

**THE APPLICATION OF LEVEL OF REPAIR ANALYSIS
TO MILITARY ELECTRONICS PROGRAMS**

by

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(ABSTRACT)

During the early stages of the acquisition cycle for a military equipment, the question arises as to how the system will be maintained at an operationally capable level. The desired level of readiness must be balanced against the cost of system maintenance. The primary question to be answered is what is the optimum (i.e., least cost) maintenance concept which will allow the system to meet its specified performance goals. In order to answer this question, one must compare the costs associated with the possible choices in maintenance alternatives.

Level of Repair Analysis, or LORA for short, is an optimization technique used to determine the optimum level of repair for each component in the system. Premised on accurately addressing selected system life-cycle maintenance costs, the methodology, data requirements, and algorithms used to conduct a LORA are found in Military Standard 1390C, Level of Repair Analysis.

LORA examines the feasibility of repair from both technical (non-economic) and economic standpoints. The optimization process will determine whether it is feasible to repair an item, and if so, where and how.

While LORA is an excellent and necessary tool, like many analyses of its type, it has limitations. Like any analytical tool, one must understand both the strengths and weaknesses of the process to properly apply its techniques and interpret its results. Data collection and entry into a computer model can be made relatively easily. Paramount however to properly applying the techniques and results is a thorough understanding of the LORA process. Therefore, the primary focus of this project and report is to illustrate the strengths and limitations of the LORA process by its application to a specific example. It is not intended to pass judgement on the LORA process as implemented and utilized by DOD. Rather, it is intended that this report present an overview of the LORA process and detail some of the nuances one could expect to encounter when performing a LORA.

This report contains a description of the Level of Repair Analysis process and how this process was applied to a specific United States Department of Defense electronics system. This report documents the analysis (data and calculations used) to reach the repair and discard decisions for the NIXIE Signal Generator Engineering Change Kit for the AN/SLQ-25, a US Navy electronics equipment. This report differs from the one submitted under the contract in that it contains more theoretical detail on the overall LORA process and does not include any classified or proprietary data.

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ACRONYM LIST

A _o	Operational Availability
ASW	Anti-Submarine Warfare
ATE	Automatic Test Equipment
CDRL	Contract Data Requirements List
CIDS	Critical Item Development Specification
CFE	Contractor Furnished Equipment
CM	Configuration Management
ECP	Engineering Change Proposal
FMECA	Failure Modes, Effects, and Criticality Analysis
GFE	Government Furnished Equipment
ICS	Interim Contractor Support
ICSP	Interim Contractor Support Plan
ICSS	Interim Contractor Supply Support
ILS	Integrated Logistics Support
ILSM	Integrated Logistic Support Manager
INCO	Installation and Check Out
LCN	Logistics Control Number
LCL	Logistic Support Analysis Candidate List
LORA	Level of Repair Analysis
LCL	Level of Repair Analysis Candidate List
LCN	Logistics Control Number
LRU	Lowest Replaceable Unit
LSA	Logistic Support Analysis
LSAR	Logistic Support Analysis Record
LSAP	Logistic Support Analysis Plan
MSD	Material Support Date
NAMO	Naval Aviation Maintenance Office
NAVAIR	Naval Aviation Systems Command
NAVSEA	Naval Sea Systems Command
NAVSUP	Naval Supply Systems Command
NSG	NIXIE Signal Generator
OBRP	On-Board Repair Parts
OJT	On-The-Job
PIO	Provisioning Item Order
PHS&T	Packaging, Handling, Storage, and Transportation
PMS	Planned Maintenance System
PPL	Provisioning Parts List
PPLI	Provisioning Parts List Index
PTD	Provisioning Technical Documentation
R&M	Reliability and Maintainability
RCM	Reliability Centered Maintenance
RCU	Remote Control Unit
RFI	Ready-For-Issue
SCD	Specification Control Drawing
SPETE	Special Purpose Support and Test Equipment
STE	Support and Test Equipment
TM	Technical Manual
TTEL	Tools and Test Equipment List

1.0 INTRODUCTION

1.1 PROBLEM DEFINITION

During the early stages of the acquisition cycle for a military equipment, the question arises as to how the system will be maintained at an operationally capable level. The acquiring agency, along with the equipment designer/developer/manufacturer, must develop a maintenance strategy for the equipment. This strategy, known as the maintenance concept, must consider equipment characteristics such as complexity, reliability, maintainability, technical feasibility of repair, physical characteristics, etc.. It must also address the usage of resources which will be available to maintain the equipment such as personnel and their respective skill levels, training, technical documentation, supply support, provisioning, support and test equipment, safety, etc..

The most important element in the maintenance concept, however, is its cost and specifically, how this cost contributes to the overall life-cycle cost of the system. Life-cycle cost is defined as all costs associated with the acquisition, maintenance, operation, modification, and retirement of a system incurred during its life span.

Accurate life-cycle cost analysis and forecasting at the beginning of a program is difficult. This is especially true in Department of Defense (DOD) acquisitions given the existence of influences beyond the control of the acquiring agency, such as politics, inflation, etc.. It is possible, however, to determine certain elements of the system life-cycle cost, one of these being the relative cost of maintenance.

When examining the cost of system maintenance, the primary question to be answered is what is the optimum (i.e., least cost) maintenance concept which will allow the system to meet its specified performance goals. In order to answer this question, one must compare the costs associated with the possible choices in maintenance alternatives.

Level of Repair Analysis, or LORA for short, is an optimization technique used to determine the optimum level of repair for each component in the system. ¹ It is based on the premise of accurately addressing selected system life-cycle maintenance costs. The data

requirements and algorithms used to conduct a LORA are found in Military Standard 1390C, Level of Repair Analysis.² While this is a DOD document, this methodology is also applicable for commercial and industrial projects. LORA examines the feasibility of repair from both technical and economic standpoints. The optimization process will determine whether it is feasible to repair an item, and if so, where and how. The LORA process will also examine the costs associated with discarding an item if it is not feasible to repair it.

LORA also produces the various costs associated with each repair level decision. As with many economic optimization analyses, the primary objective of a LORA is to determine the least possible cost solution which best allows the system to perform its mission. LORA focuses on supporting and maintaining a system sufficiently to allow the system to perform its intended function.

While LORA is an excellent and necessary tool, like many analyses of its type, it has limitations. Like any analytical tool, one must understand both the strengths and weaknesses of the process to properly apply its techniques and interpret its results. Data collection and entry into a computer model can be made relatively easily. Paramount, however, to properly applying the techniques and results is a thorough understanding of the LORA process. Therefore, the primary focus of this project and report is to illustrate the strengths and limitations of the LORA process by its application to a specific example. It is not intended to pass judgement on the overall LORA process as implemented and utilized by DOD. Rather, it is intended that this report present an overview of the LORA process and detail some of the nuances one could expect to encounter when performing a LORA.

1.2 PROBLEM IMPORTANCE

This type of analysis should be performed as part of any engineering economic analysis used to determine system costs. Since LORA is applicable to many large scale industrial, commercial and military systems, the importance of this analysis is to optimize the utilization of capital available for maintenance of a given system. Generally speaking,

the more complex the system, the more intense the maintenance process, and hence, the higher the maintenance costs.

The overall cost of a system also influences the desire to perform a LORA. Obviously, the higher the amount of capital expended for a system, the more logical it is to protect and enhance this investment by optimizing system maintenance costs.

Maintenance costs are raised even further if an extended operational life span is desired. The need to extend service life of capital systems is increased by the consideration of budgetary constraints, the expense and time incurred by developing a newer, more complex replacement, and the resistance to developing a replacement which is more capable or versatile when the old system might be able to accomplish the same mission. These factors, and others, will force organizations via the systems engineering process, to design systems which are more effective, capable, reliable, maintainable, and supportable at an optimal system cost. In order to remain competitive, industries must optimize the maintenance costs associated with their products and capital equipments.

1.3 APPROACH/METHODOLOGY

As detailed in Military Standard 1390C, the LORA process optimizes the maintenance costs associated with each different maintenance concept and totals them. The costs for each different maintenance concept are then compared and the concept having the least cost is selected.

Maintenance costs are determined by evaluating what system components will be repaired and the level of maintenance at which this maintenance will occur. The LORA also examines those costs associated with discarding an item rather than repairing it. Once again, the purpose of performing a LORA is to establish the least cost feasible repair and discard decisions for a system and its equipments/subsystems.

As described in detail in Section 3.0 of this report, the LORA process consists of planning the analyses effort, collecting data, applying the mathematical equations of Military Standard 1390C, and interpreting the results.

Obviously, maintenance costs must be optimized with respect to system constraints both in terms of minimum and maximum allowable values. Minimum required values would include performance parameters such as Operational Availability (A_0). As defined by Blanchard, A_0 is "the probability that a system or equipment, when used under stated conditions in an actual operational environment, will operate satisfactorily when called upon" ³. A_0 is generally expressed as follows:

$$A_0 = \text{MTBM} / [\text{MTBM} + \text{MDT}]$$

where: MTBM = Mean Time Between Maintenance
 MDT = Maintenance Down Time

Mean Time Between Maintenance (MTBM) is the time measured between any maintenance action, either corrective or preventive, which would prevent the system from being available for required use. Maintenance Down Time (MDT), as defined by Blanchard, "constitutes the total elapsed time required (when the system is not operational) to repair and restore a system to full operating status, and/or to retain a system in that condition. MDT includes mean active maintenance time (M), logistics delay time (LDT), and administrative delay time (ADT)." ⁴ Blanchard further defines LDT as "that maintenance downtime which is expended as result of waiting for a spare part to become available, waiting for the availability of an item of test equipment in order to perform maintenance, waiting for transportation, waiting to use a facility required for maintenance, and so on." ⁵ ADT is defined by Blanchard as "that portion of downtime during which maintenance is delayed for reasons of an administrative nature (e.g., personnel assignment priority, labor strike, organizational constraint. etc.)." ⁶

The numerator of the above equation (i.e., MTBM) represents system "Uptime" while the denominator represents the cumulative system "Uptime + Downtime". For the system examined in this paper, the A_0 requirement was .95 or 95%.

A_0 and other performance factors such as reliability and maintainability are ultimately a function of the amount of money spent on either system design or system support elements. Given a specified system with its design and performance requirements, MTBM, and operating scenario, A_0 can usually only be influenced by altering the logistics

elements, i.e., changing the MDT. These are dependent on the number of personnel trained to maintain the system, their skill levels, the type and availability of the technical documentation required to support the system maintenance, and the availability of spares and repair parts. Therefore, there exists a minimum cost value for each logistics element required to support the system, i.e., the cost of retaining a minimum number of trained personnel per operating site to support the equipment, the cost of procuring the necessary numbers and types of spare parts needed to maintain the system, etc..

There is also a set of maximum values available to support the above mentioned logistics elements. These would include the cost of maintaining the equipment in terms of monies available for spares parts and training of personnel. Clearly, a balance or optimal value must be reached between the minimum value of money spent to keep the system effectively operational and the maximum amount of money available.

The DOD method for determining optimal maintenance costs is to perform a LORA. Additionally, this analysis evaluates the repair alternatives to determine the least cost option. Given the vast sums of money dedicated to procuring military systems, both lethal and nonlethal, it is essential that these costs be evaluated early in the system acquisition process. These costs must be identified for budgetary planning purposes.

The LORA process is an iterative systems engineering function. It is performed repetitively until an optimum value each component is reached. LORA results are input into the system life-cycle cost and therefore serve to influence the system maintenance concept. These results may either verify or change the maintenance concept, but LORA should be continually updated during the system acquisition and periodically throughout the system life-cycle.

Additionally, if an initial LORA is performed early enough in the system acquisition process, results of the LORA should serve to influence system design. Preliminary LORA decisions or factors regarding the proposed system maintenance and support structure should be considered by the system design team.

1.4 SCOPE

While the LORA methodology can and is applied to many commercial and industrial items, this report delineates the LORA effort conducted for a particular military electronics system.

This report is organized to describe the overall LORA process, tell how it was applied to a specific DOD electronics acquisition program, and delineate the results obtained. It is beyond the scope of this paper to discuss every mathematical calculation used in the LORA, that being the primary function of Military Standard 1390C. Rather, this paper focuses on a particular LORA model and the analyses in which it was used.

The remainder of this report is organized as follows; Section 2 presents the reader with a description of the system which was analyzed. Section 3 is a discussion of the LORA process itself. Section 4 details the logistics elements involved with this particular LORA. Sections 5 and 6 detail the use of the LORA model and its data requirements while Section 7 examines the analysis results. Finally, Section 8 contains the conclusions and recommendations.

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- ¹ It is recognized that "true optimization" in the real world is difficult, if not impossible, when examining a systems engineering analysis of this type. The LORA process seeks to optimize maintenance costs with respect to the specific parameters and data which it examines. In this sense, the validity of the LORA is based on the confidence placed in the values used for the data elements which the LORA examines.
 - ² MIL-STD-1390C (Navy), Military Standard, *Level of Repair Analysis (LORA)*, Department of the Navy, Director, Naval Weapons Engineering Support Activity, Washington Navy Yard, Washington, D.C., 11 July 1988.
 - ³ B.S. Blanchard and W.J. Fabrycky, *Systems Engineering and Analysis*, Prentice Hall, Englewood Cliffs, New Jersey, Second Edition, 1990, page 359.
 - ⁴ Ibid, page 403.
 - ⁵ Ibid, page 403.
 - ⁶ Ibid, page 405.

2.0 PROGRAM BACKGROUND

The AN/SLQ-25 (or NIXIE) is a surface ship towed acoustic torpedo countermeasures (decoy) system. It is designed to provide an enhanced survival capability against both active and passive homing torpedoes and to create minimum interference with own-ship sonars. NIXIE is to be deployed on major surface combatants and selected auxiliaries of the U.S. and friendly foreign navies.

NIXIE was fielded in the early 1970s as a response to the increased torpedo threat. It replaced the T-MK-6 Mechanically Initiated, Acoustic Decoy. A Technical and Operational Evaluation (TECH/OPEVAL) was completed by the Navy in December 1970. The system met all test requirements and was approved for service use in February 1971.

The NIXIE is being upgraded to provide additional countermeasures capabilities and to enhance reliability, maintainability, supportability, and effectiveness. Modifications include the incorporation of an integrated electronics cabinet and an improved capability towed body. The integrated cabinet consists of a new power amplifier, power supply, and digital signal generator.

The new NIXIE Signal Generator (NSG) will be provided as an Engineering Change Kit for field retrofit of existing AN/SLQ-25 systems. The retrofit will involve the direct replacement of the existing NSG and a Remote Control Unit (RCU).¹

2.1 SYSTEM MISSION, USE, AND PLANNING FACTORS

The NSG is designed to provide microprocessor control for all modes of operation including test functions. All present modes of operation [i.e., those of the current NIXIE system] were retained and new modes of operation were added to increase the AN/SLQ-25 capabilities to provide countermeasures for the new family of threats. Its overall mission is still that of anti-torpedo defense.

Given the current torpedo threat, the NSG is required to meet an A_0 value of .95. Therefore, the design of the NSG will need to reflect high reliability, maintainability, and

supportability characteristics. As seen in the availability equation presented in Section 1.0, these elements will contribute to achieving the specified NSG A_0 goal.

The design of the NSG utilizes modular construction techniques and also provides for future expansion with additional modular units. The expansion capabilities provide flexibility for changes required by future threats. The physical dimensions and all electrical interfaces of the new NSG are exactly the same as the current NSG in order to facilitate Fleet retrofit by shipboard replacement.

2.2 FUNCTIONAL DESCRIPTION

NIXIE is an electro-acoustic decoy which is presently installed on over 300 U.S. Navy surface ships. All NIXIE electronics are in a sheltered environment. The system is located in both Main Deck and Below Deck Installations. Main deck installations have a streaming and recovery winch mounted on the fantail (stern of the main deck). These installations include aircraft carriers and antisubmarine warfare ships. Below deck installations have the streaming and recovery winch mounted on the second deck at the transom.² These installations include battleships and cruisers.

NIXIE employs an underwater acoustic projector housed in a towed body which is streamed astern of the vessel by means of a combination tow-signal cable and a streaming winch. The main electronics console selects, generates, and amplifies electrical signals which are then transmitted through the cable to the acoustic projector in the towed body. These closely resemble the noises made by ship itself and will decoy acoustic torpedoes to the decoy rather than the ship itself. An acoustic projector transforms the electrical signals into acoustic output energy. During operation, system performance is control and monitor in the Combat Information Center (CIC) of the ship by use of the RCU.

2.3 SYSTEM DESCRIPTION

2.3.1 General.

The NSG engineering changes modify both the NSG drawer, located in an electronic console, and the RCU, located in the ship's CIC. The engineering changes digitize the control circuits of the NSG while adding the fully integrated capability to generate signals for other operations, and extend the existing NIXIE signal output capabilities. The NSG is microprocessor controlled.

Certain elements of the NSG hardware description are delineated in this report but their exact function cannot be discussed due to their classified nature. They must however be maintained along with the rest of the system and were therefore included in the NSG LORA.

2.3.2 Signal Generator.

The NSG (Figure 2-1) generates all the signal outputs to the amplifiers, located in the amplifier drawers of the Electronic Console. The signal generator drawer contains: a Power Supply that generates +28, ± 15 , -8, and +5 DC voltages; a Display Circuit Card Assembly (CCA) that serves as the visual display for the NIXIE operator; a 32-position Keypad for inputting manual commands; a Display Controller CCA, containing its own Central Processing Unit (CPU), which controls the interface between the NSG's CPU, the Keypad, and the Display CCA; and a Card Cage Assembly, housing 17 CCAs consisting of, and performing, the following functions:

- a.) Five Tone Generator CCAs, generating 3 tones per card, for NSG signals.
- b.) One Noise #1 CCA for NIXIE noise generation, filtering, control, and preamplification.
- c.) One Bandpass filter CCA for NIXIE filtering.
- d.) One CPU CCA, a 16-bit microprocessor, controlling all software driven functions.
- e.) One Memory CCA, containing 192 Kbyte of Random Access Memory (RAM) and 256 Kbyte of Read Only Memory (ROM). Provisions for an additional 65 Kbyte of RAM and 256 Kbyte ROM are available for expansion.

- f.) Four Mode/Notch CCAs, providing signal conditioning, routing, and filtering.
- g.) Two Preamplifier CCAs containing two amplifiers per card, which amplify the signal to the level required to drive the power amplifiers.
- h.) One Input/Output (I/O) and one Extended I/O CCA, providing buffering, signal processing, and Built-In-Test (BIT) conditioning circuitry.

2.3.3 Remote Control Unit (RCU)

The RCU controls NSG functions from the CIC during normal operation. The RCU (Figure 2-2) uses the same type Display Controller CCA, Keypad, and Display CCA as the NSG. The RCU also contains a Power Supply that generates +5 volts DC, an Input Filter Assembly which protects the input power and signals from Electro-Magnetic Pulse (EMP) and Electro-Magnetic Interference (EMI), an audible alarm module which warns the operator of faults, and two control switches for power and reset control.

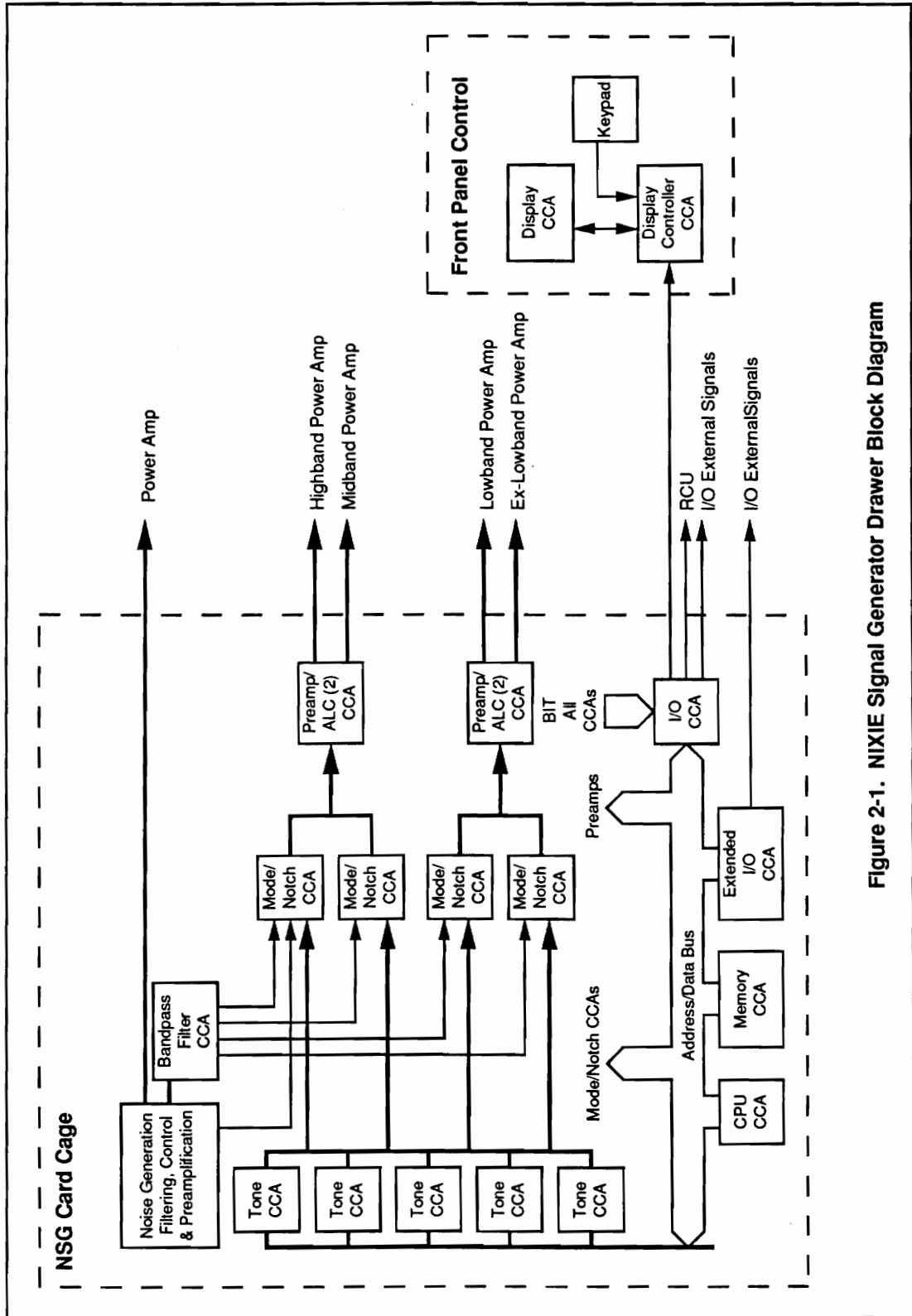


Figure 2-1. NIXIE Signal Generator Drawer Block Diagram

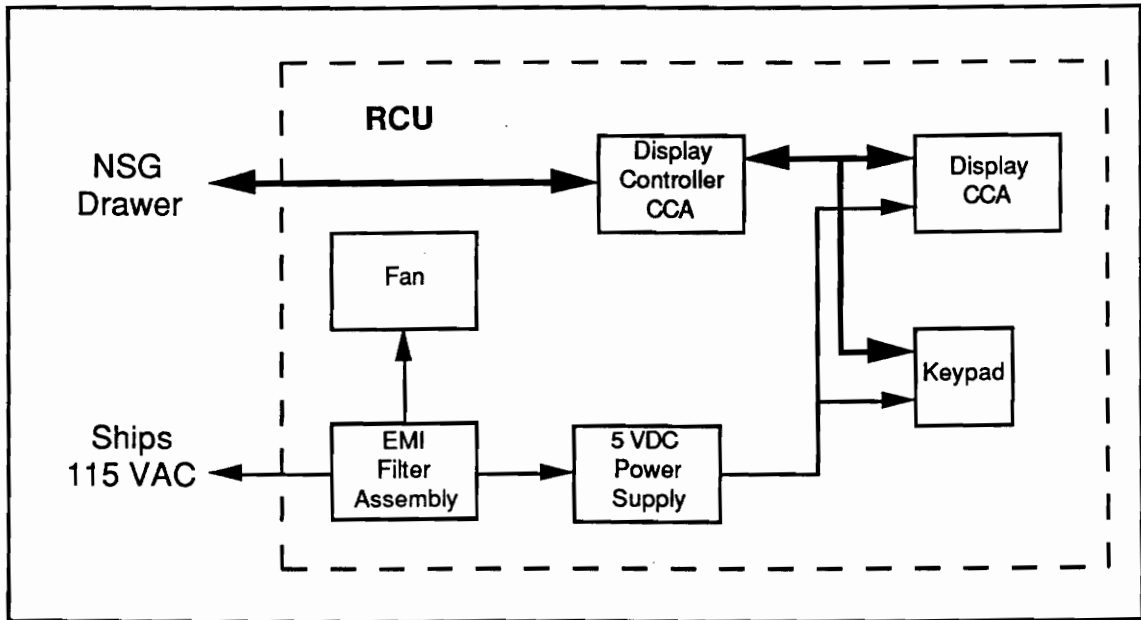


Figure 2-2. NSG Remote Control Unit Block Diagram

2.4 PROGRAM INTERFACE

It is necessary to discuss the equipment mission, function, and design because the maintenance concepts and availability requirements depend on these elements. The LORA seeks to optimize the maintenance concept with regards to program cost constraints and design specifications such as A_0 . The LORA analysis must be an integral part of the program as it is dependent upon the state of system design and the development of other system logistics areas. The relationship between the LORA analysis and other systems development activities is discussed in Section 4.

¹ In this paper, unless otherwise stated, the acronym NSG will be used to refer to the overall NIXIE upgrade program.

² Transoms are openings in the hull of a ship located on the second and third decks below the main deck. Transoms are generally used to deploy and recover items such as the NIXIE or to on and offload cargo.

3.0 LEVEL OF REPAIR ANALYSIS

Level of Repair Analysis (LORA) is a technique which is used to determine if an item should be repaired or discarded and at what level of maintenance this action should occur. LORA decisions are based on both economic and non-economic factors. These factors include the maintenance actions to be performed on the item, the cost and complexity these maintenance actions, item deployment and economic analysis of the item and its components/subsystems.

LORA is a system engineering function which seeks to optimize system cost, performance, maintenance, and support parameters. It performs calculations, using Integrated Logistics Support (ILS) data elements, to determine which is the most economical level of repair. Based on these decisions, LORA is used as a tool to develop the maintenance plan.

3.1 PURPOSE

The purpose of the LORA Report is to document the repair and discard decisions for the NIXIE Signal Generator (NSG) Program and to detail the analysis performed to reach these decisions.

3.2 SCOPE

The scope of the NSG LORA is limited to those NSG components detailed in the development contract and the Critical Item Development Specification (CIDS). Specifically, the LORA has analyzed the components of the Signal Generator Drawer and Remote Control Unit (RCU).

3.3 OBJECTIVES

The LORA identifies not only the repair or discard location for system components, but also, the extent of maintenance permitted and the resources required to support equipment maintenance. LORA has been, and continues to be an integral part of the Logistic Support Analysis (LSA) effort as defined in Military Standard 1388-1A, Logistic Support Analysis.¹ Specifically, it is LSA Task 303.2.7. which requires that repair level analyses be conducted commensurate with the level of design, operation, and support data available. As such, it is an iterative process conducted throughout all cycles of the system life-cycle.

During developmental phases (i.e., concept through full scale engineering development), the objective of the LORA is to establish the most effective and economical maintenance and support alternative and to influence design in that direction. The LORA must be a proactive process which is refined as additional information (design, LSA, etc.) becomes available.

During operational phases (i.e., production and deployment through operation and support), the objective is to review, refine, and revise the system/equipment maintenance and support structure as necessary. Updates may be required by virtue of Engineering Change Proposals (ECPs) or by new support technology.

