Supporting the Enhanced Loran-C System

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ABSTRACT

"The real world is inescapably uncertain; clinging to the illusion of certainty [will] increase the vulnerability to unfortunate surprises."

Henry Mintzberg and Fances Westly, "Decision Making: Its Not What You Think", *MIT Sloan Management Review*, Spring 2001

The ability to heal is necessary for any organism to survive. The same is true of complex engineering systems. As the United States Coast Guard, in conjunction with several other government and private sector entities, develops and deploys the enhanced Loran system the ability for the system to "heal" itself will become vitally important.

The current support system is being forced to change and adapt as new equipment is added to the system. This change has reached a point of critical mass and it is threatening to continue unfettered. Rather than allowing the system to be driven by independent events, it is important that strategic decisions are made which will drive the future support of the system.

The current support system must be analyzed and a future support system developed. The future system must meet the requirements set forth for enhanced Loran while meeting management's strategic goals.

This paper offers more questions than answers as it presents a discussion on the future support of the enhanced Loran system. It includes a brief review of the requirements, the current system, and anticipated changes to the system. Historical and future strategy in the Loran system is also presented in a general overview. Ending the paper is a suggested road map to a decision on the future support of the Loran system.

BACKGROUND

The U.S. Loran System (the "system") consists of 24 Loran Stations, 24 Primary Chain Monitor Sites, and 2 Control Stations. This system, in concert with the Canadian Loran system, provides radionavigation coverage to the entire United States. System operations are conducted by the U.S. Coast Guard (USCG) Navigation Center (NAVCEN) while configuration management, technical support and engineering development responsibilities reside at the Loran Support Unit (LSU).

Beginning in 1997, a project was started, funded by the Federal Aviation Administration (FAA), to recapitalize the system with state-of-the-art electronic equipment. Enhanced Loran had its beginnings in 2002 as part of independent studies on the feasibility of improving the system for navigation, timing and frequency user communities. E-Loran has evolved into a group of concepts and ideas in new equipment, policy, operational procedures, support and configuration/knowledge management with the goal to improve Loran navigation and timing accuracy. It is being designed as a multi-mode radionavigation and timing system to backup GPS.

The current fielding of new sub-systems and the movement toward the e-Loran system is mandating a review and update of the current support policy under the purview of today's budgetary and personnel limitations. The use of commercial-off-the-shelf (COTS) equipment and their warranties is also changing the support landscape necessitating a change to current policy and procedure.

REQUIREMENTS

The current system is being operated in the short term, while being evaluated for the long term. Two groups have been formed and are actively studying the viability of using e-Loran as a backup to GPS. These are the Loran Integrity Performance Panel (LORIPP) and the Loran Accuracy Performance Panel (LORAPP) which set requirements that the future system must meet. See Table 1, Table 2, Table 3, and Table 4 below which outline the requirements.

Table 1

Aviation Accuracy Requirements	
Accuracy (target)	307 meters
Monitor Limit (target)	556 meters
Integrity	10^{-7}/hour
Time-to-alert	10 seconds
Availability (minimum)	99.9%
Availability (target)	99.99%
Continuity (minimum)	99.9%
Continuity (target)	99.99%
(Source: FAA Loran Evaluation Report, June 2002)	

Table 2

Maritime Backup System Accuracy Requirements	
Accuracy (backup)	20 meters, 95%
Monitor/Alert Limit (backup)	50 meters
Integrity (target)	3×10^{-5}
Time-to-alert	10 seconds
Availability (minimum)	99.7%
Continuity (minimum)	99.85% over 3 hrs

Table 3

Timing and Frequency Requirements	
Frequency Accuracy (Target)	1×10^{-13}
Frequency Accuracy (Minimum)	1×10^{-12}
Antenna	Indoor/Outdoor
Integrity Data	Use/No Use Flag
Higher Accuracy Time of Day	Year, DOY, Sec, Leap Sec
Timing Accuracy (User)	<100ns
Differential Correction	Daily Correction
Ancillary Data	Leap Second Notification
(Requirements and Specification Sources: DOT Task Force, T1X1 letter of Oct 2002, TSC – LORAPP)	

From the support aspect, the most significant requirement is the availability minimum of 99.9% and the system availability target of 99.99%. This is a very high standard of performance; therefore, the support network will be critical to enabling the system to perform at these levels.

