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A Comparison of the Naval Air Systems Command Model III Method with the United States Air Force Repair Level Analysis Method of Level of Repair Analysis for Recommendation of a Lora Methodology on the Joint Service V-22 Osprey Program

John David Driessnack
Wright State University - Main Campus

A COMPARISON OF
THE NAVAL AIR SYSTEMS COMMAND MODEL III METHOD WITH
THE UNITED STATES AIR FORCE REPAIR LEVEL ANALYSIS METHOD
OF LEVEL OF REPAIR ANALYSIS
FOR RECOMMENDATION OF A LORA METHODOLOGY ON THE
JOINT SERVICE V-22 OSPREY PROGRAM

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science

By

JOHN DAVID DRIESSNACK
Capt, United States Air Force
B.S., Pennsylvania State University, 1983

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY Capt John David Driessnack ENTITLED A Comparison of the NAVAL AIR SYSTEMS COMMAND Model III Method with the United States AIR FORCE Repair Level Analysis Method of Level of Repair Analysis (LORA) for Recommendation of a LORA Methodology on the Joint Service V-22 Osprey Program BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science.

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ABSTRACT

Driessnack, John David. Capt, USAF. M.S., Department of Economics, Wright State University, 1992. A Comparison of the NAVAL AIR SYSTEMS COMMAND Model III Method with the United States AIR FORCE Repair Level Analysis Method of Level of Repair Analysis (LORA) for Recommendation of a LORA Methodology on the Joint Service V-22 Osprey Program

In the past 30 years Life Cycle Cost (LCC) and Level of Repair Analysis (LORA) has been developed within the Department of Defense (DoD). The LORA process, outlined in the new Military Standard (MIL-STD) 1390D, is required to be accomplished in each DoD weapon system acquisition program. The Standard outlines 13 different service peculiar models. The Joint V-22 Program must determine an effective LORA methodology that appropriately considers Service unique requirements while limiting the need to run both the NAVAL AIR SYSTEMS COMMAND (NAVAIRSYSCOM) Model III and the Air Force RLA methods of LORA. The two methods, compared by relating 10 cost categories, have major differences in the overall approach as well as several categories. The Support Equipment (SE) and Inventory categories are reviewed in detail. The Model III's inappropriate use of discount factors is illustrated. Recommendations are made to stop the current V-22 LORA effort, develop an interim capability to run both programs by producing a pre-processor Personnel Computer (PC) based program that outputs the input files for both methods, and start efforts to develop a common LORA model incorporating input data standardization and the best of the two methods.

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I. INTRODUCTION

The Department of Defense (DoD) acquires billions of dollars of sophisticated equipment each year. Even though the cost of acquiring the equipment seems high, it is not the highest cost to the government when considering the complete weapon system life cycle. The Life Cycle Cost (LCC) is defined as "the total cost to the government of acquisition and ownership of that system over its full life. It includes the cost of development, acquisition, operation, support, and, where applicable, disposal.[1]" Figure 1[2] illustrates a typical life cycle. A major portion of a weapon systems cost are the Operations and Support (O&S) costs of the system over its life, which is usually estimated to be 20 years, but is often much longer.[3] This can be seen by reviewing Figure 2[4],

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[1]Mary Eddins Earles, Factors, Formulas, and Structure for Life Cycle Costing, 2nd ed. (Concord, Mass.: By the Author, 89 Lee Drive., 1979), p. 1-1.

[2]U.S. Department of Defense, Office of Secretary of Defense, Operating and Support Cost Estimating Guide (Draft),1 Aug 1991, by OSD Cost Analysis Improvement Group (CAIG) OASD(PA&E), Washington DC 20301, Exihibit 2-1.

[3]Of the 50 plus aircraft types in the Air Force inventory the average age, as of 30 Sept 91, according to the May 92 issue of The Air Force Association's AF Magazine was 17.3 years. Nineteen of the aircraft types average fleet age was over 20 years. Three more aircraft types had aircraft with over 21 years of service. These figures indicate that the life cycle of an aircraft is longer then

an exhibit from the Office of Secretary of Defense (OSD) current O&S Cost Guide.

The OSD O&S guide provides the following descriptions of each portion of the life cycle phase.

Research and Development. Consist of those costs incurred from program initiation at the conceptual stage through the end of engineering and manufacturing development. It consists of costs for feasibility studies, modeling, trade-off analyses, engineering design, development, fabrication, assembly and test of prototype hardware and software, system test and evaluation, associated peculiar support equipment and documentation.

Investment. Includes those costs associated with producing or procuring the prime hardware and directly associated hardware and activities such as peculiar support, training, data, initial spares, and military construction.

Operations and Support. Includes all costs for operating, maintaining, and supporting a fielded system such as personnel, consumable and repairable materials, organizational, intermediate and depot maintenance, facilities and sustaining investment.

Disposal. Captures costs associated with deactivating or disposing of a military system at the end of its useful life. This category is seldom estimated in most analyses. The cost is normally insignificant compared to the total life cycle cost. The main exceptions (which should be addressed) include disposal of nuclear waste,

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the usually estimated 20 years. As with much of the data utilized in modeling, the standard figures should only be used as defaults when better data is not available. The area one must consider in estimating the life of an inventory item is the extent of modification an item will undergo during the aircraft's life. Systems and subsystem in the aircraft are changed to either enhance capability or simply replace out of production components.

[4]U.S. Department of Defense, Office of Secretary of Defense, Operating and Support Cost Estimating Guide (Draft),1 Aug 1991, by OSD Cost Analysis Improvement Group (CAIG) OASD(PA&E), Washington DC 20301, exhibit 2-2.

missile propellants, and other materials requiring detoxification or special handling.[5]

The life cycle phases are pictured in Figure 3[6].

Program Office

To manage the life of the system, often referred to as cradle to grave, the DoD establishes program offices that are charged with the duty of economically spending the dollars to acquire and support the weapon systems. Within these offices, in general, there is a Program Manager (PM) with overall responsibility and two primary deputies, one for engineering or systems and the other for logistics. It is the logistician who has primary responsibility for establishing the most cost effective support structure given the design of the system. The logistician attempts to influence the design early on in the design process to allow for better or enhance supportability characteristics, which may mean an increase in R&D and Investment costs, but, in turn allow for lower O&S costs. This, in general, is in terms of "...ility" goals such as Reliability & Maintainability (R&M), Supportability, Availability, etc. The approach is called Integrated Logistics Support (ILS), and the main tool used is a process called Logistics Support Analysis (LSA). The LSA process has

[5]Ibid., p. 2-3.

[6]Ibid., exhibit 2-3.

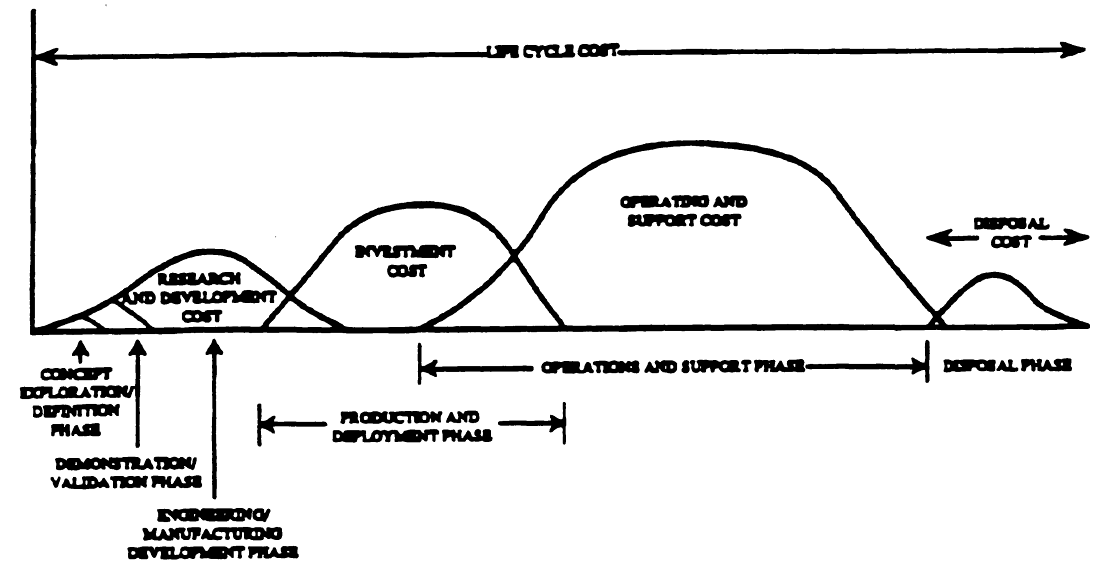

Exhibit 2-1. PROGRAM LIFE CYCLE (ILLUSTRATIVE)

System	R&D	Investment	O&S
F-16	2%	20%	78%
M-2 BRADLEY	2%	14%	84%

Exhibit 2-2. PROGRAM PHASE COSTS

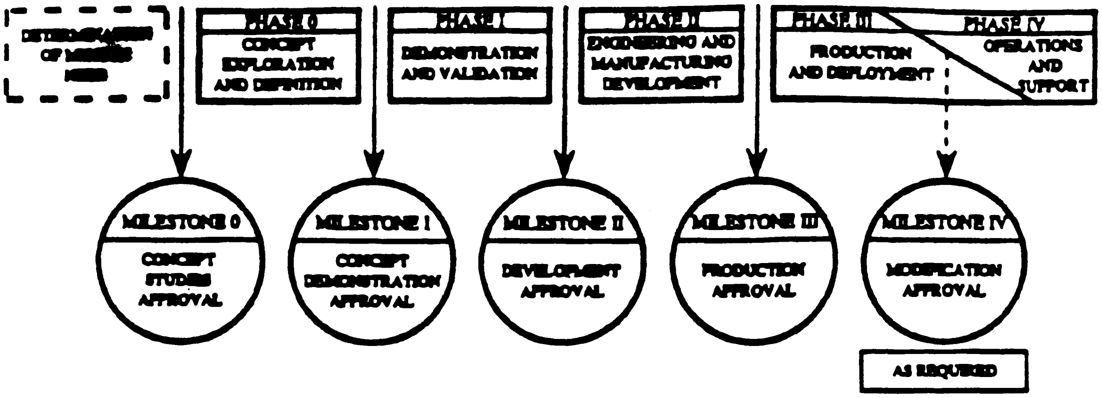

Exhibit 2-3. ACQUISITION MILESTONES AND PHASES

been standardized throughout DoD and is outlined in the MIL-STD 1388-1A.

Logistics Support Analysis (LSA)

Through use of the LSA process, a "systematic and comprehensive analysis" will be conducted on an iterative basis through all phases of the system/equipment life cycle to satisfy supportability (supportability includes all elements of ILS, as defined in DoDI 5000.2, required to operate and maintain the system/equipment) objective.[7]" The standard goes on to state that "quantitative supportability and supportability-related design requirements ... shall be defined in terms related to operational readiness, demand for logistics support resources, and operating and support (O&S) costs, ..." The process calls for the accumulation of documentation so "an audit trail of supportability and supportability-related design analyses and decision" can be established and "shall be the basis for actions and documents related to manpower and personnel requirements, training programs, provisioning, maintenance planning, resources allocation, funding decisions, and other logistics support resources requirements.[8]" The process is broken down into five general sections that are further broken down into

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[7]U. S. Department of Defense, MIL-STD-1388-1A Notice 3, Logistics Support Analysis, 28 Mar 91 p. 3, paragraph 4.1.2.

[8]Ibid., p. 3 paragraph 4.4

specific tasks to be accomplished.

In Task 203, Comparative Analysis, a Baseline Comparison System (BCS) is selected or developed to use in comparing parameters with the system being developed. In this task, "the O&S costs, logistics support resource requirements, reliability and maintainability (R&M) values, and readiness values of the comparative systems...[9]" are identified. The "supportability, cost, and readiness drivers" of the BCS are determined and are highlighted to influence the design and planning for the current system.

As the design of the new system takes shape, Task 303, Evaluation of Alternatives and Tradeoff Analysis, is accomplished. Within this task is the subtask 303.2.7, Repair Level Analysis (RLA). With this task, a Level of Repair Analysis (LORA) as specified in MIL-STD-1390 is accomplished.