The LORA must be conducted as a systems engineering process which is fully integrated with all other systems engineering functions to ensure full consideration of system life-cycle logistics requirements in the engineering and design process. The NSG LORA was conducted as a multi-disciplined engineering analysis that fully meets supportability requirements within the NSG operational and maintenance concepts. It was designed to increase system effectiveness by relating logistical design parameters, support, resources, and system parameters to readiness requirements and goals. In this sense, it supported the following Integrated Logistic Support (ILS) objectives:

- a.) Ensure that Operational Availability (A_0) requirements are met;
- b.) Identify and provide for all the ILS requirements and resources for the system during its acquisition and life-cycle;
- c.) Ensure ILS requirements are provided on schedule;

- d.) Improve supportability by designing-in supportability during the system design;
- e.) Reduce costs through system trade-offs which optimize the system with the best balance between cost, schedule, performance, readiness, and supportability;

3.4 APPROACH

To achieve the above objectives, the LORA was structured to fully interact with other ILS elements. All major support elements, as well as related engineering programs, for the NSG were addressed through the LORA process. These areas included the following:

- | | |
|-------------------------------------|---|
| a.) Design considerations | i.) Quality Assurance |
| b.) Reliability and Maintainability | j.) Computer Resources Support |
| c.) Logistic Support Analysis (LSA) | k.) Training & Training Support/Equipment |
| d.) Safety | l.) Life-Cycle Cost |
| e.) Human Engineering | m.) Technical Documentation and Manuals |
| f.) Test and Evaluation | n.) Supply Support and Provisioning |
| g.) Maintenance Planning | o.) Support and Test Equipment |
| h.) Manpower & Personnel | p.) Packaging, Handling, Storage & Transportation (PHS&T) |

Like the other ILS elements, the LORA was implemented through an iterative process of definition, synthesis, trade-off, and evaluation which selectively applied systems engineering techniques during NSG system development to achieve the best balance between system supportability, performance, cost, and schedule. Effectiveness and supportability factors, design constraints, and ILS requirements resulting from the LSA were accounted for in the LORA process. The current system configuration was recorded and maintained in an LSA Notebook and documented in the LSAR. The LSA Notebook and the LSAR provided a consistent source of validated, integrated, and design-related logistics and engineering data from which the LORA analyst was able to draw pertinent data for the LORA.

3.5 METHODOLOGY

A properly implemented LORA integrates design, operations, performance, costs, and ILS characteristics and constraints to identify and refine the system/equipment maintenance and support structure. The overall LORA process itself, as depicted in Figure 3-1, consists of eight distinct consecutive steps: ²

- a.) planning the LORA effort;
- b.) data collection;
- c.) perform non-economic evaluations;
- d.) perform economic evaluations;
- e.) perform sensitivity evaluations;
- f.) analyze and document evaluations performed;
- g.) utilize analysis results; and,
- h.) update the LORA.

These steps are addressed in detail in the course of this LORA report. The LORA decision process is presented in Figure 3-2.

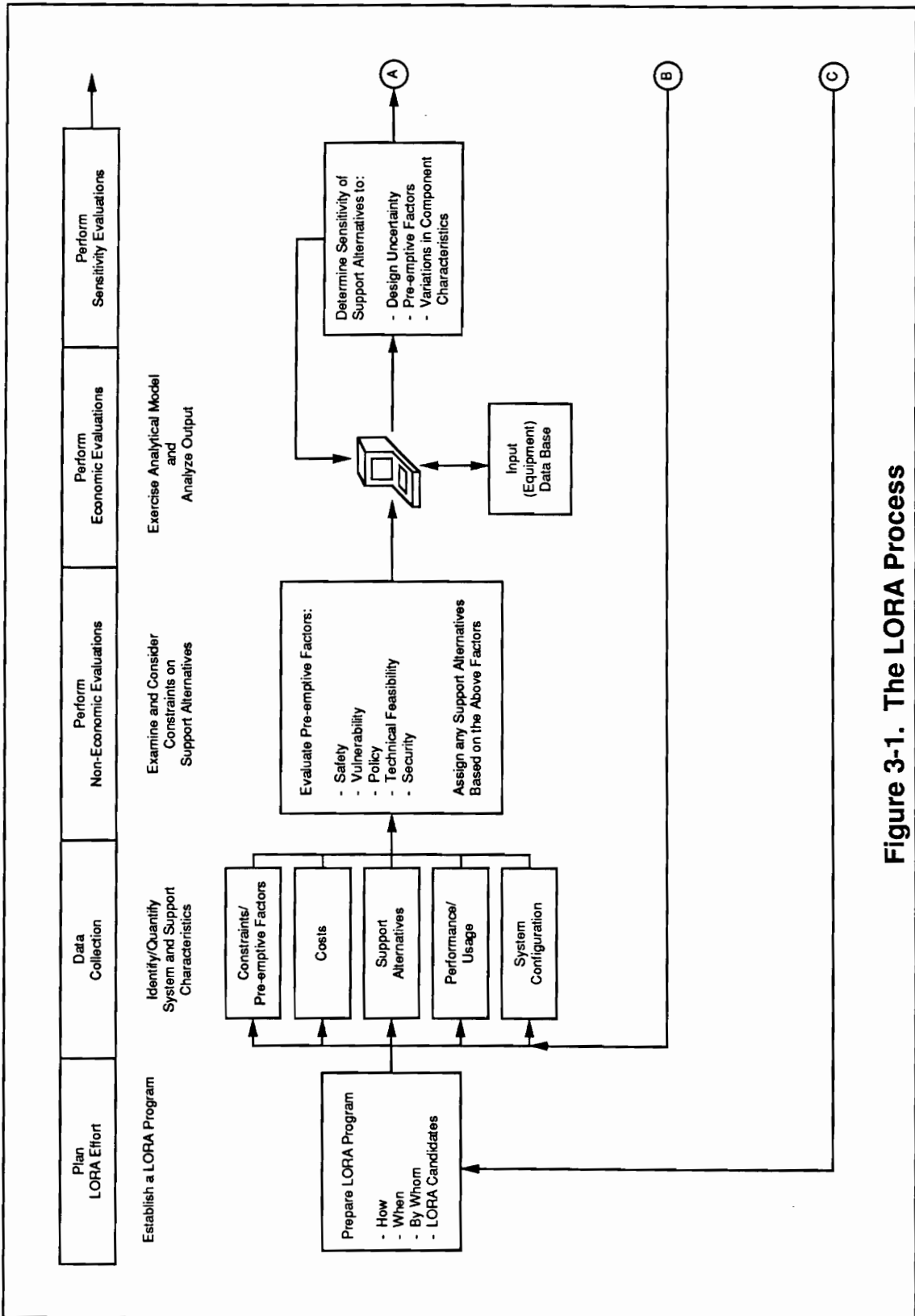


Figure 3-1. The LORA Process

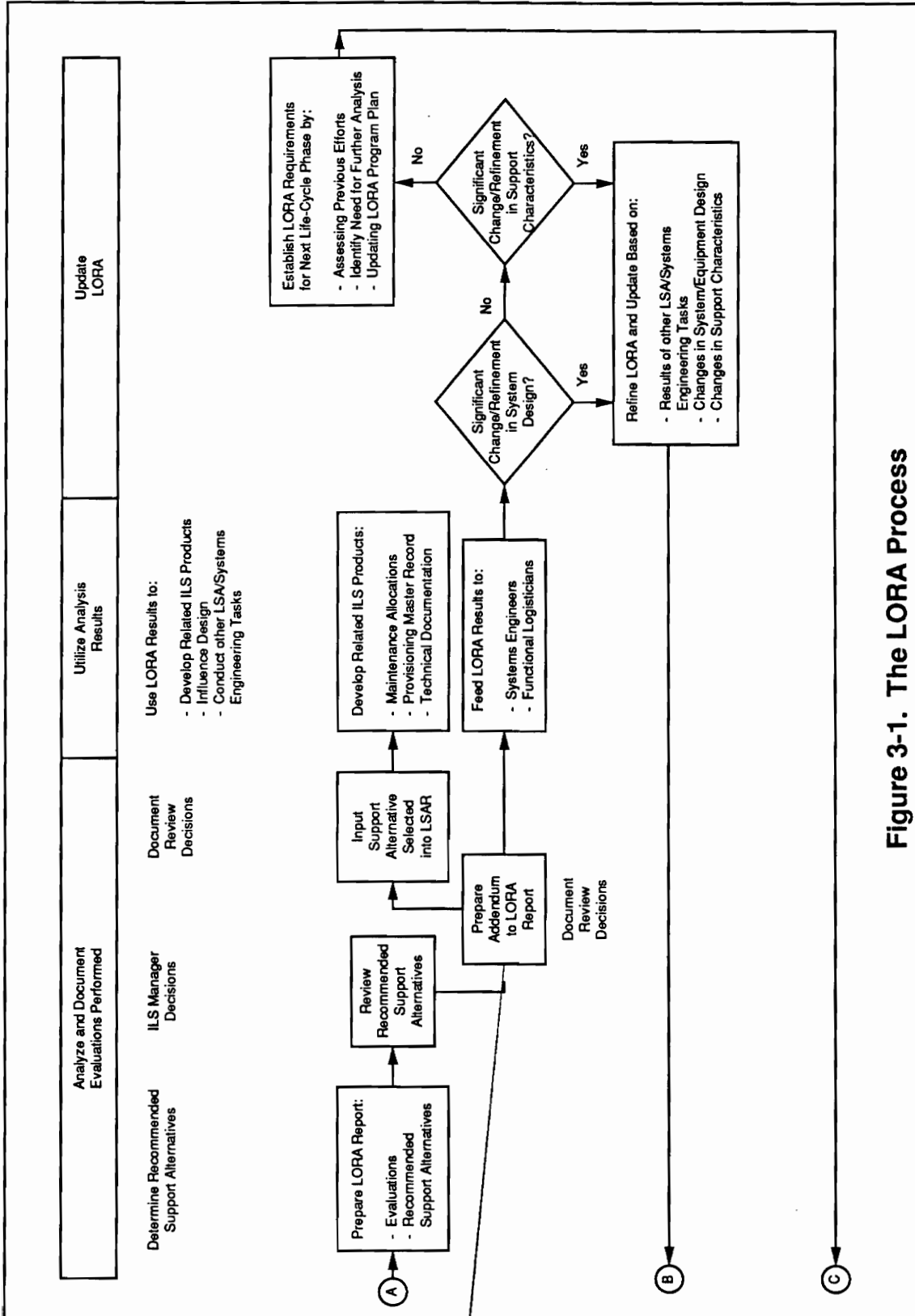


Figure 3-1. The LORA Process

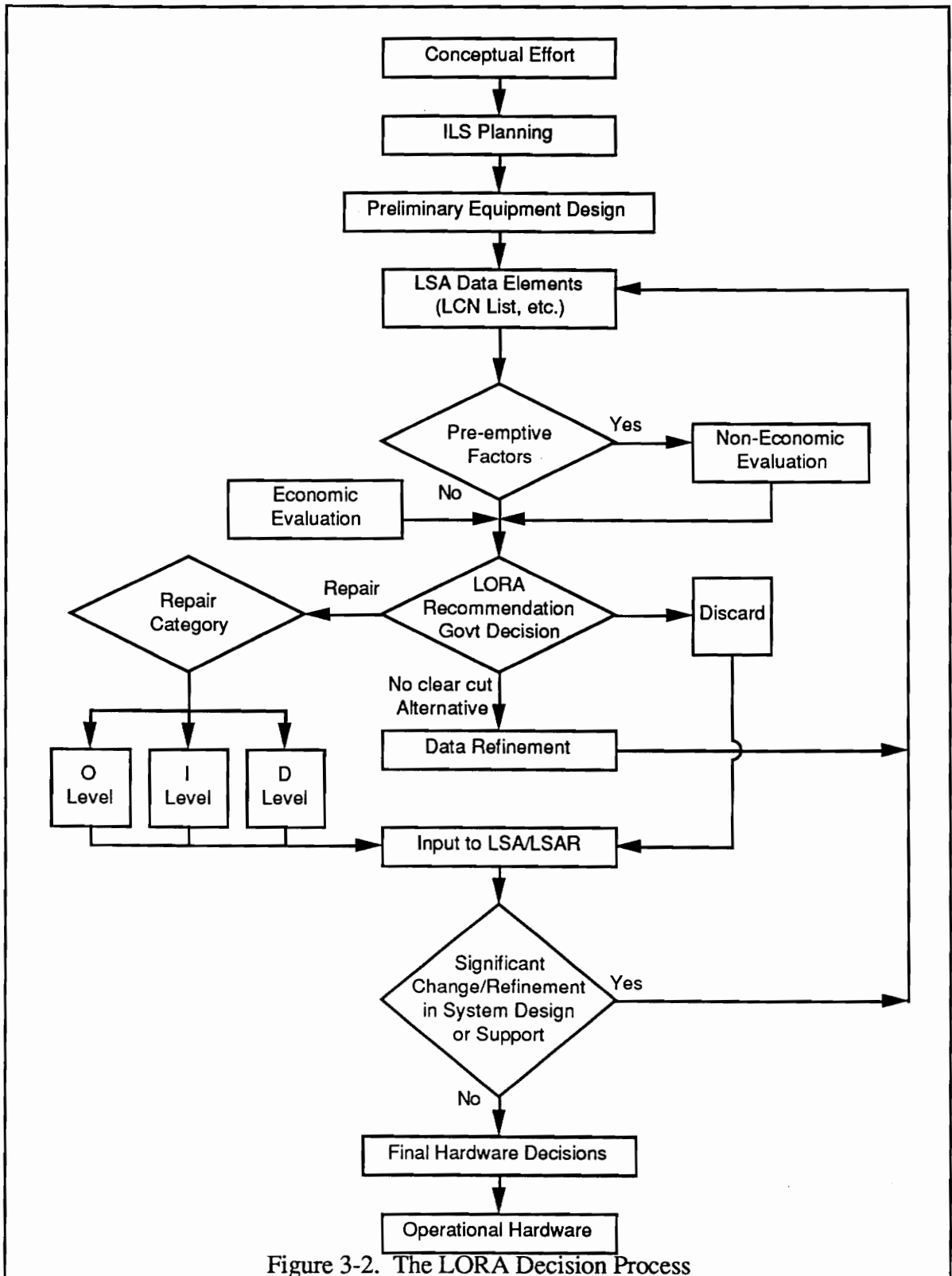


Figure 3-2. The LORA Decision Process

3.5.1 LORA Planning.

The objective of LORA planning is to establish procedures which will ensure that the LORA effort is timely and effective. It is essential that the LORA effort be coordinated with the ILS and LSA efforts as well as other systems engineering efforts. The above items are addressed in this report to the extent pertinent, specifically in Sections 4 and 5.

Normally, a document known as the LORA Program Plan is developed. This plan outlines the following areas:

- a.) the scope of contractors analysis efforts (e.g., what components will be analyzed, etc.);
- b.) who will perform the analysis;
- c.) the modeling and/or analytical techniques to be used;
- d.) the analysis schedule, and;
- e.) the overall approach to be used to include data requirements, data collection methods, interfaces with other program elements, how the results will used and/or supplied to the acquiring organization, etc..

For contractual reasons, a separate LORA Program Plan was not developed on the NSG Program. Rather, the above areas were addressed in the NSG LORA Report which was delivered to the Navy. Since the LORA planning was adequately documented, the lack of a special LORA did not hinder the NSG LORA.

3.5.2 Data Collection.

3.5.2.1 Data Sources.

Substantial data inputs from both the program office and the contractor were required to complete this analysis. As is usual procedure when conducting a LORA, an initial analysis was conducted using available information. The sources for this data were:

- a.) the NSG LSAR;
- b.) data generated via the NSG LSA and systems engineering processes, and;
- c.) the LORA Default Data Guide provided with the model.

Data from the ILS program and other systems engineering programs was addressed in the LORA. Task and resource requirements were identified through the NSG LSA effort and recorded in the NSG LSAR.

3.5.2.2 Data Requirements.

Appendix A delineates the overall data requirements for the LORA (using this particular model) as well as the data values used in the initial NSG LORA run. There were six major areas for which the LORA required data. These were:

- a.) system program and cost data (G Form);
- b.) site data (S Form);
- c.) item identification (I Form);
- d.) item characteristics (L Form);
- e.) task data (T Form); and,
- f.) manpower data (M Form).

Two more forms are included for the analyst which address LORA alternatives and sensitivity analyses. The data values contained in Appendix A reflect the available data provided to the analyst by the contractor and the Navy, data generated by contractor LSA and systems engineering, and the LORA data defaults. While this report reflects values used in the initial LORA, the analysis cannot be considered fully valid. In order to properly validate the NSG LORA, actual historical data values will have to be acquired and entered into the model. When run, this new data should provide the final LORA.

3.5.3 Non-economic Evaluations.

3.5.3.1 Pre-Emptive Factors.

Non-economic evaluations are undertaken to evaluate constraints, pre-emptive, and intangible factors which affect or restrict maintenance levels at which items can be repaired or discarded, thus affecting support alternatives. These evaluations address and consider the following types of factors:

- a.) constraints of existing logistics support structure;
- b.) safety;
- c.) deployment mobility;
- d.) technical feasibility of repair;
- e.) mission success and operational availability (A_0) requirements;
- f.) manning;
- g.) human factors;
- h.) policy;
- i.) special transportability factors;
- j.) security;
- k.) vulnerability; and,
- l.) survivability.

The key objective of non-economic analysis is to eliminate support alternatives that are not practical or feasible due to the factors listed above. There were three major non-economic constraints placed on the NSG LORA and hence the allowable NSG support structure. These conditions dealt with the maintenance concept dictated by the Navy and are discussed in Section 4.

3.5.3.2 LORA Candidate List.

The LORA does not usually or necessarily analyze the entire system and all its components. Rather, a LORA candidate list (LCL) is developed using the following criteria. A LORA candidate must:

- a.) be replaceable at the organizational (O) level of maintenance;
- b.) be technically feasible to repair;
- c.) be maintenance significant; and,
- d.) have supportability requirements.

A LORA candidate must meet all of the above four conditions. The requirement of being replaceable at the O level eliminates subcomponents which require resources, i.e., personnel (skill levels) tools, test equipment, documentation, etc., which are not present at the O level.

Given these criteria, the LORA candidates are in fact, the Lowest Replaceable Units (LRUs) of the NSG. Through Maintenance Engineering Analysis (MEA) of the NSG system and its components and through examination of the Navy's maintenance capabilities, the NSG LORA analyst developed an NSG LORA Candidate List. This list was reviewed and approved by the Navy before the NSG LORA continued into the economic evaluation.

The LORA candidate list was derived by examining the NSG Logistics Candidates Number (LCN) List (as developed via the NSG LSA/LSAR) and eliminating those components which did not meet the LORA candidate criteria. The NSG LCL is presented in Table 3-1.

Table 3-1. NSG LORA Candidate List

LORA Number	Part Number	Name
1	TBD	Signal Generator
2	M23071/29	Tubeaxial Fan
3	P875001901	Power Supply
4	K633320045	Tone Generator CCA
5	K633320045	Tone Generator CCA
6	K633320045	Tone Generator CCA
7	K633320045	Tone Generator CCA
8	K633320045	Tone Generator CCA
9	K633320080	Noise Source CCA
10	K633320065	Bandpass Filter CCA
11	K633320060	Mode/Notch CCA
12	K633320060	Mode/Notch CCA
13	K633320060	Mode/Notch CCA
14	K633320060	Mode/Notch CCA
15	K633320040	Preamplifier ALC CCA
16	K633320040	Preamplifier ALC CCA
17	K633320055	Memory ALC CCA
18	K633320050	CPU CCA
19	K633320075	Input/Output Interface CCA
20	K633320085	Input/Output Extended CCA
21	K633320035	Display Controller CCA
22	K633320030	Display CCA
23	K633320070	Backplane
24	P595000101	Keypad, 32 Position
25	K633310058	Converter, DC/AC
26	K633320009	Tubeaxial Fan/Alarm Assembly
27	P880002401	Tubeaxial Fan
28	P880002401	Tubeaxial Fan
29	K633310001	Remote Control Unit
30	P880002401	Tubeaxial Fan
31	P875001801	Power Supply
32	K633320030	Display CCA
33	K633320035	Display Controller CCA
34	K633310008	Suppressor Filter Assembly
35	P595000101	Keypad, 32 Position
36	K633310058	Converter, DC/AC

3.5.4 Economic evaluations.

In addition to non-economic factors, certain economic factors influenced the development of the LORA Candidate List (LCL). These included the consideration of unit cost and reliability (as a function of unit cost), and the NSG system configuration.

An economic analysis is undertaken to establish the least cost feasible support alternative for the system items under consideration (i.e., the LCL). This evaluation is based on cost and performance factors. While it can be performed manually using the methodology and algorithms outlined in Military Standard 1390C, the NSG LORA was conducted using the model describe earlier. This model examines the interface relationship between the system configuration and the logistic support structure. The non-economic factors mentioned earlier affect the performance factors input into the LORA model and are translated into life-cycle logistics costs associated with each given maintenance alternative.

The primary economic evaluation was conducted by the computer model itself. The data input and output sheets for the NSG and the RCU are contained in Appendices B and C respectively.

3.5.5 Sensitivity Evaluations.

Sensitivity evaluations are a continuation of the economic evaluations. They are conducted to determine the effect (s) on the LORA when selected factors in the analysis are varied. As shown in Figure 3-1, factors which may impact are uncertainty in the equipment design, changes in pre-emptive factors, and variations in component characteristics. A LORA sensitivity analysis consists of the following:

- a.) identifying specific LORA data elements which are subject to change based on variations in design, operating environment, or support structure factors;
- b.) establishing a numerical range within which the data elements is expected to fall (this is usually expressed as a percent increase or decrease in the original value used);

- c.) analyzing the impact and effects (based on the intended numerical range) on the logistics costs and maintenance alternative selected by the economical evaluation; and,
- d.) confirming or changing the recommended maintenance alternative derived from earlier economic evaluations; and,

Additionally, sensitivity analyses quantify the economic risk to the system procurer in making LORA decisions when uncertainty exists regarding hardware design and support system structure.

In the initial NSG LORA run, two sensitivity analyses were conducted. These analyses are discussed in detail in Section 7.

3.5.6 Analysis and Documentation of Evaluations Performed.

LORA results are usually forwarded to the system procurer for review in the form of a LORA Report. These results include the data elements used and recommendations regarding the most effective, yet economical, support alternative. The system procurer can accept, reject, or modify the recommendations or he can postpone decisions until further details and data are available.

The NSG LORA data input sheets are included as Appendix B of this report to document the quantitative values used in the analysis. The LORA results (the data output reports) are documented in Appendix C of this report. Sensitivity analyses are documented in Appendix D.

3.5.7 Utilization of Analysis Results.

As shown in Figure 3-1, LORA results are fed back into the iterative ILS/LSA process as well as providing data to other systems engineering functions.

The results from this LORA have impacted the NSG LSA and been incorporated into the NSG LSAR. After final government decisions are made regarding this analysis and its results, an addendum will be prepared to document the LORA results.

3.5.8 LORA Updates.

LORA is an iterative process and updates should be performed periodically throughout the system life-cycle. In general, updates are required when any major event occurs which causes refinements in LORA input values, support characteristics, or system design. In particular, the LORA should be updated when final system reliability and maintainability analyses are completed and when final system provisioning requirements are finalized.

It is planned that the NSG LORA will be updated as required during the remainder of the NSG program.

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- ¹ MIL-STD-1388-1A, Military Standard, *Logistics Support Analysis*, Department of Defense, Washington, D.C., 11 April 1983.
 - ² In addition to the methodology described in Military Standard 1390C, the NSG LORA also followed the procedures detailed by J. Crabtree and B. Sandel, "Army Level of Repair Analysis (LORA)", *Logistics Spectrum*, Journal of the Society of Logistics Engineers (SOLE), Volume 23, Issue 2, Summer 1989, (pp 27-31). It should be noted that Section 3.5 draws heavily from this article.

4.0 LOGISTICS

While the LORA is a systems engineering function, it requires inputs and interface with the ILS and LSA processes. This chapter is included to explain these relationship as well as delineate the impact of various logistics elements in the LORA.

4.1 LORA AND LOGISTICS INTERFACES

The contractor instituted an ILS program to ensure that the NSG could be supported in the Fleet. The ILS program utilized LSA as the principal analytical tool in developing ILS information and an NSG logistics data base, the Logistics Support Analysis Record (LSAR). The LSA program was conducted in accordance with Military Standard 1388-1A and 2A.¹ The contractor established and controls the ILS/LSA efforts of its suppliers and subcontractors and ensured that these efforts were in accordance with NSG logistics requirements.

Interface between contractor design and logistics personnel occurred on a constant basis. While coordinating activities through the ILSM, logistics personnel interfaced directly with all areas of the design team. ILS and support engineering personnel participated in all scheduled NSG design reviews. These interfaces were essential in the development and collection of data for LORA elements.

4.1.1 Contractor ILS Interfaces.

The NSG LORA analyst interfaced directly with the following contractor personnel:

- | | |
|--|--|
| a.) Program Manager | h.) Test Engineer |
| b.) Project Engineer | i.) Reliability/Maintainability Engineer |
| c.) Electrical Engineer | j.) Human Factors Engineer |
| d.) Mechanical Engineer | k.) Technical Data |
| e.) Digital Designer/Software Engineer | l.) Provisioning |
| f.) Engineering Support Services | m.) Training |
| g.) ILS Manager | |

The LORA effort interfaced directly or indirectly with the above areas. Coordination between the LORA and the logistics and systems engineering efforts was handled thru the contractor ILS Manager (ILSM). The ILSM was responsible for obtaining data for LORA inputs from other contractor entities (such as Purchasing for cost data and Packaging for PHS&T inputs) as well as obtaining data from the Navy .

4.1.2 Government/Contractor ILS Interfaces.

The government (the Navy) was also required to supply data essential to the LORA effort. As part of the logistics interface, the contractor submitted a data request to the Navy for government provided LORA data elements. The Navy responded and the values for these data elements were used in iterations of the LORA.

It should be noted that direct interface with government personnel regarding the LORA was also necessary, particularly the logistics staff. These personnel paralleled the contractor personnel in their respective areas of responsibility, e.g., there is a Navy ILSM and a contractor ILSM.

4.1.3 Interface Methodology.

Regarding system design, interface existed primarily through the application of LSA in identifying design related shortfalls and targets for subsequent design study. This is achieved through analysis and logistic reviews as the design effort progressed through its cycle. As mentioned before, LORA is an iterative process performed throughout the design effort and is intended to influence design.

Coordination and data exchange between the LORA analyst and design staff was necessary for several reasons. First, design engineers are not always aware of all the factors involved with the system maintenance concept and they may or may not discuss these issues with the LORA analyst. The analyst or the Maintainability Engineer must ensure that the system is being designed with the maintenance concept in mind, i.e., he must ensure that maintenance considerations (i.e., level of repair issues) are correctly addressed by the design team. Secondly, it is necessary to procure data from the engineers in order to correctly model the system and all its components down to the proper indenture.

Additionally, the LORA analyst needs to be aware of the various issues involved with attempting to maintain the system or a specific component. In the case of an electronics system for example, if one is to maintain a given component at the organization level, then the user must usually have certain pieces of support equipment which will test system performance parameters and hence, verify the proposed maintenance action. Obviously, this information is critical to the LORA effort.

4.1.4 Reliability and Maintainability (R&M) Data.

The collection and integration of system, equipment, and component reliability and maintainability data into the LORA process was achieved through the LSA. R&M parameters are critical for measuring attainment of all system objectives, and for analyzing maintenance requirements and concepts.

The key reliability figure to account for in the LORA is Mean Time Between Maintenance (MTBM). This maintenance can either be corrective or preventive. Since the NSG system (as analysed by this LORA) consists of primarily electronics or mechanical components which are not normally subject to wearout, it is anticipated that all of the maintenance will be corrective in nature. It was determined that any preventive maintenance, such as cleaning, would be unscheduled and could be conducted without making the system unavailable for normal use. Therefore, MTBM for the NSG corresponds to Mean Time Between Failure (MTBF).

Expressed in hours, MTBF is a quantitative value describing the reliability of a system, equipment, or component. The greater the MTBF value, i.e., the higher the number of hours, the less the item will fail. The more an item fails, the more demand it will place on the system support structure to provide spares or repair parts. This will usually raise the support and maintenance costs. The method by which a LORA accounts for component MTBF and the associated costs is discussed in Section 5.

4.1.5 Configuration Management (CM).

CM organization was responsible for the tasks of identifying and controlling the complete NSG configuration. Accurate records of the exact configuration were maintained

to ensure the identification of any logistics impacts of a particular change. Records are maintained for each serially numbered item fabricated. These records are used to determine the impact which a given or particular recommended design change may have on the maintenance/ support planning for an item. One of the main objectives of configuration management is to ensure that all proposed changes are measurable back to the latest baseline, and that all logistic objectives are satisfied. Specifically, a new or proposed configuration of a system or equipment may have different logistics impacts than previous versions.

CM affects the LORA in terms of using the latest drawings. These drawings (NSG design) help determine the logistics values to be used in the LORA for each NSG component (i.e., costs, R&M parameters, documentation and training requirements, etc.). As new drawings are released (i.e., design changes), they must be analyzed to determine possible impacts the LORA results.

4.1.6 Overall Program ILS Interfaces.

Supporting the Navy ILS program is the contractor ILSM, who draws upon ILS/LSA analysts to assist him in the performance of NSG ILS/LSA efforts. The contractor ILSM, in conjunction with the Navy ILSM, coordinates the logistics/systems engineering aspects of the NSG program.

The ILS program coordinates activities with all of the contractor design activities. Specifically, ILS interfaces with the contractor functions listed in Table 4-1 below.