Table 4

Maritime Primary/Redundant Specifications	
Accuracy (Target)	10 meters, 95%
Accuracy (threshold)	20 meters, 95%
Monitor/Alarm Limit (target)	20 meters
Monitor/Alarm Limit (threshold)	50 meters
Time-to-alert	10 seconds
Availability (threshold)	99.7%
Availability (target/VTS)	99.9%
Continuity (threshold)	99.85% over 3hrs
Continuity (target)	99.97% over 3hrs
(Sources: FRP, DOT Task Force, TASC DGPS Mission Needs Analysis: Harbor Entrance and Approach, IMO Resolutions A.815(19), LORAPP 3)	

NEW SYSTEMS

E-Loran may be several years away, but the systems and equipment to allow for it are being put into place now. The LSU in partnership with the FAA and NAVCEN are developing and fielding a new breed of sub-systems. Table 5, below, provides an overview of the new systems being developed and installed, and the systems they have or will replace.

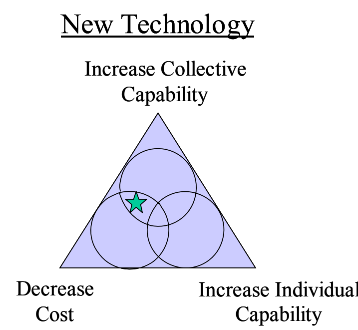

Fig. 1

Figure 1, above, depicts the three reasons organizations implement new technology. Most organizations attempt to focus the impact of a technology upgrade or refresh in one of the three areas: Increasing Individual Capability, Increasing Collective Capability, or Decreasing Cost. The Loran Recapitalization Project (LRP) has focused on decreasing total ownership cost of the system while increasing the collective capability of the system. Though it is difficult to hit two targets at once, the technology being fielded has the ability to meet expectations in both areas.

Table 5

Loran Recapitalization Project		
New Equipment	Replaced Equipment	Project Status
New Solid State Transmitter	Tube Type Transmitter (1970's)	1 of 11 complete
Timing and Frequency Equipment	FPN-41 and FPN-46 Timers (1970's)	1 of 24 complete
Remote Automated Integrated Loran	LSOS (1984-85)	Completed
Equipment Control Monitor	LSOS (1984-85)	1 of 24 complete
Ops Room UPS	N/A	18 of 24 complete
Transmitter UPS	N/A	14 of 24
Switch Cabinet Replacement	Old Switch Cabinet (1970's)	Completed
Transmitter Control Console	PATCO/TOPCO (1970's)	Initiated
New LCCS	LCCS (1997)	Initiated
Frequency Standard Set	Hewlitt Packard 5061 (1975)	Completed
Locus Receivers	Austron 2000C Loran-C (1975)	Completed

CURRENT SUPPORT SYSTEM

The current support system is based upon the standard three-tier model used throughout the USCG. Figure 2, below, shows the responsible party and their level of support.

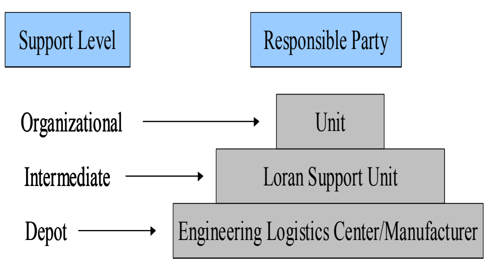

Fig. 2

The current support system meets the operational requirements as set forth. However, the current support system is fragmented and unclear at all levels. A comprehensive support system and policy must be developed to ensure the continued viability of the legacy equipment as well as the new systems.

Organizational Support

Organizational level support is provided by the Lorsta. They are responsible for performing preventive maintenance, corrective maintenance, and for ensuring the station is properly stocked with spare parts and equipment. Each Loran Station is a functioning Coast Guard unit complete with a command structure. The staffing level is dependent upon the transmitter type and the geographic location. With the exception of Alaskan stations, members do not live onboard the station. The standard does not mandate a specific maximum recall time for personnel to respond to the station, rather it refers to returning to the station in a "safe manner." This results in varying recall times.