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[9]Ibid,. p. 23, paragraph 203.2.3.

II. BACKGROUND

DoD Instruction (DoDI) 5000.2 requires the Program Office to estimate the LCC and to have a Design to Cost (DTC) program[10]. Part 4, Section E, Cost and Operational Effectiveness Analysis, states:

> ...cost analysis assesses the resource implications of associated inputs. In this regard, the concept of life-cycle cost is important. ... It is imperative to identify life-cycle costs, nonmonetary as well as monetary, associated with each alternative being considered in a cost and operational effectiveness analysis. To affect the analysis, separate estimates of operations and maintenance costs must be made, particularly manpower, personnel, and training costs.[11]

History of Life Cycle Cost in DoD

LCC has been developing in DoD for over 30 years. The following is a brief history of that development within the Department of Defense

> ... emphasis in the area of life cycle costing began in the early 1960's with studies by the Logistics Management Institute (LMI) for the assistant secretary of defense. These studies were to determine the effect that price competition, with its potential for changing supplies, might have on life cycle equipment costs. The LMI final reports, "Life Cycle Costing in Equipment

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[10]U.S. Department of Defense, DoDI 5000.2, Defense Acquisition Program Procedures, 23 Feb 91. Part 6, Section K.

[11]Ibid., Part 4, Section E, Paragraph 3a(6).

Procurement" was issued in April 1965. (Ref. 3)

It concluded that logistics costs as well as purchase price could vary significantly among bidders' products and that the "use of the predicted logistics costs, despite their uncertainty, is preferable to the traditional practice of ignoring logistics costs because the absolute accuracy of their quantitative values can not be assured in advance". (Ref. 4)

Based on this consideration, the Assistant Secretary of Defense for Installations and Logistics (I&L) initiated trail "Life Cycle Cost" procurements of the following types of equipments (Ref. 5):

* Non-Magnetic Diesel Engines for Shipboard Use
* Replacement of Siding on Family Housing
* Solid State 15 Megahertz Oscilloscopes
* Tachometers and Generators
* Aircraft Tires
* Traveling Wave Tubes
* Computer Replacement

Probably the best known case was that of the acquisition of aircraft tires. The Government bought tires from each perspective seller. mounted them on aircraft, and measured the average cost per landing. The tire demonstrating the lowest total cost per landing was then purchased in mass.

At the same time of the trial LCC procurements at the equipment level, major new emphasis was placed on logistics support and the reduction of support costs at the system level. DoD Directives 4100.35, issued in 1964, called for the design of Integrated Logistic Support such that it would minimize the total life cycle cost of a system (Ref. 6). Several new major system developments, SAM-D, FDL, LHA, etc., called for consideration of life cycle costs during an Advance Development and Contract Definition Phase of competition. These competitions served as trail cases for system level life cycle costing.

In 1969, LCC estimates were included in the requirements for economic analysis of proposed DoD investments in accordance with DoD Instruction 7041.3 (Reference 7).

Coupled with the emergence of LCC was a major concern for the projected cost growth of replacement weapons and systems. This cost growth, made more untenable by public unwillingness to support growth in the defense budget, culminated into several special studies seeking alternative solutions. Some of the better known of these were the Defense Science Board studies, the Blue Ribbons

Committee study, the "Little Four" study, the Electronics "X" study , and the Congressional Commission on Government Procurement study. Key among the recommendations from those studies was the application of life cycle costing to system and equipment acquisitions.

In 1970, the DoD issues the first guides for the application of life cycle costing. DoD Guide LCC-1 gave acquisition guidelines for equipment level acquisitions and DoD Casebook LCC-2 gave case studies in equipment level life cycle costing (Ref. 8 and 5).

In 1971, the DoD issued its key acquisition policy directive, Directive 5000.1. This directive firmly established the requirement for not only life cycle costing, but also, Design to Cost (DTC). Directive 5000.1 required that acquisition cost parameters be established which consider the cost of acquisition and ownership, and that discrete cost elements be translated into "design to" requirements (Ref. 9). Also in 1971, the Air Force issued its manual, "Optimum Repair Level Analysis (ORLA)", AFLCM/AFSCM 800-4 (Ref. 10). Repair level analysis as it pertains to life cycle cost analysis defines the equipment level and repair location projected to result in the lowest level of life cycle cost.

In 1973, the Secretary of Defense implemented the Blue Ribbon committee's recommendation to improve cost estimating with the establishment of the CAIG, the Cost Analysis Improvement Group, and culminating with the DoD Directive 5000.4 (Ref. 15). Also in 1973, the Joint Logistic Commanders, consisting of the commanders of the Army Development and Readiness Command (DARCOM), the Naval Material Command (NAVMAT), the Air Force System Command (AFSC) , and the Air Force Logistics Command (AFLC), issued its initial guide on design to cost. this guide, subtitle "Life Cycle Cost as a Design Parameter", gave guidance to military procurement agencies on the implementation and the integration of design to cost and life cycle costing (Ref. 16). Also in 1973, the level of repair analysis become a military standard, MIL-STD-1390 (Ref 17).

In 1975, DoD directive 5000.28 on design to cost was issued (Ref. 1). It called for design to life cycle cost, but, in recognizing the difficulty of making accurate long range estimates, advocated design to unit production cost and the addition of other "design-to" elements as the program progressed through the life cycle. Also, the OSD

> Visibility and Management of Support Cost study (VAMOSC) was implemented to develop peculiar weapon system operating and support cost (Ref. 19). ...
>
> In 1981, the Deputy Secretary of Defense directed an assessment of the Defense Acquisition system with the primary objectives of reducing cost, making the acquisition process more efficient, increasing the stability of programs, and decreasing the acquisition time of military hardware. That assessment, called the "Carlucci Initiatives", reaffirmed the need for life cycle costing. (Ref. 32).
>
> Today, life cycle costing is required for most major system and many equipment level DoD developments and acquisitions. ...[12]

Use of LCC Modeling in DoD

The LCC and DTC models are used to highlight cost drivers and to form a basis for performing cost benefit analysis of different approaches to design and/or the support structure of the proposed or existing design. The LCC/DTC programs are required to be established in the early phases of a program and are reviewed at each major milestone (see Figure 3). The models start out with generalities and expand as the design alternatives are narrowed and the weapon system takes shape. Cost goals for production of the item and total LCC are established early in the program. Allocations of cost goals are made to specific subparts of the system as well as to specific parts of the system's life. These then are tracked up to the production of the system as evidence of the program's progress.

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[12]Mary Eddins Earles, Factors, Formulas, and Structure for Life Cycle Costing, 2nd ed. (Concord, Mass.: By the Author, 89 Lee Drive., 1979), p. 1-2 thru 1-5.

LCC models are typically broken into four cost categories. These consist of Research and Development, Investment, Operating and Support, and Disposal costs. As previously illustrated (see Figure 1), the O&S costs are the largest contributors to the overall LCC. One of the most influential decisions a program can make in effecting the O&S cost is the maintenance concept for the system. The maintenance concept decision is one part of the LCC definitization processes. As the overall maintenance concept is selected and then further defined at the subsystem and component level, the LCC is updated to reflect the appropriate costs related to the decisions. The alternatives for the maintenance concept range from discarding an item and performing no repair, to performing repair functions at each level. The typical levels are organizational, intermediate, and depot. The different DoD services have developed a Level of Repair (LOR) Analysis (LORA) to help in determining the most economical maintenance concept to adopt. The analysis can be accomplished on the whole system, subsystem, box, card, or component indenture.[13] The number of separate analyses performed on one aircraft can potentially be in the hundreds

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[13]Note: The services use different terms for the different indentures of the system. For the purpose of this paper, the generic descriptive terms will be used. The Navy terminology would be system, subsystem, Weapons Replaceable Assembly (WRA), Shop Replaceable Assembly (SRA), and sub-SRA. The equivalent Air Force terms would be system, subsystem, Line Replaceable Unit (LRU), Shop Replaceable Unit (SRU), and component.

if the analysis is taken down to the component indenture. The LORA process is not usually accomplished for items that are already in the inventory and have an established maintenance concept, unless the additional use of the particular item is significant. If it is the concept may be changed. This is determined by the item manager, who is the government person assigned to manage a particular item in the military inventory.

Use of LORA Modeling in DoD

The DoD either repairs an item through an Operational to Depot (O-D or Two-Level) or Operational to Intermediate to Depot (O-I-D or Three-Level) process. In some cases the I-Level is divided into a direct and general support. The general support, referred to in the Navy as Primary Intermediate Maintenance Activity (PIMA) or in the Air Force as Regional Maintenance Center (RMC), is used when efforts can be consolidated. The system Program Office must decide what maintenance concept is going to be utilized. The LORA process is used to help make the decision. MIL-STD 1390, Level of Repair Analysis, has been written to provide direction on how to perform LORAs. It states,

> The basic objective of the LORA program shall be to analyze support and design alternatives; utilize the results to influence system design and maintenance planning; and, achieve a maintenance concept which is the most effective compromise between economic and non-economic factors or characteristics related to the system/equipment and

its support.[14]

> The LORA program shall be implemented through a process of systematic and comprehensive LORA evaluations conducted on an iterative basis throughout the life cycle to arrive at a maintenance concept that is effective, yet economical. The process shall integrate design, operation, performance, cost, and logistics support characteristics or constraints to identify and update the maintenance concept for the system/equipment. The level of detail of the evaluations and the timing of task performance shall be tailored to each system/equipment and shall be responsive to the acquisition program's schedules.[15]

The LORA evaluation and resulting recommendation on the maintenance level and the repair activities to be performed at each selected level are dependent on the input data utilized. As with any model, the analysis is only as good as the data loaded. Much of the data utilized is known and thus available and accurate, but much is predicted, mainly the Reliability and Maintainability (R&M) and various predicted cost information. These often can be 100 percent off or more and can change drastically with the number of weapon systems being produced and the annual rate of that production.

As the program progresses through the acquisition phases, the data becomes more accurate and, hopefully, the program information related to numbers produced and rate is stable. The decision of what level to repair an item must be made

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[14]U. S. Department of Defense, <u>MIL-STD-1390D, Level of Repair Analysis (LORA) (draft), 20 Mar 91</u>, by NADC Code 5312, Lakehurst, NJ 08733-5100. p. 3, paragraph 4.1.

[15]Ibid., p. 3, paragraph 4.3.

before actual cost and R&M figures can be obtained in the production phase of the program. A large financial commitment to the support structure is required in the latter part of the Engineering and Manufacturing Development (EMD) phase in the form of sinking nonrecurring costs of developing the depot and/or intermediate level of repair capability. Not until the system is in the inventory for several years will anybody really be able to assess, using mature empirical figures, whether the most cost-effective level of repair was selected.[16]

The two primary acquisition phases where the LORA process has the greatest impact is in Demonstration and Validation (DEVAL) and Full Scale Development (FSD), also referred to as EMD. MIL-STD-1390 states for DEVAL,

A LORA is generally applicable in this phase. In

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[16]Note: The V-22 program has developed a concept referred to as "Big O, Little I, and Big D" to limit the mistakes that may be made. The concept entails only deploying those I-Level assets that are absolutely operationally necessary or are insensitive to 100 percent changes in the data. As field data become available, which is scheduled to happen within the first four years of production, the assessment of moving I-Level capability out of the depot and into the field would be made. This eliminates the recurring cost of I-Level capability from being spent early in a program when it may not be necessary. The approach has several problems. For a replacement program, like the MV-22 is for the H-46, going back to get an I-Level established, when manpower and other resources are lost initially, is hard. Also, the loss of acquisition dollars as the program goes out of production and O&S cost concerns take over, to spend money to save money becomes increasingly harder as money is shorter and shorter and more of a direct impact on today's operations than tomorrow's projected operations. What ever the approach, it is very hard to recover from a bad decision when the DoD programming and budgeting process takes three to five years.

this phase performance characteristics of the system are more or less established. The actual design is still flexible. Support, design, and operation alternatives are being investigated through tradeoff analysis. In this phase, a LORA is an excellent method for performing these tradeoffs and influencing the design of the system. When effectively timed and tailored, LORA assists in establishing the maintenance concept; assists in establishing cost effective reliability requirements, and, allocating these system level requirements to lower indenture levels; and, assist in establishing cost effective testability requirements. A DEVAL phase LORA is also conducted to identify items which should clearly be designed for discard, instead of repaired.[17]

The standard goes on to say for FSD,

As in the DVAL phase, a LORA is also generally applicable in the FSD phase. The FSD phase results in a prototype system for test and evaluation, including the associated support concept. Detailed design engineering, parts selection, and fine turning of performance are primary activities of this phase. Design influence is limited to items at the subsystem/item level, as well as to details such as, packaging, partitioning, testability, and accessibility. The support system is fairly well defined. The LORA is used to optimize the support system and determine an optimal maintenance concept for the system. LORA, in conjunction with detailed engineering design analyses, can verify the economics and engineering viability of repair level or discard alternatives at the module level; and, built-in-test (BIT) versus automated test equipment (ATE) tradeoffs can result in design optimization. LORAs conducted in this phase are usually detailed and consider both the economic and non-economic factors of the repair level or discard alternatives.[18]

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[17]Ibid., p. 32-34, paragraph 40.3.2 f.(2).