Table 4-1. ILS Process Inputs/Outputs

Inputs to the LORA will come from the following subprograms:

- | | | |
|-------------------------------------|----------------------------|----------------------|
| a.) Design considerations | g.) Test and Evaluation | m.) LSA/LSAR |
| b.) Reliability and Maintainability | h.) Technical Publications | n.) Facilities |
| c.) Configuration Management | i.) Quality Assurance | o.) Supply Support |
| d.) System Safety | j.) Computer Resources | p.) Life-Cycle Cost |
| e.) Human Engineering | k.) Training | q.) Support and Test |
| f.) Maintenance/Supportability | l.) PHS&T | Equipment |

Outputs from the LORA will be used by the following areas:

- | | | |
|-------------------------------------|-------------------------|----------------------|
| a.) Navy Program Management | f.) Test and Evaluation | k.) Facilities |
| b.) Technical Documentation | g.) Life-Cycle Cost | l.) PHS&T |
| c.) Configuration Management | h.) Design | m.) Provisioning |
| d.) Maintenance Plan | i.) Personnel/Training | n.) Support and Test |
| e.) Reliability and Maintainability | j.) LSA/LSAR | Equipment |

Clearly, the LORA utilizes the same inputs and outputs as the ILS and LSA programs.

4.2 MAINTENANCE ENGINEERING PROGRAM

4.2.1 Maintenance Planning.

Initial maintenance planning for the NSG was structured to ensure that the following objectives were properly addressed:

- a.) Interim Contractor Support (ICS) by the contractor for the repair or disposition of failed NSG components for the period immediately following introduction of the system.
- b.) Depot level maintenance by the contractor.
- c.) Direct Fleet Support (DFS) by the Navy .
- d.) Transition of repair support from the contractor to the Navy

(It is envisioned that maintenance planning for NSG components will be impacted by engineering change proposals (ECPs) to the NSG design as well as future iterations of the LORA).

4.2.2 Maintenance Engineering Analysis Interrelationships.

As shown in Figure 4-1 (page 34), the NSG Maintenance Engineering Analysis (MEA) requires substantial interaction between various elements of logistics. As shown earlier in Figure 3-1, the LORA must impact this effort by forcing the design and support staff to consider support and maintenance in the system design. This impact is achieved through Logistic Support Analysis (LSA) tasks and systems engineering functions.

LSA Tasks are defined in Military Standard 1388-1A and range from 100 level to 500 level efforts. The LSA Tasks which relate to the identification of maintenance and support requirements lie primarily in what are called the 300 and 400 level tasks. The 300 level tasks are called "Preparation and Evaluation of Alternatives", of which LORA is a defined subtask.² The 400 level tasks are called "Determination of Logistic Support Resource Requirements".³ The quantitative data resulting from the performance of these tasks is recorded in the LSAR, specifically in what are known as the "C" and "D" records. The C record is called "Operation and Maintenance Task Summary" while the D record is called

"Operation and Maintenance Task Analysis".⁴ These records provide a sequential task listing for all the system maintenance tasks and are summarized in an LSA Output Report, number 015. This report is then used by Technical Documentation and Training specialists to develop the system Technical Manuals and Training curriculum.

As an input to the performance of the LSA 300 and 400 level tasks, a LORA and a Failure Modes, Effects, and Criticality Analysis or FMECA is performed. The FMECA is a systems engineering effort which seeks to identify possible system element (component) failures, assess their probability of failure based on component reliability data, assess the effects of given possible and probable component and subsystem failures on the overall system operation, and assess the criticality of given possible and probable component and subsystem failure on system operation. The data from both the LORA and the FMECA is promulgated to the analysts performing the LSA and is recorded in the LSAR "B" records, Reliability and Maintainability Characteristics.⁵

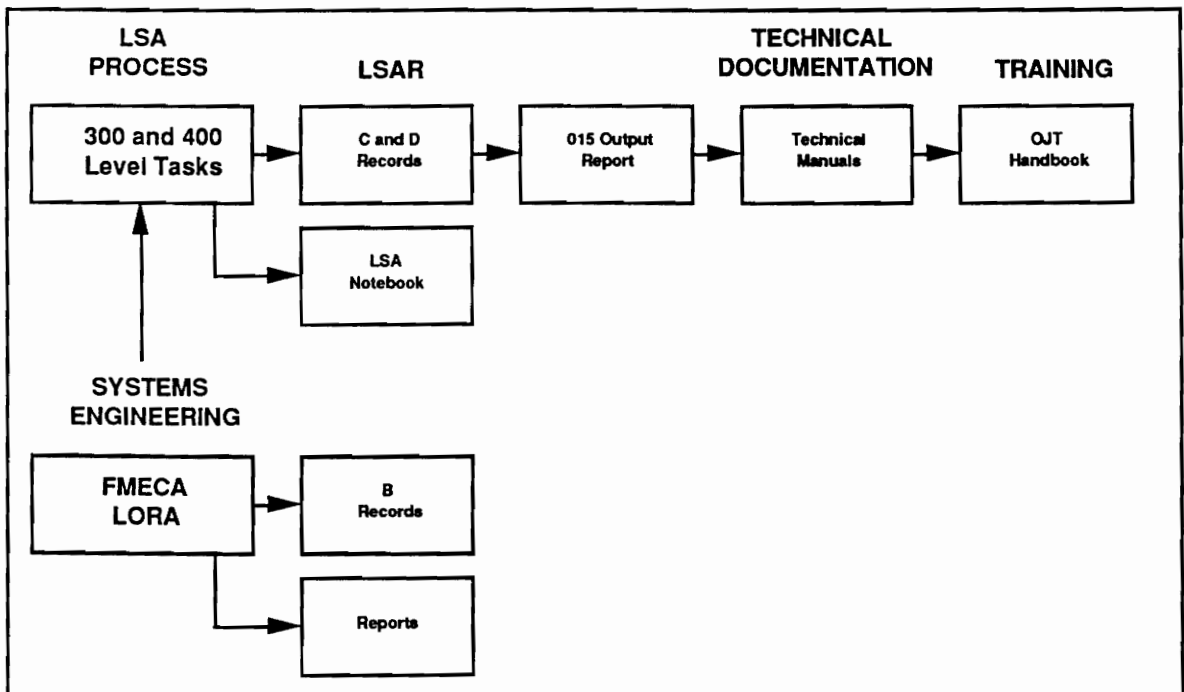


Figure 4-1. NSG MEA Relationships

It can be stated that the NSG LORA successfully impacted the NSG LSA. Specifically, the LORA identified the maintenance tasks to be performed and the resources needed to accomplish them. The results of the LSA 300 and 400 level tasks were recorded in the NSG LSA Notebook and formed the basis of the LSAR C and D sheets. This data in turn formulated the LSA-015 Output Report, Technical Manuals, and Training deliverables.

4.2.3 Maintenance Concept.

As dictated by the Navy, the NSG will utilize a maintenance concept consisting of two levels of maintenance; Organizational (O) and Depot (D). Organizational maintenance will be performed by trained shipboard personnel but no detailed electronics work on intricate parts will be performed. There will be no Intermediate maintenance performed on NSG. Depot repair will be performed either at a Navy depots or the contractor's facilities. (Current planning calls for all NSG depot maintenance to be performed by the contractor.) Exact O and D level maintenance tasks and procedures will be determined by the LSA and the LORA.

4.2.3.1 Organizational Maintenance.

Organizational maintenance includes the following types of maintenance actions that can be performed by trained personnel of the Navy rank of Petty Officer third class level:

- a.) Corrective adjustments, lubrication, and alignment of mechanical components;
- b.) Corrective adjustments and alignment of electrical/mechanical components;
- c.) System testing using Built-In-Test (BIT) fault location capability to monitor performance and detect system faults;
- d.) Removal and replacement of Lowest Replaceable Units (LRUs);
 - 1. electronic modules,
 - 2. circuit card assemblies,
 - 3. lamps/fuse,
 - 4. chassis mounted piece parts, and,
 - 5. mechanical parts within the organizational maintenance capability; and,
- e.) Discard of selected components as determined by the LORA.

4.2.3.2 Depot Maintenance

Depot maintenance includes repair and overhaul of all repairable components of the NSG. Maintenance at the depot will be performed by trained contractor mechanical and electrical/ electronic personnel at the Contractor facilities and includes the following types of maintenance actions:

- a.) Testing/fault isolation of returned NSG components;
- b.) Disposition of LRUs (repair/discard of LRUs as determined by the LORA);
- c.) Reassembly and retesting, as required, to meet NSG operating requirements as detailed in the technical manuals and technical repair standards; and,
- d.) Return of NSG components to Navy supply inventory as required.

There were three major non-economic constraints placed on the NSG LORA and hence the allowable NSG support structure. These conditions dealt with the maintenance concept dictated by the Navy and were:

- a.) There will be no repair or maintenance of NSG components at the Intermediate (I) level of maintenance.
- b.) There will be no electronic repair of NSG Circuit Card Assemblies or their components at the Organizational (O) level of maintenance.
- c.) NSG components (specifically, the Lowest Replaceable Units (LRUs) will be removed and replaced, but not repaired, at the O level of maintenance.

These constraints dictated a strictly O and D level maintenance concept which is reflected in the LORA, LSA/LSAR, and ILS elements. ⁶

4.3 MANPOWER/PERSONNEL AND TRAINING

4.3.1 Manpower/Personnel.

Organizational level NSG maintenance will be performed by trained Navy Electronics Technicians (ETs). Additional tasks imposed by the incorporation of the NSG into the

existing system (the AN/SLQ-25) will not entail a significant increase in the NIXIE workload and it is planned that these tasks will be accomplished by existing shipboard personnel. The reason little additional organizational level maintenance is anticipated is because the new NSG has a much greater reliability and much less preventive maintenance. NSG depot level tasks will be performed by qualified contractor or Navy personnel.

Consideration of manpower/personnel requirements is mandatory in the LORA process. It is necessary to determine and optimize the costs associated with using various types of technicians at the different maintenance levels. These skill levels were accounted for in the NSG LORA calculations.

4.3.2 Training.

It is also necessary to account for any additional training required by the introduction of a new system into a given maintenance structure. The maintainers may or may not have the skills necessary to support the system maintenance concept. If not, they will need to be trained. In the case of the NSG, training will consist of classroom instruction combined with on-the-job training.

Additionally, system training curricula, training aids, course and course materials usually require update in order to reflect the incorporation of new equipments into the overall system. These are usually covered under the technical documentation requirements.

Training costs for NSG users/maintainers were considered in the LORA.

4.4 SUPPLY SUPPORT

Consideration of NSG supply support requirements is essential to the LORA because they impact discard and repair decisions via the costs associated with them. The following section is intended give the reader an understanding of NSG supply support planning.

4.4.1 Material Support Requirements.

The contractor utilized LSA/LSAR data and LORA outputs to identify the spare and repair parts necessary to maintain the NSG. This data was also used to initiate management and planning tasks which ensure that provisioning is accomplished in order to support NSG logistics requirements.

4.4.2 Transition to Government Support.

The contractor will recommend spares, repair parts, maintenance items, and all support items required to support and maintain the NSG during the Interim Support Period. These recommendations will include:

- a.) At sea tests,
- b.) Installation and Check-Out (INCO),
- c.) On-Board Repair Parts (OBRPs) kits to support NSG; and,
- d.) the use of Maintenance Assist Modules (MAMs), if required.

Recommendations for interim support items and quantities will be presented to the Navy for approval. Replenishment spares for the Interim Support Period will be stocked at the contractor. Since many LORA computer models provide the necessary data (i.e., the numbers and types of spares), the prime basis of these recommendations will be from the final LORA outputs.

4.4.3 Spares Procurement and Outfitting.

The Navy will procure OBRPs and NSG stock requirements as identified by the results of the LORA and the Interim Support Items Provisioning Conference. The range of spares and repair parts required to support the NSG will be identified at the various provisioning conferences to be conducted over the course of the program. Final decisions regarding parts procurements will be based on the LORA and documented in the Provisioning Item Order (PIO).

4.5 SUPPORT AND TEST EQUIPMENT

The contractor needed to identify the support and test equipment (STE) required to support the NSG at both levels of maintenance. The use of standardized STE, or those STE types which are already in the system support structure, is usually a design requirement to the extent possible in order to minimize STE acquisition costs. In other words, it is extremely cost effective if a system or equipment can be designed whose test parameters and methods are compatible with existing STE which is already in the systems users' STE inventory. STE to support modern electronics systems is usually very expensive. This is especially true with DOD electronics systems since most of the military services own a plethora of STE which can readily test many electronic functions.

Those requirements identified in the NSG LSA and LORA efforts were detailed in the NSG Tools and Test Equipment List. All standard STE will be available at the NSG users activities and selected from Military Standard 1364G, Standard General Purpose Test Equipment and the Navy Preferred Off-Line Test Equipment List.⁷

Given the high acquisition costs associated with STE, determination of NSG STE requirements was crucial to the LORA process due the costs usually associated with procuring any additional STE for the user.

4.5.1 Tools and Test Equipment.

The purpose of the TTEL is to delineate those tools and test equipment needed to maintain the NSG at the organizational level of maintenance. Specifically, this list contains those support items which are required to inspect, test, service, and repair these NSG end items. Table 4-2 presents a consolidated list of these tools.

This data is derived from the LORA and LSA 400 level tasks and is contained in the NSG LSAR data base, i.e., the LSAR H Records and the LSA-036 Output Report. Since these tools are all standard, i.e., they should already be present at the user sites, they are not specially accounted for in the NSG LORA calculations.

Table 4-2. NSG Tools and Test Equipment List (TTEL)

Item Name	Reference Number	National Stock Number	Unit Cost
Screwdriver, Cross Tip	GGG-S-121 TY6CL1	5120005960861	1.71
Screwdriver, Cross Tip	1509026	5120005293101	1.03
Screwdriver, Flat Tip	1255565	5120005968653	.57
Key Socket Headscrew (Allen wrench 5/64")	0181-6	5120002242504	.03
Socket, Socket Wrench (Size 9/16")	A-A-1404	5120002276704	.51
Handle, Socket Wrench (3/8" Drive)	395259	5120002405364	5.66
Strap, Wrist Grounding	2066	4240011658865	6.23

4.5.2 Special Purpose Support and Test Equipment.

No special purpose STE (SPETE) was identified via the LSA or LORA processes. It is currently envisioned/intended that none will be necessary. If any SPETE were identified at a later date, it would/will be incorporated into subsequent iterations of the LORA. Given that SPETE costs are usually significant, identification of SPETE would need to be accounted for in future LORA calculations.

4.6 LOGISTICS TECHNICAL DOCUMENTATION

Technical documentation for the NSG includes technical manuals, software data and manuals, engineering drawings, operation and maintenance instructions, and other logistic support drawings, operation and maintenance instructions, and other logistic support documentation. Like STE definition and acquisition, the procurement of the above mentioned technical documentation can be relatively expensive and must therefore be accounted for in any LORA effort.

4.6.1 Technical Documentation/Data Requirements.

The logistics technical data required under the NSG contract consisted of all documentation necessary to conduct the operation, training, maintenance, modifications, repairs, installation, and overhaul of the NSG. This included all deliverable documentation (CDRLs) and non-deliverable documentation (LSA Tasks, etc.). The results of the LORA were documented in the NSG LSA Notebook and LSAR.

4.6.2 Technical Manuals (TMs).

The primary documentation cost in most acquisition programs, and hence the LORA, is usually the TM effort. The cost of the NSG TMs was accounted for in the NSG LORA.

The NSG TM effort consisted of six separate CDRLs and produced a new RCU TM as well as change pages to the original NSG TM. This effort reflected the design upgrades of the NSG program. These TMs were developed and delivered in the electronic media specified in the NSG contract (i.e., reproducible copies on computer diskette).

Table 4-3. NSG Training and Technical Manual CDRLs

CDRL	TITLE
C001	Technical Manual Permanent Change Pages
C002	Technical Manual Quality Assurance Plan
C003	Technical Manual Validation Plan
C004	Technical Manual Validation Certificate
C005	Technical Manual Standard (Signal Generator)
C006	Technical Manual Standard (RCU)

4.6.3 Installation and Check-Out Procedures.

Installation and appropriate check-out procedures for the NSG will be developed under the another contract and thus, the cost for these procedures was not accounted for in this LORA.

4.6.4 Planned Maintenance System (PMS) Requirements.

A planned maintenance system includes the scheduling of both preventive and corrective maintenance. Preventive maintenance includes necessary scheduled system cleaning, lubrication, adjustment, calibration, and replacement of expendable parts, i.e., the cleaning or disposal and replacement of air filters. As mentioned earlier, the NSG maintenance concept assumes little in the way of preventive maintenance.

A new concept in the Navy however, is to attempt to schedule corrective maintenance based on calculated reliability figures. Given the high reliability goals of the NSG system and therefore, correspondingly high reliability requirements, corrective maintenance requirements could not accurately be determined until final reliability data (i.e., MTBF, MTBM, etc.) and the results of the NSG FMECA made available. Additionally, the contractor has not yet received cost data regarding the PMS effort for incorporation into the NSG LORA. As such, the PMS cost for this LORA iteration was assumed to be zero.

4.7 **CONTRACTOR ENGINEERING TECHNICAL SERVICES**

When contracted, the contractor shall provide engineering services, including qualified personnel, to support NSG personnel (military and/or civilian) as directed by PMS 415. These services, provided by the contractor personnel, shall include, but not be limited to the following:

- a.) Support of Installation and Check-Out (INCO);
- b.) Engineering/technical services;
- c.) Training liaison;
- d.) Field training;

- e.) Installation of the Change Kits at specified locations; and,
- f.) Support of Government at-sea-testing.

As mentioned earlier, these services would be accomplished by qualified contractor personnel. Since these services have not yet been contracted or identified by the LSA as integral to the NSG maintenance concept, the LORA was not able to account for their cost(s).

4.8 CONTRACTOR DEPOT SUPPORT

When contracted, the contractor will provide Contractor Depot level maintenance. The types of tasks to be performed as part of NSG this maintenance are delineated in Paragraph 4.2.3.2 of this report. Key elements of the contractor's Contractor Repair Depot (CRD) include but are not limited to the following: inspect, disassemble, clean, repair, overhaul, modify, assemble, test, mark, preserve, package, and label all Government owned equipment.

Since contractor depot maintenance is an important part of the maintenance concept, it was essential to derive accurate depot level maintenance costs. The NSG LORA allowed for the consideration of contractor depot maintenance and the costs associated with that maintenance.

4.9 FACILITIES

No new or unique supply or maintenance facilities will be required to support NSG during or subsequent to the NSG Interim Support Period of the production phase. Interim Contractor Supply Support (ICSS) will be accomplished at the contractor facilities. Training/school facilities will not be impacted as new training will be integrated with current NIXIE training activities. The NSG LORA therefore, assumes no additional costs associated with NSG maintenance or training facilities.

4.10 PACKAGING, HANDLING, STORAGE, AND TRANSPORTATION (PHS&T)

The contractor established a Packaging, Handling, Storage, and Transportation (PHS&T) program to ensure that PHS&T requirements were fully considered in NSG design and supportability development as well as the LORA. The contractor ensured that tools, equipment, and procedures selected/developed for the NSG did not adversely affect PHS&T requirements.

PHS&T costs impact the LORA decisions in that they may represent a substantial percentage of the costs associated with transporting an failed item to a higher echelon of maintenance for repair. These costs are great enough that each military service has a minimum value for a failed item which must be superceded before the item may be considered as a repairable. This value varies between each service but in the case of Circuit Card Assemblies (CCAs), for example, this value is somewhere between \$400.00 and \$700.00. In other words, any CCA less than the set minimum is automatically considered a discard item upon failure if repair would incur transportation.

This minimum item cost requirement is usually accounted for in the LORA effort when developing the LORA Candidate List. Items not meeting this cost criteria are excluded from the LORA economic analysis and assigned a discard LORA code.

Since no special PHS&T requirements were identified via the LSA or systems engineering processes, the NSG LORA calculations assume no special costs for PHS&T of NSG components. Navy default values for the PHS&T data fields were used and the standard PHS&T calculations are delineated in Appendix A and B.

¹ MIL-STD-1388-1A, Military Standard, *Logistics Support Analysis*, Department of Defense, Washington, D.C., 11 April 1983 and MIL-STD-1388-1A, Military Standard, *Logistics Support Analysis Record*, Department of Defense, Washington, D.C., 11 April 1983.

² MIL-STD-1388-1A, page 7.

³ Ibid, page 8.

⁴ MIL-STD-1388-2A, pages 71-92.

⁵ Ibid, pages 44- 70.

⁶ The NSG maintenance concept is fully detailed in Section 4.2.3 of this report.

⁷ MIL-STD-1364G, Military Standard, *Standard General Purpose Test Equipment*, Department of Defense, Washington, D.C., 5 February 1987.

5.0 LORA MODEL

5.1 MODEL DESCRIPTION

The NSG LORA was conducted using a computer based model provided by the government. The application of this model to the NSG LORA is described detail in the following paragraphs. Despite the NSG being a surface ship system procured by Naval Sea Systems Command (NAVSEA), a LORA model developed for analyzing naval avionics was used. ¹ This model was the Naval Aviation Systems Command (NAVAIR) Mod II/III MICROLORA Plus (Version 89-007, July 1989). ² This model is based on Military Standard 1390C, Level of Repair. This model (and subsequent updates) were acquired from the Naval Aviation Maintenance Office (NAMO) Code 331 located at the Patuxent River Naval Air Station, Maryland. ³

5.1.1 Main Features.

The Mod III version was the first LORA model to be used by NAVAIR which derived the optimal (least cost) LORA solutions by presenting cost evaluations of prescribed LORA alternatives.

The model can analyze and optimize up to one hundred items for a single configured system. These items will be analyzed at three maintenance indenture levels. Model can handle ninety-nine different user (system) locations. The model can also perform sensitivity analyses on ten different input parameters. The purpose of these analyses is to evaluate the effect of changes in any one parameter or a combination of parameters on the decisions of the model. The model breaks out all recurring costs associated with each repair alternative thus indicating the most important factors. The model allows the user to input self-defined maintenance alternative scenarios and compare the variations from the standard alternatives.

5.1.2 General Description.

The model recommends levels of repair for three levels of components for the system/equipment under analysis. The model's decisions are based on a comparison of the total life-cycle logistics support costs for the equipment for the various maintenance alternatives. There are six basic alternative in the model and these are discussed on page 48 and in Section 5.1.5. The least cost alternative for each part of the equipment is recommended.

The model considers up to three indenture levels at a time. The relationship between components is defined in a parts hierarchy. System items in the first indenture level are classified as the Lowest Replaceable Units (LRUs) (the model defines LRUs as Weapon Replaceable Assemblies (WRAs)), those in the second level are Shop Replaceable Assemblies (SRAs), and those in the third level are Sub-Shop Replaceable Assemblies (SSRAs).

These components generally exhibit the following characteristics:

- a.) WRA - Removed from the equipment
 - Repaired by removing and replacing lower level assemblies and piece parts ⁴
- b.) SRA - Removed from the WRA
 - Repaired by removing and replacing lower level assemblies and piece parts
- c.) SSRA - Removed from the SRA
 - Repaired by removing and replacing piece parts

While most systems/equipments under analysis have more than three indenture levels, it doesn't matter to the model as long as a hierarchy of parts is defined. Specifically, SSRAs are identified as subcomponents of SRAs which are in turn components of WRAs. Piece parts are not considered in a LORA in terms of repairability but their cost is considered in the analysis calculations.

The LORA begins at the O level with a non-economic analysis to determine technical feasibility of repair. When repair is recommended, the model determines at which level.

The model accounts for these levels of maintenance, with Navy supply points, as the available logistic support system. The flow of NSG repairables is shown in Figure 5-1. All assemblies sent for repair must be replaced by Ready-For-Issue (RFI) items from the supply system.

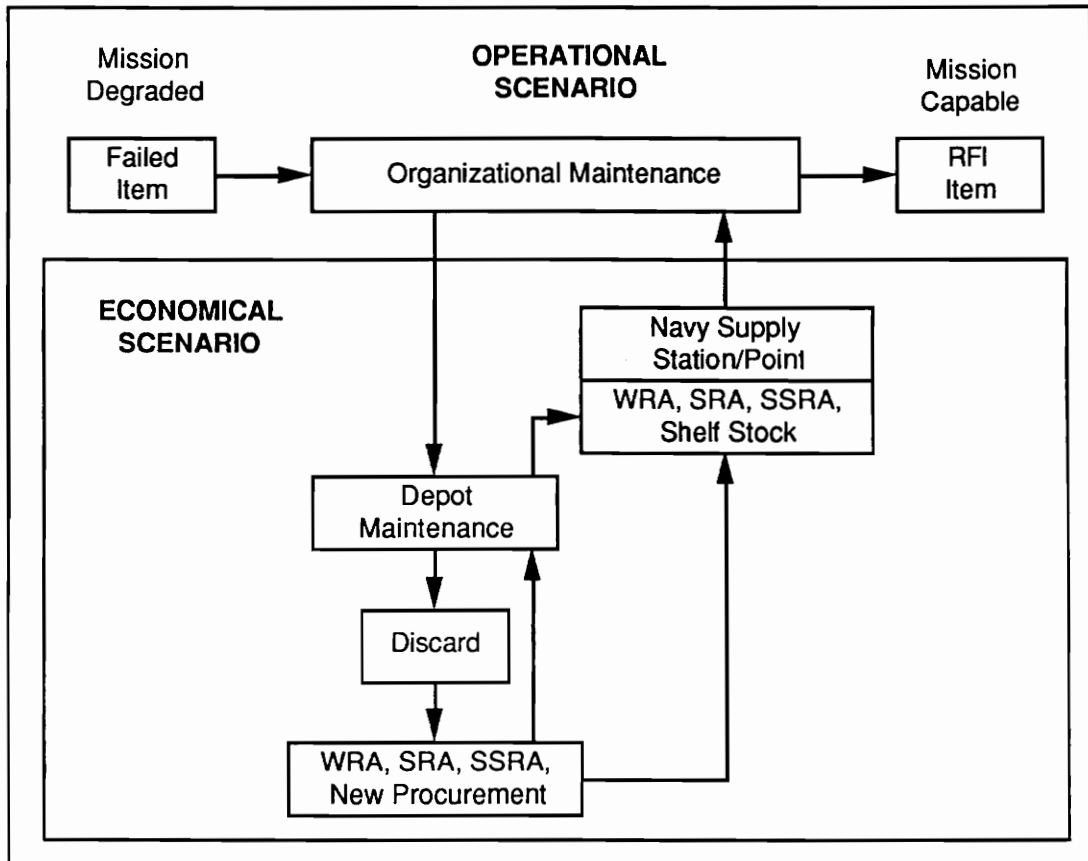


Figure 5-1. NSG Component Repair Flow

There are two major assumptions regarding the flow of repairables built into the model. The first dictates that when a component is discarded, all of its subcomponents and parts are discarded with it. The second is that an item can never flow backwards in the support system. Specifically, if a WRA is sent to the Depot for repair, its SRAs and SSRAs cannot be sent to an Organization unit or an Intermediate Maintenance Activity (IMA) for repair. They must go with the WRA to depot for disposition. Because of these assumptions, LORA recommendations for an assembly affect the cost and recommendation of all lower assemblies.

Additionally, the model accounts for the differences in operating environments between different users. These values, along with reliability values (MTBFs, etc.) are used by the model to estimate the number of component failures at each operating site for each item under analysis.

In the analysis, the model starts by considering the following six standard LOR alternatives:

- a.) All WRAs discard;
- b.) All WRAs local, SRAs discard;
- c.) All WRAs local, SRAs local, SSRAs optimized;
- d.) All WRAs local, SRAs Intermediate Maintenance, SSRAs optimized;
- e.) All WRAs local, SRAs Depot, SSRAs optimized; and,
- f.) All WRAs Depot, SRAs optimized, SSRAs optimized.

Local repair is the user Organization maintenance structure. "Optimized" simply means that the model finds the least cost alternative for each item. Alternative f.) is known as the "O to D" concept and is the one which was specified for NSG components by the Navy.

The least cost alternative and any user specified alternatives are calculated each time the model is run. In each of the standard alternatives, LOR decisions are assigned for some or all of the equipment components. The model then calculates the least cost alternative for all components. This is called the "optimize, optimize, optimize" alternative.

The analyst may also specify up to forty of his own alternatives. In each alternative, the model uses the defined system parts hierarchy and support system to calculate the support costs and LORA recommendations.

5.1.3 LORA Codes.

While the model is capable of assessing four level of repair options, only two (O and D) were considered in the NSG LORA. The capabilities and types of maintenance performed by these levels is described Section 4.2.3 of this report.