During the acquisition phase of the Loran Recapitalization Project, the general support philosophy was to purchase extended warranties for each piece of equipment. Most projects relied on the standard vendor warranty and purchased extensions for five or ten years of coverage. The result is a variety of support entities with whom the field must interact. Table 6, below, shows the relationship between equipment, support philosophy and sparing.

Table 6

Support Matrix		
System	Support Philosophy	Spares
Accufix 7500	Warranty (10yr)	Spare parts on the Shelf
Timing and Frequency Equipment	Warranty (10yr)	Spare parts on the Shelf
Remote Automated Integrated Loran (RAIL)	Warranty (5yr)	Spare RAIL on the Shelf
Operations Room UPS	Warranty (5yr)	None
Transmitter Room UPS	Warranty (5yr)	None
Frequency Standard Set	Warranty (10yr)	Installed Spare
Routers	LSU Support (3yr)	Spare router on the Shelf
Equipment Control Monitor	Warranty (5yr)	Spare parts on the Shelf
New Switch Cabinet	Warranty (1yr)	Fly away kit at LSU

Intermediate Support

LSU provides intermediate level support to the entire system. In 2002, the LSU adjusted its internal support policies in an effort to move from a reactive to a proactive support model. The hub of the new proactive model is the LSU groom team. Groom teams generally consist of three technicians, who visit each Loran Station annually and each Primary Chain Monitor Site every other year. During their visit they optimize Loran equipment, provide targeted training, and assist with management of the system. Groom teams have become instrumental in identifying and addressing support issues before they manifest themselves into off-air or out-of-tolerance conditions.

Backing up this proactive system is a reactive hotline to address time-critical issues. LSU mans a 24/7 hotline for the units to contact in the event they are off air or their signal is out of tolerance. An email system is in place to answer questions that are not time-critical. The hotline integrates with the proactive model as the LSU reviews the data that is captured by hotline calls. The data is used to identify system-wide problems and potential system improvements.

Depot Level

Depot level support provides the stocking and repairing of modules and equipments that cannot be repaired at the unit. For many years Loran was a stable system that did not undergo very much change. As such, it used the federal stock system, primarily what has become the USCG's Engineering Logistics Center (ELC), to stock and repair the vast majority of the Loran unique parts. The ELC has been involved in both the tube-type transmitter (TTX) and the solid-state transmitter (SSX).

The influx of new equipment has resulted in a diversification of depot-level sites. The paradigm now is that legacy TTX and SSX equipment still continues to reside at ELC. Spare parts associated with RAIL and routers are stored at LSU. TFE and the oscillators have no depot-level spares; instead all spares are distributed throughout the system. ECM and the switch modules for the new switch cabinet are stored at ELC.

The most thoroughly supported system for new equipment is the new solid-state transmitter (NSSX). Depot spares for the NSSX are stored at Megapulse and the field has access to them via an online ordering interface. This same interface gives LSU visibility into the reliability and status of all spare parts associated with the new solid-state transmitter.

Training

Human intervention is generally in three areas: corrective maintenance, preventive maintenance and watch standing. Historically, technicians who provide corrective and preventive maintenance were trained at Training Center Petaluma (TRACEN) at the Loran-C school. The school taught timing and maintenance for both TTX and SSX transmitters. TRACEN has recently had the new RAIL equipment installed and is working to integrate the new system into the current course material. Control station personnel standing watch via the LCCS receive on-the-job training via a Personnel Qualification Standard system.

The new equipment is considered commercial-off-the-shelf (COTS) equipment. As such, it has come with much less documentation and training than previous Loran systems. Both the new transmitter and the new timing and frequency equipment (TFE) focus the majority of their training on a computer-based training (CBT) application. For all other systems, Lorstas are provided with on-the-job-training during installation. LSU is working with the TRACEN to install the new equipment and integrate it with the curriculum.

STRATEGIC OVERVIEW

> "The quality of any strategy will never exceed the quality of thinking that gave rise to it…"

Robert Keidel, "A Few Good Forms: Tools for Strategic Thinking"

The structure of the future support system will have a dramatic impact on management of the system. It could conceivably alter personnel and budget allocations at all levels. Therefore, conceptually understanding the strategic management of the system is necessary to understanding the impact the variety of support solutions could have. Following is a brief strategic review of the system past, present, and future. The focus is limited to general management and support systems.