[18]Ibid., p. 32-34 paragraph 40.3.2 f.(3).

III. PURPOSE

Historically, most weapon system programs are single service programs. A joint program is created when the needs of several DoD services (Navy, Army, Air Force, Marines, and Coast Guard) are combined. In the joint program, one of the services is considered the lead service and the others secondary. To manage these programs, a Joint Program Office is created within the lead service's acquisition command. This is the case for the V-22 program. The Marine Corps has the requirements for the most V-22s (designated MV-22). The Navy and the Air Force have particular designs of the V-22 designated as HV-22 and CV-22 and referred to as variants of the MV-22 baseline aircraft. The Marines acquire their "air" vehicles through the Navy air acquisition command known as NAVY AIR SYSTEMS COMMAND (NAVAIRSYSCOM). Thus, the Navy is the lead service for the V-22 because the Marines do not have an "air" acquisition command.

Many of the same tasks in the acquisition process are performed differently by the services. In general, the following services' own regulations are waived and the lead service's regulations and standards take precedence for all services participating in a Joint Program. But, in many cases, the lead service's regulations and standards do not perform the specific analysis required by a particular participating service. This presents a unique problem within a Joint Program like the V-22. This situation is true for the LORA process.

The current documents governing this process are Military Standard (MIL-STD) 1390C, LORA, issued by the Navy, and AFLCP/AFSCP 800-4 pamphlet, RLA Procedures, issued by the Air Force. The Navy is currently preparing a MIL-STD 1390D that will have all DoD related LORA type models. A common approach to the LORA modeling is described in the beginning of the new MIL-STD, but it does not seem to change any of the models themselves, but simply combines the different services' models into a common standard that applies a common approach. The differences in the services' models, a total of 13, are maintained in the proposed new standard.

V-22 LORA Problem

The Deputy Program Manager for Logistics (DPML), the lead logistician for the Air Force on the V-22 program, must determine what level of repair he plans for the support of the CV-22, the Air Force particular variant of the V-22. To do this he can utilize the Air Force RLA method or use the Navy LORA method referred to as Method III. He has available to him the data from the Method III that have been run by the V-22 development contractors for the MV-22 fleet. This data is available on disk and potentially with minor changes could be used for the CV-22 (or HV-22) level or repair determination. The question is whether or not the Method III is appropriate to use for the Air Force. Off hand, one should assume that the models are different or the services would not have different models.

The initial hypothesis is that the Model III program can be used for the Air Force needs with only minor modification in the use of the model and the data utilized.[19] This should be true since the Air Force operates in a straight three- or two-level of maintenance concept. The Navy follows the same concept, but must also consider its shipboard operations for part of its fleet. In general, the shipboard operations part of the Method III could be bypassed and the resulting model reflect Air Force operations.

This approach is further enhanced by the common design

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[19]So far (as of May 1992), the V-22 developing contractors, a joint venture between Bell and Boeing, has produced some 400 LORAs for the MV-22. There are over 100 more scheduled to be run in the coming months. Unfortunately, it appears the LORAs are not being run correctly. There are several concerns. The way the contractor has broken down the V-22 system and is running individual or group component LORAs doesn't seem logical. The LORAs should be run on each item considering the complete fleet of aircraft in the Navy, including the HV-22s. The CV-22 population should also be considered. The difference between I-Level and D-Level may be determined by the number of items in the inventory and, by the number of I-Levels needed to provide support. Without considering the other variant aircraft, the total picture is not being modeled. Additionally, it appears the model is being used on parts that share repair equipment with other components. The model applications do not seem to be handling this situation in a realistic manner.

philosophy. Within the V-22 program, there is a basic design, known as the MV-22, and currently two variant designs that are based on the basic design. The Full Scale Development (FSD) contract, which was let in 1985, bought six development V-22s. These aircraft are being used to establish the design of the MV-22 and the additional equipment to be added that makes up the HV-22. More equipment is added and little is removed to form the configuration of the CV-22.[20]

The issue of a common LORA approach and utilization of similar models appears for the common components. With the current design of the program, almost everything on the MV-22 is common to the HV-22 or CV-22. Almost everything on the HV-22 is common to the CV-22. The commonality approaches over 95 percent between the different versions of the aircraft. Additionally, the V-22 program is attempting to develop a common support structure that will be utilized by each service. The emphasis on a common design and support structure means most of the inputs to the LORA will be common, among the services using the V-22, for any particular common component.

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[20]Note: The full design of the HV-22 and CV-22 was not placed on contract. In some cases, only space, weight, and power provisions were made for the additional requirements. The additional equipment will be specified later, and the contractor paid to make the specific integration into the over design. In most cases, the reason for delay in buying the full design represented lack of funding by the services.

IV. COMPARATIVE ANALYSIS

The comparison of the Navy and Air Force models was accomplished using the March 20 1991, draft of MIL-STD-1390D, from now on referred to as "the STD," which will supersede MIL-STD-1390C (NAVY) and Air Force Logistics Command/Air Force Systems Command Pamphlet 800-4. The March 1991 draft version is the latest and, with minor changes, will be approved as the next version in mid-1992. Additionally, User's and Programmer's Guides as well as Student Lessons Guides among other documents are used as secondary references.

The STD contains 13 different models in its appendixes. The comparative analysis will be done between the Naval Air Systems Command Method 1, Avionics Model III, and the Air Force Method 2, Item Repair Level Analysis. They will be referred to as Model III and RLA respectively.

A general overview of the input data to the models is provided. Then a general overview is conducted of the two services' approaches and general differences are noted. From this review, the two models' formulas are matched and correlated with each other and placed into general cost categories. A basic overview of each cost category is then conducted. The Model III use of Discount Factors is discussed; then, finally, the two major cost categories, Support Equipment (SE) and Inventory, are compared in detail.

Overview of Input Data

The STD outlines in TASK 201, Input Data Compilation, the requirements for assembling the appropriate input data. The STD states, "The values for the data elements shall be established, to the maximum extent possible, from existing sources.[21]" This point is critical in any modeling program. The data sources should be consistent between the overall Life Cycle Cost (LCC) and Design to Cost (DTC) efforts in terms of the programmatics (projected flying hours, basing concepts, etc.) as well as the system engineering analysis (LSA program, reliability program, maintainability program, etc.) that is influencing the system design.

The STD outlines definitions in Appendix Q, Lora Input Data Element Definitions (DED). The appendix lists 148 different definitions of data used in the models. The STD states, "it will be necessary to convert certain data elements to different units of measure for input into a particular mathematical method,[22]" thus recognizing the differences in the various models listed in the STD. Each particular model

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[21]U. S. Department of Defense, MIL-STD-1390D, Level of Repair Analysis (LORA) (draft), 20 Mar 91, by NADC Code 5312, Lakehurst, NJ 08733-5100. p. 17, Section 201.2.1.

[22]Ibid., p. 364.

listed in the STD has a Data Element Table that converts information from the standard in appendix Q to the particular model definition. There is no comparison between the models' definitions

Through the comparison of the Model III and RLA input data it will be shown how the input data elements are not always consistent in units with the standard provided in appendix Q. Both models increase the possibilities for critical mistakes by not keeping consistent with the appendix Q definition whenever possible. The individual models themselves should manipulate any figures needed instead of relying on the individual users to make the appropriate unit changes.

The input data needed comes mainly from the LSA process or other sources from the developing contractor.[23] In reviewing the different input data requirements, it is apparent that many of the same data elements use different units. One example is the Appendix Q 30.3.81, Repair Cycle Time. The Model III uses days as prescribed by the STD, while the RLA uses months. Appendix Q provides for six different subfield definitions for the Repair Cycle Time. In both the Model III and RLA data element tables, it is not clear which subfield definition should be used. The RLA indicates a

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[23]Note: If you are not careful, the contractor can get the model to say whatever the contractor wants it to say. This is especially true when he provides the input data and controls the modeling process.

Continental United States (CONUS) and overseas depot repair cycle time that appears to break the STD's appendix Q 30.3.81 subfield (e), Repair Cycle Time at Depot/Shipyard, into two further subfields. The individual models should convert the standard input data as needed. The lack of standardization makes it very difficult to run the Model III data in the RLA to make a comparison. A conversion program would need to be developed to convert the Model III data to RLA-acceptable data.

Out of the scope of this effort, but a concern, is whether the overall LORA appendix Q definition are consistent with the other data sources, mainly the LSA Record (LSAR). A program needs to be developed that produces a standard LORA input file from the other standard DoD data sources, like the LSAR. The government provided data could be preloaded in the program with a service peculiar selection available. The program would provide a methodology for a particular program to input the weapon system program particular data that is standard among programs. Such a program would "ensure consistency and cohesiveness" of the data appropriately called for in the STD. Finally, using cost values that are expressed in a particular base year is critical. The whole purpose of the modeling effort is to compare costs. An effort that will be wasted if the costs being compared are not from the same base year.

The NAVAIRSYSCOM provides a default data guide for use with the LORA modeling effort. The latest copy is dated June 1990. The guide notes, "The parameters contained in this guide may be used for all NAVAIRSYSCOM LORA's, unless other more representative values are calculated." This allows each program that uses the model to either use the data or develop it's own. The Air Force RLA procedures outlined in AFLC/AFSC Pamphlet 800-4, 25 Nov 83 states, "Most of the standard cost factors are available in AFLCP 173-10. The AFLCP 173-10 factors should be used only if applicable. Table 2-1 lists both NRLA names and IRLA acronyms and relates then to AFLCP 173-10, table of contents.[24]" The Air Force provided standard cost guide is the same guide for LCC and other efforts. The Navy guide is specific to LORA, leaving it up to the individual program to address if their costing efforts are using the same assumptions when it relates to the cost data provided in the guides.

Most of the data in the guides are service particular and thus appropriate for each service to calculate its' own figures. The "personnel attrition rate" is one good example. The retention rate of personnel will differ between services and between type of personnel. The current "personnel attrition rate" in the default guide for the NAVY is 0.09 for civilian and 0.381 for Military. This is a significant difference, but representative of the stability in the

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[24]AFLC/AFSC Pamphlet 800-4, dtd 25 Nov 83 Acquisition Management Repair Level Analysis (RLA) procedures. p. 5, section 2-4, part (a).

civilian work force and the relative "up or out" environment in the military.

Overview of Models

The models have some general differences in approach. The Model III has three levels of indenture box, card, and component, where the RLA has only box and card. The RLA takes into account the actual failure rate of a specific failure at the box, but not at the card level. The Model III assumes failure of the item, which is caused by a lower indentured level part, does not affect the level of repair assignment. The RLA takes the more detailed approach so it can assign different types of SE to different types of failures, thus attempting to get a more accurate estimate of the amount of SE needed. It considers if the SE is occupied or not and if a second piece of SE needs to be bought if you add an additional item to the repair facility. This is not possible with the LORA without breaking an item into subcomponents and running multiple LORAs.

The RLA states that it is not a LCC model and does not include total cost of O&S. The example given is it does not consider "costs associated with repair-in-place maintenance and removal from the end item ... because they are incurred regardless of the off equipment repair level decision.[25]"

[25]Department of Defense, United States Air Force, Acquistion Logistics Devision, Network Repair Level Analysis Model User's Guide, January 1986. p. 2.