The final LOR decision is discard. This decision is made when the costs associated with repairing an item exceed those associated with discarding it. There are no set rules dictating what is or is not a discard item but some of the following guidelines may impact this decision:

- a.) relatively low unit cost;
- b.) high MTBF;
- c.) high SE costs;
- d.) high training/manpower cost, etc.

When the model decides to discard an item, it also discards all lower level components on that item. If any salvage operation is possible, required or desired, this becomes by definition, a repair action and would have been considered by the model (either economically or non-economically) before the decision was made.

5.1.4 LOR Code Assignments.

In the NSG LORA, there were three possible LOR code assignments. These are:

- a.) O - Repair at O level by removal and replacement of subcomponents;
- b.) D - Repair at D level by removal and replacement of subcomponents or physical repair of failed component/item; and,
- c.) X - Discard at either O or D level.

When assigning LOR codes, the model makes several assumptions to simplify the process. The first is that the LOR code assignment is independent of the particular lower level part that caused the failure. For example, a WRA containing two SRAs could be discarded if the failure is caused by the first SRA but could be locally repaired if the failure was caused by the second SRA.

While the above assumption might seem odd or overly restrictive, it could realistically occur if WRA and SRA costs and salvage values are less than the associated maintenance costs. In this example, the LORA would examine the salvage values of the SRAs before arriving at a LOR decision. In other words, it is readily apparent that an entire item along

with all of its subassemblies could be discarded if the salvage of these items is outweighed by the maintenance cost incurred by retrieving them. The model allows for this option.

The second assumption that affects the LOR code assignment deals with the restriction of the flow of repairables. As discussed in Section 5.1.2, a repairable item can only be shipped from lower maintenance levels to a higher maintenance activity. In the case of the NSG LORA, this was an important consideration because there is no I level maintenance and repairables can only flow from the NIXIE users to the Depot. This process has already been depicted in Figure 5-1.

Given the above two assumptions, it should be clear that while the LORA decision of a lower level item does not effect the decision of a higher level item, the LOR decision of a higher assembly constrains the possible LOR code assignments for all its subassemblies.

5.1.5 Analysis Alternatives.

To further define the NSG maintenance concept (as delineated in Section 4.2.3), Table 5-1 shows the possible maintenance actions for NSG assemblies.

Table 5-1. NSG Assembly LOR Options

WRAs:

- a.) Repair at O level by removing and replacing SRAs and/or SSRAs;
- b.) Repair at D level by removing and replacing SRAs and/or SSRAs or their piece-parts, or by removing and replacing piece-parts associated directly with the WRA or by physical repair of the WRA itself; or,
- c.) Discard at either O or D level.

SRAs:

- a.) Repair at O level by removing and replacing SSRAs;
- b.) Repair at D level by removing and replacing SSRAs or their piece-parts, or by removing and replacing piece-parts associated directly with the SRA, or by physical repair of the SRA itself; or,
- c.) Discard at either O or D level.

SSRAs:

- a.) Repair at D level by removing and replacing piece-parts, or by physical repair of the SSRA itself; or,
- b.) Discard at either O or D level.

Based on the NSG maintenance concept dictated by the Navy and as further defined in Table 5-1, the following possible LOR alternatives were considered in the NSG analysis:

Table 5-2. Constrained Optimization LOR Code Assignment

<u>Case #</u>	<u>WRA</u>	<u>SRA</u>	<u>SSRA</u>
1	O	O	D
2	O	O	X
3	O	D	D
4	O	D	X
5	O	X	X
6	D	D	D
7	D	D	X
8	D	X	X
9	X	X	X

5.2 MODEL LOGIC

The Mod II/III LORA model has undergone many revisions since it was first written, however, the actual calculation process is remarkably similar to the first Mod III release. The original could run only on a mainframe, later a program to create input files for this model (CMAIN) was developed for use on a PC. In 1987 the model was reprogrammed in Fortran language and re-sized so it could be used on IBM compatible PC. Called MICROLORA and along with a revised version of the input program (CMAINPC), the entire analysis process could be done on a PC. In 1988 MICROLORA Plus was developed as an enhanced, menu driven, error checking, integrated version of MICROLORA written in the compute language "C". MICROLORA Plus has an on-line data editor and validator, an on-line printer utility and several features for manipulating the input data and sensitivity analysis data (including a graphic depiction of the sensitivity analysis).

The six steps which are used by the model to perform a successful LORA run are:

- a.) Model input;
- b.) Rate calculations;
- c.) Inventory calculations;
- d.) Life-cycle logistic support cost calculations;
- e.) Optimization, and;
- f.) Model output.

5.2.1 Model Inputs.

The first and most important step is obtaining and preparing the model input, because it is the input which drives all of the other steps. The input formats, developed for use in preparing the input data for the model, are grouped so that similar or related data elements are together. The original model inputs were made on 80 column punch cards. The card formats are still used because they are a simple way to organize and read the tremendous number of data fields required by the model and to teach users how to enter data for a model run. Descriptions of each form and instructions for filling them out are given in Section 5.3.1.

In MICROLORA Plus, the input data must be validated by the Input Data Editor before it can be run by the model. This data is validated by the model and errors are indicated in the input file when the validation process is run. Just as in the other versions, all errors need to be resolved before the output is analyzed.

In addition to information from the data cards, some supplementary data is needed to operate the model. In particular, tables of inventory levels are used to determine inventory requirements at the various operating sites. This data is resident in the model because it is not changed very often. Other data known as "Default Data" is also provided inside the model and stored in the appropriate data fields, primarily on the G format. This default data does not usually change significantly when analyzing different Navy systems, and like the inventory data, is updated periodically by the NAMO LORA Office. While NAMO is currently updating its Default Data Guide, this update was not available for the NSG LORA.

5.2.2 Rate Calculations.

The first rate computed by the model is the number of annual failures for each item in the analysis. The first annual rate computed is the 'natural failure rate'. This is the annual number of expected failures of an item at an operating site, i.e., the number of failures caused by the inherent susceptibility of the item to malfunction during operation. The model assumes a failure rate based on an exponential distribution function.

Total failures per year of an item are determined by examining the item population and total annual operating hours. Total operating hours are divided by the product of the MTBF and the MTBF degradation factor giving the total expected failures during a year or the natural failure rate. (The MTBF degradation factor is explained in Section 6 under System Program and Cost Data.)

$$(\text{no. of ships}) \times (\text{steaming hrs/month}) \times (12 \text{ months/year}) \times (\text{no. of systems/ship}) \times (\text{deployment factor}) \times (\text{operating hrs/steaming hr}) \times (\text{quantity of items/installations})$$

$$= \text{total operating hours/year}$$

Thus,

$$\frac{(\text{total system op. hrs/year})}{((\text{MTBF}) \times (\text{degradation factor}))} = \text{total number failures per year for the entire system population}$$

A repair starts with the removal of the item from its next higher assembly. Various annual rates are derived from repair actions that apply to the natural failure rate of an item. Repair action calculations are made according to the item, site, and LORA case ('case' means LORA alternative).

The average number of 'real' removals of an item per year is called 'R'. Real removals are the total number of removals due to a malfunction of the item. R is calculated from the item's natural failures.

Items removed as failures and later determined to be operational are called false removals. The average annual number of false removals is determined by multiplying R by the item's false removal rate. The number of false removals detected as false before repair

of the item, is calculated by multiplying the false removals by the false removal detection rate. The total removals, real plus false, less the number of detected false removals, are identified as net removals which are subject to further analysis according to various LORA alternatives that are possible for an item at a given site.

There are a maximum of two decisions (for NSG components) for the net removals at an operating site. They may be (1) scrapped or discarded at the operating site, or (2) sent depot for repair or discard. The number of net removals in each alternative will depend on the repair action and the type of site being considered.

The number of items sent to higher levels of repair (i.e., Depot) is determined by multiplying the net removals by the item's BCM (Beyond the Capability of Maintenance) rate for that site. Items beyond the site's maintenance capability are sent to a higher maintenance level-of-repair or discard. The net removals minus the BCM'd items represent the number of items subject to further disposition at the operating site. Of this amount, the number to be scrapped is determined by a scrap rate which is input as a percentage of the total number of items processed by a type of site. Those not scrapped are repaired at the site. A repair is defined, by the model, as removing and replacing a failed lower level item to restore the item to RFI.

In the NSG LORA, failed items are either be discarded at O level or shipped to Depot for disposition. Items shipped to the depot are subject to limited repair level alternatives, i.e., scrap or repair. The items designated for repair at each site type are broken down to their lower indenture levels. The repair decision process is repeated for each of the lower indenture levels.

The various annual rates calculated by the model are associated with the processing described above. If the LOR alternative calls for discard, then a discard loss applies; otherwise, a scrap loss applies to the calculated scrapped amounts. Thus, the scrap loss and discard loss rates are separate for a given item, site, and case. One or the other must always be zero.

The following rates are also calculated and used by the model:

- a.) **Verify Rate** - The average number of times per year that an item is a suspected failure at a site. It is calculated as the sum of real and false removals of an item at a site plus the number of items received from lower level repair sites. The site(s) where the verify actions take place will depend on the LORA coding and can therefore change from one case to another.
- b.) **Demand Rate** - This is the expected number of demands upon supply for an item at a site. Calculated as the number of verify actions minus the number of false removals.
- c.) **IMA Induction Rate** - The annual percentage of the total population of an item sent from an operational site to an Intermediate Maintenance Activity (IMA). Calculation depends on the LORA alternative. (This rate was not calculated/used in the NSG LORA since there was no I level maintenance.)
- d.) **Depot Induction Rate** - The annual percentage of the total population of an item shipped from an operational site to the depot site for repair.
- e.) **Repair Rate** - The expected average yearly total of the item inducted into the repair process at a site.
- f.) **Scrap Loss** - The annual number of items scrapped. It is a percentage of the number considered for repair at the site.
- g.) **Discard Loss** - The annual number of items discarded. It will either be zero (for other than discard policies) or equal to the DEMAND RATE.

Based on user input, these rates are calculated for each item, site, and alternative and are stored in data arrays. The Verify and Repair rates may be selected for each item, site, and alternative from a menu in MICROLORA Plus but the LORA analyst must decide which rates to use based on his own experience, default data, or data given to him by the system procurer.

The following shows an example calculation of total net removals of an item:

NATURAL.FAIL.RATE (Next Higher Assembly)	=	100	(G)
NATURAL.FAIL.RATE (Item)	=	10	(G)
Number of Repairs of Next Higher Assembly at Site	=	200	(G)
Number of Real Removals at Site = $R = (10/100) \times (200)$	=	20	(C)
False Removal Rate	=	.5	(G)
Number of False Removals = $(20) \times (.5)$	=	10	(C)
False Detection Rate	=	.5	(G)
Number of False Removals Detected = $(10) \times (.5)$	=	5	(C)
Number of Net Removals (Y) = $20 + (10-5)$	=	25	(C)

In MICROLORA Plus, as shown above, those items annotated with a (G) are those items determined and entered by the LORA analyst. Those items annotated with a (C) are automatically calculated by the model for use elsewhere within the model.

5.2.3 Inventory Calculations.

Inventory levels are calculated for two levels, operating sites and the system as a whole. These levels are based on an Economic Order Quantity (EOQ) determination which is modified to account for mission criticality considerations for each type of equipment and component. Different rules and formulas are applied for each level. Inventory levels are calculated for each item, site and alternative. Many of these levels will be zero, because there is no demand for the item at particular sites due to the LORA coding associated with its case.

The policies and procedures to be followed in determining the inventory quantities of spares and repair parts for both a system and its support equipment are known as the Operating Support Inventory (OSI) Policy. The inventory rules for operating sites are extracted from FASOINST 4441.15F⁵ and FASOINST 4441.16H.⁶ These two Navy documents are used together and the basis of the inventory calculations used by the model. (Allowance calculations for depot stock levels are contained in NAVSUPINST 4440.160A.⁷)

In this inventory policy, a stock level for each item and site, is calculated as the sum of two amounts. The Part 1 allowance amount is based upon attrition. The Part 2 allowance

amount is based upon local repairs (rotatable pool) at the site. It is a fixed allowance level. A repair item may have both a Part 1 and a Part 2 allowance. One or both allowances may be zero depending upon the removal rate and fraction of removals repaired locally. For the repair item, the Part 1 allowance is based on the items sent elsewhere for repair, considered as attrition, and upon the amounts scrapped; the Part 2 allowance is based upon the number of items locally repaired. When calculating the Part 1 allowance, different rules apply depending on if there is or is not a Part 2 allowance.

The Raw Allowance Quantity (RAQ) is an important intermediate result of determining the Part 1 and Part 2 allowance. The RAQ has the following definitions:

Part 1 RAQ: The expected number of attritions (BCMs for a repairable item) and scraps during the REQUIRED DAYS OF STOCK period.

Part 2 RAQ: The expected number of local repairs during a local REPAIR CYCLE TIME.

Once the RAQs are calculated, the final allowances are given as follows:

Part 1 Allowance - Repairables with no Part 2 Allowance:

Unit Cost > \$5000:

If the RAQ < .50, Allowance = 0

If the RAQ >= .50, Allowance = RAQ rounded off

Unit Cost < \$5000, and > \$100:

If the RAQ < .34, Allowance = 0

If the RAQ >= .34, Allowance = RAQ rounded off

Unit Cost <= \$100:

If the RAQ < .18, Allowance = 0

If the RAQ >= .18, Allowance = RAQ rounded off

Part 1 Allowance - Repairables with a Part 2 Allowance:

If the $RAQ < 1$, Allowance = 0

If the $RAQ \geq 1$, Allowance = RAQ rounded off

Part 2 Allowance - (Locally Repaired Items Only) ⁸

The above rules give the final allowances once the RAQs are calculated. The RAQ values are determined from the annual rates previously calculated and input factors for the stockage period and the local REPAIR CYCLE TIME.

The system stock level is calculated as the sum of two amounts. The first amount is determined on the basis of scrapped items during a procurement lead-time plus safety level which are given as input factors. The second amount is determined using BCM'd items during repair cycle times. The repair cycle times used in this computation are input factors.

In the Operational Support Inventory (OSI) Policy, a raw attrition quantity and a raw Local Repair Cycle Requirement (LRCR) quantity are calculated in the same way the Part 1 and Part 2 allowances were calculated in the Initial Outfitting Policy.

An LRCR allowance is calculated first based upon the raw LRCR quantity. In FASOINST 4441.16F, the LRCR allowance is given by a table. LRCR allowance is entered according to the repair turnaround time in days and the raw LRCR quantity, expressed as the number of repairs in 30 days. Formulas used in the model are derived from those in the FASOINST and use the Poisson probability distribution with a .90 protection level.

5.2.4 Life-Cycle Logistic Support Cost Calculations.

Logistic support costs are determined for each item, cost category, and LORA alternative by the model so they can be compared. Two classes of costs are determined, dedicated (D) and shared (S). Dedicated costs are those that can be associated with a particular item throughout the service life of a system. Shared costs are the costs of resources that are used by several items.

There are thirteen categories that may be defined as dedicated costs:

- Inventory
- Scrap Material
- Documentation
- Inventory Administration
- Packaging and Transportation
- Repair Material
- Repair Work Space
- Inventory Storage Space
- Direct Labor
- Support Equipment (SE)
- Support of Support Equipment
- Support Equipment Space
- Personnel Training

There are six categories that may be defined as shared costs:

- Documentation
- Repair Work Space
- Personnel Training
- Support Equipment
- Support Equipment Space
- Support of Support Equipment

In each of these cost categories, the life-cycle cost is calculated using the verify and repair rates and appropriate cost factors as inputs.

Much of the input data for calculating life-cycle costs comes from input Form T - Task Data. On this form, resources (support equipment, documentation, manpower, space) required for verify and repair tasks are identified as either "dedicated" or "shared". The peculiar (or dedicated) resources are the basis for calculating dedicated costs and common (or shared) resources are used to determine shared costs. The specific definitions of these two types of resources and their use are described below in the discussion of optimizing procedures. Instructions for preparing the data are given in Section 5.4.2.

Another important distinction with regard to resource requirements for cost estimating purposes is whether they are "normal" or "backup". This distinction affects the way in which life-cycle costs are calculated in several of the cost categories.

For the purposes calculating life-cycle costs, the model requires an interest rate (i) and a length of system life span. The NSG LORA, assumed an interest rate of 10% over a twenty year system life-cycle.

In the NSG LORA model, each site is in one of the following three categories:

<u>ID CODE</u>	<u>TYPE</u>
1	NIXIE User (1) (Aircraft Carriers)
2	NIXIE User (2) (Others)
3	Depot (either Navy or contractor facilities) ⁹

Resources for depot sites are assigned differently than other sites in that they are always provided for items coded for depot repair. These resources however, are only provided to the depot (to perform maintenance on items not coded depot (BCM'd items)) if the workload can support it. The model provides for a "DEPOT BACKUP FACTOR" which is used to identify extra depot resources. These resources are called BACKUP resources and are marked with a "B" on the T sheets. If the workload exceeds the "DEPOT BACKUP FACTOR", then all resources are provided. This is called FULL Depot operation. This entry is rarely used because it is difficult to understand, so in most LORA's no number is entered for "DEPOT BACKUP FACTOR" and it defaults to 0 (zero). In this case, the depot always operates in the FULL mode, so all of the resources assigned to depot are provided. The NSG LORA assumed full contractor depot operation.¹⁰

5.2.5 Optimization.

In previous LORA models which calculated costs associated with designated LORA decisions for each item, the optimum set of LORA codes could be found only by evaluating each possible assignment. The number of possible LORA code combinations may be far too large to make this method feasible. In Mod III, a technique is provided which, under certain restrictions, finds the optimal assignments without looking at every possible combination. As discussed earlier, it uses several special rules to shorten this procedure. First, the item may not flow 'backwards' in the maintenance system. This has already been discussed.

Second, lower level parts must move with their higher level parts. For instance, if an SRA is discarded at O level, then its SSRAs are discarded with it. If a SRA is repaired at a Depot, it may be less expensive to repair the SSRA at a O or I level, but this option is

excluded by Navy policy, the model, and the NSG maintenance concept. The SSRA can only be considered for repair at the Depot or discard. The optimization procedure used in the model is described below, first for the case of shared costs and then for the case of dedicated costs. The net result is that the optimum LOR is determined for every WRA, SRA, and SSRA in the equipment.

The model has two optimization cases for LOR decisions, the general and the restricted. These can better be defined as unconstrained and constrained. The NSG maintenance concept however dictated a restricted case for optimizing the NSG LORA and the general case will not be discussed.

5.2.5.1 Constrained Optimization.

It is necessary to find optimal assignments of LORA codes when not all levels-of-repair are allowed for particular items. This was particularly applicable to the NSG LORA in that repair of NSG SRAs and SSRAs can only occur at the depot. During the processes of finding the conditional optimums for for NSG SRAs and SSRAs, optimal assignments were determined for the cases (and only those cases) listed in Table 5-2.

It should be noted that the decision to discard an SRA (or an SSRA) at the depot cannot be made by the model. Clearly, the model would not recommend incurring the transportation and inspection costs associated with sending a component to depot simply to have it discarded upon arrival unless there were special considerations involved with the item, i.e., scrap or salvage work to be performed at depot. This would be a preemptive non-economic factor. The decision to discard at the depot is made only after the item is received and inspected by the depot. If the cost to repair the item is more than 80% of its replacement cost, the item is discarded and replaced by a new component.

Further, as shown in Table 5-1, WRAs are repaired at O level only thru the removal and replacement of SRAs and SSRAs. They can also be repaired at the depot by the removal and replacement of piece-parts associated directly with the WRA but this type of repair is not analyzed because the LORA does not go down to the piece-part indenture level. Tables 5-1 and 5-2 do not imply any other type of O level WRA repair.

5.2.5.2 Optimization of Shared Costs.

An assembly with sub-assemblies of the next lower indenture level will be called a group. All the WRAs of an equipment are a group, all of the SRAs of a WRA are a group, and all of the SSRAs of an SRA are a group. The optimization technique for shared resources associated with groups of assemblies and levels-of-repair, is that a cost will be charged for resources at a site if at least one member of the group uses that resource at that level. This has the effect of requiring that shared costs act like those of dedicated resources for groups of assemblies. When an assembly from a group is assigned to a LOR, then every site at that level must be furnished with the necessary resources.

Shared costs depend both on the LOR assignments for the assembly and the next higher level assembly. For NSG WRAs, there are two possible costs, corresponding to the two possible LORA decisions. For NSG SRAs, there are three corresponding to the possible combinations of assignments for the assembly and its next higher level assembly. These are shown as below:

<u>Category #</u>	<u>Level-of-Repair</u>
1	Depot
2	Discard
3	Depot, Discard

The first step of the optimization process is to compute for each assembly in the equipment, the costs corresponding to each possible LORA assignments for it and its next higher assembly, if applicable. The process starts by optimizing the costs of the SSRAs. These costs are then used as the inputs for optimizing the SRA LOR assignments. SRA costs are then used to optimize WRA LOR decisions.

5.2.5.3 Optimization of the SSRAs.

The cost procedure is initiated by finding for each SSRA the optimal LOR assignment for each possible assignment of its SRA. This is done by choosing the least cost alternative from the three cases above. The net result of this procedure is, for every possible choice of assignment for any SRA, the optimal assignments and their costs for its SSRAs are

determined. Given the restrictions of the NSG maintenance concept, the possible NSG SSRA LOR codes were given in Table 5-2.

Since all the sets of assignments in any category use the same levels of repair, the best assignment in any category is one that minimizes dedicated costs. The lowest dedicated cost is found in each category and summed with the shared costs for the category. The category with the lowest cost would be the optimum assignment. For any category and each SSRA, the lowest cost among those assignments allowed by that category is chosen.

The costs of the optimum assignments of all the SSRAs are compiled for each of the SRAs and their LOR assignments. At this point, for every possible assignment of each SRA, the optimum assignments for its SSRAs are given and the total of the costs of these assignments have been determined.

If the SRA is discarded, there is no need to assign LOR codes to the SSRAs, i.e., they are automatically discarded. Just like the allocatable costs, the total cost of the optimum assignments for the SSRAs is summed for each assignment of the SRA.

5.2.5.4 Optimization of the SRAs.

The next step is to find the optimum assignment for each SRA for each possible assignment of its WRA, including consideration of the costs of the SSRAs of each SRA. For each of the combinations of LORA assignments for an SRA and its WRA, the life-cycle support costs of the SRA are already available via the SSRA calculations. Also, for each of the three cases, the optimum LOR assignment for the SSRAs is known as well as the costs of these assignments.

In each case, the costs of the optimum assignments for its SSRAs are added. For example, for a particular SRA with a Discard assignment and a Depot assignment for its WRA, its cost is incremented by the total cost of the optimum assignments of its SSRAs for the case where the SRA is assigned to Discard. The rationale for this step is, since the optimal set of assignments for the whole equipment is sought no matter what the assignment of the SRA, the SSRA should be assigned so this added cost would

automatically be incurred. Referring to the table of possible LORA combinations the following cost relationships are derived:

Cases	Action
1, 2	The SRA cost is incremented by the sum of the optimum SSRA costs;
3, 4, 6, 7	The SRA cost is incremented by the sum of the optimum SSRA costs when the SRA is assigned to Depot;
8	The SRA cost is incremented by the sum of the optimum SSRA costs when the SRA is assigned to Discard and the WRA assigned to Depot; and,
5, 9	The SRA cost is not incremented since the SRA is discarded in this case and there are no life-cycle support costs for its SSRAs.

The next step parallels what was done with the SSRAs. For each possible assignment for the WRA, the optimal assignment for each of its SRAs is found, considering both the SRA costs and the cost of the optimal assignments of their SSRAs. Having found the optimum assignments for each WRA considered at each possible level-of-repair, the costs of the optimum assignments of its SRAs are summed. At this stage, the best assignments for all of its SRAs and their SSRAs are determined, as well as the costs of these assignments. All of these decisions take into account the restrictions of repairables flow discussed earlier.

The technique for finding the optimum assignments for the SRAs is identical to the one used for the SSRAs except that the total cost of the optimal assignments of the SSRAs must be added to the allocatable costs of the SRA at each level-or-repair, with the sum being used in place of the allocatable costs for the SRA. The net result of this phase is that for every possible assignment of the WRA, the optimal assignments for each of its SRAs are determined as well as the total costs, both allocatable and non-allocatable. Again, for each possible assignment of each WRA, the costs of the conditional optimal assignments of its SRAs are added.

5.2.5.5 Optimization of the WRAs.

For each possible assignment of the WRA, the life-cycle support cost of the WRA is known, as well as the optimum assignments of its SRAs and SSRAs, with their associated costs. To find the optimal assignments for a WRA and its sub-assemblies, the least cost of the following of the two quantities is selected:

- a.) The life-cycle support cost from the WRA when assigned to Depot plus the sum of the optimal costs for all its SRAs and SSRAs for this assignment of the WRA.
- b.) The life-cycle support cost for the WRA assigned to discard.

Again, the same technique is used for the WRAs that is used for SRAs and the SSRAs, except that the total costs of the optimum assignments of the SRAs are added to the dedicated costs of the WRA for each possible assignment, with the total being used for the dedicated costs of the assignment of the WRA.

The net result of the entire process is the optimal LOR assignments and their costs have been determined for each WRA, SRA, and SSRA of the system.

5.3 ASSUMPTIONS

The assumptions listed in this section include all those economic and non-economic factors and parameters which significantly impacted the LORA results. They are presented in numerical order simply because they tend to overlap in both scale of importance and subject area. While some of these assumptions have already been discussed earlier in this report, they are summarized here for further clarity.

5.3.1 Despite the obvious differences in the operating environments of NSG users, constants were used for such factors as number of operating hours, reliability values (MTBFs), etc..

5.3.2 Despite differences in the support environments and maintenance philosophies between NAVAIR and NAVSEA systems commands, the level of repair decisions reached

by the model are considered valid for NAVSEA applications. These results will however, be subject to further analysis and review to ensure compatibility with NAVSEA policies.

5.3.3 Despite differences in sparing philosophies between NAVAIR and NAVSEA systems commands, the level of repair decisions reached by the model are valid for NAVSEA applications. NAVSEA will develop its own sparing calculations for the NIXIE system using a different model at a later date. ¹¹

5.3.4 For the initial NSG LORA run, many default values were used. These were drawn from the model's Default Data Guide. While the procedures used in this analysis were correct, the NSG LORA cannot be considered truly valid until more accurate input data (if available) is provided by the Navy and the model is rerun.

5.3.5 As part of the iterative LSA process, the model will be updated later when better data is provided by the Navy or design changes dictates a reevaluation of the current LORA.

5.3.6 Component repair flow can only move in the "upwards" direction.

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- 1 NAVSEA is short for Naval Sea Systems Command, the organization responsible for maintaining all U.S. naval surface equipment. NAVSEA is basically responsible for developing, procuring, and maintaining all U.S. navy equipment with the exception of aircraft, submarines, and special electronics equipments.
 - 2 NAVAIR is short for Naval Air Systems Command, the organization responsible for maintaining all U.S. naval aviation equipment.
 - 3 Much of Section 5 is summarized from the Naval Aviation Maintenance Office (NAMO), *Level of Repair Analysis Mod II/III MICROLORA Plus User's Reference Manual*, Naval Air Station (NAS), Patuxent River, Maryland, 14 July 1989. This manual is also known as the "User's Guide" and is abbreviated as such in this report.
 - 4 Piece parts are normally defined as smaller, discrete components such resistors, capacitors, etc., located on SRAs and SSRAs.
 - 5 Fleet Aviation Support Office (FASO) Instruction 4441.15F, "OPERATIONAL SUPPORT INVENTORY (OSI) FOR SHIPS AND MARINE AIR GROUPS (MAGS) UTILIZING THE AVIATION CONSOLIDATED ALLOWANCE LIST (AVCAL) PROCESS", 12 May 1983.
 - 6 Fleet Aviation Support Office (FASO) Instruction 4441.16H, "AVIATION OPERATIONAL SUPPORT INVENTORY (OSI) FOR ACTIVITIES USING THE SHOREBASED CONSOLIDATED ALLOWANCE LIST (SHORCAL) PROCESS", 13 June 1986.
 - 7 Naval Supply Systems Command (NAVSUP) Instruction 4440.160A, "POLICY FOR MANAGEMENT OF AUTHORIZED STOCK LEVELS (FIXED ALLOWANCES) FOR NAVY DEPOT LEVEL AND FIELD LEVEL REPAIRABLES", 26 February 1986.
 - 8 Ibid.
 - 9 It necessary to define whether Navy or contractor depot facilities will be used since the maintenance costs between the two will be different.
 - 10 The development and depot maintenance contractor for the NSG was Frequency Engineering Laboratories (FEL) of Farmingdale, N.J.. It is necessary to recognize the FEL acronym because it is used in the model input and output sheets.
 - 11 These calculations, using a sparing model specified by Naval Supply Systems Command (NAVSUP), are required by the Department of the Navy in order to validate any independent spares calculations performed by the acquiring organizations.