Strategy is the controlling of the relationship between two or more variables. More than three variables is difficult to represent and difficult to comprehend at any level. Therefore, to simplify the discussion, strategy for the system will be described using a series of triads to relate three variables. Generally, organizations will exhibit elements of all three variables but will tend to let one variable dominate. The complete strategy for the system is actually the interrelation between triads.

Figure 3, below, represents management. The dot represents the current position and the star represents the desired future position. The arrows indicate the path the system is currently on.

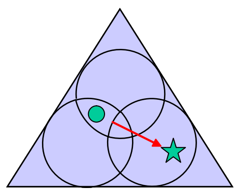

Fig. 3

The term management is being used in a generic sense and is intended to represent the entire USCG Loran community. The general terms autonomy, control and cooperation are applied to the system as a whole. Autonomy is analogous to baseball; interaction between parties only happens occasionally and is forced by outside influences. Control is analogous to football; scripted, run by the coach, play in the system. Cooperation is analogous to basketball; free flowing interactions between various parties to create the best result possible.

The current and former systems were located somewhere between autonomy and control. This was due to the design of the system itself along with the dispersement of various portions of control at different commands within the USCG. This gave rise to a system that, at a strategic level, is disjointed and difficult to understand. The structure of the new system is demanding an unprecedented level of cooperation between commands, especially during the installation of the new equipment. While the interaction is occurring it can not yet be characterized as full cooperation between commands. A good analogy for the current management is a pre-season basketball team. The components for a great season are present on the court but they have not yet learned to function as an integrated team.

Figure 4, below, represents the support system. The dot represents the current location and the star represents the future. The red line represents the path to the future that may best fit the system's needs.

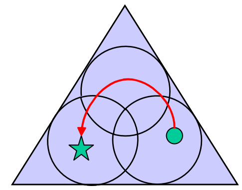

Fig. 4

In general, all support systems are to some extent flexible, efficient, and different. The sum of these three characteristics define the system and its ability to meet the variety of challenges it faces. Throughout the life-cycle of the Loran system it has always had a support system in place that has maintained the equipment at the level required to meet operational commitments. The uniqueness of the equipment in the system created a culture of differentiation. Specialists were grown within the system and these specialists have ensured the continued availability of the system over the past 30 years. The legacy support system demonstrated the minimum level of efficiency needed to ensure operational commitments were met.

The current influx of new equipment, which is based on industry standards, is forcing the current system to shift towards flexibility. The specialists grown in the previous system are still in place but they are now forced to maintain equipment they have no experience maintaining. This shift is a necessary, yet painful, move required for the system to continue to function. Eventually, the hardware in the field will settle out and the support system will be able to move from flexibility towards efficiency.

Figure 5, below, depicts the support systems three areas; organizational, intermediate, and depot levels. All three are necessary and it is the balance between them that defines the system. Historically, the emphasis has been on organizational-level support. Training, funding, and manning have always focused the lion's share of the resources at the Lorsta. Today there is an ongoing shift occurring that is moving the support focus from the historic organizational-level focus to the intermediate-level. This shift is occurring due to a series of decisions that have been made by a variety of individuals. The primary drivers of the shift are warranty support, reduced communication with the training command, and groom visits. All of these have positive aspects as well as negative aspects. The shift itself is not necessarily bad; it is important, however, that management understand the movement and the potential long-term impacts. This paper begins the thought that data needs to be gathered and options analyzed to determine the proper balance of priorities. Generally speaking, an even balance between the three will not give you the required outcome due to a lack of focus.

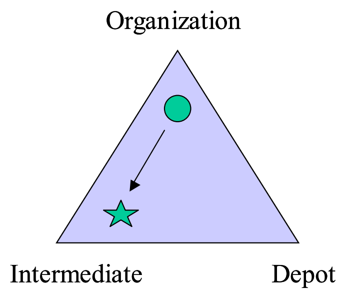

Fig. 5

It is important that as the support system adjusts, it remains instep with management strategy. If the support system shifts out of step with management, there may be internal system conflict that could result in reduced system maintenance that would likely manifest itself in reduced system performance.

