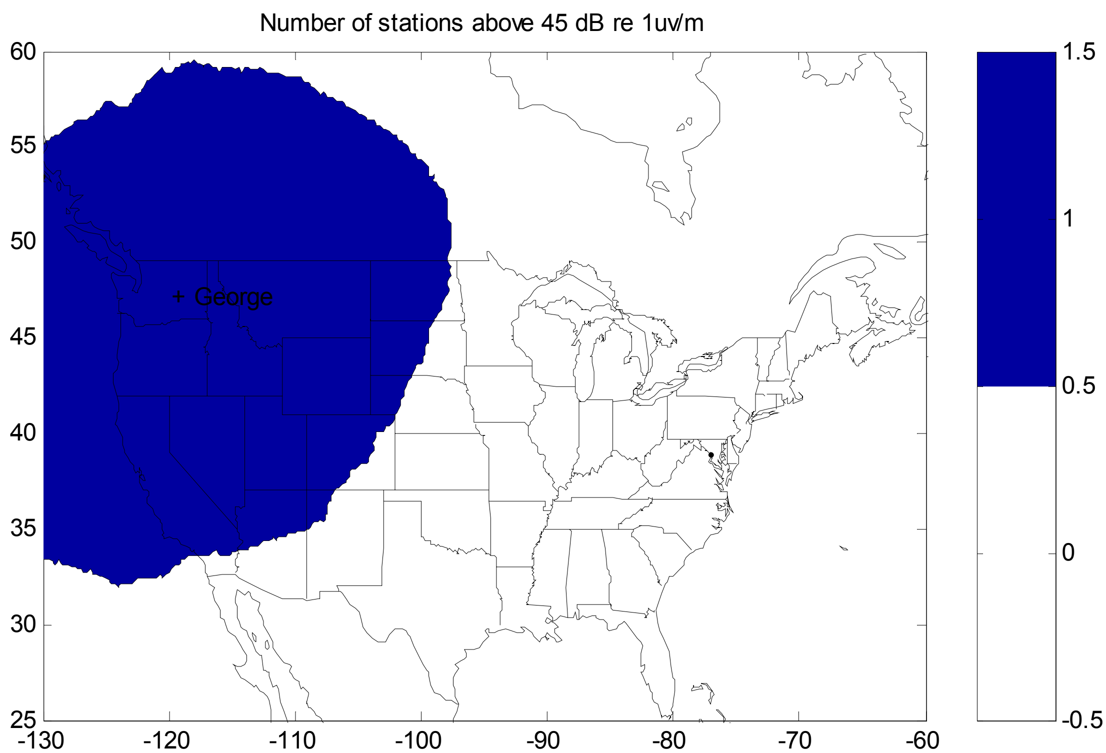

Figure 1: Coverage of Lorsta George (illustration only)

(2) First Geographical Area Covered: The first major geographical area that will be covered with a new Loran triad will be the Great Lakes and the multimodal transportation infrastructures in both the United States and Canada. Establishing this triad on the Great Lakes will require conversion of one tube-type Loran Station (Lorsta Dana, IN) and the conversion of two Legacy-SSX Loran station (Lorsta Baudette, MN, and Lorsta Seneca, NY). Thus both installations paths are involved in this plan.

At this time, the construction of the new transmitter building at Lorsta Dana has commenced. The New-SSX for Lorsta Dana has already been built and successfully tested at the factory. New versions of three suites of software have been written and will soon be tested and site surveys have been completed at Lorstas Baudette and Seneca by LSU.

An additional benefit of this approach is that when Lorsta Seneca is converted, its modernized signal will be able to be monitored by the U. S. Naval Observatory (USNO) and analyzed for timing applications.

Figure 2 shows the predicted coverage of Lorstas George, Dana, Baudette, and Seneca. The colors indicate the number of stations in a given location where the users can expect to receive signals with strengths greater than 45 dB referenced to 1 micro-Volt/meter. [Coverage diagram is courtesy of Dr. Benjamin Peterson of Peterson Integrated Geopositioning.]