The Model III purpose statement says, "The model estimates the most economical level of repair by comparing the life cycle costs of several repair scenarios[26]" and thus implies that it is a LCC model. In fact, each is not a complete O&S model. The Model III doesn't include the O-Level repair costs, and neither does the RLA. It may be considered a LCC for I-Level and D-Level costs, but under those rules so would RLA. The models are basically the same in this area.

The RLA allows for one Central Test Intermediate Facility (CTIF) or Primary Intermediate Maintenance Area (PIMA). The Model III allows for several PIMAs along with I-Level sites, which may include shipboard (CV) and normal land base (LB) or Naval Air Station (NAS).

The Model III appears to use then-year dollars since it utilizes discount values. The RLA does everything in current-year dollars and thus needs no discounting methodology. The Model III use of the discount factors, discussed later in more detail, are inappropriately used since the Model III utilizes the same present-year input cost data as the RLA. The three different discount formulas used by Model III account for the situation when you count the first year or the last year differently than the other years' costs. RLA makes no distinction.

The costs of common support equipment (CSE) and peculiar

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[26]U. S. Department of Defense, MIL-STD-1390D, Level of Repair Analysis (LORA) (draft), 20 Mar 91, by NADC Code 5312, Lakehurst, NJ 08733-5100. P. 51, paragraph 10.1.

support equipment (PSE) and how they are allocated (or non-allocated) are very different. The RLA looks at groups of items and doesn't allocate costs of expensive SE across each component, but considers the cost when figuring out the level of repair of the group. Model III, on the other hand, considers only what is defined as PSE, and the costs are either allocated or non-allocated. The Model III guide states that you can consider PSE for groups and thus it is a non-allocated cost. The Model III doesn't consider the opportunity costs of the CSE, which in many cases can be a major cost. This also violates DoD 5000.4 rules relating to O&S costs. It states, "Use of existing assets or assets being procured for another purpose must not be treated as a free good. The opportunity cost of these assets should be estimated, where appropriate, and considered as part of the program cost.[27]"

The Air Force RLA can be run on individual items, called Item RLA (IRLA), or with several items, call Network RLA (NRLA), with a network theory using a max-flow min-cut algorithm. The use of the network theory allows the RLA to consider several items in a system at a single time. The theory utilization is discussed in detail in the January 1986 NRLA Model User's Guide.

In summary, the models are clearly different even before

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[27]U.S. Department of Defense, DoD Directive 5000.4, OSD Cost Analysis Improvement Group, 30 Oct 1980, enclosure 1, section B(3).

comparing the detailed formulas. In general, the RLA is going into detail on the item and its type of failures and SE required, while the Model III goes into more detail about the type of sites. It appears that the Model III could pick up some of the RLA detail with its use below the card level, but this would need to be done in separate Model III runs and not networked as in the RLA. The Model III and IRLA simply compile the costs in a variety of areas. The RLA use of networking represents a fundamental difference in how the final results are reached. The network approach allows the NRLA to handle multiple items at one time.

Review of Cost Categories

The Model III and RLA cost equations are grouped differently, but cover the same basic areas. The RLA uses 12 parameters while in the Model III 10 broken down into six major categories but are added together in 10 areas. A little confusing, but Table 1 correlates the formulas using appropriate model references.

Cat #	Model III	Ref. #	RLA	Ref. #
1	Support Equipment	2.6	Support Equipment Acquistion & Maint Support Equipment Software Acq/Maint	C10 C11
2a	Inventory Inventory Admin	2.2 2.1	Depot Spares Base Spares Supply Admin Item Entry	C4 C3 C7 C6
2b	Material Repair Scrap	2.4 2.3	Repair Material & Replacement Spares	C1
2c	Transportation	2.5	Pack and Ship	C2
3	Labor	2.8	Repair Labor	C5
4	Training	2.9	Maint Training	C9
5	Documentation	2.10	Technical Data Acq	C8
6	Space - Inventory Strg - Repair Space - SE Space	2.7	Facilities (SE space costs in C10)	C12

Table 1. LORA Cost Category Correlation Matrix.

The RLA calculates costs in each C category, except seven, for Depot (D), each C category, except four, for Intermediate(B), and only calculates costs for C1, C2 and C3 for Scrap (S). The same formulas are utilized, but the figures used to calculate the numbers change depending on box/card, for the Depot/Intermediate/Scrap alternatives.

The following will compare each of the Model III and RLA formulas as collated in the above chart. Seven different areas will be compared. The second cost category is broken into three parts (2a, 2b, and 2c), while the sixth category is not compared since there is not a complete equivalent in the

RLA model (SE space is in the RLA SE formulas).

CATEGORY 1 - SUPPORT EQUIPMENT

The Model III uses two types of formula. The first, 40.2.6.1, computes the cost of the SE and its support over the life of the program for each type of SE. The second, 40.2.6.2-5, computes the costs of SE for each type of support, Discard, Intermediate, PIMA or Depot. The cost of SE at each type of location is included in the formula; the locations are CV, NAS, PIMA, and Depot. The figures used in the model are inputs except for the input from the first formula, SE cost of a type of SE. The STD notes that several of the terms should be put to zero under certain cases. Also, non-allocated costs of SE that are shared are discussed but not explained.[28]

The RLA model uses three types of formulas to figure hardware SE, software SE, and SE facilities costs, once for Depot (card) and once for Intermediate (box). Several of the figures utilized are figured by other formulas (this is explained in the detailed section on SE). The "Discard" or "Scrap," as it is referred to in the RLA, is not mentioned. No calculations are made in this area, and thus the model must not consider the difference of SE for repair versus SE to verify failures. The assumption is for reliance on O-Level personnel to determine if an item is scrapped at I-Level and

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[28]Note: The V-22 LORA plan also notes this as an issue, but provides no direction on how to handle.

I-Level personnel to scrap an item before going to depot. This is generally true; if a card is discarded, then the Intermediate shop does it using the I-Level SE that tested and repaired the box.

There are considerable differences in the handling of SE. The Model III does not calculate hardware and software costs separately as the RLA does. Also, the Model III does not consider common SE (defined as items already at the base or in the inventory). This makes the Model III tend toward recommending I-Level, since a potential major cost, the opportunity cost of common SE, is not considered. The RLA considers CSE as a cost if the quantity of CSE has to be increased. The item causing the increase bears the appropriate costs. This can be a significant difference in the models.[29] Both consider SE facilities. The Model III formula is outlined with other space costs.

In general, as stated in the overall review, the Model III looks for a single SE cost per box or card where the RLA looks at SE costs per failure possibility and accounts for workload on SE used for several items.

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[29]Note: In the CV-22 versus MV-22 example, the situation could be completely different. The MV-22, being a replacement program for the H-46 aircraft, could already have a considerable amount of SE on base. The CV-22, considered a force-add program, will be an additional workload for the CSE already on base and could drive additional pieces of CSE.

CATEGORY 2A - INVENTORY COSTS

The models handle three types of inventory costs, item entry, item retention, and field/base level supply administration. The Model III has two formulas, one for discard items and one for repaired. The same formula is utilized; except in the repaired formula, an additional cost is added for "the parts which are used to repair the item and are not included in the analysis.[30]"

The RLA has two formulas, C6 and C7. C6 handles inventory entry costs and the life cycle costs of being in the system. Formula C7 handles the field costs that are mult' ¯'ed by the number of bases. All costs are assumed to be t ame for each base, which is also assumed by the Model III.

The Model III does not calculate the item retention cost, where the RLA does. Model III uses an annual item management cost and multiplies by number of years of life. The RLA does the calculations for I-Level and then D-Level, while making sure they do not recalculate the box costs at base level twice using formula C6B/D and C7B (no D or box O-D separate cost since box management at base level happens under O-D or O-I-D, also even under scrap the item must be managed at the base level).

Both models have a cost for the Scrap or Discard options,

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[30]Note: Formula 40.2.1.1.2 uses "# of sites <u>Discarding</u> the item" when it should use <u>repairing</u>. This is probably a misprint in the formula.

RLA in C3 and Model III in 40.2.1.1.1.

CATEGORY 2B - REPAIR MATERIAL

The Repair Material category is straight forward in each model. The Model III uses two types of formulas, 40.2.4.1-3 and 40.2.4.4. The first type calculates costs for the three types of locations, LB IMA, and CV IMA, and Depot. The second adds the figures from the three site calculations. The two types of calculated figures used in the category are the Present Discount Factor (40.1.2) and the Annual # of Repair of an items of a site. The RLA uses a single type of formula, C1 (S or D, the B figures is the same as the D calculation). As in other areas, the RLA uses the calculated TLCD, Total Life Cycle Demands, figure for an item at an intermediate location that is calculated using the MTBF, Mean Time Between Failure, of the item.

The Model III uses the unit cost multiplied by a repair material rate, defined in appendix Q 30.3.89, Repair Material Rate. The RLA uses the UCPP(S) or (FM), defined in appendix Q 30.3.88, Repair Material Cost. The S is for the SRU costs versus the FM for failure mode at LRU costs (this distinction is not noted in appendix Q). The calculations here could be standardized between the models. The RLA calculates the cost external to the model, while the Model III calculates the cost within the model.

The calculations within the models allow more flexibility and are preferred. In this case, if the unit cost would change the RLA would need to make an adjustment to the repair material cost external to the model. The Model III would automatically adjust the repair material cost when the unit cost input was changed. The repair material rate for each service should be the same for the same item. The costs should be the same for each service given the same item and level of repair.

The discard option calculations for replenishment spares are handled the same within each model. RLA handles scrap material by just buying more spares in C1S. Model III does the same in 40.2.3.4 and buys more spares for scrap. This is why it is also known as replenishment spares. The Model III goes into detail on each site and also provides for the possibility that not all items will be repaired. It uses the BCM, Beyond Capable Maintenance, rate that is the percentage of parts not repairable. The other often used term is NRTS, Not Repairable This Station. Neither of these definitions are in appendix Q. The BCM implies that some parts are not repairable and are not sent to the next repair level. This represents items that are run over by a truck, burned in fire, etc. RLA does not consider BCM, but does NRTS at I-Level. All items are repairable or NRTS at I-Level.

CATEGORY 2C - PACKAGING, HANDLING, SHIP, and TRANSPORTATION (PHS&T)

The Model III uses a single type of formula, 40.2.5, that figures the cost of PHS&T over the life of the program for either discard or repair. The cost of PHS&T at each type of location, CV, NAS, PIMA, and Depot, are included in the formula. The figures used in the model are inputs except for the 40.1.1, Normal Discount Factor, and those from 40.1.5, Annual Number of Real Failures Removed at a Site, which is used in 40.1.6, Annual Number of Real Failures Sent From a Site.

The RLA model uses a single type of formula (C2); again, once for Depot (or card) and once for Intermediate (box). The same type of annual number figure in the Model III is also figured by other formulas.

For transportation, there are two calculated figures in both models. The first is for the number of items to be shipped. The RLA uses the same calculated figure, TLCD, Total Life Cycle Repair Demands, figure for a item utilized in other categories. The Model III uses a separate calculation then the one used in Labor cost category. The differences in 40.1.5, Annual Number of Real Failures Removed at a Site, and 40.1.6, Annual Number of Real Failures Sent from a Site, is in the BCM rate. The 40.1.5 calculated figure is multiplied by the BCM rate in 40.1.6.

The second calculated figure is the cost of transportation. The Model III varies the transportation rate between different sites while holding the pack and handling cost constant for any shipping action. The RLA allows for not only a different shipping rate for overseas versus conus, but also a different pack/handling rate. The Model III uses the Inventory Storage Space to figure the pack and handling by size while using Weight of the Item for shipping. The RLA considers the costs all by weight. The Model III use of the size of a package for the cost of packaging is more realistic, since size probably effects cost more then weight. The bulkier the item the more it should cost to pack. This differences in the models is minor and should not make any difference in the outcome. This is true when the model is considering the cost for each of the different options and the cost calculation doesn't weight the model toward one option or the other. Both, appropriately, use weight for transportation costs.

The origin of the factors could be important. The RLA has a packed to unpacked weight ratio to factor in the weight of the packaging in the shipping costs. This is not done in the Model III. The definition of weight in the Model III is correlated with the appendix Q, Unit Pack Weight, that already includes the weight of packing with the weight of the item. The RLA uses the appendix Q, Unit Weight, that doesn't include the weight of the packing. Both of the Data Element Definitions (DEDs) are found in the LSA Record. In this area, the models could be changed to use one DED or the other and calculate the same costs.