6.0 DATA INPUTS

The results of the LORA model depends on the input data used to describe the system and the logistic support being analyzed. Because there are many input parameters required to run the model, input data forms have been developed to help the analyst organize the information. There are eight different forms. The data fields on each form are related and each form has a different kind of data on it.

Form G - Parameters and system data; Global data. These inputs are used by all of the items in the analysis and the basic relationship between maintenance sites are established. Since most of the data on this form changes very little between Navy systems and is difficult to find, much of the data on this card is contained in the Default Data Guide provided with the model.

Form S - Site Data; This data is used to tell the model what the repair scenario for the item being analyzed is like. The numbers and types of users of the equipment under analysis are entered here. (NOTE: No classified information can be entered in the LORA models. No names of site locations may be used. This does not effect the accuracy of the model because it only needs to know the 'site type' and what its distant repair site is.)

Form I - Item Identification; This form lists all of the items being analyzed and how they are related to each other. The model accepts up to three levels of indenture. The analyst can also identify the item by part number (16 spaces) and/or name.

Form L - Item Characteristics; The parameters that define the items listed on the I form are recorded here. They include size, weight, cost, MTBF, etc.

Form T - Task Data; The verify and repair tasks required to perform maintenance on each item listed in the analysis are described here. The data includes the resources available at each of the repair levels, including the necessary support equipment, training, documentation, man-hours, and space.

Form M - Manpower Data; This form is an extension of the T form which further describes the manpower resources required for maintenance on the items under analysis.

All of the man types listed on the T cards are listed along with the training costs, total man loading, and attrition rates.

Form N - Alternatives; The analyst can assign LORA codes to specific items using this form. Three different groups of analyst defined LORA assignments (one or more analyst assignments per group) can be run at a time by the model. This is an optional card.

Form Q - Sensitivity Analysis Data; This form allows the analyst to define specific system parameters that he wants to vary so he may study the effects on the maintenance costs and repair assignments of the system. This form is also optional.

Once all of the data elements are collected, it is put into the correct format using the LOREDIT program (part of MICROLORA Plus). Once the data has been entered and validated, it is sent to the main model where the actual LOR calculations are performed and the output reports are generated. For the model to operate properly the cards must be in the following order (The cards are automatically put in the proper order by LOREDIT):

G - Parameters and System Data

- A - Analysis Identification
- P - Option Selections (All options switches are menu selections in the model)
- Y - Parameters
- Z - Parameters

S - Site Data

I - Item Identification

L - Item Characteristics

M - Manpower Data

T - Task Data

N - Maintenance Alternatives

Q - Sensitivity Analysis Specifications

The input data should be prepared in the order that the cards appear above simply because much of the data in the later cards is tied to the earlier cards. The only exception is the M card, which cannot be completed until the T cards are finished. The definitions and exact data inputs required for each of the above areas (cards) are detailed below.

The data elements used in the NSG LORA and their specific values are included as Appendix A of this report.

6.1 PARAMETERS AND SYSTEM DATA (Form G)

The data elements in this form apply to all the items in the analysis. Model options and some of the relationships between maintenance site types are set up here. (MICROLORA Plus does not respond to most of the option switches on the P card because all of them are represented by menu selections inside the main model.)

1. Card A - Analysis Identification (78 sp)

Analysis Identification - Any alpha-numeric characters that identify a run of the model for the user. The contents of this field are printed at the top of each page of the output reports. MICROLORA Plus takes the current date and time directly from DOS and prints it at the top of each page of the output report when the model is run. Hence, the reviewer knows when the data was compiled.

2. Card P - Options for Running the Model

- a.) Basis - A code to identify the units in which the data on the Technical Factors report are to be expressed. A code is assigned according to management responsibility. The code used in the NSG LORA represented that this value was expressed in years and managed by Ships Parts Control Center (SPCC), Mechanicsburg, Pa.
- b.) Options - Various option switches are available in older versions of the model. These options had no impact on the NSG LORA calculations or outputs and were not used.

3. Card Y - System Program and Cost Data

- a.) Life Cycle - (year) the number of years the equipment is expected to be operating and supported by the logistics support system. A value of twenty years was used for the NSG.
- b.) Discount Rate - (%) (i.e., $i = 10 = 10\%$) (DDG) "The government must determine the approximate value of the money it spends from the private sector's savings, since those savings would earn interest at some rate if they were not spent by the government. DoD currently uses a discount rate of 10% (as established by DoDINST 7041.3) to be used in all economic analyses of proposed Defense investments. This rate was determined by what the defense department felt would be fair and honest approximation of the present value rate for an aggregate of defense investments. However, on any particular system acquisition, a more applicable or alternative discount rate can be used, provided it is a supplement to an analysis using the prescribed 10% rate." ¹ This value is entered as a whole number and is interpreted as a percentage by the model. If a negative percentage rate is entered it will operate as an inflation factor.

Present Value: "Since most expenditures will be time phased, the model must consider the time value of money. Economic analysis expands cost analysis activities by examining the effects of the time-value of money on the investment decision. Once cost estimates have been generated, they must be time-phased (i.e., the obligated money is paid out over several years) to allow for alternative expenditure patterns. The time-value of money is considered by computing present value costs. Present value costs are computed by applying a discount rate to the time-phased expenditure amounts. The present value of \$100 payable in two years can be defined as the amount of money necessary to invest today at compound interest in order to have \$100 in two years. Thus, present value depends on the rate of interest, the frequency of compounding, and the time horizon selected.

The present value of the alternative is the cost which would be required to finance the alternative when a specified percentage could be earned, thus representing the "opportunity cost" of capital. Assuming equal benefits, the alternative whose

present value cost is least is the more desirable, because it implies a more efficient allocation of resources. The lowest present value cost means that resources are allocated more efficiently in the sense that fewer current resources must be diverted to satisfy the requirement.

"The discounting technique requires an analyst to use an interest rate to discount future alternative costs to present values. The present value of X dollars which will be received at the end of n years from now may be computed by use of the following formula:

$$P.V. = \frac{1}{(1+i)^n}$$

: Where i is the applicable interest or discount rate.

It is realized that present value is being considered here in much the same way that it is considered in the private sector of the economy. That is, money not expended on current projects can be invested and will yield investment costs. Some would argue that the government is not a profit making concern and present value analysis is inapplicable because money not immediately spent on one project would be spent on another and in no case could it be saved as interest as in the private economy. However, the Federal Government as investor should have as its objective the maximum well being of the Nation as a whole as reflected in national income; therefore no public investment should be undertaken when it earns a return which is less than the alternative use of the funds which is absorbs." ²

- c.) Field Supply Administration Cost - (\$/item/year) The annual cost of supply administration for an item at a repair location. Used to calculate the recurring portion of inventory administration cost.
- d.) Item Entry Cost - (\$/item) The cost of entering a new item into the Nation Stock Number (NSN) database. This field is used to calculate the non-recurring portion of inventory administration cost.
- e.) Item Retention Cost - (\$/item/year) The annual cost of retaining an item in the NSN system. Used to calculate the recurring portion of inventory administration cost.

- f.) Packaging Cost - (\$/ft³) The cost of labor and materials to package an item that is sent to a distant repair site. The volume is shipping volume. Used to calculate packaging costs.
- g.) MTBF Degradation Factor - (fraction of 1.0) A fraction of 1.0 (or equal to 1 if the analyst does not want to use this field) that is multiplied by the predicted MTBF (Mean Time Between Failures, 1/R) on Form L to get the "Expected MTBF". The degradation factor can be used to account for any lowering of the predicted MTBF due to operating conditions or support considerations. For example, if an item under analysis has a predicted MTBF of 10 hours on the L card and the system MTBF Degradation Factor of .80, then the expected MTBF for the item would be $(10 \times .8) = 8$ hours.
- h.) Procurement Lead-Time - (weeks) The elapsed time before a resupply order of an item is obtained from the manufacturer. Or the total time it takes to completely fabricate an item from scratch and deliver it. Used in the calculation of inventory quantities of repairable assemblies.
- i.) Safety Level - (weeks) The amount of stock, measured in weeks worth of demand (at the estimated weekly demand rate), established to avoid stock-outs due to demand uncertainty while the stock is being replenished. Or the amount of stock on-hand above the normal use rate to account for changes in the use rate. Used in calculation of inventory quantities of repairable assemblies.
- j.) Repair Cycle Time - (days) The number of days required to transport an item (SRA or SSRA) to a repair facility, repair it, and return it to the site where the failure occurred. Used in the calculation of inventory quantities of repairable assemblies. Values are required for each of the different routes repairable can take through the repair system.

CP: (days) the average number of days it takes for a failure that occurs at a carrier (CV) and is sent to a Primary IMA (PIMA) for repair and returned to complete the repair cycle. If there is no PIMA level site in the maintenance system, no entry is required.

CD: (days) the average number of days it takes for a failure that occurs at a CV and is sent to a depot for repair and returned, to complete the repair cycle.

- LP: (days) the average number of days it takes for a failure that occurs at a land-based IMA and is sent to a PIMA for repair and returned to complete the repair cycle.
- LD: (days) the average number of days it takes for a failure that occurs at a land-based IMA and is sent to a depot for repair and returned to complete the repair cycle.
- CPD: (days) the average number of days it takes for a failure that occurs at a carrier and is sent first to an PIMA then to the depot and finally returned to the carrier to complete the repair cycle.
- LPD: (days) the average number of days it take for a failure that occurs at a land-based IMA and is sent first to a PIMA then to the depot and finally returned to the IMA to complete the repair cycle.
- CC: (days) the average number of days it takes for a failure to be repaired and returned to RFI at a carrier site. Called a "local repair". There is no local depot repair because depots are not operating sites.
- LL: (days) the average number of days it takes for a failure to be repaired and returned to RFI at a land-base IMA.
- PP: (days) the average number of days it takes for a failure to be repaired and returned to RFI at a PIMA. If there are no PIMA sites in the maintenance scheme of the item under consideration, no entries should be made in any block that refers to a PIMA.

- k.) Required Days of Stock - Discard - (days) the length of time during which stock must satisfy demands at operating sites (i.e., sites that have user stationed at them. Depots are never operating) because of parts discarded in the course of maintenance. Two values are entered, one for carrier sites and one for land-based sites (CV and LB).

4. Card Z -

- a.) SE and Repair Work Space Cost - (\$/ft²) The cost of floor space in a shop for Support Equipment or for repair work. A value is entered for each site type (carrier, NAS, PIMA and depot). The purpose of this entry is to enter the relative

costs of repair space between carrier and land-based repair centers. Because space on board ships is very limited it is much more expensive.

- b.) Inventory Storage Cost - (\$/ft³) The cost for storage space in a shop for storage of spares of the repairable assemblies. Values are input for carriers and depot sites.
- c.) Hourly Labor Rate - (\$/hr) The burdened hourly labor rate to verify and repair failures. A value is entered for military personnel on carriers and one for civilian personnel at depots. Although personnel on carriers receive roughly the same salary as shore personnel, the rate for the carrier man is lower than the shore man because the carrier man works much longer hours than the shore. About 70 hours/week compared to 40 hours/week.
- d.) Depot Backup Factor - (% i.e., 10 = 10%) The percent of the depots' normal workload, if exceeded for items sent to the depot that do not have a 'D' code, results in the backup resources (men, support equipment, etc.) being assigned to the depots. Entered as a whole number, interpreted as a percentage by the model. This entry is rarely used.
- e.) Repair Cycle Times - WRA - (days) The number of days required to transport an item (WRA) to a repair facility, repair it, and return it to the site where the failure occurred. Used in the calculation of inventory quantities of repairable assemblies. Values are required for each of the different routes repairables take through the repair system. If the entries are the same as those for the SRA's and SSRA's then no entry must be made in these blocks, the model will pick them up automatically. However, if only one entry is different, then only that entry need be entered.

6.2 SITE DATA (Form S)

The repair facilities, type and quantity of user and the relationship between sites that make up the support system are described on this form. There is a maximum of 30 Site cards that can be listed in any one LORA run. Two or more sites of the same site type, with similar user data (i.e., the number of equipments can be averaged between two sites) and the same distant repair data may be listed in a single entry.

The sites listed on the S cards are identified as operating sites, which means they have an equipment stationed at them, or non-operating sites. Depots are never operating sites, however all of the other site types can be.

- a.) Site Name - (15 sp) Alpha-numeric characters used to identify the site or group of sites. NOTE: the actual site names associated with the user or equipments being analyzed are classified and should/can not be used. The only thing the model needs to know about a site is what site type it.
- b.) Site Type - (##) a code identifying the kind of site. For the NSG LORA, these codes were:

<u>Code</u>	<u>Site Type</u>
1	NIXIE Users (Carriers)(CVs)
2	NIXIE Users (Others)
3	Depot (FEL)

- c.) Number of Locations - (##) the number of similar activities represented by the site name. For example, if the site is defined as all Pacific carriers and if there are six of them, then that number is entered. The rest of the data is entered as it would if it were a single site.
- d.) Required Days of Stock (Repair) - (days) The length of time during which stores of spares at an operating site must satisfy all demands resulting from repair actions at the site. The number is set by policy used by the model to calculate inventory levels. This field is left blank for non-operating sites (i.e., Depots or IMAs that do not have NSG assigned to them).

USER DATA - These data elements describe the types and quantity of equipment at an operating site. No entries are made for non-operating sites. A line of data is entered for each type of equipment at the site. Additional lines of data may be added for sites that operate more than one type of equipment without entering the site name, site type, number of locations and required days of stock a second time. If two groups of the same type of equipment operate at a single a site, but have different operating scenarios, they should be listed separately.

- e.) User Type - (6 sp) Any alpha-numeric characters that identify the system that the LORA is being run on.
- f.) Number of equipments - (###) The average number of equipments of the type listed that are stationed at a particular site.
- g.) Steaming Hours per Month - (stmg hrs/mo) The average number of hours per month that the equipment is used at a particular site.
- h.) Deployment Factor - (.XX) The average fraction of year that the user is actually deployed.

DISTANT REPAIR DATA - These fields set up the relationship between the sites in the analysis. The sites are numbered sequentially as each site is entered in the form (site number) to identify the site where a repairable item is sent if it is BCM'd from the given site. A different line is entered for each distant repair site that receives repairable items from the site. Like the user data fields, for entries after the first line, the first five fields of Form S can be left blank. Because there are no higher level sites than Depot sites, this data is not completed for them. The distant repair data is for the 'site name' listed and NOT the user data.

- i.) Site ID - (##) The "site number" of the activity to which a site sends its BCM items. If the site sends its repairables to two (2) sites, then two Site ID's are entered.
- j.) Distribution Fraction - (.XX) The fraction of repairables sent to the given distant repair "site type". The distribution fractions for a "site type" must add to 1.0.
- k.) Transportation Cost - (\$/lb.) The average cost of shipping a repairable to the distant repair site. This is the cost sending items out of the repair site.
- l.) Supply Shipping Cost - (\$/lb.) The average cost of shipping RFI repairable assemblies from system supply to the given site. This is the cost of receiving items.
- m.) Site Number - (###) A number that uniquely identifies the defined site. Site numbers are assigned sequentially as they are listed on the form and must be entered on every line. If for instance the first site listed takes up three lines of the S Form, then the number one (1) is entered at the end of all three lines.

6.3 ITEM IDENTIFICATION (Form I)

The repairable assemblies and parts that are to be studied during the analysis are listed on this form. Up to three indenture levels can be considered by the model WRAs, SRAs, and SSRAs. Only repairable items should be entered into the model and it is not necessary for an item to have all three levels. It is also not necessary for the items called WRAs in the model, to actually be WRA's.

A line of data is entered for each item in the analysis. The items should be entered so the first WRA is listed first, then the first SRA that is part of the first WRA, then the first SSRA to the first SRA and so on until all of the items are entered. (Using MICROLORA Plus up to one hundred (100) items can be included in one run.)

- a.) Item Number - (###) A three digit alpha-numeric code assigned to each repairable assembly that identifies the item uniquely. The number is usually assigned so the first WRA is entered as item number 100 with its first SRA called 110 and the first SSRA called 111. The second SRA to the first WRA would be 120 and so on. If there are more than nine items attached to a higher level item then letters can be used. For example, 110, 120, 130, ..., 190, 1A0, 1B0. The numbers assigned in this field are used on the L, T, N, and Q Forms as well as in the next field on this form.
- b.) Next Higher Assembly - (###) The item number of the next higher assembly for the given part. This field shows the relationship of items to each other and is very important for the optimization routines run in the model. WRAs have no next higher assembly, so the field is left blank and the next higher assembly is assumed to the system.
- c.) Quantity - (###) The number of the item that are installed in the next higher assembly. For the WRA, it is the number of items installed in the system.
- d.) Part Number - (16 sp) The National Stock Number (NSN), contractor's identification number, or any other identifying number. This entry is not used by the model but is printed on the output reports.
- e.) Item Nomenclature - (40 sp) The name of the repairable assembly given to identify it further in the output reports.

6.4 ITEM CHARACTERISTICS AND ACTION TAKEN CODES (Form L)

6.4.1 Item Characteristics.

All items listed on Form I must be listed on Form L, in the same order. This card defines the operating and maintenance characteristics of each item for use in various calculations of the model.

- a.) Item Number - (###) The code that identifies the item on Form I.
- b.) Unit Cost - (\$) The unit cost of the item. Used in the calculation of the inventory, repair material and scrap material costs. A "K" may be entered in column 12 which tells the model that the cost is in thousands of dollars (e.g., 10,000 = 10K).
- c.) Weight - (lbs.) The shipping weight of the part. Used to calculate transportation costs.
- d.) Volume - (ft³) The volume of the item, including the packaging, as it is shipped. Used to calculate the packaging costs.
- e.) Peculiar Piece Parts - (###) An estimate of the number of new peculiar piece parts (i.e., those not already in the National Stock Number (NSN) system) that must be entered and maintained in the NSN system in order to repair the assembly. This includes the item listed, however care should be taken not to count an item more than once. In general, the lower level items should have more piece parts. Used to calculate the inventory administration costs.
- f.) MTBF - (hours/failure) The estimated average number of hours that an item expected to operate before it fails (e.g., A lower level item must be removed and replaced to return the item to RFI condition). The prediction is the sterile environment failure rate and does not usually take into consideration the operating environment. The MTBF Degradation Factor is used to adjust the MTBF listed here to the operating MTBF. If the Degradation Factor is 1.0, then the operating MTBF is entered.
- g.) Item Operating Factor - (operating hrs./steaming hrs.) The ratio of the item's operating time to the user operating time. The number can be less than, equal to or greater than one. Used to calculate the failure rate.

- h.) False Removal Ratio - (false removals/total removals) This fraction multiplied by the number of removals gives the number of false removals of the item. A false removal is an item that is removed and found not to have failed. If detected as false, they are returned to the pool as RFI in accordance with NAVAIRINST 4790.2.
- i.) False Detection Rate - (detected false removals/false removals) This fraction multiplied by the number of false removals gives the number of false removals that are detected as false at an operating sites.
- j.) BCM Rates - (BCM'd Items/total removals) The fraction of failures that cannot be repaired as a site and are sent to the next higher site in the repair system for one of the nine BCM conditions. ("Higher" level sites are sites with more repair capability. Carrier IMAs are "lowest" site type and depots are the "highest".)

6.4.2 Action Taken Codes.

BCM conditions and Action Taken Codes are taken from the NAVAIR Work Unit Code Manual. Action taken codes 1 through 9 are restricted to those repairable items of material which have been administratively or technically screened and found to be non-repairable at an IMA (by designated I-Level personnel authorized to make these determinations). In keeping with the philosophy of repair at the lowest practicable level, the IMA is normally authorized to perform any and all functions for which it has or can be granted authority and the capability to perform and meet performance specifications.

The NSG maintenance concept however, excludes any I level maintenance. Therefore, all repairs of NSG components will take place at O level via the removal/replacement of subcomponents or at depot via the necessary maintenance actions. The BCM rate for NSG components is either zero or one depending on which of the above two conditions is applicable. The following conditions were considered in making this determination:

CODE:

1. **BCM - REPAIR NOT AUTHORIZED.** This code is applicable when the activity is specifically not authorized to repair the item in applicable directives, for example, engineering investigation exhibit, required maintenance function is not assigned by SM&R code/MIMS/maintenance

plan or technical decision, required repair data is unknown and/or cannot be determined, item is under warranty, peculiar item from an equipment is not supported by an activity and SM&R coded XXXXD.

2. **BCM - LACK OF EQUIPMENT, TOOLS OR FACILITIES.** This code is applicable when the repair is authorized but cannot be performed because of lack of equipment, tools or facilities, for example, required equipment is on the activity repair list but authorized quantity is zero, receipt of authorized the activity repair list equipment is not expected within 30 days, non-the activity repair list tools/equipment not on-hand, lack of permanently installed facilities, specifically directed by the Type Commander.
3. **BCM - LACK OF TECHNICAL SKILLS.** This code is applicable when repair is authorized but cannot be performed because of a lack of technical skills. For example, permanent or temporary additional duty billet(s) will be vacant for more than 30 days, billet incumbent absent (TAD, leave, etc.), formal technical training is non-existent, formal technical training exists but cannot be used due to lack quota/funds, rating/NEC/MOS required is not reflected on manpower authorization, rating/NEC/MOS is on board but billet not assigned to the activity.
4. **BCM - LACK OF PARTS.** This code is applicable when repair is authorized but cannot be performed because required parts will not be available within guidelines established by applicable directives. For example, requisition status indicates more than 30 days lead-time prior to receipt of required part(s), required part(s) not stocked in the supply system and cannot be procured or manufactured within 30 days, specifically directed by the Type Commander.
5. **BCM - FAILS CHECK AND TEST.** This code is applicable when some level of repair beyond check and test is authorized but the maintenance function required to return the item to RFI condition is not assigned by SM&R code/MIMS/maintenance plan or other technical decision.
6. **BCM - LACK OF TECHNICAL DATA.** This code is applicable when repair is authorized but cannot be performed because of a lack of technical data. For example, maintenance manuals/test program sets exist but cannot be obtained within 30 days, maintenance manuals/test program sets do not exist or cannot be identified within 30 days, applicable manuals/test

- program sets are available but do not provide adequate technical information.
7. **BCM - BEYOND AUTHORIZED REPAIR DEPTH.** This code is applicable when some level of repair beyond check and test is authorized but the maintenance function required to return the item to RFI condition is not assigned by SM&R code/ MIMS/maintenance plan nor other technical decision.
 8. **BCM - ADMINISTRATIVE.** This code is applicable when repair is authorized and feasible but not attempted due to budgetary limitations, excessive backlog or materials in excess of requirements. For example, excess of ship/activity requirements (as determined by the Type Commander), budgetary limitations (insufficient funds available which are reserved for repair of components considered to be of a more urgent priority), specifically directed by the Type Commander, as determined jointly by the activity maintenance and supply officers.
 9. **BCM - CONDEMNED.** This code is applicable when a repairable item is so severely worn or damaged that repair is not feasible, as determined by local maintenance personnel or specifically directed by the Type Commander. The item is locally condemned and returned to the supply department for survey, retrograde or scrap, as appropriate, in accordance with the maintenance plan and applicable directives.
-
- k.) **Material Rates - (.XXX)** The fraction of the unit cost that is used for the material (piece parts, safety wire, oil, etc...) used for repair. Different values are entered for each repair site type.
 - l.) **Scrap Rates - (.XXX)** The fraction of failures that cannot be repaired at a type of site and are scrapped at the site. Different values are entered for each repair site type.

6.5 TASK DATA (Form T)

The task data cards are the heart of the NAVAIR LORA model. Each task or maintenance action performed, on every item, at every maintenance level, with all of the required resources (support equipment, personnel, training, documentation, repair space,

etc.) is accounted for on this form. All of these tasks are listed at all of the site types on the site cards so the model can choose between them to find the most economic level of repair. Tasks are divided into verify tasks (tasks required to determine which items are not operating properly) and repair tasks (tasks required to return the items to RFI condition). The verify task is performed before any repair actions are taken and are done on every item inducted for repair or discard.

The task cards can also be separated into dedicated and shared. By employing shared task cards the analyst can significantly reduce the amount of typing required to enter all of the required data.

- a.) D or S - (Dedicated or Shared) Enter "D" if the task card describes a task or resource that is dedicated to the item listed. Enter "S" if the task or resources listed are intended for several items one indenture below the listed item. If the task is intended for all the WRAs, then the item field is left blank, thus sharing this task and its resources at the system level.
- b.) Item Number - (###) The item number from the Form I. If the task is shared for several items at the same indenture level (e.g., all of the SSRAs of a single SRA), then the item number of the next higher assembly is entered. If the task is dedicated, then the item number on which the resources are used is entered.
- c.) V or R - (Verify or Repair) "V" is entered if the task listed is to verify a failure. "R" is entered if the task is a repair task. Repair tasks include fault isolation, remove and replace of the failed lower level item and test after the repair.
- d.) Man-hours - (man-hours) the average number of man-hours required to accomplish the verify or repair task for a dedicated task. No man-hours are entered for a shared task, after a shared task is entered all of items covered by the task must be shown as dedicated tasks to account for the man-hours associated with the verify and repair tasks. (see the sample problem)
- e.) Site Type - (1) NIXIE Users (Carriers), (2) NIXIE Users (Others), or (3) depot (FEL) the type of site to which the task applies. All site types in the maintenance system should be included in each task, unless the task cannot be done at a given site (i.e., the support equipment will not fit on a carrier), so the model can look at every possible repair alternative before making its decisions.

Support Equipment (SE) - The following data elements describe the SE used to perform a task. If more than one kind of SE is defined for a task (e.g., normal and backup SE defined) additional lines on the form may be used. A maximum of twelve separate resources can be used on any one item. If SE is used at more than one site type for the same task, all the data should be entered the first time it is identified; only the name and quantity needs to be entered in each subsequent listing (i.e., unit cost, square feet, initial support fraction and subsequent support fraction are only entered the first time the support equipment is entered, thereafter each time the model sees the name it will refer to the first line to find the costs).

- f.) Name - (8 sp) A name which uniquely identifies the SE. For depot site, if the SE is used as a backup resource as well as a normal resource then it should be given different names for each use.
- g.) Authorized Quantity - (##) The number of units of SE to be procured for the given site type, so the site can handle the expected number of inductions.
- h.) Unit Cost - (\$) The cost of the SE. If the SE is already at the site, the cost should be entered as a negative number. If the model reads a negative, it does not add the cost of the SE to the repair cost. The model does however use the absolute value of the number to figure the initial and subsequent support costs. The unit cost is only entered the first time the SE name appears.
- i.) Square Feet - (ft²) The amount of floor space occupied by the SE. This value is entered only the first time the SE name is listed.
- j.) Initial Support - (.XX) A fraction of the unit cost of the SE. The product of the initial support fraction and unit cost is the support cost for the SE its first year of operation. The support includes the non-recurring costs for setting up support for the SE if it is a new procurement.
- k.) Subsequent Support - (.XX) A fraction of the unit cost of the SE. The product of the subsequent support fraction and the unit cost is the annual support cost for the SE in the years of operation from the 2nd to the end of the equipment's life cycle. It is the recurring cost for supporting the SE.
- l.) Backup - (B) A code which defines the SE as a backup resource. A "B" entered in this field indicates the SE is a backup (i.e., when depot backup factor is greater than 0). This field is left blank for normal SE. Code used is only entered for depot sites.

Manpower - These fields show the number of men that must be trained for the listed task and the "name" of the training. To avoid listing the same training twice, if an assembly has training listed against a shared task, when the dedicated task is listed a "generic " man name should be used.

m.) Required Number - (##) The number of men needed to complete the task.

n.) Manpower Type - (4 sp) The name of the manpower required to complete the task at a given "site type." The name assigned is arbitrary except for the first one or two characters. The characters that identify the manpower type are:

C - Carrier IMA

L - Land Based IMA

P - PIMA

DP - Depot Normal

DB - Depot Backup

"Generic" man names are just these characters with the number of men required to complete the task. They are used when no training is required. All these names must begin with these letters.

Documentation - These fields describe the documentation that must be developed and procured to perform the given task. If a document is used for more than one task, like the support equipment block, only the document name and the required number need be entered after the first entry.

o.) Required Number - (##) The number of documents needed to complete the task at one site.

p.) Name - (6 sp) The name of the document. The name may be any alphanumeric characters that are used distinguish it from other documents.

q.) Cost - (\$) The unit cost of developing and procuring the given documentation. Like the I-card 'unit cost', a "K" entered in the last space of the field indicates that the cost is in thousands of dollars (10K - 10,000).