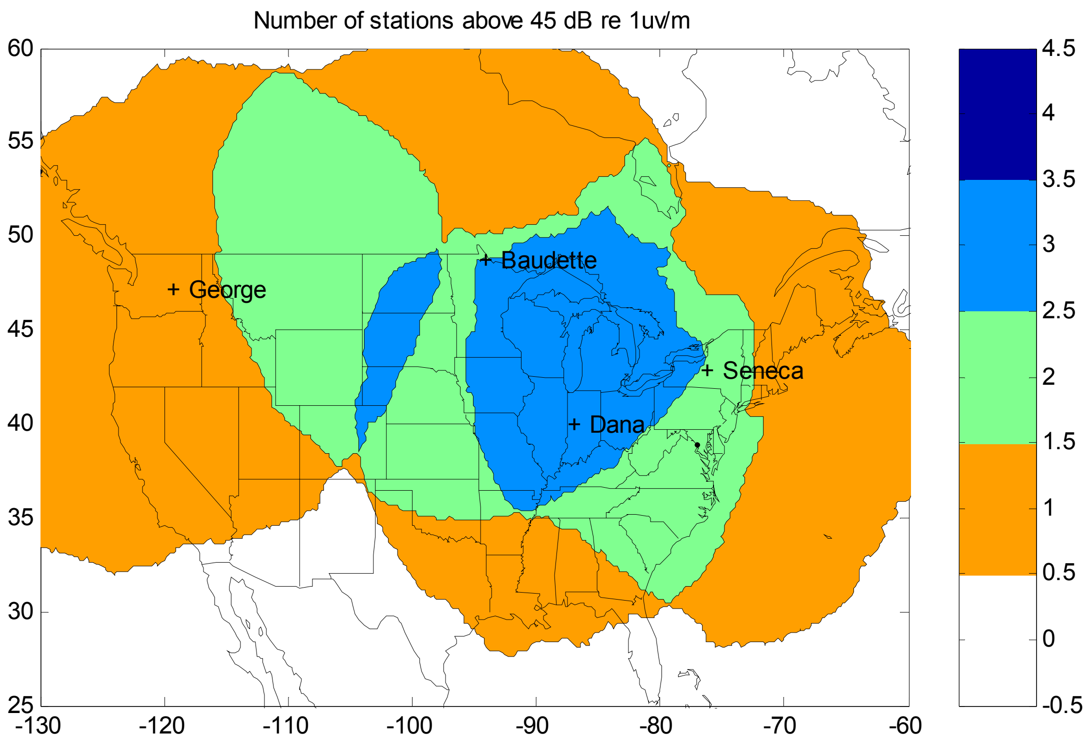

Figure 2: Combined coverage of Lorstas George, Baudette, Dana, and Seneca

(3) First Modernized Loran Chain: The first Loran chain to be converted will be the Great Lakes (GLKS) Chain, Group Repetition Interval (GRI) 8970. The site surveys for the conversions of Lorstas Malone and Boise City have been completed by LSU. (It should be noted that although the concept of chain operation no longer be relevant for an "all-in-view" Loran system, continuation of the chain concept as a group of stations sharing the same GRI is expected to continue).

This new improved GLKS chain will provide much improved and expanded services to a major portion of the multimodal transportation infrastructures, including major inland waterways, of the United States and Canada. It is also significant that by taking this tact, we are able to establish early in the process the option of switching the control philosophy of an entire Loran chain from system-area monitor (SAM) control to time-of-transmission (TOT) control.

While the decision to switch control methodologies has not yet been made officially, and there are many other associated items to be addressed prior to such a switch, we believe it is important to present the TOT option to decision makers as early as possible. It is also important to note that before conversion of the GLKS chain to TOT control, the new version of the Loran Control and Communications System (New-LCCS) will have to be completed and fielded. The New-LCCS will give the Navigation Center access to the new TOT data to allow TOT control of all chains. The New-LCCS will also give the Navigation Center the ability to control a dual-rated station using different control methodologies for the station's two rates. If the decision is made for a chain-by-chain conversion to TOT control, this ability will be important as modernization progresses and individual modernized stations may be broadcasting on one rate converted to TOT control and on another rate still under SAM control.

Figure 3 depicts the predicted coverage of Lorstas George, Dana, Baudette, Seneca, Malone, and Boise City. The colors indicate the number of stations in a given location where the users can expect to receive signals with strengths greater than 45 dB referenced to 1 micro-Volt/meter. This graph shows that after converting the first six Loran stations, users throughout the Continental U. S. will be able to receive Loran signals from at least one modernized Lorsta. [Coverage diagram is courtesy of Dr. Benjamin Peterson of Peterson Integrated Geopositioning.]