Overall, if the annual number calculation were made the same between the models the cost calculation in this area could be made the same. Tailoring options for the different services basing would need to be available.

CATEGORY 3 - LABOR

The models are set up the same way. The Model III uses a single type of formula, 40.2.8, that figures the cost of labor over the life of the program for each type support possibility, Discard, Intermediate, PIMA, and Depot. The cost of labor at each type of site is included in the formula. The figures used in the model are inputs except 40.1.1, Normal Discount Factor, and 40.1.5-6, Annual number ..., figure. The RLA model uses a single formula, C5, once for Depot and once for Intermediate. The RLA counter to the Model III 40.1.5-6 series annual number figure, TLCD, Total Life Cycle Demand, for ... is utilized.

Both models use the appendix Q, 30.3.47, Mean Time to Repair, figure in similar formulas for each option except scrap or discard. The RLA has no calculation for the scrap option, thus assumes no labor costs involved. The Model III uses formula 40.2.8.1, Direct Labor Hours per Discard Action. The Model III uses a "Direct Maintenance Man Hours at a Site for a Action" figure correlated to the appendix Q, 30.3.47., Mean Time to Repair, definition. The Model III calls for a different figure for "Discard Action" versus "Repair Action" utilized at I-Level and D-Level that is not specified in appendix Q. The data field is not mentioned in the current Default Data Guide published by NAVAIRSYSCOM.

Should the cost of labor for repair versus labor to discard or scrap be calculated? The RLA assumes the O-Level personnel determined if an item is scrapped at I-Level and I-Level personnel to scrap item before going to D-Level. This is generally true if a card is discard, then the Intermediate shop does it using the I-Level SE that tested and repaired the box (next higher assembly). It would generally not be true for the O-Level to scrap a box before it was checked at I-Level. The assumptions each model takes could be correct depending on the item being modeled. A options should be allowed for the labor costs to be considered or not for discard depending on the item being modeled.

Overall, if the annual number calculation were made the same between the models the cost calculation in this area could be made the same. Tailoring options for the discard case would need to be available.

CATEGORY 4 - TRAINING

This category is straight forward in each model. The Model III uses a single formula, 40.2.9, that includes costs for two separate types of training, Depot personnel and Navy personnel. The Navy personnel is further broken down between the three type of locations, PIMA, NAS and CV. All the figures used in the model are inputs except 40.1.2, Present Discount Factor. For the Discard cases section 40.2.9.4 states "training costs are incurred for the sites which repair the higher assembly.[31]" This assumption doesn't seem to correlate with the labor calculations done in the labor cost category. For the discard case, the item is discarded and not repaired at either I-Level or D-Level. The "sites which repair the higher assembly" could be the O-Level which costs are not considered in the model. Under Labor, the Model III has costs for each type of site under the discard option.

The RLA uses a single type of formula, C9, once for Depot (or card) and once for Intermediate (box). This is the same as the Model III Depot and Navy personnel. The RLA doesn't break down the service members training between different types of locations as in the Model III. Several of the figures utilized are figured by other formulas. The scrap option is not considered an area having training costs. No calculations are made in this area, thus if you scrap an item before it gets to depot, then you have no depot training costs. If both box and card are scrapped at O-Level then you have no training costs. This is consistent with the RLA assumption that O-Level personnel determined if an item is

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[31]U. S. Department of Defense, MIL-STD-1390D, Level of Repair Analysis (LORA) (draft), 20 Mar 91, by NADC Code 5312, Lakehurst, NJ 08733-5100. p. 99, Section 40.2.9.4.

scrapped.

The cost element can be broken into two basic areas, number of people to train over the life cycle and the cost to train. First, the number of men to train is reviewed. The Model III obtains this figure from the input data. The table in appendix D indicates the "Manpower Total Authorized Quantity" is equal to the appendix Q, 30.3.59, Number of Repairmen, definition. The RLA can use either a input figure or calculate one. The results of PGMB, Monthly End-Item Utilization at a Base, and MTBCT, Mean Time Between Corrective Tasks, are used in calculating TQCTGM, Total Questionable Corrective Tasks Generated Monthly at each Base. TQCTGM is used in calculating NUMT(B/D)[32], I-Level (B) and D-Level (D) repair manhours required per month. First the calculation for "hours", Number of Repair Man-Hours Required per Month, is computed. The "hours" figure is divided by DAA, Monthly Available Hours per Man at the Facility, resulting in NUMT(B/D), Maintenance Men Required. The NUMT(B/D) figure is used or the "Number Repairmen" equivalent is utilized. It is unclear how the single "Number of Repairmen" figure is broken into D-Level and I-Level. The Navy uses this figure broken differently between depot and Navy with Navy personnel broken

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[32]Note: The NUMTD is referred to as MANREQ in the Jan 1986 RLA Users Guide. The calculation for NUMTD are not included in the new STD. The NUMTD figure is not in the Data Element table either, thus is not an input figure. The calculation for NUMTD was probably accidentally left out of the new STD. This section of the thesis uses the 1986 guides calculations.

into three types of sites. For a direct correlation the "Number of Repairmen" would need to be broken between at least Depot and I-Level and the I-Level broken down by type of site.

The second area is cost of training. The Model III obtains this figure from the input data. The model uses an input figure Manpower Training Costs equivalent to the appendix Q, 30.3.133, Training Costs. The RLA calculates this figure by taking the training costs as an input and converting it to costs per week. The cost of the personnel salary per week is then added to this cost. The number of hours required to train are then multiplied by the weekly costs for a total training cost. The training time is an input equal to appendix Q, Training Time, converted to weeks.

The RLA accounts for the salary separately in the cost of training, assuming it is not in the input figure, where the Navy model must assume it is already in the cost of training figure. Thus, if the same figure is used as a basis for input to either model, one model is either under or over emphasizing training costs. The appendix Q, 30.3.133, definition doesn't indicate whether the wage of the person being trained is included in the training cost figure or not.

The Model III assumes the training cost figure is the total cost per person. The RLA takes the training cost by item, that is a different definition. The Model III figure is indicated to be a MIL-STD-1388 LSA figure which the RLA is an input from the contract. This category can be clarified and made to model the same.

The Model III, having some of the costs calculated external to the model, should add the calculations from the RLA. The RLA use of MTBCT, which is based on MTBF, allows for easier sensitivity analysis. Standardization the remaining input figures and the models could be made the same.

CATEGORY 5 - DOCUMENTATION

The Model III adds documentation costs for the three type of sites, IMA, PIMA and Depot. It does not consider the different locations of the IMA sites as causing a difference.

The RLA calculates the cost by using a single formula, C8, once for I-Level and once for D-Level. This is realistic since the level and type of documentation is different for the two activities. The RLA uses number of papers of technical data multiplied by a cost per page.

Unlike in other areas, like SE, the recurring costs of supporting the documentation is not considered in either model. Maintaining a page of documentation in the military costs. The users continually find mistakes in documentation that require correction over the life of the item, thus people are maintained to implement corrections that are found. When so many changes are made, a specified percentage of the book has been updated by change pages, the complete manual is republished. These costs are not in the RLA. They could be in the Model III if they are considered when the calculations for documentation costs are made external to the model.

The RLA uses an input figure, TD, the cost per page of tech data, that is not referenced in the appendix M data table. In appendix Q their are inputs definitions for 30.2.120, Technical Documentation Cost, that is the cost of one page of technical data along with 30.3.122, Technical Documentation Update Factor, that is the fraction of pages that are changed each year (as discussed before neither model considers). Other models in the STD must use this data.

The Model III, having the costs calculated external to the model, should add the calculation from the RLA. The support costs of the documentation should be added to both models.

Other Model Differences

The Model III use a figure False Removals that seems not to be accounted for in the RLA. False removals can be a significant amount of work load on electronic components, ranging from five percent to over 20 percent. These actions are often referred to as RTOK, ReTest OK, or CND, Can Not Duplicate, or A-799s (a code within the Navy). Both models calculate the number of tasks/actions. In Model III uses formula, 40.1.5-6, Annual Number of Real Failures Removed at a Site, compared to the RLA formula TLCD, Total Life Cycle Repair Demands, of a box or card at each base. The Model III is more generic while the RLA goes into specific failure modes of the box. The Model III adds to its number of failures or actions required a figure for the false removals. This is calculated using a figure, Fraction of Items Falsely Removed, that is correlated to appendix Q 30.3.26, False Removal Rate. Appendix Q also defines a False Removal Detraction Fractions as

> The Fraction, expressed in decimal form, of false removals (removals that are really operational items) that are detected by screening the item. For example, if there is a total of 110 removals including 10 false removals, then a detection fraction of 0.80 would mean that 8 of the 10 false removals would be detected during screening. Therefore, these 8 items would be returned to stock, and the remaining 102 items would be sent on for repair.

The fact that the RLA is not considering the False Removal Rate may mean that it is significantly underestimating the workload (10% extra at I-Level and 2% extra sent on to D-Level in the example). Considering the false removal rate without also considering the faction of those false removal that will be detection mean the model is estimating a workload that may be significantly higher than what will actually be experienced. It is not clear whether the failure rate used in the Model III would consider those detected as false removal.

Both models should have the option to consider these figures. Part of the modeling effort is to influence design and reduce false removals and increase the false removal detection rates. Without considering the figures the modeling effort can not influence the design process in this area.

Model III Use of Discount Factors

The Model III uses three types of discount factors, formula 40.1.1, the Normal Discount Factor, formula 40.1.2 , Present Discount Factor, and formula 40.1.3, the Reduced Discount Factor. The Normal Discount Factor is a uniform series present worth formula that takes an annual given amount, say (A), over a series of years, (n), and calculates a single present worth, say (P) (see appendix A, graph 1). The Present Discount Factor is the same uniform series, except the payments, A, start to occur not at the end of the year after the present year but occurs at the beginning of the year (see appendix A, graph 2). This is done by taking the normal discount and multiplying the result by a single sum present worth formula that moves the payment from the end of the year to the beginning (see appendix A, calculations 1). The reduced discount factor does the opposite of the present and moves the normal discount profile out one year. This moves the nth year payment into the n+1 year, so the last year is removed; thus, in a 20 year case, only 19 payments are in the series (see appendix A, graph 3). This is done by taking the normal discount and using "n-1" instead of "n", then dividing the result by the single sum present worth so the payment A is moved are moved out one year instead of moved in as in the previous calculation for "P_p (see appendix A, calculation 2). Once the factor is calculated it is multiplied by the annual uniform payment to obtain the present-value of the annual payments.

For the Model III discount factors and the RLA multiplication of annual cost figures, the formulas used assume a discrete expenditure of funds versus a continuous expenditure. This is not true in all cases. The spending on manpower, fuels, etc. would be better represented by a more continuous compounding, say monthly or weekly, and not by a discrete annual expenditures. The funds may be budgeted on an annual bases, but contractors submit for progress payments monthly or even weekly while payments for manpower is made biweekly. On the other hand, the discount factor or interest rate utilized may represent inflation and is really an effective interest rate and not a discrete compounding rate. Inflation figures are inherently the effective rate and not the discrete. It would be appropriate to use the discrete formulas while using the inflation rate as the discount figure. The guide provides no insight into how the discount factor, currently 10% in the 1990 guide, was developed. The difference between using the discrete or compounded methods is typically small, less than .25%. It is unclear what the Discount Factor of 10 percent is supposed to represent.

The following example of the calculation for each of the discount factors for the 10% inflation/discount rate for a $1M uniform series illustrates the impact of the discount rate (see appendix A, calculation 3). In the example the highest cost is associated with the Present Discount Factor. The increase of $851,000 in costs over the Normal Discount factor comes from starting incurring costs at the start of the year instead of the end of the year. Spending a dollar at the start of the year deprives you of the "opportunity" of using the dollar through the year. The Reduced Discount Factor follows its name and reduced costs by $910,000 from the Normal Discount Factor. It eliminates the first end of year payment.