Space - These fields are for the extra work space (that space needed in addition to the space already available) required for the task. The space must be required specifically to perform the task it is listed against. If the space is used for any other reason, it should not be listed. Like Documentation and Support Equipment, only the name of the space and the quantity need be entered after the first entry.

- r.) Required Number - (##) The number of spaces needed to complete the task.
- s.) Name - (6 sp) The name used to identify the space.
- t.) Amount - (ft²) The size of the space needed.
- u.) Backup - (B) "B" entered, in this field indicates the work space is a backup resource. The field is left blank for work space that is normal. Code is only entered for depot sites.

Development/Training Hardware Cost - These fields are in the same location as the Support Equipment Name, Authorized quantity and Cost fields of the Form T. In place of the quantity, a two character code is entered.

- v.) Name - (6 sp) A name of SE, used on a previous T card.
- w.) Code - (XX) A code that indicates what the cost are for. The codes are:
 - DD - non-recurring development costs
 - T1 - training hardware for non-depot sites
 - T4 - training hardware for depot sites
- x.) Unit Cost - (\$) The cost of the development on training equipment.

6.6 MANPOWER DATA (Form M)

This form is an extension of Form T. Additional manpower data is given that describes the manpower requirements and the training costs. Although this card appears on the menu before Form T, it usually cannot be completed before the T cards.

The training described is any special training needed by personnel to perform the listed task. The form is divided into three identical sections so that three man types can be

identified on each line. "Generic" man types must be listed on this form, however no other information is required. All of the man types on the T cards must appear on the M card.

- a.) Man Type - (4 sp) The name of the given manpower type as described on Form T. The name must be exactly the same as it appears on the Form T.
- b.) Authorized Quantity - (##) The total number of men of a particular type that are required. The product of the number of sites where the men are stationed times the number needed to perform the task.
- c.) Training Cost - (\$) the cost of training one man.
- d.) Attrition Rate - (average fraction of men replaced/year) The annual rate of attrition of man type. This value multiplied by the value for the authorized quantity gives the number of men of the given type that must be trained each year to replace those lost through attrition.

6.7 LORA ALTERNATIVES (Form N)

User specified LORA alternatives are defined on this form. LORA codes can be assigned for any combination of the repairable assemblies that do not violate the rules of Navy maintenance planning, discussed earlier. A set of LORA alternative. Up to forty different LORA alternatives can be defined on this form, but only three can run in any single run of the model. In each alternative, the optimization routine assigns LORA codes to an assembly, the analyst restricts the LORA codes assignments of its higher level assemblies. More than one line of data may be used to assign LORA codes to a repairable assemblies in an alternative. The same item may not be assigned to two different levels of repair in the same alternative.

- a.) Alternative Number - (##) A number assigned to identify the analyst alternatives.
- b.) Item Number - (###) From the Form I, the number that identifies the item to the model.
- c.) Code - (#) The LORA code assignment.

1 - NIXIE Users (CVs)

3 - DEPOT

2 - NIXIE Users (Others)

4 - DISCARD

6.8 SENSITIVITY ANALYSIS DATA (Form Q)

Sensitivity analysis is a way the analyst can test the volatility of LORA decisions to changes in input parameters. Sensitivity analyses can be performed with or without re-optimizing the results. When the re-optimizing routine is not used, the sensitivity analysis only changes the dollar values of the output without changing the repair decisions. When the re-optimizing routine is used, the sensitivity analysis changes both the repair decision and the dollar figures as the input value is varied.

There are two types of Form Q used to create sensitivity analysis data. One QH card is required for each group of Q cards. They tell the model which elements to consider and the maintenance alternatives the parameters are to be varied against.

Up to five sensitivity groups (QH cards) can be run at a time (i.e. any one run can have five QH cards and their associated Q cards). All ten of the different data elements can be varied in one group of Q cards. All of the data elements in one group are varied according to the information on their header (QH) card. In the NSG LORA, the data elements to be varied were done so individually in order to determine the sensitivity of each given parameter.

- a.) Number of Increments - (#) The number of times the data element is varied between the low and high value.
- b.) Re-Optimized Alternatives - (X) These fields specify which of the maintenance alternatives will be optimized in the output reports. 'All' will re-optimize the seven standard alternatives (i.e. the six usual alternatives plus the least cost alternative). The analyst specified alternatives are selected by entering the analyst specified alternative number from the Form N. When these blocks are selected, the model changes both the cost associated with the repair alternative and the repair level as the input parameter is changed. This field does not operate in MICROLORA Plus as the function is performed by a menu selection.
- c.) Non-Reoptimized Alternatives - (X) When 'All' is selected, the model changes only the dollar values associated with each maintenance alternative. The analyst specified alternatives are selected by entering the analyst specified alternative

number from the Form N. This function is performed by a menu selection in MICROLORA Plus.

A sensitivity analysis can be run on ten different data elements. Each element can be varied as function of itself or against other elements in the model. Figure 6-1 lists these elements and shows the areas against which these elements can be varied. For example, "Life-cycle" cannot be varied against any of the items listed across the top of the table, but it is possible to vary the "# of equipments" at any particular site individually. In any one run of an analysis, a parameter cannot be varied against more than one of the areas at a time.

- a.) Data Element Number - (#) The number that identifies the data element to be varied.

1 - life-cycle	6 - flight hours
2 - discount rate	7 - unit cost
3 - MTBF degradation factor	8 - MTBF
4 - IMA percent	9 - BCM rate
5 - number of equipments	10- SE cost

- b.) Site Type - (X) These fields are selected to indicate that the parameter chosen in the "Data Element Number" will be varied against the "site type" (CV, Other, and/or depot).
- c.) Indenture Level - (X) These fields are selected to indicate that the parameter chosen in the "Data Element Number" will be varied against the indenture level" (WRA, SRA and/or SSRA).
- d.) Task Type - (X) These fields are selected to indicate that the parameter chosen in the "Data Element Number" will be varied against the "task type" (dedicated and/or shared).
- e.) Resource Type - (X) These fields are selected to indicate that the parameter chosen in the "Data Element Number" will be varied against the "resource type" (dedicated and/or shared).

- f.) Specific Sites or Items - (###) the identification numbers of the sites or items (as entered in the S and I cards) so that they can be selected separately from other sites or items.
- g.) Specific Equipment Types - the equipment name that is listed on the S card.
- h.) A or M - Addition or multiplication. If the data element under analysis is to be varied from a specific low value to a specific high value, then enter A. If the analyst wants the increments as a fraction of the original value, then M is entered. Unit cost, MTBF and SE cost (data elements 7, 8 and 10) can be varied using multiplication only.
- i.) Range of values - the values entered in the low and high the extreme values of the data elements.

Description	Area 1			Area 2			Area 3		Area 4		Area 5	Area 6	Area 7
	Site Type			Indenture			Task Type		Res. Type		Specific		
	CV	Oth	Dep	WRA	SRA	SSRA	V	R	S	D	Sites	Items	User Types
Life-Cycle													
Discount Rate													
Degrad. Factor													
IMA Percent	X	X									X		
# Equipments	X	X									X		X
Operating Hrs	X	X									X		X
Unit Cost				X	X	X						X	
MTBF				X	X	X						X	
BCM Rate	X	X		X	X	X						X	
SE Cost	X	X	X	X	X	X	X	X	X	X		X	

Figure 6-1. Sensitivity Analysis Data Elements

¹ ALM 63-3149-H8 Economic Analysis Handbook, p. 15.

² Ibid.

7.0 SUMMARY OF LORA RESULTS

7.1 REPAIR/DISCARD DECISIONS

The NSG LORA resulted in determining the least cost maintenance alternative. This decision is highlighted in Appendix C, page 129. The final LORA repair and discard decisions recommend the removal and replacement of all of the NSG WRAs at the O level. These WRAs are then sent back to the contractor Depot for repair. Failed NSG SRAs will be discarded at the Depot during the repair of their WRAs. Since failed SRAs are discarded, the SSRAs on those SRAs are also discarded. The reader is directed to Appendix C which details the costs associated with the various NSG maintenance alternatives.

7.2 INTERPRETATION OF LORA RESULTS

7.2.1 General.

The LORA results must always be reviewed and interpreted. It is a given that in terms of professional engineering, it is always prudent to ensure that the data inputs were accurately entered, the modeling was realistic, and the analysis was correctly conducted. In the end, it is the outputs which bear the highest scrutiny.

In a LORA, it is not always the case that the least cost alternative [maintenance concept] is selected. For example, a maintenance concept costing more than the least cost alternative may need to be selected for non-economic reasons. The least cost alternative may not meet the availability requirements as well as a higher cost alternative. The user may want to spend more money to gain a higher availability. Hopefully however, this requirement would have been identified and examined as part of the LORA process.

It is the job of the analyst to present all the alternatives to the system user, make his recommendations, and allow the user to decide which alternative best suits his needs. This is why all the information and results relating to each maintenance concept are presented in

the final LORA report rather than just the least cost alternative. Additionally, while the least cost alternative may be the best at the time the LORA is performed it is possible that the client may need to use one of the other alternatives at a later date due to changing conditions or extenuating circumstances. For example, budget cuts may well force the system user to modify the maintenance procedures used at his Organizational and Intermediate level maintenance facilities. While he may save money in a larger sense, the system may have to choose higher maintenance costs for a given particular system.

7.2.2 Interpretation of NSG LORA Results.

The constraints dictated by the Navy meant a strictly O and D level maintenance concept which was reflected in the LORA, LSA/LSAR, and ILS elements.¹ As a non-economic factor, this concept limited the LORA in terms of allowable maintenance/support alternatives.

The reasons for this concept center primarily on the hesitation of the Navy to fully utilize its Intermediate level maintenance facilities to support electronics systems. At face value, it would make sense to utilize maintenance personnel, facilities, and equipment already available but the Navy sometimes has difficulty supporting electronics systems at the I-level. (It is beyond the scope of this paper to fully detail why this is so, but certain factors relating to the NSG LORA and the Navy I-level will be briefly discussed below.)

One major reason is that while the technical talent in terms of trained or trainable electronics technicians is resident at these facilities, providing I-level system specific maintenance training for a new system can be expensive and sometimes cost prohibitive. Another reason is that in order to maintain a system at the I-level, the Navy would have to initiate the effort and paperwork to support another echelon of maintenance. This would of course, also entail the procurement of the necessary spares and repair parts for this level. Bluntly, the Navy Supply system (NAVSUP) does not have the personnel or budget to do so for all new Navy electronics system. It must support the I-level for new system acquisitions selectively. The organization chartered with the system acquisition would need to fund this procurement if it is required. Therefore, whereas, at the system level, it might be more economic to support an electronics system at the I-level of maintenance, it is

uneconomical from a higher level Navy view. This was the case with the NSG and hence the maintenance constraints.

Given these maintenance constraints and the costs involved with the specified maintenance concepts, the NSG LORA decisions to repair WRAs at the contractor make sense, at least in the short-term. They should only be accepted as a reasonable starting point remembering that the LORA is an iterative process which will be updated as better data becomes available. After the system is fielded, the Navy will rerun the NSG LORA using historical data. This effort will serve to either validate the NSG maintenance concept or to provide rationale for changing to a more cost-effective one.

7.3 SENSITIVITY ANALYSES

Two sensitivity analyses were conducted on the NSG LORA. These analyses examined the impacts on total system life-cycle costs by varying selected characteristics of individual system components. These components were the same items analyzed by the LORA itself, i.e., the LORA Candidate List.

The first sensitivity analysis consisted of varying the individual item unit cost (in nine increments) from between 50% and 300%. These variations resulted in potential changes in the overall system life-cycle cost from between 86% and 135% of the original calculated cost figures. The reason that individual item unit cost was selected as a variable for sensitivity analysis was because the question arose regarding what benefits can be derived from purchasing higher quality and hence, higher cost components.

The results of this analysis are presented in Tables 7-1 and 7-2 and Figure 7-1. Table 7-1 shows the different costs associated with each basic MICROLORA maintenance alternative for each individual item unit cost sensitivity increment. Option 7 is the least cost alternative. Figure 7-1 depicts this data graphically. Table 7-2 breaks out the logistics support costs for Option 7 for each major cost area.

The second sensitivity analysis examined the potential life-cycle cost changes if the Mean Time Between Failures (MTBF) for the LORA candidates is varied. This analysis

was also done in nine increments ranging between 50% and 300% of the original values. These variations resulted in a variance of between 119% and 84% of the original calculated life-cycle costs.

The results of this analysis are presented in Tables 7-3 and 7-4 and Figure 7-2. Table 7-2 shows the different costs associated with each basic MICROLORA maintenance alternative for each MTBF sensitivity increment. Option 7 is the least cost alternative. Figure 7-1 depicts this data graphically. Table 7-2 breaks out the logistics support costs for Option 7 for each major cost area.

Table 7-1. Life-Cycle Cost Variations as a Function of Varying Individual Item Costs

SENSITIVITY ANALYSIS STEP									
7-Item Cost	50%	81%	113%	144%	175%	206%	238%	269%	300%
1 XRD	1355	1439	1523	1606	1690	1774	1858	1941	2025
2 LOC-XRD	1470	1618	1767	1915	2063	2212	2360	2508	2656
3 LOC-LOC-OPT	1445	1579	1712	1846	1979	2113	2247	2380	2514
4 LOC-PIM-OPT	0	0	0	0	0	0	0	0	0
5 LOC-DEP-OPT	1445	1579	1712	1846	1979	2113	2247	2380	2514
6 DEP-OPT-OPT	1243	1376	1508	1641	1774	1907	2039	2172	2305
7 OPT-OPT-OPT	1243	1376	1508	1602	1679	1756	1833	1909	1985
Within 20% of Least Cost									

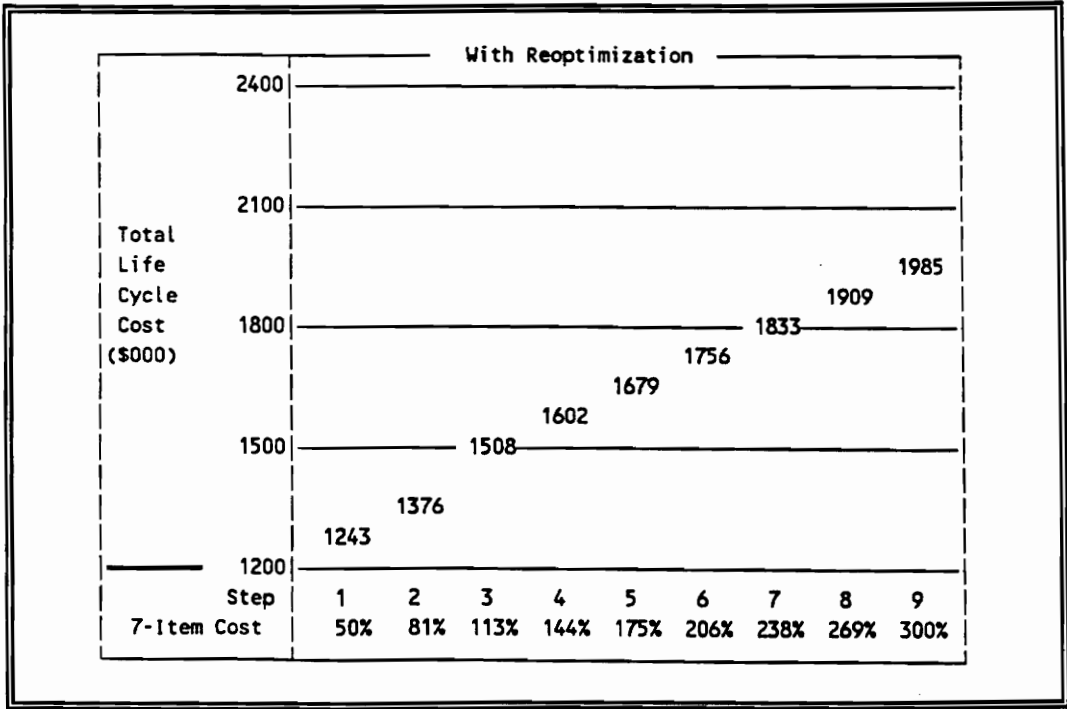


Figure 7-1. Life-Cycle Cost Variations as a Function of Varying Individual Item Costs

**Table 7-2. Life-Cycle Cost Variations in Logistics Areas
as a Function of Varying Individual Item Costs**

7-Item Cost	SENSITIVITY ANALYSIS STEP								
	50%	81%	113%	144%	175%	206%	238%	269%	300%
Support Equip.	0	0	0	0	0	0	0	0	0
Support of SE	0	0	0	0	0	0	0	0	0
Inventory	10	16	23	95	119	140	182	219	245
Inv. Admin.	602	602	602	596	595	595	595	595	595
SE Space	0	0	0	0	0	0	0	0	0
Inv. Storage	0	0	0	44	46	46	50	52	52
Repair Space	0	0	0	0	0	0	0	0	0
Labor	11	11	11	5	5	5	5	5	5
Material	198	322	446	247	296	349	380	416	464
Transportation	23	23	23	19	19	19	19	19	19
Repair Scrap	4	7	10	12	14	17	18	20	22
Training	385	385	385	385	385	385	385	385	385
Documentation	10	10	10	200	200	200	200	200	200
Total	1243	1376	1508	1602	1679	1756	1833	1909	1985

Table 7-3. Life-Cycle Cost Variations as a Function of Varying Individual Item Mean Time Between Failure (MTBF)

SENSITIVITY ANALYSIS STEP									
8-Item MTBF	50%	81%	113%	144%	175%	206%	238%	269%	300%
1 XRD	1769	1554	1458	1404	1369	1345	1327	1313	1303
2 LOC-XRD	2193	1819	1653	1559	1499	1457	1426	1402	1383
3 LOC-LOC-OPT	2096	1760	1610	1526	1471	1434	1406	1384	1367
4 LOC-PIM-OPT	0	0	0	0	0	0	0	0	0
5 LOC-DEP-OPT	2096	1760	1610	1526	1471	1434	1406	1384	1367
6 DEP-OPT-OPT	1894	1557	1407	1322	1267	1230	1202	1180	1163
7 OPT-OPT-OPT	1747	1552	1407	1322	1267	1230	1202	1180	1163
Within 20% of Least Cost									

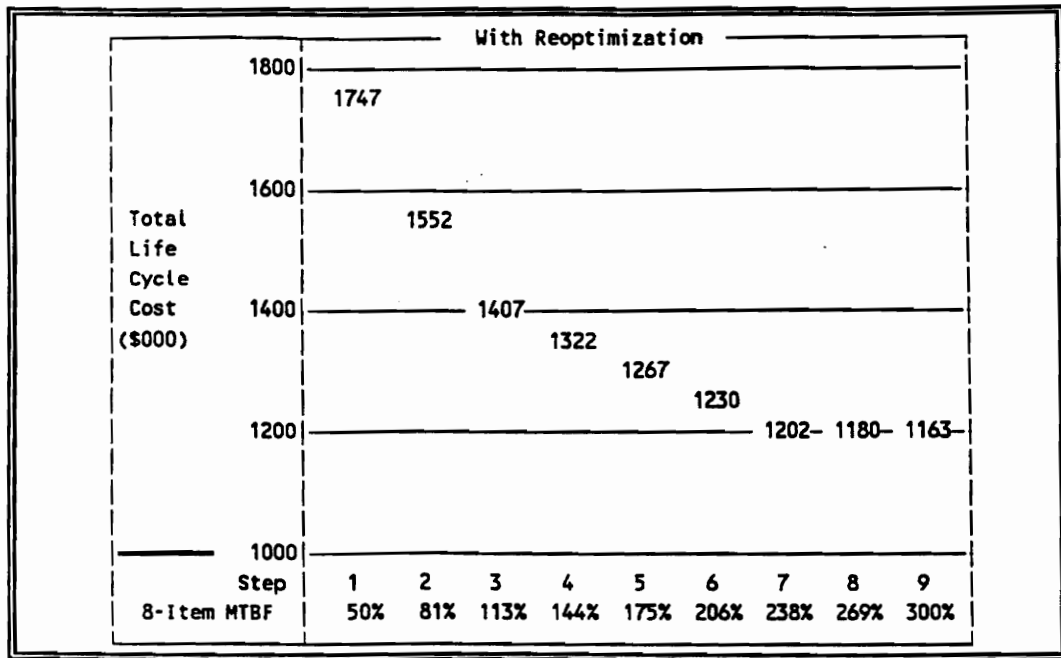


Figure 7-2. Life-Cycle Cost Variations as a Function of Varying Individual Item Mean Time Between Failure (MTBF)

Table 7-4. Life-Cycle Cost Variations in Logistics Areas as a Function of Varying Individual Item Mean Time Between Failure (MTBF)

8-Item MTBF	SENSITIVITY ANALYSIS STEP								
	50%	81%	113%	144%	175%	206%	238%	269%	300%
Support Equip.	0	0	0	0	0	0	0	0	0
Support of SE	0	0	0	0	0	0	0	0	0
Inventory	112	76	20	20	20	20	20	20	20
Inv. Admin.	596	596	602	602	602	602	602	602	602
SE Space	0	0	0	0	0	0	0	0	0
Inv. Storage	40	40	0	0	0	0	0	0	0
Repair Space	0	0	0	0	0	0	0	0	0
Labor	10	6	10	8	6	5	5	4	4
Material	349	215	352	276	226	192	167	147	132
Transportation	37	23	20	16	13	11	10	8	8
Repair Scrap	17	11	8	6	5	4	4	3	3
Training	385	385	385	385	385	385	385	385	385
Documentation	200	200	10	10	10	10	10	10	10
Total	1747	1552	1407	1322	1267	1230	1202	1180	1163

These two analyses are directly related since, generally speaking, component reliability and cost are directly related. Specifically, the higher the desired component reliability, the higher the cost. This relationship is caveated by the knowledge that, in many cases, the stated reliability of two electronics components may not necessarily differ due to their construction or materials. Rather, the more reliable component may simply have a more rigid quality assurance inspection and test regimen. The more a part is screened, expressed as a percentage of its production lot, the more reliable it is deemed to be. Or rather, a higher confidence can be placed in the stated MTBF value for that component. This additional screening costs the manufacturer more money which is reflected in the price of the component.

In reality, it is possible to have higher costing parts which may perform the exact function and have the same MTBF as lower cost ones, yet these components cost more because they are more thoroughly screened. This can often be the case when dealing the parts in the upper end of quality spectrum in the grading system of electronics parts used by the U.S. military. This was certainly a consideration of the NSG design.

In the end, a cost-trade off was done with regards to both item cost and reliability. The contractor was required by the Navy to deliver fully tested systems. This testing included vigorous environmental stress screening of the NSG components. NSG design and test personnel felt that since they would be doing very detailed screening (down to the piece-part or CCA component level), it would be more cost-effective to purchase less expensive components and screen most of these components themselves as part of the overall manufacture and test processes. The end result would be the same part reliability at a slightly lower component price. It was however, decided to purchase more reliable and higher costing parts for a small number of the NSG components which the contractor did not desire to test/screen himself.

More importantly however, the second question to be answered by the sensitivity analyses was that of using more reliability parts in order to decrease overall system life-cycle costs. In simple terms, the contractor has basically three directions he can choose on this topic. He can ignore this issue with the idea that less reliable parts mean more sales of spare parts during the system life-cycle. Even if the contractor meets his specified reliability requirements, this practise is frowned by DOD and is falling into disfavor.

The contractor is wiser to produce the most reliable system he can within his contract budget. It is in his better business interests to deliver a system with the lowest possible life-cycle costs for it enhances his reputation. In good faith, most engineers would like to design and deliver a system which exceeds the reliability requirements but this desire is tempered by the contract budget. Most new DOD contracts are "Firm-Fixed-Price" contracts in which the contractor is given a set of system specifications, a design, production, and delivery schedule, and a set dollar amount with which to complete the intended work. Profit on these contracts is generally based on a set percentage fee of the total contract award. If however, there is unspent money left at the end of the contract, this money becomes additional profit. Therefore, on Firm-Fixed-Price contracts, unless he has some special arrangement for additional compensation from his client, the contractor is generally forced to produce a system which minimally conforms to the system specifications for the least price. He may, in the course of his research and development effort, discover new capabilities beyond the stated system requirements. If these opportunities require additional funding, they are usually presented to the client in the form of an Engineering Change Proposal (ECP).

Such can be the case of performing a LORA sensitivity analysis with regards to MTBF and item cost. The contractor should (and in this case, did) present his LORA results to the client and if possible, recommend the use of more expensive and reliable parts (as applicable) as a means of lowering overall system life-cycle costs. If additional contractor costs associated with this change are anticipated, the contractor should recommend this change as part of an ECP.

There are usually several problems with this logic. The first is that both the contractor and the client must realize the long term implications of such a strategy. It should benefit both parties. The client gets a more reliable system for overall lower costs. The contractor benefits both in the immediate and future business aspects. Second, while the client may save significant sums money over the system life-cycle, he may not have the money in this years budget to incorporate the desired changes. Depending on the clients' funding situation, this can sometimes a very difficult problem to overcome.

It is beyond the scope of this paper to discuss the above issue in further detail. Suffice it to say that in many cases, despite the obvious logic of doing so, unless there is unique

communication and cooperation between the contractor and the client, buying more expensive components to increase system reliability can be when lower cost parts will meet the specified reliability can become impractical.

In some, the solution for the NSG program became problematic. The Components Engineer, in conjunction with the Reliability Engineer, was required to select more reliable (and more expensive) parts simply in order to meet specified subassembly and assembly and ultimately system reliability requirements. Since the NSG was a fixed-price contract, his direction was to do this at the lowest cost.

It should be remembered that both unit cost and MTBF sensitivity analyses were conducted at the equipment and assembly levels. The analysis undertaken by the NSG design team focused on the component level and studied how changes in part cost and MTBF would contribute to cost and MTBF at higher levels.

It should be noted, that in and of themselves, the two sensitivity analyses conducted have not yet directly impact NSG design or component selection. They were however, successful in causing the design team to commence review selected items for analysis in terms of cost and reliability. Specifically, the design team examined the possibility of purchasing more expensive parts (higher MTBF) in an effort to realize higher assembly, equipment, and hence, overall system reliability.

The next logical step would be to directly compare individual item costs against potential gains in system reliability and lower life-cycle costs. Unfortunately, further examination of the sensitivity analyses for the NSG LORA by the LORA Engineer is currently prohibited by the cost and schedule constraints of the contract. While certain informed deductions can be derived, it is difficult to make any meaningful or mathematically based correlations between the two variables. This effort has however been conducted informally on a case by case basis by the NSG Reliability and Components Engineers.

Given current redesign efforts and possible NSG redesign efforts which may be incurred by virtue of the proposed redesign of the overall AN/SLQ-25A system, it is anticipated that these analyses/variations will be reexamined and cost trade-off analyses

conducted to determine whether varying item cost and/or MTBF will produce cost-effective results. These variations could offer the design team cost-effective alternatives. The results of this LORA (specifically the results of the sensitivity analyses) are being reviewed by both the contractor and Navy Program Managers and Project Engineers. This issue has not yet been decided and so its ultimate effect on the NSG program can not be fully assessed.

¹ The maintenance concept is fully detailed in Section 4.2.3 of this report.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 ASSESSMENT OF THE NSG LORA

8.1.1 General.

The NSG LORA accomplished its initial objectives. In short, these were to influence system design via the LSA process, to impact the NSG support structure by analyzing the maintenance alternatives, to optimize the costs associated with each maintenance alternative (and hence, the life-cycle costs for system maintenance), to provide initial life-cycle cost figures to the Navy, and to provide system maintenance and support structure recommendations to the Navy. In addition to achieving its objectives, the NSG LORA (or at least this phase of it) was completed within the contract cost and schedule constraints.

The NSG LORA was able to successfully interact with other NSG design, logistics, and systems functions within the NSG Program. The key to this interaction was the cooperation of the personnel assigned to these areas. Generally speaking, this requires a good working professional relationship to be established. The analyst performing the NSG LORA was able to secure the assistance of these personnel in several ways. The first was to demonstrate the importance of the LORA effort to these personnel by showing the possible impacts of the LORA on their individual specialty areas. The LORA analyst was able to show that the NSG LORA required data inputs from almost all of the NSG Program team. After seeing the input and output flow, NSG personnel were very receptive to working with the LORA analyst.

Obviously, establishing the above discussed relationship is extremely important to the analyst since without it, the LORA input/output flow becomes very difficult. The validity of the LORA results are limited to the validity of the data which the analyst receives. The effects of the LORA impacting the system design are negated if the analyst does not establish credibility with the design team and communicates LORA considerations to them. This is particularly true when the LORA analyst is not an engineer, or is not organizationally part of the design team, or when the design team does not understand the LORA process.