FUTURE SUPPORT OPTIONS

There are a variety of support options and systems that would fulfill the 99.9% requirement. While many would work there are probably only a handful of good options. It is important that one of these options be selected. It is imperative that the option selected be inline with the strategic vision, as well as the reality of the program.

To simplify the decision process the support system can be viewed as a combination of four separate decisions. From a high level the four areas are organizational level support, intermediate level support, depot level support, and training. Chart 1, below, displays a series of options for each area. This is by no means an inclusive list, but rather a point at which to begin analyzing options. Each area requires a study, performed concurrently, and the decisions brought together into a strategic plan. The strategic plan must not only outline the end state for the future support system, but must outline a plan on how to move from the present to the future.

All support systems strike a balance between risk and cost. If cost was not a constraint, or if resources were unlimited, the choice would be simple. However, cost is a factor and resources are limited; therefore, the final subset of support systems that meet the requirements will be compared based on total cost over the expected lifecycle of the system.

It is anticipated that the e-Loran system will have a greatly reduced preventive maintenance requirement. This, combined with the new remote control capability, has encouraged the discussion of de-staffing the stations, recouping the billets into the Coast Guard and saving money. At this point, however, we need to understand the system being supported and the requirements to which to operate to before we can properly address de-staffing the stations.

Because of environmental extremes and logistical challenges associated with Alaska the support decision should be broken into two parts: a support system for the lower 48 states, and a support system for the Alaskan Loran stations. The following sections will offer a breakdown of information that should be collected and reviewed before making a decision for each area.

ORGANIZATIONAL SUPPORT STUDY

The fundamental question, and the last question to answer, is whether or not to reduce staffing at the stations. The equipment is designed to be, and currently is being, operated remotely via the LCCS system. This narrows the scope of questions down to preventive maintenance, corrective maintenance, and emergency loss of communications procedures requiring local control of the station.

A study of the Enhanced Loran system will have to be conducted to identify single points of failure that take the station off-air or out-of-tolerance. Once the failures have been identified, statistics and historical data should be applied to determine the probability of those failures occurring.

The manufacturers have provided preventive maintenance guidelines for the new systems during acquisition. The Coast Guard has not yet developed its own preventive maintenance cards using the reliability-centered maintenance philosophy. Prior to determining a staffing level, the final preventive maintenance guidelines must be developed. This will give the planners a grasp of the workload required to maintain the system and what the periodicity of human involvement. In addition to this workload an estimation of casualty repair hours must be added to fully understand the total workload required to maintain the system.

Many of the sub-systems incorporated in the new Loran station are new and therefore have no failure history. This poses a challenge when trying to determine the amount of corrective maintenance that must be performed in order to keep a station operational. Detailed records of all corrective and preventive maintenance must be kept at new stations and legacy station upgrades. After a period of six months to a year, these records should be evaluated. The stations should also be inspected to determine the condition of the equipment. Dependent upon the findings it may be appropriate to go back and adjust the preventive maintenance procedures.

Overlaid with the likelihood of failures occurring, should be the likelihood of the failure occurring while an assigned technician is onboard the station. A review of the current response requirement must be made. Is this requirement based on availability requirements, should it be reduced, increased, or stay the same? If e-Loran embraces the “all-in-view” capability, the response criteria will vary depending upon the station. Some stations will become critical to maintain availability while others will decrease in importance to the system.