The Model III uses these three discount factors throughout the model implying that some type of then-year costs are utilized. The RLA model doesn't use any discount factors, mainly relying on a calculated annual cost figures multiplied by the number representing the life cycle. The STD states in Task 201, Input Data Compilation, Section 201.2.1, "All values related to cost shall be expressed in terms of a particular base year to ensure consistency and cohesiveness". Further discussion of cost data is not provided in the STD appendix for either model relating to what type of dollars to use, then-year or present-year. In the STD in appendix Q 30.3.4, Base Year, is defined as, "The fiscal year in which all quantitative data elements related to costs are to be adjusted against and expressed." This DED is not utilized in either model. All other definitions dealing with cost have no reference to present-year or then-year.

The use of a discount factors, using the Model III default data guide discount rate of 10 percent, versus the number of years reduces the costs calculated by over 50 percent (see appendix A, calculation 4). Within the RLA, using the one million dollar annual cost example again, the cost over a 20 year life would be $20 Million. The Model III, using any of the discount factors, the cost would be under $10 million. How this impacts the results of the model would take extensive analysis. Since the discount factors are used in many of the formula the overall effect on the Model III recommendation may not be significant. In general, the inappropriate use would tend to reduce the costs of yearly expenditures more versus single up-front investment costs. This would have the tendency for the Model III to recommend discard or only D-Level repair since I-Level repair usually requires the largest initial investment.[33]

The Model III use of discount factors is not understandable. Each formula that uses a discount factor is using a present-value cost figure. The use of the discount factors is only appropriate when then-year costs are utilized in the formula and thus a need to bring those costs back to a base year is required. Even if then-year costs where being utilized they would not be spent over the life of the program in a "uniform series". Costs over a period of time, due to inflation, should grow in some "geometric series".

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[33]Note: When this problem was discovered a letter was sent to the NAVAIRSYSCOM cognizant office describing the problem in the Model III. No formal response has been receive, though I have had several conversation with representatives from the office. An assessment is in progress.

The discount factor in most cases should be replaced with a number representing the appropriate number of years predicted for the life of the system. The Model III use of reduced factors would be appropriately replaced with this number minus one, thus maintaining the elimination of the first year costs. This approach would align the Model III with the RLA approach.

V. DETAILED REVIEW OF SE COST CATEGORY

The Model III starts with formula 40.2.6.1, Unit and Support Cost of a Peculiar Support Equipment (PSE). The cost is derived from three input figures: A. the "Unit Cost of the PSE", B. the "Support of the SE Rate for the First Year", and C. the "Support of the SE Rate for the Succeeding Years." Figures B and C are discounted to bring there values to the present. The B figure is divided by one plus the discount rate, effectively bringing the B costs from the end of the first year to the present. The C figure is multiplied by the Reduced Discount Factor that effectively brings the support costs in years 2 through 20 to the present. The A figure is assumed to be in the present and is not discounted.

The input figures with the STD Input Data Element Definitions (DEDs) outlined in appendix Q with the appendix D description for Model III and Appendix N for the IRLA. Figure A equivalent is defined in appendix Q section 30.3.144, Unit Price listed in dollar units. The RLA equivalent is UCSE, Unit Cost of SE, that is also listed in dollar units. Both tables in appendixes D and N indicate that the value is obtained from the contractor and is not available in the LSAR. In fact, as noted in the V-22 LORA plan, the value is obtainable from the LSAR in E07, Block 5.

Figure B equivalent is defined in section 30.3.114, SE Installation Cost Factor, listed in decimal units. The RLA doesn't use this factor, but utilizes the 30.3.113, SE Installation Cost, listed in dollar units. Both tables in appendixes D and N indicate that the values are obtained from the contractor and/or government. A conflict exists with the definitions and how the Model III uses the figure. Figure B is to represent not just the installation cost factor but also the cost factor for the initial year of operation and support. The 30.3.114 definition states, "A factor which is used to account for the one time cost associated with setup or installation of a piece of support equipment at a particular maintenance level." Appendix Q has a definition, 30.3.118, Support of SE Cost Factor, that is defined as,

> A decimal value which expresses the cost factor for supporting support equipment. This factor is derived from the ration of the yearly support equipment costs to the support equipment unit costs. There are two subfields defined as follows:
>
> a. First subfield. This value includes the installation cost and the first year's maintenance cost
>
> b. Second subfield. The yearly maintenance cost factor.

The 30.3.118 subfield (a) would be more appropriately match the use of figure B in the Model III.

Figure C equivalent, according to the table in appendix D, is 30.3.118, Support of SE Cost Factor. The RLA doesn't use this factor, but utilizes the 30.3.67, Operating and Support Costs, listed in dollar/year units. Both tables in appendixes D and N indicate that the values are obtained from the LSAR. Unlike for figure B, the Model III here is using the correct appendix Q reference, but doesn't indicate which subfield. The appropriate subfield here would be (b).

Next the Model III calculates with formula 40.2.6.2 through 5, the Item PSE cost for <u>Site</u>, with Discard, Intermediate, Primary Intermediate (PIMA), and Depot as the four possibilities. The formula is a simple addition of four similar calculation done for CVs, non-PIMA NAS, PIMAs, and Depots. The formula 40.2.6.2 through 5 thus consists of three elements. The first, figure A, Unit and Support Cost of PSE, is the value calculated from the previous formula. This must be calculated twice for the two types, discard and repair, of PSE possible. These will be referred to as A1, Discard PSE, and A2, Repair SE. The second, figure B, Number of PSE Required, is an input value, SE Authorized Quantity, and is equivalent to appendix Q 30.3.64, Number of SE. Eight values are needed. Four for each of the two types of SE, Discard and Repair. The four represent the possible locations CV, NAS IMA, Primary IMA, and Depot. These will be referred to as B1 and B2 for Discard and Repair and then add "a" for CV, "b" for NAS, "c" for PIMA, and "d" for Depot. Thus the number of Discard PSE needed for the Carrier is represented by "B1a". The third, figure C, Number of Locations, is an input value, Number of Locations and is equivalent to appendix Q 30.3.55, Number of Locations. Appendix Q has several definitions that also may better describe this figure. These would include 30.3.56, Number of Operating Locations, 30.3.63, Number of Shops, and 30.3.53, Number of Facilities. The definitions for each could, depending on the interpretation, better fit the figures used in the Model III. Figure C requires four values. One for each type of location. We will refer to these as Ca, Cb, Cc, and Cd, using the established nomenclature above. Thus the number of location for PIMA PSE is represented by "Cc".

The Model III produces four SE cost figures relating to the four different options available. It does not appear that the acquisition costs, or non-reoccurring costs, of the PSE is used in the model even though the table in appendix D lists SE Development as a dollar unit.

The wording in section 40.2.6 does discuss the allocation of the PSE costs across several items when PSE is designed for a group of items. No details are given on doing the allocation then running the Model III for the group of items. The Model III also doesn't separately calculate the cost for software to run the PSE hardware. This software is commonly referred to as Test Program Sets (TPS). Often several items can be tested using the same TPS and numerous TPSs run on the same PSE hardware. The Model III, as previously stated, does not consider the common SE costs that may be incurred by addition of new items into the workload. Each of these areas could have major effects on the outcome of the economic analysis and thus represent major flaws in the Model III.

RLA

The RLA ends with the same basic calculation as the Model III, the addition of the SE cost (figure A) with the SE maintenance cost (figures B and C),[34] but takes a completely different and more detailed approach to calculating those costs. The RLA calculates a hardware cost with formula C-10 and a software cost with C-11 for both Depot and Intermediate. Appendix N notes, "These computations must be accomplished for each applicable type of SE" or "... each applicable type of Test Program Set TPS." Additionally, for common SE, the number of units per location and the current usage and potential total usage is noted. The RLA calculates a SE acquisition cost and the life cycle SE operations and maintenance costs by going through a series of calculations. This is unlike the Model III which combines input data that is calculated external to the model. The approach in RLA prorates the SE and the SE maintenance costs across items by using the network RLA case.

The input values used in the RLA are outlined in Table 2.

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[34]Note: That the RLA adds the installation cost, which is the difference between the figures B and C in Model III to the SE cost, figure A

Ref Term	RLA Term	Ref. #	Appendix Q Term
SSECF	Support of SE Cost Factor	*30.3.118	Support of SE Factor
PIUP	Years of System Life	*30.3.69	Operation Life
UCSE	Unit Cost of SE	*30.3.144	Unit Price
SEAVAIL	Available Time for SE	30.3.109	SE Available Hours
SEINST	SE Installation Cost	*30.3.113	SE Installation Cost
HDEVP	Hardware Development Price	30.3.110	SE Development Price
UEBASE	Equil Weapon Sys per Base	30.3.52	# of End Items
UR	Utilization Rate	30.3.2	Annual Operating Requirement
QTY	LRUs per End Item	30.3.76	Quantity per Item
UF	Utilization Factor for LRU	30.3.9	Conversion Factor
RIP	Repair in Place Fraction	30.3.43	Maint Task Distribution
FAILP(i)	Failure Mode Ratio	30.3.24	Failure Mode Ratio
SEHR(i)	Se Hrs per Rapair for Item	30.3.116	SE Time Used
MTBF	Mean Time Between Failures	30.3.44	Mean Time Between Failures
M	# Bases or Oper Locations	*30.3.56	Number of Oper Locations
* indicate the figures used for Model III also.			

Table 2. RLA SE Input Values versus Appendix Q

Table 2 shows the considerable difference in the RLA and Model III by showing the increase in input values utilized in the calculations. The RLA calculates the figure for number of SE required, while they are input values for the Model III. The RLA make a calculation for Load Factor on the SE which allows it to account for already available capital assets, referred to as common SE, that maybe are not utilized to the fullest, addressing "opportunity costs" for common SE. It also allows for the calculation of the number of SE required. The RLA also considers the SE development costs that is not used in any Model III formula. Similar to the Model III, the RLA would have the calculation completed for each type of SE required, discard or repair.

The RLA has a simply formula, C11, to calculate the costs related to software. It add TPSDEV, TPS Development Cost, and (I/D)SW1, Software Maint Cost for either Depot or Intermediate. The (I/D)SW1 is calculated by taking the TPSMAINT, TPS Maint Factor, of the TPSDEV cost times the number of years needed to maintain the TPS. The number of maintenance years is calculated to be one less then the operating years. The assumption being the TPS doesn't need to maintain the first year of operation.

In the Model III the software costs could be considered in the total cost of the SE. The problem would be in using a single figure for common or peculiar hardware SE with numerus TPSs for particular or groupings of items. This is very common among avionic items that the Model III is supposed to be specifically structure to model. The impact can be seen in the case where numerus PSE TPSs covering several groupings of items that are to be used on common hardware SE.

Because of this lack of consideration for CSE and potentially S/W cost the Model III and RLA (especially the Network RLA) costs could vary widely. The Model III, since it doesn't consider the cost of potential common SE required and could not cover the software costs, is biased to recommending Intermediate repair. In addition, since the Model IIIs calculation for the numbers of SE required are input values, calculated outside the model, sensitivity analysis with the Mean Time Between Failure (MTBF) has little affect. The MTBF increase, thus lessening the total number of failures should decrease the need for SE. The RLA could be use to indicate the MTBF value that would decrease the need for an additional piece of common or peculiar SE for workload purposes. The Model III is dependent on the input value being changed and thus less able to be utilized to influence design.

Use of Discount Factors

The Model III assumes a discrete stable cost for the life of the program that is "discounted" to the present value. The RLA assumes the same discrete stable cost for the life of the program but doesn't discount the value but simply multiplies it either by the life of the system or in the case of Software Maintenance Cost one year less then the life of the system. The example calculation (see appendix) illustrates the difference in costs that are obtained by the models.

The Model III is using the wrong approach when calculating support cost for the SE. It figures the support cost by multiplying a set factor by the unit costs. In the example, the support fraction is 10 percent of the $2 Million in initial costs of SE resulting in an annual $.2M cost. The Model III then multiplies this value by the discount factor to obtain a value of $1.7M. For the purpose of this example it has been assumed the first year support factor is the same as the 2-20th year. The RLA takes the same support of SE cost factor and also multiplies it by the cost of the SE to obtain annual support costs. RLA takes the $2 Million piece of equipment and with a factor of 10% the support cost would also be $.2M. The RLA multiplies the support cost by the number of years, 20, and obtains a present value of supporting the SE of $4 Million. A substantially larger cost then the Model III's $1.7 Million.