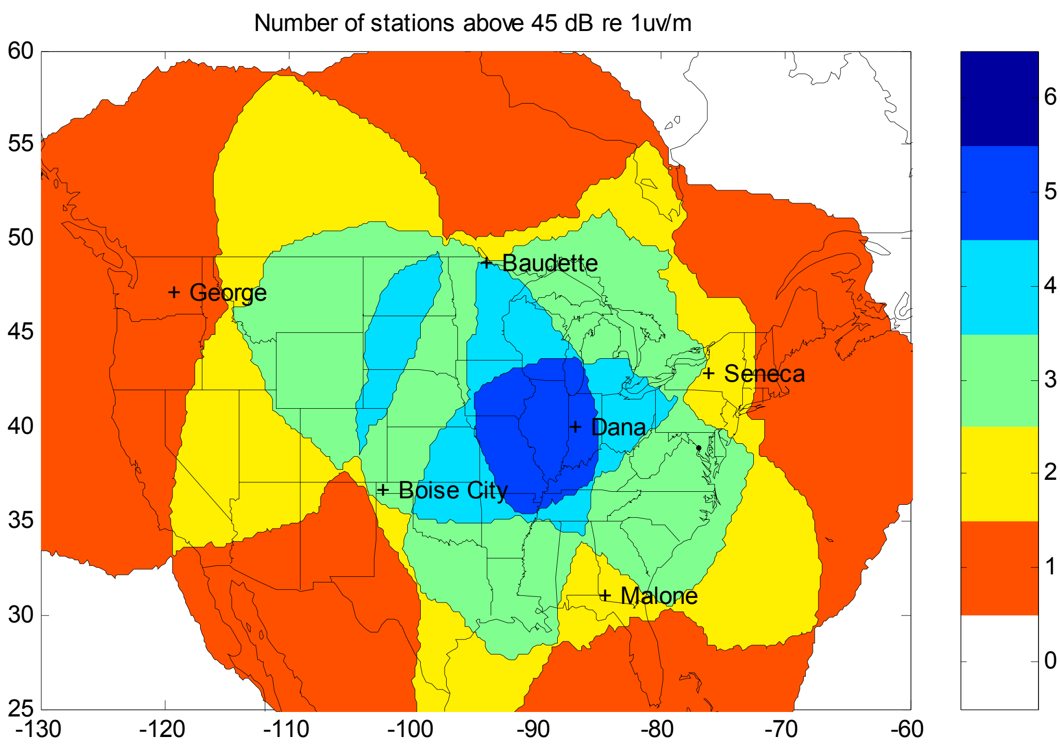

Figure 3: Combined coverage of Lorstas George and entire GLKS chain.

(4) Chain-by-Chain Conversion: Although it is difficult to perform a perfect chain-by-chain modernization, our modernization efforts have been scheduled to support conversion of Loran chains to be converted to TOT in the following order: Great Lakes (GLKS), U. S. West Coast (USWC), Northeast U. S. (NEUS), Southeast U. S. (SEUS), South Central U. S. (SOCUS), North Central U. S. (NOCUS), Gulf of Alaska (GOA), North Pacific (NORPAC). The ability of the Loran team to accomplish this work on an aggressive schedule, especially for Alaska, is dependent upon the continued substantial funding of the Loran Recapitalization Project. Additionally, while we have so far only determined the schedule for modernization of Loran stations operated by the U. S. Government, it will also be important to establish the intent of the Canadian government and incorporate their expectations into our overall plan to achieve a truly enhanced North American Loran System.

Conclusion

On October 23, 2003, the Loran Recapitalization Project passed an important milestone: the operational broadcast from the new solid-state transmitter at Lorsta George. This achievement marked the culmination of years of design, manufacturing, construction, and integration of the several components of the recapitalized Loran system. This endeavor also served as a means to strengthen the already well established Government, Academic, and Industry teamwork that will be necessary to achieve our overall goals.

Unfortunately, on October 29, 2003, the project encountered a setback when a major electronics-system casualty occurred and forced the station to be reverted to the vacuum-tube transmitter. At the time of this paper, the team is working together to determine the cause and solution of the current problems. We feel confident this current challenge will be overcome and we will be able to continue on our important mission.

Current plans include the conversion of the Great Lakes (GLKS) Loran chain, the probable switch of the GLKS chain to time-of-transmission control, the chain-by-chain conversion of the remainder of CONUS Loran stations, and the recapitalization of Alaskan Loran stations.

Concurrently with the recapitalization of the Loran infrastructure, the team is also conducting feasibility tests of differential-Loran techniques to improve the accuracy of the system. Depending upon the results, follow-on work would have to be performed to design and implement an operational realization of differential Loran nationwide.

With these enhancements the Loran-C system will be positioned to offer a significantly improved service to the timing and multimodal transportation user communities. Critical SPS-based applications will have an independent, complementary timing, positioning, and navigation service to help them alleviate security concerns. By improving the security aspect, Loran-C will be able to help users fully exploit the advantages in safety and efficiency that SPS offers their applications and the nation.

Biographies

CDR John J. Macaluso, USCG is currently serving as the Commanding Officer of the Coast Guard Loran Support Unit in Wildwood, New Jersey. He graduated from the U. S. Coast Guard Academy in New London, Connecticut, in 1983 and received a Bachelor of Science degree in Electrical Engineering. In 1988, he graduated from The Pennsylvania State University with a Master of Science degree in Electrical Engineering. From 1988 to 1991, he served at the Electronics Engineering Center in Wildwood, New Jersey, as the Loran Receivers Section Chief. From 1991 to 1993 he served in Italy as the Coordinator of Chain Operations for the Mediterranean Sea Loran-C chain. From 1998 to 2000, he served in the Office of the Secretary of Transportation Radionavigation Policy Staff as the Coast Guard Liaison Officer and as the Chairman of the Policy and Implementation Team for the Nationwide Differential Global Positioning System.

Mitch Narins received the Bachelor of Engineering (Electrical Engineering) from the City College of New York in 1973 and the Master of Engineering Administration Degree from the George Washington University in 1989. He is currently the Senior System Engineer in the FAA's Navigation Integrated Product Team and is responsible for the ongoing evaluation of Loran-C. In his twenty-seven year career with the US Government, Mr. Narins has served the FAA as the Program Manager for Air-to-Ground Communications, the Program Manager for ATC Terminal Automation, and the Program Manager for Systems Engineering and Integration, the Navel Electronic Systems Command as the Head of the Electronic Warfare and Terminal Communication Branches, the Federal Communications Commission's Field Operations Bureau as a standards and facilities engineer.

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