In the case of the NSG LORA, the analyst was a subcontractor who had several hurdles to overcome in conducting the analysis. The first was working with a prime contractor whose personnel were primarily electrical, mechanical, software and test engineers. These personnel, having never seen or been part of a LORA effort, had little concept of the technical effort or requirements involved with performing a LORA. Therefore, initially, these engineers viewed it as simply another logistics function to be contracted out and performed by the "logisticians". This relegated the LORA to a lower priority on their lists of requirements. This lack of participation was virtually eliminated when these engineers were shown how they could ease certain design problems by utilizing certain Navy operational and maintenance philosophies. For example, the NSG design was extremely concerned about designing in various extra test points on the CCAs. When it was determined that the Navy did not need these extra test point, e.g., the Navy would only need certain test points to fault isolate selected CCA functions, the design was able to eliminate these test points and concentrate on other maintainability and test considerations.

Overall, the NSG LORA worked well as part of the larger NSG LSA effort.

8.1.2 Time and Budget Constraints.

The time was a critical factor in performing the NSG LORA. While there was a short learning curve for the analyst/engineer, it takes a significant period of time to perform a LORA correctly. Entering data into a computer is not very difficult but gathering the LORA data inputs is. Data collection is not entirely automatic from the LSAR and requires time-consuming research if it is to be accurate. It is often the case that the LSA efforts have not yet yielded the data elements necessary for input into the LORA. Further, the data must usually be massaged before entry so that meaningful results can be obtained.

Additionally, the time and money available under contract allocated to perform the LORA bound the amount of effort which can be devoted to a LORA. Rarely is the analyst or engineer given a free hand in determining the amount of time and effort which he needs to complete the LORA. Usually, program management will issue the LORA budget and schedule, hopefully with input from the engineer who will actually perform the LORA. However, it has been the experience of the engineer who performed the NSG LORA that program management frequently does not consult the LORA engineer or analyst. LORA

tends to be little understood process amongst most program management and design personnel since most of them have never performed a LORA themselves. The result is sometimes a LORA budget and schedule that are too small and short in the eyes of the engineer to adequately complete the work. The engineer must consider these factors when formulating his LORA approach and use these factors to guide the overall conduct of his LORA.

While the NSG LORA was both accurate and efficient given the model and information available, the analysis should only be considered valid within the confidence in the values of the data used. Simply put, if the default values used are in fact the desired values, then the analysis is entirely valid. It should be noted that minor changes in any of just a few data elements could radically change the analysis results. If this is so, the question must be raised regarding the sensitivity analyses. One of the limitations of the model is that changing certain default values was not an option for sensitivity analysis. However, the detailed exploration of these parameters was prohibited since there were time and budgetary constraints on continuing the analysis in the terms of the contract under which the analysis was performed.

8.2 ASSESSMENT OF THE LORA MODEL

8.2.1 Model Selection.

The first question which arose was the choice of which model to use for the NSG LORA. Throughout DOD there are at least twenty-five (and probably more) LORA models currently in use. The feasibility of using other DOD models, among them one from NAVSEA and one from the Marine Corps, was explored. These models were found to be unacceptable for several different reasons which are discussed below.

- a. Certain models, while looking very promising and applicable to the NSG, were simply unavailable at the time the NSG LORA needed to be performed.
- b. In several cases, difficulty existed in procuring a particular model from another organization. The difficulty lay in the certain degree of parochialism which exists between

various DOD organizations. This is particularly true with regards to the different organizations possessing their own models. Some DOD organizations are hesitant [to phrase it mildly] to approach another DOD organization and ask to borrow its LORA model. There seems to be some sort of stigma attached to doing this.

- c. Several models were inappropriate because they were developed to analyze a specific type of system, (i.e., a model which analyzes mechanical or aircraft systems vice a model which is suitable for the analysis of an electronics system.)
- d. Some models required a mainframe computer. This was feasible but undesirable given that the computer configuration of the NSG LORA engineer was a PC. It was deemed unnecessary to expend the cost and effort associated with establishing a modem-data link with a mainframe while there were several acceptable PC-based LORA models available.
- e. Most LORA models are not particularly generic in nature in that they are developed with a particular maintenance organizational structure in mind. Specifically, the model is based on the logic of the maintenance system (s) of the developing organization. It was found that the more flexible the model, i.e., the greater variety of maintenance and support alternatives it can analyze, the more likely it is to be based on a mainframe, harder to procure and the more difficulty in obtaining support or training in the model's use.

The question of the applicability of using a naval avionics application to model a surface ship electronics system was examined in depth. Given the different types of systems for which they are responsible, it would seem that NAVAIR and NAVSEA would have much different maintenance and support philosophies. While this is true to some extent, many Navy electronics systems are very similar in configuration/composition and are therefore similarly maintained. An initial analysis determined that the NAVAIR model would suit but that sparing requirements and allowances calculated by the model would have to be reexamined due the differences in sparing philosophies between US Navy surface and air communities.¹ This was deemed acceptable because both of these commands perform their own independent sparing calculations anyway.

8.2.2 Model Usability.

While the model produces accurate results in accordance with Military Standard 1390C and Navy policy, there is room for improvement. The model was originally coded in FORTRAN, but was converted to a PC version using DOS version 2.0. (This created a few minor problems since many PC now use a DOS version of 3.0 or later.) It is based on an 80-column card format. These factors make the model easy to comprehend and use (user friendly) but there are nuances within the model which require an individual knowledgeable in both LORA procedures and computers to figure out. There are key notes on how to structure or enter certain critical LORA data elements. One must enter these elements a specific way which is not necessarily the one which logic would dictate. Unless the analyst is aware of these nuances, he will waste much time trying (unsuccessfully) to run the model. In less debilitating cases, the analyst will expend more time trying to interpret LORA results which might not make much sense.

8.2.3 Model Support.

The obvious question regards how well the MICROLORA User's Reference Manual is written. It is a capable document, clear and easy to apply. The actual techniques of data entry are not difficult and the User's Reference Manual is accompanied by a Default Data Guide. The User's Reference Manual cannot however, prepare the analyst for all the situations to be encountered especially if the system under analysis requires a certain amount of special modeling. While NAMO MICROLORA personnel were extremely helpful in assisting the NSG LORA engineer, a certain amount of time was lost due to minor discrepancies in the model.²

NAMO personnel admit that MICROLORA is not perfect and they are working hard to fix it. They have identified various shortfalls and bugs in the program and plan to continually update and expand the capabilities of the model. Clearly however, this is a function of their budget. NAMO allots a quarterly budget for updating the model which is fairly small in comparison with the work which needs to be done on it. A computer programmer confers with one of the NAMO LORA personnel on required areas of change within the model. Work continues until the budget for that quarter is expended. As with many types of computer models, major changes in the logic cannot be implemented

individually. Depending on the amount of work performed, NAMO will issue an update to MICROLORA users. Documenting these changes in the User's Reference Manual sometimes takes much longer. Since NAMO issues an updated User's Reference Manual approximately every nine months, this would account for certain discrepancies between an older Guide and the current model the analyst may be using.

One cannot fault NAMO for the discrepancies which exist between the model and the User's Reference Manual nor for the quirks in the model itself. NAMO regularly gives classes on the application of its model and makes a point to advise all MICROLORA users of some the foibles and inconsistencies of the model. Given these issues, an analyst intending to use MICROLORA Plus for his LORA is advised to take the NAMO LORA class prior to commencing his efforts. NAMO personnel should also be contacted with any questions regarding the use of the model.

One recommendation would be a short term cost plus fixed fee contract for a few individuals to get this work done quickly and efficiently. This concept is probably unfeasible given the pending cuts in DOD spending.

8.2.4 Model Flexibility.

As mentioned in Section 6, the model is designed to perform LORAs on NAVAIR avionics equipments and it is streamlined for this use. The model received inputs and generates outputs in accordance with requirements and specifications of NAVAIR. Even for NAVAIR LORAs, the model is very rigid in its approach. The analyst is limited to the formats and data elements specified within the model.

As with most LORA models (at least those in the experience of this analyst), MICROLORA Plus can and must be manipulated to produce the desired results. The model can be "fooled" if desired but this would produce skewed results. A more accurate approach however, is for the analyst must learn how the model can be manipulated to produce the results in the format he requires. This can only be done by experimenting with the model and learning the "ins and outs" of how this, or any LORA model, really works.

For example, one of limitations of the model is that it is only capable of addressing a two-level system of maintenance. However, this did not impact the LORA in terms of allowable maintenance/support alternatives because one of the constraints dictated by the Navy was that the NSG maintenance concept was limited to Organizational and Depot activities. These constraints were reflected in the LORA, LSA/LSAR, and ILS elements.³ Through learning the model, the analyst was able to structure this maintenance concept into the LORA by substituting Organizational maintenance assets for those specified by the model. This manipulation was invisible to the Navy but was essential to accurately reflecting the support elements available to the NSG in the real world.

This experimentation is additionally necessary due to the quirks in the model. In reality, most of these oddities can only be overcome through research into the model with the model developers and maintainers, i.e., NAMO personnel. Many of these quirks are due to changes or software structure inadequacies which have not been either resolved by software modification or by inclusion in the MICROLORA Plus User's Reference Manual. The analyst must have some communication with NAMO in order to avoid a guessing game when using this model.

What the model loses in flexibility due to formatting constraints, it recovers somewhat due to its simplicity. Since the model is easily understood, given the benefit of "inside information" from NAMO personnel, the analyst will readily learn how to model LORA inputs to accurately reflect the support structure for his hardware system.

8.3 ASSESSMENT OF THE LORA ANALYST

Probably the most important points learned in conducting this analysis were in gaining an appreciation for the time and skill factors involved with conducting a LORA. Learning and comprehending the model required a relative amount of technical acumen, i.e., an engineer or otherwise technically oriented individual. It also required a detailed knowledge of Navy logistics and program acquisition procedures. Understanding the technical inputs and their relationships within the model as well as meaningful interpretation of the model results required a high level of knowledge and experience in these fields.

It is helpful but not required that the LORA analyst be an engineer. It is mandatory however that he be at least technically oriented. The LORA process is technically demanding and should not be undertaken by someone not experienced in logistics, maintenance, and an engineering familiarity with the type of system being analyzed. He must also be knowledgeable with the maintenance capabilities of the end user organization. One approach is to have the Maintainability engineer perform the LORA.

As mentioned earlier, the LORA is made more difficult if the analyst is not part of or organizationally related to the entity requiring the LORA effort. Data collection is more difficult if the LORA analyst cannot approach the design staff or does not receive full cooperation from them. He must have an open door to the design staff in order to discuss technical issues. He must also have open communication with the logistics (ILS) manager in order to discuss support considerations. As mentioned in Section 8.1.1, the NSG LORA analyst, despite being a subcontractor, had the full cooperation of the prime contractors' design and logistics staffs.

8.4 RECOMMENDATIONS

- a. Have a qualified engineer or technically oriented person conduct the LORA. This individual should be experienced in computer modeling and must understand the LORA process. He should have detailed knowledge or information concerning both the system and its intended operational and maintenance environments. Without this type of background, as well as thorough understanding of the LORA process and the model with which he is working, the analyst cannot hope to accurately conduct the LORA or to correctly interpret and present the LORA and its results.
- b. A preliminary LORA should be performed as early as possible in the system acquisition process. Preliminary LORA results and maintenance and support considerations should serve to influence system design, specifically the system maintainability characteristics. Design engineers should be made aware of the proposed system support structure to include its capabilities and limitations. This type of information is usually developed via the systems engineering and Logistic Support Analysis (LSA) processes of which LORA is a part.

- c. Analysis should be conducted which compares any maintenance alternatives which are within twenty percent of the least cost alternative. In the case of the NSG, only one other alternative fell into this category. The focus of this analysis should be to examine and compare any cost elements which are significantly different from the least cost alternative or those which, if altered, might change the LOR decisions. The ideal method for this comparison is to conduct sensitivity analyses on these parameters.
- d. Conduct sensitivity analyses after the initial LORA is completed. These analyses, if properly selected and focused on the appropriate LORA areas can serve to critically impact by highlighting system areas for design improvement.
- e. Further examination of the sensitivity analyses should also determine the optimal cost alternative for each item. This alternative should be compared to the LOR decision dictated by the overall least cost alternative. If significantly different, one should investigate the feasibility of using the maintenance alternative for that individual item vice the maintenance alternative specified for that item by the overall least cost alternative.
- f. The NSG LORA must be conducted again when better Navy data is made available and or NSG design changes require a reexamination of the LORA. The LORA must be updated periodically throughout the life-cycle of the system.
- e. On a higher level, DOD might be advised to standardize its LORA models. There are many different versions available each based on MIL-STD-1390 but, as discussed in Section 7.2, they are not standardized to the point where the LORA analyst has real freedom of choice in his model selection. Standardization of LORA models would allow greater use of computer generated data between organizations using this information. For example, if all contractors working for a given military service were required to use the same LORA model, this data would be readily exchangeable between organizations working on the same or similar projects. Additionally, standardization of LORA models would facilitate government review of contractor LORA results and reports. There are many difficulties associated with this suggestion but it is conceivable that the benefits derived would greatly outweigh the costs incurred by implementing such a policy.

-
- ¹ Sparing refers to the process of planning, acquisition, distribution, and positioning (storage) of the spares and repair parts needed to support the system.
 - ² Naval Aviation Maintenance Office is located in Patuxent River, Md. and is responsible for the maintenance and upgrade of the MICROLORA Plus model.
 - ³ The maintenance concept is fully detailed in Section 4.2.3 of this report.

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APPENDIX A
NSG LORA DATA REQUIREMENTS

NSG LORA Data Requirements

Data Element	Responsible Organization	Units	Contractor or Default Value	Data Source
System Program and Cost Data				
Life Cycle	Navy	years	20	LSA
Discount Rate	Navy	%	10	D
Field Supply Administration Cost	Navy	\$/item/yr	33.44	D
Item Entry Cost	Navy	\$/item	701.00	D
Item Retention Cost	Navy	\$/item/yr	199.00	D
Packaging Cost	Navy	\$/ft ³	42.90	D
MTBF Degradation Factor	Navy	fractional	1.0	D
Procurement Lead Time	Navy	weeks	52	D
Safety Level	Navy	weeks	6.6	D
Repair Cycle Times	Navy	days		
CD (User to Depot)			80	D
CC (Local Repair)			23	D
Required days of Stock - Discard	Navy	days	90	D
SE and Repair Work Space Cost		\$/ft ²		
NIXIE Users	Navy		52.40	D
Depot	Cntr		8.17	D
Inventory Storage Cost		\$/ft ³		
NIXIE Users	Navy		10.20	D
Depot	Cntr		2.72	D
Hourly Labor Rate		\$/hr		
NIXIE Users	Navy		9.18	D
Depot	Cntr		52.12	D
Site Data				
NIXIE Users:				
Site Name	Navy	Al	NIXIE Users	LSA
Site Type	Navy	Nu	1 (CVs)	N
Number of Locations	Navy	Nu	15	LSA
Site Name	Navy	Al	NIXIE Users	LSA
Site Type	Navy	Nu	2 (Others)	N
Number of Locations	Navy	Nu	99	LSA
Required Days of Stock	Navy	days	90	D
User Type	Navy	Al	CV	SE
Hours per Month of Usage	Navy	hrs/mo	180	N
Deployment Factor	Navy	Nu	1.0	N
Distant Repair Site Data	Navy	Al	Cntr	N
Site Identification	Cntr	Al	Cntr	LSA
Distribution Factor	Cntr	%	1.0	LSA
Transportation Cost	Navy	\$/lb	2.47	SE
Supply Shipping Cost	Navy	\$/lb	2.47	SE
Site Number	Navy	Nu	1-99	SE
Depot:				
Site Name	Navy	Al	Cntr	LSA
Site Type	Navy	Nu	4 (Depot)	SE
Number of Locations	Navy	Nu	1	N
Supply Shipping Cost	Navy	\$/lb	0.47	SE

NSG LORA Data Requirements

Data Element	Responsible Organization	Units	Contractor or Default Value	Data Source
Item Identification Data ¹				
Item Number	Cntr	Nu	1-220	SE
Next Higher Assembly	Cntr	Nu	1-200	SE
Quantity	Cntr	Nu	1-5	SE
Part Number	Cntr	Nu	K6333000XX, etc.	SE
Item Nomenclature	Cntr	Al	Signal Gen., etc.	SE
Item Characteristics Data ²				
Item Number	Cntr	Nu	1-220	SE
Unit Cost	Cntr	\$	per item	SE
Weight Cntr	Cntr	lbs.	per item	SE
Volume	Cntr	ft ³	per item	SE
Peculiar Piece Parts	Cntr	Nu	0-6	SE
MTBF	Cntr	hrs	per item	SE
Item Operating Factor	Navy	op hrs/mission hrs	1.0	LSA
False Removal Ratio	Navy	false removals/ total removals	0.0 - 0.10	SE
False Detection Rate	Navy	detected false removals/ false removals	.99	SE
BCM rates	Navy	BCM'd items/ total removals	1.00	SE
Material Rates	Navy	fractional	0.16 - 0.91	SE
Scrap Rates	Navy	fractional	0.00 - 0.05	SE
Task Data				
Dedicated or Shared Assets	Navy	dimensionless	All SE shared	LSA
Item Number	Cntr	Nu	1-220	SE
Verify or Repair Task	Cntr	dimensionless	item dependent	SE
Site Type	Navy	dimensionless	user or Depot (Cntr)	N
Support Equipment ³	Navy			N
Name		Al	TBD	LSA
Authorized Quantity		Nu	TBD	LSA
Unit Cost		\$	TBD	SE
Square Feet		ft ²	TBD	SE
Initial Support		fractional	TBD	SE
Subsequent Support		fractional	TBD	SE
Manpower	Navy			
Required Number		Nu	1	LSA
Manpower Type		Al	C (NIXIE Users)	LSA
		Al	D (Depot)LSA	
Documentation	Navy			
Required Number		Nu	2 (NSG TMs)	LSA
Name		Al	NSG TMLSA	
Cost		\$	200,000 LSA	
Space ⁴	Cntr			
Required Number		Nu	TBD	SE
Name		Al	TBD	SE
Amount		ft ²	TBD	SE
Development/Training				

NSG LORA Data Requirements

Data Element	Responsible Organization	Units	Contractor or Default Value	Data Source
Hardware Cost ⁵	Navy/Cntr			
Name		AI		
Code		AI: Nu	DD: TBD	SE
		AI: Nu	T1: TBD	SE
		AI: Nu	T4: TBD	SE
Unit Cost		\$	DD: TBD	SE
		\$	T1: TBD	SE
		\$	T4: TBD	SE
Manpower Data				
User				
Mantype	Navy	AI	C (NIXIE Users)	SE
Authorized Quantity	Navy	N	TBD	LSA
Training Cost	Navy	\$/man	TBD	SE
Attrition Rate	Navy	average fraction of men replaced/yr	0.224	D
Depot				
Mantype	Cntr	AI	DP (Depot)	SE
Authorized Quantity	Cntr	N	TBD	LSA
Training Cost	Cntr	\$/man	TBD	SE
Attrition Rate	Cntr	average fraction of men replaced/yr	0.168	D
Data Source Codes:		Unit Dimensions Codes:		
D	- LORA Model Default Data Guide	AI	- Alphabetical Code	
N	- Navy	Nu	- Numerical Code	
Cntr	- Contractor			
LSA	- Logistic Support Analysis (Contractor)			
SE	- Systems Engineering (Contractor)			

¹ This data must be provided for each component.

² This data must be provided for each component.

³ This data must be provided for each different type of support/test equipment to be used by the contractor for NSG repair.

⁴ These fields only apply to additional space required at the Depot facilities.

⁵ Three entries are required: DD; non-recurring development costs, T1; training hardware for non-depot sites, and T4; training hardware for depot sites).

APPENDIX B
NSG/RCU DATA INPUT DATA SHEETS

NSG RUN #1

01/24/90 14:17:18

NAVAL AIR SYSTEMS COMMAND
LEVEL OF REPAIR ANALYSIS - MOD 3 RELEASE 3C (SN 88-007)

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RUN SPECIFICATIONS

[MAX]		[MAX]		[MAX]	
[100]	19 = NUMBER OF ITEMS	[50]	0 = NUMBER OF GSE TYPES	[50]	0 = NUMBER OF SPACE TYPES
[30]	3 = NUMBER OF SITES	[50]	4 = NUMBER OF PERSONNEL TYPES	[10]	7 = NUMBER OF MAINT. ALTERNATIVES
[10]	1 = NUMBER OF AIRCRAFT TYPES	[50]	2 = NUMBER OF DOCUMENTATION TYPES	[5]	2 = NUMBER OF SENSITIVITY GROUPS

SYSTEM DATA

20 = LIFE CYCLE (YEARS)	33.40 = FIELD SUPPLY ADM. COST (\$/SITE-ITEM-YR)	1.00 = DEGRADATION FACTOR
10.00 = DISCOUNT RATE (PCT)	701 = ITEM ENTRY COST (\$/ITEM)	1 = EQUIPMENT/AIRCRAFT
52.00 = PROCUREMENT LEADTIME (WEEKS)	199 = ITEM RETENTION COST (\$ ITEM-YR)	0.00 = PERCENT DEPOT BACKUP
6.60 = SAFETY LEVEL(WEEKS)	42.90 = PACKING COST FACTOR (\$/CU.FT.)	

REPAIR CYCLE TIMES (DAYS)

	CV-PIMA	CV-DEPOT	LB-PIMA	LB-DEPOT	CV-PIMA-DEP	LB-PIMA-DEP	CV-CV	LB-LB	PIMA-PIMA
WRA	0.00	80.00	0.00	0.00	0.00	0.00	23.00	0.00	0.00
SRA, SUB-SRA	0.00	80.00	0.00	0.00	0.00	0.00	23.00	0.00	0.00

REQUIRED DAYS STOCK
(DAYS)GSE SPACE COST
(\$/SQ.FT.)INVENTORY STORAGE COST
(\$/CU.FT.)HOURLY RATES
(\$/HR)

90.00 = CV DISCARD
0.00 = LB DISCARD

52.40 = CV
0.00 = LB
0.00 = PIMA
8.17 = DEPOT

10.20 = CV
0.00 = LB
2.72 = DEPOT

9.18 = MILITARY - CV
0.00 = MILITARY - LB
52.12 = CIVILIAN

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NAVAL AIR SYSTEMS COMMAND
LEVEL OF REPAIR ANALYSIS - MOD 3 RELEASE 3C (SN 88-007)

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INPUT DATA - SITE

SITE NO.	NAME	# OF DAYS				AIRCRAFT DATA				DISTANT REPAIR DATA			SUPPLY SHIPPING COST
		TYPE	SITES	STOCK	PIMA PCT	TYPE	#	HOURS	FACTOR	ID	PCT	COST	
1	NIXIE Users (1)	1	15	90.0	0.0	NIXIE	2	180.0	1.000	3	100	1.16	0.80
2	NIXIE Users (2)	1	99	90.0	0.0	NIXIE	1	180.0	1.000	3	100	1.16	0.80
3	FEL, N.J.	4	1	0.0	0.0								0.00

NSG RUN #1

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NAVAL AIR SYSTEMS COMMAND

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EQUIPMENT BREAKDOWN

ITEM	MFG PART NO.	NOMENCLATURE	PREDICTED MTBF	EXPECTED MTBF	EXPECTED MTBR	UNIT COST
WRA	110	M23071/29-	361271	361271	361271	1000
WRA	120	P875001901	66999	66999	60908	1000
WRA	130	K633320045	248601	248601	226001	1000
WRA	140	K633320080	1213908	1213908	1103553	1500
WRA	150	K633320065	2170732	2170732	1973393	1500
WRA	160	K633320060	593686	593686	539715	1500
WRA	170	K633320040	4888833	4888833	4444394	1500
WRA	180	K633320055	396747	396747	360679	1500
WRA	190	K633320050	377049	377049	342772	1500
WRA	200	K633320075	601294	601294	546631	1500
WRA	210	K633320085	664071	664071	603701	1500
WRA	220	K633320030	127419	127419	115835	1500
WRA	230	K633320035	312854	312854	284413	1500
WRA	240	K633320070	1600000	1600000	1454546	2500
WRA	250	P595000101	134770	134770	134770	250
WRA	260	K633310058	700000	700000	636364	1500
WRA	270	K633320009	113801	113801	113801	2000
SRA	271	P880002401	22900	22900	22900	1000
SRA	272	P630006601	300000	300000	300000	50

INPUT DATA - ITEM

ITEM	QUANTITY	WEIGHT	VOLUME	PIECE OP PARTS	HRS/ FLT-HR	FALSE REMOVALS		BCM RATE		MATERIAL RATE			SCRAP RATE			
						TOTAL	NET	IMA	PIMA	IMA	PIMA	DEPOT	IMA	PIMA	DEPOT	
WRA	110	1	4.00	2.0000	0	1.00	0.00	0.99	0.99	1.00	1.00	0.00	0.79	1.00	0.00	0.00
WRA	120	1	20.00	2.0000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.79	1.00	0.00	0.00
WRA	130	5	5.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.79	0.00	0.00	0.05
WRA	140	1	2.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.85	0.00	0.00	0.05
WRA	150	1	2.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.85	0.00	0.00	0.05
WRA	160	4	2.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.85	0.00	0.00	0.05
WRA	170	2	2.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.85	0.00	0.00	0.05
WRA	180	1	2.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.85	0.00	0.00	0.05
WRA	190	1	2.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.85	0.00	0.00	0.05
WRA	200	1	2.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.85	0.00	0.00	0.05
WRA	210	1	2.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.85	0.00	0.00	0.05
WRA	220	1	2.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.85	0.00	0.00	0.05
WRA	230	1	2.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.85	0.00	0.00	0.05
WRA	240	1	4.00	1.0000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.91	0.00	0.00	0.05
WRA	250	1	5.00	2.0000	0	1.00	0.00	0.99	0.99	1.00	0.98	0.00	0.49	1.00	0.00	0.00
WRA	260	1	1.00	0.2000	0	1.00	0.10	0.99	0.99	1.00	1.00	0.00	0.85	0.00	0.00	0.05
WRA	270	1	20.00	4.0000	0	1.00	0.00	0.99	0.99	1.00	1.00	0.00	0.88	1.00	0.00	0.00
SRA	271	2	4.00	0.5000	0	1.00	0.00	0.99	0.99	1.00	1.00	0.00	0.79	1.00	0.00	0.00
SRA	272	1	1.00	0.5000	0	1.00	0.00	0.99	0.99	1.00	0.92	0.00	0.16	1.00	0.00	0.00

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INPUT DATA - TASKING									
ITEM	SITE LEVEL	VERIFY			REPAIR				
		TYPE	DURATION	RESOURCE	TYPE	TYPE	DURATION	RESOURCE	TYPE
110	CV	S	0.20	CTRN	MANPOWER	S	0.50	CTRN	MANPOWER
		S	0.20	NSG TM	DOCUMENTATION	S	0.50	NSG TM	DOCUMENTATION
		D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
110	DEPOT	S	0.20	DPFL	MANPOWER	S	0.50	DPFL	MANPOWER
		S	0.20	NSGTRS	DOCUMENTATION	S	0.50	NSGTRS	DOCUMENTATION
		D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER

120	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
120	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER

130	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
130	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER

140	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
140	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER

150	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
150	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER

160	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
160	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER

170	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
170	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER

180	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
180	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER

190	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER

HSG RUN #1
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NAVAL AIR SYSTEMS COMMAND
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INPUT DATA - TASKING									
ITEM	SITE LEVEL	VERIFY			REPAIR				
		TYPE	DURATION	RESOURCE	TYPE	TYPE	DURATION	RESOURCE	
190	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER
200	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
200	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER
210	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
210	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER
220	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
220	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER
230	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
230	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER
240	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
240	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER
250	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
250	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER
260	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
260	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER
270	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
270	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER
271	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER

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NAVAL AIR SYSTEMS COMMAND
LEVEL OF REPAIR ANALYSIS - MOD 3 RELEASE 3C (SN 88-007)

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INPUT DATA - TASKING									
ITEM	SITE LEVEL	VERIFY				REPAIR			
		TYPE	DURATION	RESOURCE	TYPE	TYPE	DURATION	RESOURCE	TYPE
271	DEPOT	D	0.20	DP	MANPOWER	D	0.50	DP	MANPOWER
272	CV	D	0.20	C	MANPOWER	D	0.50	C	MANPOWER
						D	0.50	DP	MANPOWER
272	DEPOT	D	0.20	DP	MANPOWER	NO RESOURCES GIVEN FOR THIS TASK			

NSG RUN #1
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NAVAL AIR SYSTEMS COMMAND
LEVEL OF REPAIR ANALYSIS - MOD 3 RELEASE 3C (SN 88-007)