The RLA is correctly representing the cash flow series, a uniform series of present value costs over 20 years. The Model III uses a uniform series cash flow type calculation that assume the same amount of cost will be incurred each year even when accounting for inflation. In other word, the cost of maintenance in the first year, $.2M, is the same in then year dollars 20 years later. The series the Model III calculates is similar to an individual who wished to deposit a sum today, in our case the $1.7M, that will allow him to make annual withdrawals for 20 years of $.2M and deplete the fund with the last withdrawal.

SE Support Factors

Looking at the real world, the cost of supporting a new piece of SE should gradually increase at the start of the system and stabilize at some point. True costs, not just accounting for inflation, of repair will gradually increase in the out years as the components used in the system, the repairables and consumables, are not readily available and produced in quantity. In many cases they may even go out of production. Both the RLA and the Model III data tables indicate that the SE support factors should be obtained from the contractors. The question would be how is the factor calculated. What assumptions are made and considered when the factor is determined. Is the factor based on any historical data. It very well may be better for the government to produce a series of factors for different types of SE based on government historical experience with the SE. A factor that would account for all of the true costs. If the contractor providing the factor is potentially the contractor that will produce the SE, he has a conflict of interest in establishing the figures. In our example, the support costs are twice the acquisition costs of the SE.

Summary

The RLA calculates the number of SE required using MTBF allows for easier sensitivity analysis. It doesn't suffer from the constraints, costing of only CSE, in the Model III. The RLA User guide describes the method to look at the "Regional Maintenance Concept" that would be similar to the Navy "Primary Intermediate Maintenance Activity (PIMA)." Modification to the RLA to allow for this option within the model would allow the RLA to cover all the options in the Model III while retaining its flexibility. The Model III use of the discount factor in the SE equation is invalid and further reduces the cost of SE in it's calculation. This further prejudices the Model III towards recommending intermediate level maintenance when it may not truly be the most cost effective.

VI. DETAIL REVIEW OF INVENTORY COST CATEGORY

The Model III and the RLA take the same overall approach to the problem. They calculate the number of inventory items, figure A, needed and then multiply by the cost of the item, figure B. This is done for several different inventory "pools" or "stocks". Stock, depending on the repair recommendation, is needed at base level (ship and shore for the Navy model), items and repair parts at Intermediate, and items and repair parts at depot. Figure A will be calculated several times for the different situations.

Figure B is equivalent to appendix Q 30.3.144, Unit Price, with the Appendix D and N descriptions being the same. This figure is the same input for both models, provided by the contractor and is not listed as being in the LSAR. The Model III also, in three of the four type of inventory calculations, utilizes the present-discount factor inappropriately versus the RLA use of number of years. The Discard, Scrap, and Repair material quantities are calculated as "annual" figures. These figures are multiplied by the unit cost, providing the "annual" cost for a particular type of inventory.

The Model III calculates the quantity of inventory required. The Model III starts using formula 40.1.4, Annual

# of Items for Disposition at a Site. The figure is derived from formula 40.1.5, Annual Number of Real Failures Removed at the a Site. Their are four basic input figures: A. The Number of Systems in the Weapon System, B. The Operating Hours, C. The Number of Weapon Systems, and D. the Real Mean Time Between Failure (MTBF). Figure A is the same for the Model III and RLA using the appendix Q 30.3.76, Quantity per End Item, definition. Figure B is calculated using two basic inputs. The first is the same for the Model III and RLA using the appendix Q 30.3.9, Conversion Factor, definition. The factor converts the airplanes operating hours to the systems under analysis operating hours. The second part is the total number of operating hours. For the Model III, this is calculated using monthly flight hour program. This figure is the converted to monthly from the appendix Q 30.3.2, Annual Operating Requirement, figure that is used directly by the RLA. The Model III converts the monthly back to annual within the equation, thus making the Model III and RLA figures the same. Figure C is calculated using the appendix Q 30.3.52, # End Items Supported. For the Model III, the figure is also multiplied by a "deployment factor". This factor is used to remove the NAS aircraft that have deployed onto the CV from the NAS. The calculation is simply reaccomplished for the CV type sites. RLA uses the same figures, but doesn't need to

split between shore and land sites.[35] Figure D is calculated using appendix Q 30.3.44, Mean Time Between Failure (MTBF), and 30.3.45, MTBF Degradation Factor. The Model III uses both figures where the RLA only uses the MTBF. The degradation factor is defined in appendix Q as "A factor, expressed in decimal form, used to account for any lowering of the technical (inherent) MTBF due to operating conditions or support considerations." This degradation factor on some equipment can be as low as 50% and thus half the reliability and double the number of items needing repaired.

The Model III uses the Beyond Capability Maint (BCM) rate that has no appendix Q equivalent noted in appendix D data table. The RLA uses the appendix Q 30.3.43, Maint Task Distribution. This figure has five subfield definitions relating to the different levels of repair possible. The RLA takes one minus the task distribution to get the number of items not repaired at the maintenance level. The 30.3.43 equivalent is known as the PIMA rate which is not used in this series of Model III formulas. The Model III used the BCM rate when addressing components moving from the Intermediate to the PIMA or the depot. The RLA used the 30.3.43 always since it doesn't have a calculation for discarding the box as the Model III does. The RLA assumes you will at least repair

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[35]Note: It should be made clear in the model that the 30.3.52 figure should represent the aircraft "assigned" to the NAS. The deployment factor should then, when multiplied by the 30.3.52, represent the number of aircraft on the carrier.

the box at Intermediate or depot level. You will then have the option to discard the SRA at either the Intermediate or depot. The Model III provides the additional option for discard of box at intermediate.

The RLA and the Model III are very similar, as noted in the above review of the Model III. The RLA uses the input values outlined in Table 3.

Ref Term	RLA Term	Ref. #	Appendix Q Term
PIUP	Years of System Life	*30.3.69	Operation Life
UEBASE	Equil Weapon Sys per Base	30.3.52	# of End Items
UR	Utilization Rate	*30.3.2	Annual Operating Requirement
QTY	LRUs per End Item	*30.3.76	Quantity per Item
UF	Utilization Factor for LRU	*30.3.9	Conversion Factor
RIP	Repair in Place Fraction	30.3.43	Maint Task Distribution
FAILP(i)	Failure Mode Ratio	30.3.24	Failure Mode Ratio
MTBF	Mean Time Between Failures	*30.3.44	Mean Time Between Failures
M	# Bases or Oper Locations	*30.3.56	Number of Oper Locations
* indicate the figures used for the Model III also.			

Table 3. RLA Inventory Input Values versus Appendix Q

Table 3 illustrates the same data, unlike in SE, is used in Model III and RLA. The RLA allows for the box and card to be accomplished in the same model run and thus the 30.3.24 figures is used to address the MTBF for each card that make up the box. The Model III would input the MTBF for each item separately.

For the Model III the calculated Annual Number of Real Failures Removed is increase by the "false removals" that are not detected as such. This is done in formula 40.1.4. The false removals, as noted in this categories previous summary, is over considered by the Model III and not considered at all by RLA. These basic calculation are then accomplished for the various type of locations and situations. The Model III has a series of calculations attempting to take into account the carrier and shore-base differences along with the Primary IMA option. The RLA simply completes the calculation for scrap, intermediate and depot.

Use of Discount Factor

The same example used in SE can be used here to illustrate the problem with the use of the discount factor. If the item cost $20K and 10 were required each year, the annual inventory costs would be $.2M. For the RLA, this figure is multiplied by the operational life, 20 years, and the total inventory cost is calculated to be $4M. With both of the models you should be using costs that a based in the same year. The Model III would, using a 10% discount factor from the LORA default data guide, multiply the $.2M by 9.365

(the Present Discount Factor using a 10% discount rate) and obtain a total cost of $1.873M (see appendix A). Just as in the SE section, the RLA figure is more than twice that of the Model III figure. The Model III, by using the present discount factor, is assuming the then-year costs for inventory will be $.2M at the start of year 1 and in year 20. The LORA default data guide tells you to use a 10% discount factor. This discount factor represents the inflation rate. If you only have $.2M in year 20 to buy spares, in todays dollars (what we have been referring to as present-value), you only have $29,720 worth of buying power. The $.2M is multiplied by 0.1486, which is the single sum present worth factor that brings $.2M back 20 years considering a 10% inflation rate.

The use of the discount factor causes the Model III to understate the sparing costs for discard, scrap, and repair material and in general leans the Model III towards a discard or depot repair concept that required the high spare quantity. This is opposite of the SE affect of using the discount factors.

Summary

The models take the same basic approach and use the same input data. With definitions clarifications on some of the input data, including MTBF, BCM, and False Removals, the Model III calculations could be used in both models.

VII. DISCUSSION

The Department of Defense (DoD) has developed over the last 30 years the Life Cycle Cost (LCC) and other related cost models to assist the program manager in developing and fielding the most cost effective weapon system. The accomplishment of Level of Repair Analysis (LORAs) in the acquisition program is required and an important tool in the overall program goal of producing a cost effective system as well as the specific Integrated Logistics Support (ILS) goal of fielding a cost effective support structure for the system. Logistics Support Analysis (LSA) process is the method the DoD logistician uses to help obtain the goal. This process should be utilized throughout the system development. The LORA process, which provides a critical impact to the analysis, should thus also be utilized throughout the system development.

Differing Approaches

For a single service program the LORA model is provided by the service. For the joint program, such as the V-22, whether to utilize a single model or several needs to be addressed. Through the comparison of the Model III, the Naval Air standard method, and the RLA, the Air Force standard method the answer is not clear. As outlined in the comparative analysis, each method addresses the same basic cost categories and in most cases the correlated categories are at the top level accumulating the same costs. The difference become apparent when the input data utilized for each cost category is compared. In some categories, the input data differs vastly and thus the calculation to obtain the top level cost figures are different. This is the case in the SE area, the RLA calculates the needed SE where the Model III uses an input figure. In other categories the differences in input data are few, but some potentially critical cost drivers are addressed differently. This is the case in the Inventory area, the Model III considers the "false removals" while the RLA doesn't, otherwise the approaches are very similar.

The methods also differ in their focus. The Model III having more detail/options relating to the type of sites, while the RLA focuses on calculating the item workload under a standardized basing concept. The difference in focus can be traced to the services unique concerns. The Navy, having to operating from shore and sea sites also has many primary I-Level facilities. The Air Force has a more standardized basing concept, whether in the CONUS or overseas, and has traditionally in the past limited centralized (similar to the

Navy "Primary") I-Level facilities to contain items, such as engines.

The RLA, under the network approach, allows for a more system look at the LORA. The networking of the item RLA into a system allows for a more realistic assessment. The I-level support package for a system is typically integrated. Programs have a mandate to utilize common SE and common mission equipment first before particular systems and support is purchased. The Model III method can be utilized in a system approach, but as in the V-22 program, leans the user to run the method in limited groupings if not individually.

Finally, though each approach has its strength and weaknesses, the Model III has a basic flaw in the use of the discount factors. The Model III formulas need to be reassessed and appropriately changed to reflect a sounder economic approach.

Which Method to Utilize on V-22

Neither method is superior and until changes are accomplished in both models the prudent approach would be to run both analyses and make a comparison of the results. With a relatively low initial investment, a personnel computer (PC) based preprocessing input data program could be developed that would take the source data from the Navy and Air Force data guides, the particular V-22 program data related to the three variants, and the common specific data related to the actual design of the V-22 and output Model III and RLA (either IRLA or NRLA) input files. The single program would allow for common data elements to use a single source and clearly identify when alternative data is being utilized. The cost of running the two models should only be slightly increased over the cost of running either one of the other models and be less then running the models separately under individual service efforts. The cost of collecting and preparing the input data, with the preprocessing program, should be less then the current cost of running the Model III without the preprocessing program. Actual running of the PC based programs is nominal and being reduced greatly as PCs become more powerful and faster. In any scenario, the models should be run numerous times as sensitivity analyses is conducted. The automation of the input file preparation should greatly reduce the effort involved. The evaluation of the result and the additional non-economic evaluation cost should be reduced in a combined effort versus any individual service efforts. The V-22 program is a joint program that has had a high priority placed on joint approaches. The results of this emphasis can be seen in the high degree of commonality in the variant designs. The logistics support structure is also being develop with the same emphasis on commonality. Current plans call for the development of joint training, tech manuals, and no unique PSE for a particular service. An evaluation process that was not accomplished with a joint decision would be contrary to the overall program acquisition strategy. Individual service evaluation would have to eventually be addressed in a joint manner because of the potential effects on currently planned joint approaches.