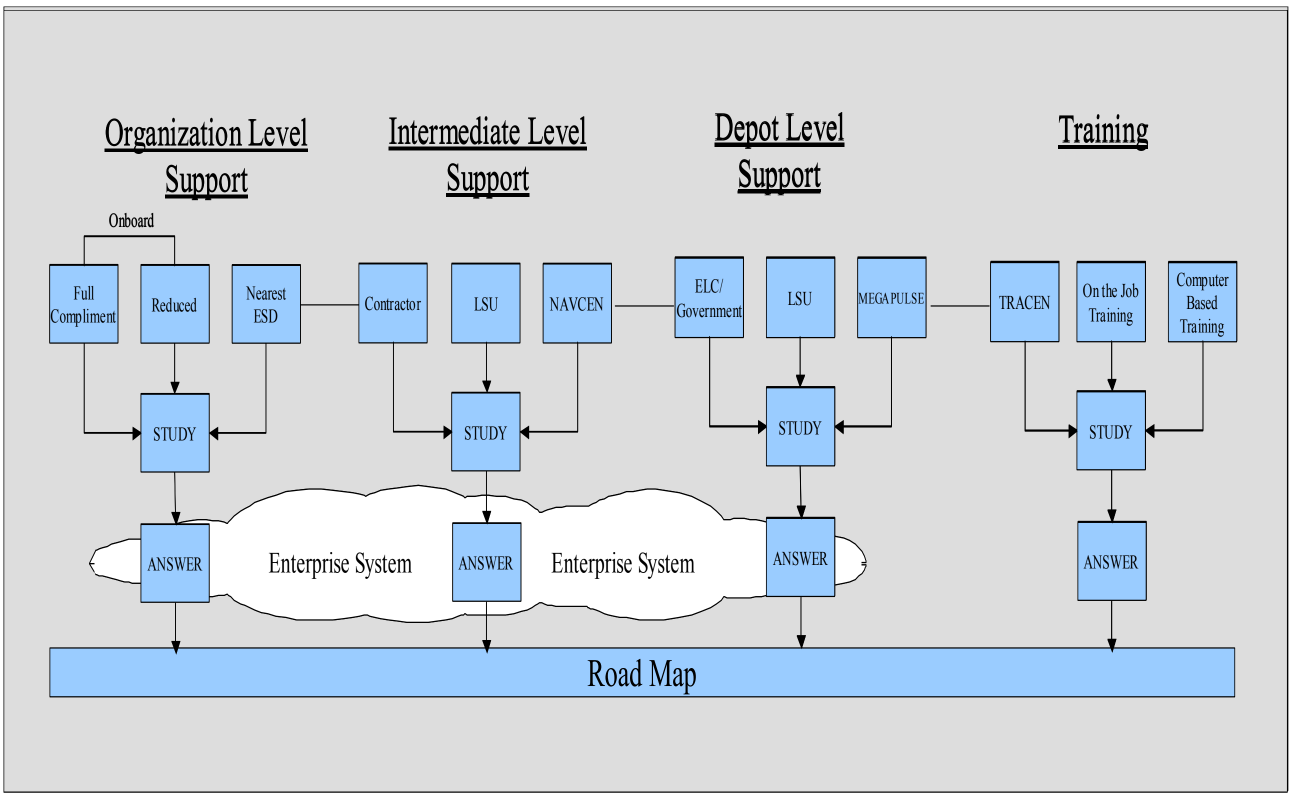

Chart 1

The sparing levels of the new equipment have been, in general, based upon recommendations by the manufacturer. Initially these sparing levels may appear adequate but they should be reevaluated after extended operation to determine if inadequate sparing has resulted in a loss of operations. Should the decision be made to de-staff the stations, the sparing should be reviewed again. A de-staffed station will most likely require a different set of spare parts to ensure operational availability is maintained. This will be necessary due to the system accepting the risk of taking bad time while waiting for the tech to travel to the station.

The capability and practicality of remote diagnostic tools must be evaluated. The systems that are being installed are very software intensive and built into the software is diagnostic capability. This software can be accessed remotely, potentially by intermediate level support, and detailed diagnostics could be conducted before a technician ever arrived on station.

Once all of the analytical study and empirical data is collected, a judgment on station staffing must be made. There is no right answer, only tradeoffs and assumption of risk.

Intermediate Support Study

An intermediate level support entity must be able to provide the same capability and functionality the LSU provides today.

The intermediate-level support entity must be able to effectively interface with the Loran Stations on a technical level and with USCG headquarters units on a program level. This interaction ensures that the intermediate-level support is in line with current initiatives and changes to the system.

Depot Support Study

The depot-level-support system must provide adequate response to ensure the operational availability of the system. The new paradigm has caused a new set of requirements to be placed upon the depot level. The set of requirements an adequate depot level support entity or entities must provide need to be determined. Processing of funding and accountability of property are other issues that will require resolution depending upon the selection of a depot-level support paradigm chosen.

The historical precedent of one depot-level support entity does not need to limit the scope of this study. With the advent of the Internet and improved communications, the answer may be to have multiple depots dependent upon equipment type.