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INPUT DATA - MANPOWER				
NAME	AUTH	COST	ATTRITION	BACKUP
			RATE	
CTRW	54	2000	0.224	
DPFL	20	2000	0.168	
C	0	0	0.000	
DP	0	0	0.000	

INPUT DATA - DOCUMENTATION AND SPACE

DOCUMENTATION		SPACE		
NAME	COST	NAME	AMOUNT	BACKUP
NSG TM	200000.00			
NSGTRS	10000.00			

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NAVAL AIR SYSTEMS COMMAND
LEVEL OF REPAIR ANALYSIS - MOD 3 RELEASE 3C (SN 88-007)

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SENSITIVITY ANALYSIS SPECIFICATIONS

NO. OF GRP STEPS DATA ELEMENT	A	LOW VALUE	HIGH VALUE	SITE CLASS C L P D	INDENT LEVEL W S X	TASK TYPE V R	RES. TASK D S	SPECIFIC SITES OR ITEMS	SPECIFIC A/C TYPE
1 9 7. ITEM COST	M	0.50	3.00		X X				

REOPTIMIZED ALTERNATIVES: ALL STANDARD ONES

2 9 8. ITEM MTBF	M	0.50	3.00		X X				
------------------	---	------	------	--	-----	--	--	--	--

REOPTIMIZED ALTERNATIVES: ALL STANDARD ONES

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NAVAL AIR SYSTEMS COMMAND
LEVEL OF REPAIR ANALYSIS - MOD 3 RELEASE 3C (SN 88-007)

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TOTAL LIFE CYCLE LOGISTICS COST
(ALL COSTS ARE IN \$000)

	ALL WRA'S DISCARD	ALL WRA'S LOCAL ALL SRA'S DISCARD	ALL WRA'S LOCAL ALL SRA'S LOCAL SUB-SRA'S OPTIMIZED	ALL WRA'S LOCAL ALL SRA'S PIMA SUB-SRA'S OPTIMIZED
WRA LEVEL	1538.6	1521.6	1521.6	0.0
SRA LEVEL	0.0	238.2	189.7	0.0
SUB-SRA LEVEL	0.0	0.0	0.0	0.0
TOTAL	1538.6	1759.8	1711.3	0.0

	ALL WRA'S LOCAL ALL SRA'S DEPOT SUB-SRA'S OPTIMIZED	ALL WRA'S DEPOT ALL SRA'S OPTIMIZED SUB-SRA'S OPTIMIZED	LEAST COST ALTERNATIVE
WRA LEVEL	1521.6	1316.4	1316.4
SRA LEVEL	189.7	191.6	191.6
SUB-SRA LEVEL	0.0	0.0	0.0
TOTAL	1711.3	1507.9	1507.9

APPENDIX C
NSG/RCU DATA OUTPUT DATA SHEETS

MSG RUN #1
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NAVAL AIR SYSTEMS COMMAND
LEVEL OF REPAIR ANALYSIS - MOD 3 RELEASE 3C (SN 88-007)

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ITEM SUMMARY REPORT WITH MAINTENANCE SCHEME
(ALL COSTS ARE IN \$000)

ALL WRA'S DISCARD			ALL WRA'S LOCAL ALL SRA'S DISCARD		ALL WRA'S LOCAL ALL SRA'S LOCAL SUB-SRA'S OPTIMIZED		ALL WRA'S LOCAL ALL SRA'S PIMA SUB-SRA'S OPTIMIZED	
ITEM	COST	LOR ALT	COST	LOR ALT	COST	LOR ALT	COST	LOR ALT
SHARED	534.6		647.5		647.5		0.0	
WRA 110	62.4	X	43.3	I	43.3	I	0.0	-
WRA 120	97.3	X	75.6	I	75.6	I	0.0	-
WRA 130	90.0	X	81.1	I	81.1	I	0.0	-
WRA 140	40.0	X	39.5	I	39.5	I	0.0	-
WRA 150	38.6	X	38.2	I	38.2	I	0.0	-
WRA 160	63.4	X	60.1	I	60.1	I	0.0	-
WRA 170	38.4	X	38.0	I	38.0	I	0.0	-
WRA 180	46.7	X	45.4	I	45.4	I	0.0	-
WRA 190	47.3	X	45.9	I	45.9	I	0.0	-
WRA 200	43.4	X	42.4	I	42.4	I	0.0	-
WRA 210	42.7	X	41.9	I	41.9	I	0.0	-
WRA 220	67.8	X	64.0	I	64.0	I	0.0	-
WRA 230	49.4	X	47.8	I	47.8	I	0.0	-
WRA 240	48.9	X	41.5	I	41.5	I	0.0	-
WRA 250	61.1	X	41.5	I	41.5	I	0.0	-
WRA 260	42.4	X	41.6	I	41.6	I	0.0	-
WRA 270	124.2	X	86.4	I	86.4	I	0.0	-
SHARED	0.0		0.0		0.0		0.0	
SRA 271	0.0	-	234.8	X	186.9	I	0.0	-
SRA 272	0.0	-	3.4	X	2.7	I	0.0	-
TOTAL	1538.6		1759.8		1711.3		0.0	

* INDICATES OPTIMIZED LOR DECISION

I = IMA(LOCAL) P = PIMA D = DEPOT X = DISCARD

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NAVAL AIR SYSTEMS COMMAND
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ITEM SUMMARY REPORT WITH MAINTENANCE SCHEME
(ALL COSTS ARE IN \$000)

		ALL WRA'S LOCAL ALL SRA'S DEPOT SUB-SRA'S OPTIMIZED		ALL WRA'S DEPOT ALL SRA'S OPTIMIZED SUB-SRA'S OPTIMIZED		LEAST COST ALTERNATIVE	
ITEM		COST	LOR ALT	COST	LOR ALT	COST	LOR ALT
SHARED		647.5		447.5		447.5	
WRA	110	43.3	I	42.2	D	42.2	D *
WRA	120	75.6	I	76.4	D	74.4	D *
WRA	130	81.1	I	80.9	D	80.9	D *
WRA	140	39.5	I	39.5	D	39.5	D *
WRA	150	38.2	I	38.2	D	38.2	D *
WRA	160	60.1	I	60.1	D	60.1	D *
WRA	170	38.0	I	38.0	D	38.0	D *
WRA	180	45.4	I	45.4	D	45.4	D *
WRA	190	45.9	I	45.8	D	45.8	D *
WRA	200	42.4	I	42.4	D	42.4	D *
WRA	210	41.9	I	41.8	D	41.8	D *
WRA	220	64.0	I	63.9	D	63.9	D *
WRA	230	47.8	I	47.7	D	47.7	D *
WRA	240	41.5	I	41.5	D	41.5	D *
WRA	250	41.5	I	41.2	D	41.2	D *
WRA	260	41.6	I	41.6	D	41.6	D *
WRA	270	86.4	I	84.2	D	84.2	D *
SHARED		0.0		0.0		0.0	
SRA	271	186.9	D	188.8	D *	188.8	D *
SRA	272	2.7	D	2.7	D *	2.7	D *
TOTAL		1711.3		1507.9		1507.9	

* INDICATES OPTIMIZED LOR DECISION

I = IMA(LOCAL) P = PIMA D = DEPOT X = DISCARD

Least Cost Alternative

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COST BREAKDOWN AND PERCENT OF TOTAL LIFE CYCLE LOGISTICS COSTS
(ALL COSTS ARE IN \$000)

	ALL WRA'S DISCARD		ALL WRA'S LOCAL ALL SRA'S DISCARD				TOTAL	
	TOTAL		WRA		SRA		TOTAL	
	\$	%	\$	%	\$	%	\$	%
SUPPORT EQUIP.	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
SUPPORT OF SE	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
INVENTORY	268.1	17.43	24.3	1.59	226.1	94.90	250.3	14.22
INV. ADMIN.	591.8	38.46	596.6	39.21	5.4	2.25	602.0	34.21
SE SPACE	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
INV. STORAGE	132.7	8.62	0.3	0.02	0.0	0.00	0.3	0.02
REPAIR SPACE	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
LABOR	0.4	0.03	6.1	0.40	2.2	0.93	8.3	0.47
MATERIAL	0.0	0.00	214.8	14.12	0.0	0.00	214.8	12.21
TRANSPORTATION	11.1	0.72	22.6	1.49	4.6	1.92	27.2	1.54
REPAIR SCRAP	0.0	0.00	9.4	0.62	0.0	0.00	9.4	0.54
TRAINING	334.6	21.74	437.5	28.75	0.0	0.00	437.5	24.86
DOCUMENTATION	200.0	13.00	210.0	13.80	0.0	0.00	210.0	11.93
TOTAL	1538.6	100.00	1521.6	100.00	238.2	100.00	1759.8	100.00

ALL WRA'S LOCAL
ALL SRA'S LOCAL
SUB-SRA'S OPTIMIZED

	WRA		SRA		SUB-SRA		TOTAL	
	\$	%	\$	%	\$	%	\$	%
SUPPORT EQUIP.	0.0	0.00	0.0	0.00			0.0	0.00
SUPPORT OF SE	0.0	0.00	0.0	0.00			0.0	0.00
INVENTORY	24.3	1.59	0.0	0.00			24.3	1.42
INV. ADMIN.	596.6	39.21	5.4	2.83			602.0	35.18
SE SPACE	0.0	0.00	0.0	0.00			0.0	0.00
INV. STORAGE	0.3	0.02	0.0	0.00			0.3	0.02
REPAIR SPACE	0.0	0.00	0.0	0.00			0.0	0.00
LABOR	6.1	0.40	5.3	2.82			11.4	0.67
MATERIAL	214.8	14.12	179.0	94.36			393.8	23.01
TRANSPORTATION	22.6	1.49	0.0	0.00			22.6	1.32
REPAIR SCRAP	9.4	0.62	0.0	0.00			9.4	0.55
TRAINING	437.5	28.75	0.0	0.00			437.5	25.56
DOCUMENTATION	210.0	13.80	0.0	0.00			210.0	12.27
TOTAL	1521.6	100.00	189.7	100.00			1711.3	100.00

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COST BREAKDOWN AND PERCENT OF TOTAL LIFE CYCLE LOGISTICS COSTS
(ALL COSTS ARE IN \$000)

ALL WRA'S LOCAL
ALL SRA'S DEPOT
SUB-SRA'S OPTIMIZED

	WRA		SRA		SUB-SRA		TOTAL	
	\$	%	\$	%	\$	%	\$	%
SUPPORT EQUIP.	0.0	0.00	0.0	0.00			0.0	0.00
SUPPORT OF SE	0.0	0.00	0.0	0.00			0.0	0.00
INVENTORY	24.3	1.59	0.0	0.00			24.3	1.42
INV. ADMIN.	596.6	39.21	5.4	2.83			602.0	35.18
SE SPACE	0.0	0.00	0.0	0.00			0.0	0.00
INV. STORAGE	0.3	0.02	0.0	0.00			0.3	0.02
REPAIR SPACE	0.0	0.00	0.0	0.00			0.0	0.00
LABOR	6.1	0.40	5.3	2.82			11.4	0.67
MATERIAL	214.8	14.12	179.0	94.36			393.8	23.01
TRANSPORTATION	22.6	1.49	0.0	0.00			22.6	1.32
REPAIR SCRAP	9.4	0.62	0.0	0.00			9.4	0.55
TRAINING	437.5	28.75	0.0	0.00			437.5	25.56
DOCUMENTATION	210.0	13.80	0.0	0.00			210.0	12.27
TOTAL	1521.6	100.00	189.7	100.00			1711.3	100.00

ALL WRA'S DEPOT
ALL SRA'S OPTIMIZED
SUB-SRA'S OPTIMIZED

	WRA		SRA		SUB-SRA		TOTAL	
	\$	%	\$	%	\$	%	\$	%
SUPPORT EQUIP.	0.0	0.00	0.0	0.00			0.0	0.00
SUPPORT OF SE	0.0	0.00	0.0	0.00			0.0	0.00
INVENTORY	20.0	1.52	0.0	0.00			20.0	1.33
INV. ADMIN.	596.6	45.32	5.4	2.80			602.0	39.92
SE SPACE	0.0	0.00	0.0	0.00			0.0	0.00
INV. STORAGE	0.1	0.01	0.0	0.00			0.1	0.01
REPAIR SPACE	0.0	0.00	0.0	0.00			0.0	0.00
LABOR	5.6	0.42	5.4	2.82			11.0	0.73
MATERIAL	215.3	16.35	180.8	94.38			396.1	26.27
TRANSPORTATION	22.8	1.73	0.0	0.00			22.8	1.51
REPAIR SCRAP	8.6	0.65	0.0	0.00			8.6	0.57
TRAINING	437.5	33.23	0.0	0.00			437.5	29.01
DOCUMENTATION	10.0	0.76	0.0	0.00			10.0	0.66
TOTAL	1316.4	100.00	191.6	100.00			1507.9	100.00

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NAVAL AIR SYSTEMS COMMAND
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COST BREAKDOWN AND PERCENT OF TOTAL LIFE CYCLE LOGISTICS COSTS
(ALL COSTS ARE IN \$000)

LEAST COST
ALTERNATIVE

	WRA		SRA		SUB-SRA		TOTAL	
	\$	%	\$	%	\$	%	\$	%
SUPPORT EQUIP.	0.0	0.00	0.0	0.00			0.0	0.00
SUPPORT OF SE	0.0	0.00	0.0	0.00			0.0	0.00
INVENTORY	20.0	1.52	0.0	0.00			20.0	1.33
INV. ADMIN.	596.6	45.32	5.4	2.80			602.0	39.92
SE SPACE	0.0	0.00	0.0	0.00			0.0	0.00
INV. STORAGE	0.1	0.01	0.0	0.00			0.1	0.01
REPAIR SPACE	0.0	0.00	0.0	0.00			0.0	0.00
LABOR	5.6	0.42	5.4	2.82			11.0	0.73
MATERIAL	215.3	16.35	180.8	94.38			396.1	26.27
TRANSPORTATION	22.8	1.73	0.0	0.00			22.8	1.51
REPAIR SCRAP	8.6	0.65	0.0	0.00			8.6	0.57
TRAINING	437.5	33.23	0.0	0.00			437.5	29.01
DOCUMENTATION	10.0	0.76	0.0	0.00			10.0	0.66
TOTAL	1316.4	100.00	191.6	100.00			1507.9	100.00

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NAVAL AIR SYSTEMS COMMAND
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TOTAL INVENTORY VALUES

		ALL WRA'S DISCARD		ALL WRA'S LOCAL ALL SRA'S DISCARD		ALL WRA'S LOCAL ALL SRA'S LOCAL SUB-SRA'S OPTIMIZED		ALL WRA'S LOCAL ALL SRA'S PIMA SUB-SRA'S OPTIMIZED	
ITEM		LIFECYCLE NON-RECURRING	ANNUAL RECURRING	LIFECYCLE NON-RECURRING	ANNUAL RECURRING	LIFECYCLE NON-RECURRING	ANNUAL RECURRING	LIFECYCLE NON-RECURRING	ANNUAL RECURRING
WRA	110	114	0.77	1	0.01	1	0.01		
WRA	120	114	4.16	1	0.04	1	0.04		
WRA	130	114	5.61	1	0.28	1	0.28		
WRA	140	114	0.23	1	0.01	1	0.01		
WRA	150	114	0.13	1	0.01	1	0.01		
WRA	160	114	1.88	1	0.09	1	0.09		
WRA	170	114	0.11	1	0.01	1	0.01		
WRA	180	114	0.70	1	0.03	1	0.03		
WRA	190	114	0.74	1	0.04	1	0.04		
WRA	200	114	0.46	1	0.02	1	0.02		
WRA	210	114	0.42	1	0.02	1	0.02		
WRA	220	114	2.19	1	0.11	1	0.11		
WRA	230	114	0.89	1	0.04	1	0.04		
WRA	240	114	0.17	1	0.01	1	0.01		
WRA	250	114	2.07	1	0.02	1	0.02		
WRA	260	114	0.40	1	0.02	1	0.02		
WRA	270	114	2.45	1	0.02	1	0.02		
SRA	271			0	24.09	0	0.00		
SRA	272			0	0.92	0	0.00		

		ALL WRA'S LOCAL ALL SRA'S DEPOT SUB-SRA'S OPTIMIZED		ALL WRA'S DEPOT ALL SRA'S OPTIMIZED SUB-SRA'S OPTIMIZED		LEAST COST ALTERNATIVE	
ITEM		LIFECYCLE NON-RECURRING	ANNUAL RECURRING	LIFECYCLE NON-RECURRING	ANNUAL RECURRING	LIFECYCLE NON-RECURRING	ANNUAL RECURRING
WRA	110	1	0.01	0	0.00	0	0.00
WRA	120	1	0.04	0	0.00	0	0.00
WRA	130	1	0.28	1	0.28	1	0.28
WRA	140	1	0.01	1	0.01	1	0.01
WRA	150	1	0.01	1	0.01	1	0.01
WRA	160	1	0.09	1	0.09	1	0.09
WRA	170	1	0.01	1	0.01	1	0.01
WRA	180	1	0.03	1	0.04	1	0.04
WRA	190	1	0.04	1	0.04	1	0.04
WRA	200	1	0.02	1	0.02	1	0.02
WRA	210	1	0.02	1	0.02	1	0.02
WRA	220	1	0.11	1	0.11	1	0.11
WRA	230	1	0.04	1	0.04	1	0.04
WRA	240	1	0.01	1	0.01	1	0.01
WRA	250	1	0.02	0	0.00	0	0.00
WRA	260	1	0.02	1	0.02	1	0.02
WRA	270	1	0.02	0	0.00	0	0.00
SRA	271	0	0.00	0	0.00	0	0.00
SRA	272	0	0.00	0	0.00	0	0.00

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NAVAL AIR SYSTEMS COMMAND

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LEVEL OF REPAIR ANALYSIS - MOD 3 RELEASE 3C (SN 88-007)

PER SITE INVENTORY VALUES

WRA SRA SUB-SRA
 ALTERNATIVE - ALL DISCARD

ITEM	INPUT	SYSTEM	NIXIE Us			NIXIE Us			FEL, N.J		
	I.D.	STOCK	RP	AQ	SC	RP	AQ	SC	RP	AQ	SC
WRA	110	0	0	15	0.2	0	99	0.6	0	0	0.0
WRA	120	0	0	15	1.0	0	99	3.2	0	0	0.0
WRA	130	0	0	15	1.3	0	99	4.3	0	0	0.0
WRA	140	0	0	15	0.1	0	99	0.2	0	0	0.0
WRA	150	0	0	15	0.0	0	99	0.1	0	0	0.0
WRA	160	0	0	15	0.4	0	99	1.4	0	0	0.0
WRA	170	0	0	15	0.0	0	99	0.1	0	0	0.0
WRA	180	0	0	15	0.2	0	99	0.5	0	0	0.0
WRA	190	0	0	15	0.2	0	99	0.6	0	0	0.0
WRA	200	0	0	15	0.1	0	99	0.4	0	0	0.0
WRA	210	0	0	15	0.1	0	99	0.3	0	0	0.0
WRA	220	0	0	15	0.5	0	99	1.7	0	0	0.0
WRA	230	0	0	15	0.2	0	99	0.7	0	0	0.0
WRA	240	0	0	15	0.0	0	99	0.1	0	0	0.0
WRA	250	0	0	15	0.5	0	99	1.6	0	0	0.0
WRA	260	0	0	15	0.1	0	99	0.3	0	0	0.0
WRA	270	0	0	15	0.6	0	99	1.9	0	0	0.0

WRA SRA SUB-SRA
 ALTERNATIVE - ALL LOCAL ALL DISCARD

ITEM	INPUT	SYSTEM	NIXIE Us			NIXIE Us			FEL, N.J		
	I.D.	STOCK	RP	AQ	SC	RP	AQ	SC	RP	AQ	SC
WRA	110	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	120	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	130	1	0	0	0.0	0	0	0.0	0	0	0.3
WRA	140	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	150	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	160	1	0	0	0.0	0	0	0.0	0	0	0.1
WRA	170	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	180	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	190	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	200	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	210	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	220	1	0	0	0.0	0	0	0.0	0	0	0.1
WRA	230	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	240	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	250	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	260	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	270	1	0	0	0.0	0	0	0.0	0	0	0.0
SRA	271	0	0	0	0.0	0	0	0.0	0	0	24.1
SRA	272	0	0	0	0.0	0	0	0.0	0	0	0.9

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NAVAL AIR SYSTEMS COMMAND
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PER SITE INVENTORY VALUES

WRA			SRA			SUB-SRA					
ALTERNATIVE - ALL LOCAL			ALL LOCAL			OPTIMIZED					
ITEM	INPUT I.D.	SYSTEM STOCK	NIXIE Us			NIXIE Us			FEL, W.J		
			RP	AQ	SC	RP	AQ	SC	RP	AQ	SC
WRA	110	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	120	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	130	1	0	0	0.0	0	0	0.0	0	0	0.3
WRA	140	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	150	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	160	1	0	0	0.0	0	0	0.0	0	0	0.1
WRA	170	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	180	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	190	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	200	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	210	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	220	1	0	0	0.0	0	0	0.0	0	0	0.1
WRA	230	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	240	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	250	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	260	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	270	1	0	0	0.0	0	0	0.0	0	0	0.0
SRA	271	0	0	0	0.0	0	0	0.0	0	0	0.0
SRA	272	0	0	0	0.0	0	0	0.0	0	0	0.0

WRA			SRA			SUB-SRA					
ALTERNATIVE - ALL LOCAL			ALL DEPOT			OPTIMIZED					
ITEM	INPUT I.D.	SYSTEM STOCK	NIXIE Us			NIXIE Us			FEL, W.J		
			RP	AQ	SC	RP	AQ	SC	RP	AQ	SC
WRA	110	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	120	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	130	1	0	0	0.0	0	0	0.0	0	0	0.3
WRA	140	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	150	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	160	1	0	0	0.0	0	0	0.0	0	0	0.1
WRA	170	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	180	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	190	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	200	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	210	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	220	1	0	0	0.0	0	0	0.0	0	0	0.1
WRA	230	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	240	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	250	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	260	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	270	1	0	0	0.0	0	0	0.0	0	0	0.0
SRA	271	0	0	0	0.0	0	0	0.0	0	0	0.0

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PER SITE INVENTORY VALUES

ITEM	WRA		SRA			SUB-SRA			FEL, N.J		
	INPUT I.D.	SYSTEM STOCK	ALL DEPOT			OPTIMIZED					
			RP	AQ	SC	RP	AQ	SC	RP	AQ	SC
SRA	272	0	0	0	0.0	0	0	0.0	0	0	0.0

ITEM	WRA		SRA			SUB-SRA			FEL, N.J		
	INPUT I.D.	SYSTEM STOCK	ALL DEPOT			OPTIMIZED					
			RP	AQ	SC	RP	AQ	SC	RP	AQ	SC
WRA	110	0	0	0	0.0	0	0	0.0	0	0	0.0
WRA	120	0	0	0	0.0	0	0	0.0	0	0	0.0
WRA	130	1	0	0	0.0	0	0	0.0	0	0	0.3
WRA	140	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	150	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	160	1	0	0	0.0	0	0	0.0	0	0	0.1
WRA	170	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	180	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	190	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	200	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	210	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	220	1	0	0	0.0	0	0	0.0	0	0	0.1
WRA	230	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	240	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	250	0	0	0	0.0	0	0	0.0	0	0	0.0
WRA	260	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	270	0	0	0	0.0	0	0	0.0	0	0	0.0
SRA	271	0	0	0	0.0	0	0	0.0	0	0	0.0
SRA	272	0	0	0	0.0	0	0	0.0	0	0	0.0

ITEM	WRA		SRA			SUB-SRA			FEL, N.J		
	INPUT I.D.	SYSTEM STOCK	OPTIMIZED			OPTIMIZED					
			RP	AQ	SC	RP	AQ	SC	RP	AQ	SC
WRA	110	0	0	0	0.0	0	0	0.0	0	0	0.0
WRA	120	0	0	0	0.0	0	0	0.0	0	0	0.0
WRA	130	1	0	0	0.0	0	0	0.0	0	0	0.3
WRA	140	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	150	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	160	1	0	0	0.0	0	0	0.0	0	0	0.1
WRA	170	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	180	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	190	1	0	0	0.0	0	0	0.0	0	0	0.0

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PER SITE INVENTORY VALUES

WRA			SRA			SUB-SRA					
ALTERNATIVE - OPTIMIZED			OPTIMIZED			OPTIMIZED					
ITEM	INPUT	SYSTEM	NIXIE Us			NIXIE Us			FEL, N.J		
	I.D.	STOCK	RP	AQ	SC	RP	AQ	SC	RP	AQ	SC
WRA	200	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	210	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	220	1	0	0	0.0	0	0	0.0	0	0	0.1
WRA	230	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	240	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	250	0	0	0	0.0	0	0	0.0	0	0	0.0
WRA	260	1	0	0	0.0	0	0	0.0	0	0	0.0
WRA	270	0	0	0	0.0	0	0	0.0	0	0	0.0
SRA	271	0	0	0	0.0	0	0	0.0	0	0	0.0
SRA	272	0	0	0	0.0	0	0	0.0	0	0	0.0

VITA

Mr. R.N. Godshall is currently a Senior Logistics Engineer working for E-Systems, a military and space electronics manufacturer located in Falls Church, Virginia. His qualifications and logistics experience (to include Level of Repair Analysis) are detailed below and are abbreviated for the purposes of this paper.

Special Areas of Expertise

Logistic Support Analysis (LSA) and Integrated Logistics Support (ILS) for U.S. Army, Air Force, and Navy communications/electronics systems. Expertise in systems engineering, Level of Repair Analysis (LORA), Environmental Stress Screening (ESS), Reliability, Maintainability, and Availability (RMA) engineering, and logistics engineering and management. Specific hands-on experience in ESS, and RMA and Level of Repair Analysis (LORA) calculations and modeling. Unique knowledge of DOD safety requirements.

Summary of Professional Experience

03/90 - Present: E-Systems, Melpar Div.; Senior Logistics Engineer; Developed and conducted Level of Repair Analysis (LORA) using US Army LORA Model based on MIL-STD-1390C for major US Army and Air Force electronics program. Performed System Hazard Analyses using MIL-STDs-454M, 882B, and 1472D; developed Environmental Stress Screening (ESS) plans and procedures; conducted Human Factors Engineering Analysis; and wrote Maintainability and LSA Program Plans for several different US Army, US Air Force, and National Security Agency electronics programs

06/88 - 03/90: SWL, Project Engineer/ILS Manager; Managed support engineering efforts for USN electronics program, supervised technical staff of seven and performed financial planning for program. Was responsible for development, and technical quality of contract deliverables. Specialty areas included ILS, LSA/LSAR, RMA, provisioning, technical documentation, safety/human factors engineering, and training activities. Wrote

and managed ILS and LSA plans/programs, directed and assisted in development of automated LSAR data base using SLIC software. Assisted in proposal and bid development on related electronics programs. Performed LORA using NAVSEA Model based on MIL-STD-1390C. Assisted in the development of Preliminary and System Hazard Analyses using MIL-STD-882B.

06/86 - 06/88: CACI, Senior Engineering Associate; performed project management and logistical engineering/planning for USN electronics programs. Developed and managed tasks and products focused on systems analysis, ILS/LSA/LSAR (MIL-STD-1388-1A/2A, NAVSEA 5900.39M, etc.), software support of embedded computer resources, civil engineering applications, maintenance analysis and planning, technical manual requirements and planning, quality assurance program planning, safety and test equipment concerns. Conducted RMA and sparing calculations and developed operational scenarios and quantitative engineering factors for use in RMA and sparing computer models (TIGER, ACIM, Costpro, etc.). Tasks also included participation in critical program design reviews and USN Logistics Review Group (LRG) functions.

01/86 - 06/86: TRW, Senior Engineering Technical Writer; developed, wrote, and edited text material and drawings for technical documents in support of classified material produced for the U.S. Army by TRW. Conducted LSA for maintenance tasks of the Communications Restoral System (CRS) project. Involved with electrical, electronics, and mechanical subsystems. Special experience in government technical manual requirements, development, and production.

10/82 - 12/85: United States Marine Corps, Field Artillery Officer; As unit Executive Officer, devised, coordinated, and implemented all unit training. Was responsible to the Commanding Officer for all activities conducted by unit in both field and garrison. Supervised approximately ninety enlisted personnel and twelve officers. Special expertise in material maintenance, communications equipment, fire direction (gunnery), nuclear weapons, and security procedures. Extensive management applications in logistics engineering in supply, maintenance, operations, and training areas while serving in USMC.

Education

Bachelor's of Science, Civil Engineering, Virginia Military Institute, 1982.

Master's of Engineering Systems Engineering, Virginia Polytechnic Institute and State University, 1990.

Professional Affiliations

United States Marine Corps Reserve (Captain)

Society of Logistics Engineers (SOLE)