New Single Joint Model Required

The best solution, which is currently not available, would be the utilization of a Joint model that allows for the addressing of each services unique requirements. Through the evaluation of the different methods, it is clear that changes could be made to either method that would allow for a more common input data file and allow a single result. Several areas would require major changes. These areas could be approached with options within the program. The detail in sites could be added to the RLA model and either utilized or not depending on the particular service requirements. The workload equations could be added to the Model III allowing for calculated SE requirements vis using input data. Whether common SE was utilized in the evaluation or not could be an option. Either model could be taken as the core and modified with minor changes and options added to address the major approach differences.

The LORA MIL-STD 1390 has additional methods for the Army, Marine Corps, and FAA that should be assessed and the unique requirements integrated into the single joint model. A cursory review of the other methods indicates that similar input data is used and similar cost categories are calculated. The DoD in the past several years has greatly reduced the number of unique services polices and procedures and has consolidated them into the DoD 5000.1 and 5000.2 series regulations.

The MIL-STD-1390D draft utilized for this paper was a product of a Joint Service Level of Repair Analysis-Working Group (JSLORA-WG) "chartered by DoD to streamline the LORA process and eliminate duplication of LORA requirements between the military services.[36]" The Forward to the draft STD states,

> This revision contains several fundamental changes from MIL-STD-1390C as a result of the JSLORA-WG efforts. The following paragraphs highlight four of the key changes made to MIL-STD-1390C.
>
> a. The structure and language of the standard has been changed so that requirements are stated in performance or "what-is-necessary" terms, rather than "how to" perform a task.
>
> b. More detailed application guidance has been provided in the standard and organized into an appendix to provide noncontractual information on when and how to use this standard.
>
> c. The standard now accommodates and reflects the LORA requirements and mathematical equations of all the military services in preforming LORA economic evaluations.
>
> d. A closer interface has been defined between the LORA process and the LSA process.

These changes, especially those outline in (b), (c), and (d)

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[36]U. S. Department of Defense, <u>MIL-STD-1390D, Level of Repair Analysis (LORA) (draft), 20 Mar 91</u>, by NADC Code 5312, Lakehurst, NJ 08733-5100. p iii, paragraph 6.

eased the review of the two different models. The changes outline in (a) will greatly standardize how the LORA models are placed on contract and further assure the same basic tasks are followed no matter which model is utilized. The working group apparently did not change any of the models. The previous Model III and RLA documentation representing the calculations the model perform match the formulas in the draft standard. The addition of the Data Element Tables for each model that correlating input data with the standard in appendix Q helped to highlight the many similarities in the models.

VIII. RECOMMENDATION

The V-22 program should discontinue the use of the current Model III because of its discount factor flaws and allow for the development of a joint approach to the LORA effort. The program should concentrate on clearly defining a single source for the input data utilized in the LORA effort as well as the other cost modeling efforts, such as the LSAR, LCC, DTC, and O&S. Once the source information is defined, a preprocessing input data program should be developed for the LORA effort. The program should be capable of producing the input files for both the Model III and the RLA programs. The data should be expanded to include all V-22 aircraft variants and should not be limited to the MV-22 fleet, as in the current V-22 effort. The evaluation of the LORA outputs should be conducted in a joint fashion that allows for as joint of a level of repair approach as the economic and non-economic factors dictate.

The issue with the Model III use of the discount factors should be resolved and a new model developed.

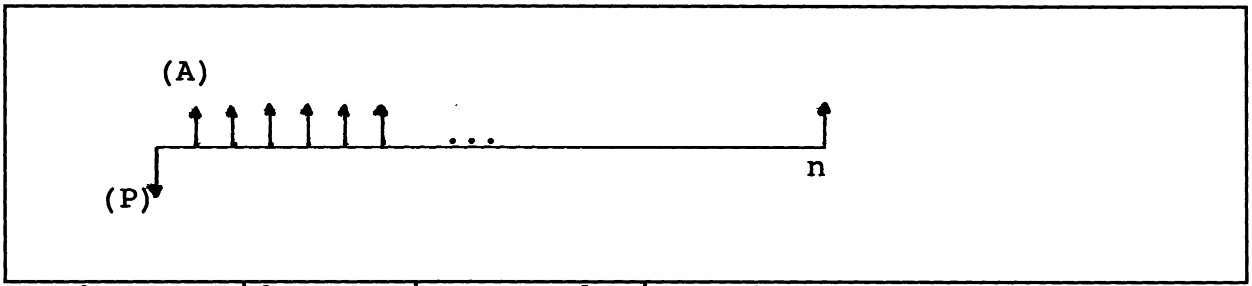
The JSLORA-WG should embark on an effort to develop a single LORA model that standardizes the minor differences and allows for options to be selected so service or program tailoring is an option in the model. The V-22 developed preprocessing input data program should be expanded to allow for all the data required under the new model to be accommodated in as automated a fashion as possible. The V-22, being a multi-service program, would be an excellent program to validate a joint LORA model.

APPENDIX A

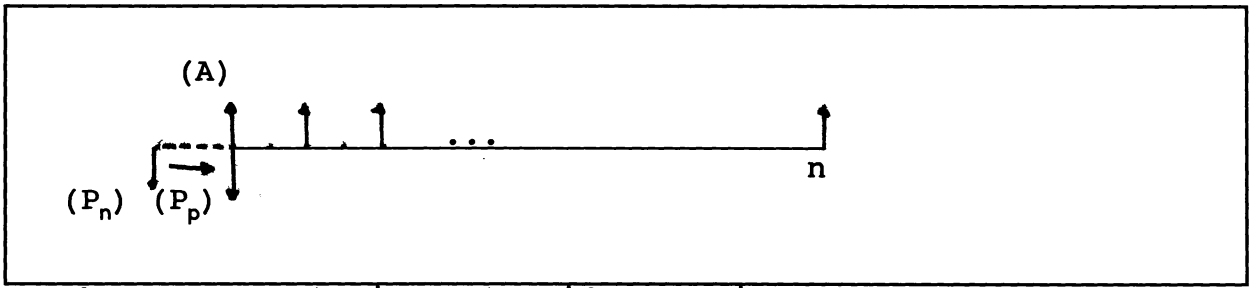
DISCOUNT FACTOR EXAMPLE

$$\left(\begin{array}{c}\textit{NORMAL}\\ \textit{DISCOUNT}\\ \textit{FACTOR}\end{array}\right) = \left[\frac{(1.0 + \textit{DISCOUNT RATE})^{\left(\begin{array}{c}\textit{Number of}\\ \textit{Years per}\\ \textit{Life Cycle}\end{array}\right)} - 1.0}{(\textit{DISCOUNT RATE})\,(1.0 + \textit{DISCOUNT RATE})^{\left(\begin{array}{c}\textit{Number of}\\ \textit{Years per}\\ \textit{Life Cycle}\end{array}\right)}}\right]$$

Formula 40.1.1. Normal Discount Factor (P_n)



Graph 1. Uniform Series Normal Discount



Graph 2. Present Discount Uniform Series (P_p)

Single Sum Present Worth $P_s = A(1+i)$

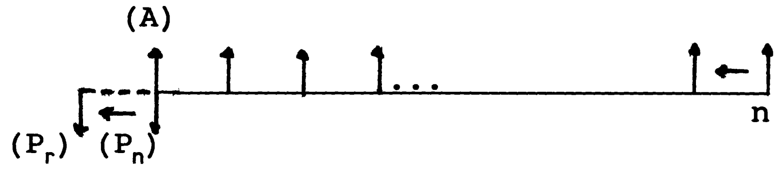
Present Discount Uniform Series $P_p = (1+i)(P_n)$

The P_p is reduced to the following:

$$\begin{pmatrix} PRESENT \\ DISCOUNT \\ FACTOR \end{pmatrix} = \left[\frac{(1.0 + DISCOUNT\ RATE)^{\begin{pmatrix} Number\ of \\ Years\ per \\ Life\ Cycle \end{pmatrix}} - 1.0}{(DISCOUNT\ RATE)\ (1.0 + DISCOUNT\ RATE)^{\left[\begin{pmatrix} Number\ of \\ Years\ per \\ Life\ Cycle \end{pmatrix} - 1.0\right]}} \right]$$

Formula 40.1.2. Present Discount Factor

Calculations 1. Deriving Present Discount Factor from Normal



Graph 3. Reduced Discount Uniform Series (P_r)

The number of years is "reduced" by one year so n = n-1

Reduced Discount Uniform Series $P_r = \frac{1}{(1+i)}(P_{n-1})$

The P_r is reduced to the following:

$$\begin{pmatrix} REDUCED \\ DISCOUNT \\ FACTOR \end{pmatrix} = \left[\frac{(1.0 + DISCOUNT\ RATE)^{\left[\begin{pmatrix} Number\ of \\ Years\ per \\ Life\ Cycle \end{pmatrix} - 1.0\right]} - 1.0}{(DISCOUNT\ RATE)\ (1.0 + DISCOUNT\ RATE)^{\begin{pmatrix} Number\ of \\ Years\ per \\ Life\ Cycle \end{pmatrix}}} \right]$$

Formula 40.1.3. Reduced Discount Factor (P_r)

Calculations 2. Deriving Reduced Discount Factor from Normal

$$\text{Normal Discount} = \frac{(1+.1)^{20}-1}{.1(1+.1)^{20}} = 8.514$$

$$\text{Present Discount} = \frac{(1+.1)^{20}-1}{.1(1+.1)^{19}} = 9.365$$

$$\text{Reduced Discount} = \frac{(1+.1)^{19}-1}{.1(1+.1)^{19}} = 7.604$$

Given A = $1,000,000

P_n = 1,000,000 * (8.514) = 8,514,000

P_p = 1,000,000 * (9.365) = 9,365,000

P_r = 1,000,000 * (7.604) = 7,604,000

Calculations 3. Example Model III Discount Figures

SE Inputs

SE Acquisition = $2,000,000

Support Fractions = 10%

Annual Cost of Support = .10 * (2,000,000) = $200,000

Model III

SE Costs = $2,000,000 + [$200,000 * (8.514)] = $3,700,000

RLA

SE Costs = $2,000,000 + [$200,000 * (20 yrs)] = $6,000,000

Inventory Inputs

Annual Item costs = $20,000 * (10 units) = $200,000

Model III

Inv costs = $200,000 * (8.514) = $1,700,000

RLA

Inv costs = $200,000 * (20 yrs) = $4,000,000

Calculations 4. Example Figures

APPENDIX B

ACRONYMS UTILIZED

APML	Assistant Program Manager for Logistics
BCS	Baseline Comparision System
BIT	Built in Test
CSE	Common Support Equipment
CONUS	Continental United States
CV	Carrier Class Ship
DED	Data Element Definition
DoD	Department of Defense
DoDI	Department of Defense Instruction
DPML	Deputy Program Manager for Logistics
DTC	Design to Cost
EMD	Engineering and Manufacturing Development
ILS	Integrated Logistics Support
IMA	Intermediate Maintenance Activity
LCC	Life Cycle Cost
LOR	Level of Repair
LORA	Level of Repair Analysis
LRU	Line Replaceable Assembly
LSA	Logistics Support Unit
MIL-STD	MIlitary-Standard
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
NAS	Naval Air Station
NAVAIRSYSCOM	Naval Air Systems Command
OSD	Office of Secretary of Defense
O&S	Operatrions and Support
PHS&T	Packaging, Handling, Ship, and Transportation
PIMA	Primary Intermediate Maintenance Activity
PSE	Peculiar Support Equipment
R&D	Research and Development
R&M	Reliability and Maintainability
RLA	Repair Level Analysis
RMC	Regional Maintenance Center
SE	Support Equipment
SRA	Shop Replaceable Assembly
SRU	Shop Replaceable Unit
TPS	Test Program Set
WRA	Weapons Replaceable Assembly

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