Training Study

Training is essential to the long-term success of any system or organization. Loran is no exception; it is a complex system that requires human intervention on various levels to ensure proper operation.

The new Loran system is a system of systems. Each subsystem has some level of training attached to it. However, a front-end analysis of the entire Loran system may need to be conducted. From this analysis will come the best way to train responders and who should deliver the training.

Outsourcing

The potential to outsource all, or portions, of Loran system support exists. It is important to separate the potential of outsourcing from development of a support model. Following development and acceptance of the support model, outsourcing options can be overlaid to determine the potential benefit to the USCG.

While there may be benefits from outsourcing in terms of personnel reallocation, there can also be negative impacts. Personnel reallocation is in itself both a positive and negative consequence of outsourcing. Those left in the program may become transient and rigid in their defined roles. This can, in the future, limit the ability of the system to evolve to overcome new challenges and satisfy new demands.

The question is whether the current and future Loran systems grows talent organically. Historically, the Loran system was a very robust organization. Coast Guard personnel could specialize in Loran and spend their entire career in the field. The old system demanded this type of organization due to its maintenance and operations requirements.

The evolution of the system has become increasingly complex as well. Many of the new systems are commercial off-the-shelf (COTS) systems developed by contractors and integrated by Coast Guard personnel. LSU's project managers ran the contracts but the engineering work was done outside of the USCG. How much of the operational Loran system will be contracted out? To decide this will be to choose the set of trade-offs for the future of the operational system?

These questions need to be asked, and they need to be answered after adequate understanding of the new system and its new expectations has been developed. The right data must be gathered, the right study must be undertaken, and the right individuals must be involved in the decision.

Implementation

Once the decisions have been made, an implementation plan must be developed. This plan must clearly outline the process for the transition from the current support system to the future support system. The difficult part in the transition will be ensuring support is maintained throughout the transition period.

Strategic decisions are not easily implemented, they generally involve significant shifts in corporate thinking and there may be substantial resistance to change. These are perfectly natural reactions to change in any organization and should be anticipated. It is advisable to involve the parties that could potentially be affected by a change during the study of potential systems including; USCG Headquarters, ELC, LSU, NAVCEN, and TRACEN.

Conclusion

Figure 6, below, represents the support system as a triad. While each part of the triad is important to the structure, it is vital for management to define the priorities in order to focus resources. Training can be viewed as an overlay to the triad. The focus of the training must be inline with the strategic focus of the organization both in subject and in student.

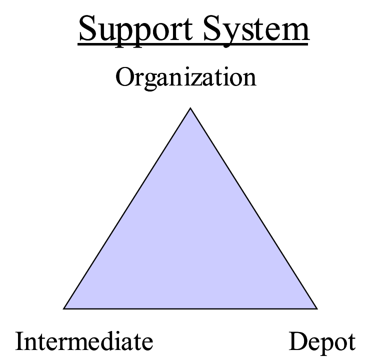

Fig. 6

Understanding the complexity of the system, acknowledging how systems fail, and embracing a new vision will allow for the implementation of a support system that will meet all the requirements for future support of the Loran system.

The initial data gathering and the following stand-up of the support system are essential to enabling the future support system. The following bullets are a brief review of the information that may need to be analyzed in order to make an informed decision.

- Loran Station single point of failure study.
- Preventive maintenance procedure development and review.
- Collection of initial failure history.
- Response time review.
- Sparing level review at the station and at the depot site.
- Remote access ability review.
- Intermediate level support review.
- Depot level support review.
- Enterprise system review and implementation.
- Training front-end analysis for the system.

Simply asking the question generally indicates that the questioner has some inkling of the answer. Loran has asked the question, the next step is to design an answer.

Biographies

Zachariah S. Conover is a Lieutenant Junior Grade in the U.S. Coast Guard and is presently assigned as the Configuration Management Branch Chief at the Loran Support Unit in Wildwood, New Jersey. He has completed a previous tour as a Deck Watch Officer onboard U.S. Coast Guard Cutter STEADFAST in Astoria, Oregon. He received his Bachelor of Science degree in Electrical Engineering from the U.S. Coast Guard Academy and is currently completing his MBA at Drexel University.

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