AN EVALUATION OF THE UNITED STATES AIR FORCE NETWORK REPAIR LEVEL ANALYSIS MODEL AS A TOOL FOR ROYAL AUSTRALIAN AIR FORCE REPAIR LEVEL ANALYSIS

THESIS

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Squadron Leader, RAAF

AFIT/GLM/LSM/89S-17

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Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Master of Science in Logistics Management

John D. Eckel, B. Eng (Comm)

Squadron Leader, RAAF

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Preface

The purpose of this research was to evaluate the suitability of the USAF Network Repair Level Analysis model as the primary Repair Level Analysis tool for the Royal Australian Air Force. This is my first major research effort and it would not been possible to complete without the help of several people.

I am deeply appreciative of the help, guidance, and encouragement given to me by my advisor LTCOL David E. Lloyd. LTCOL Lloyd's penchant for good research and the proper reporting of research is infectious and has made this thesis many times better than it might have been.

My thanks also go to current and former members of Capital Projects Division and Directorate of Maintenance Planning for their involvement in the interview process. In particular, I want to thank Squadron Leader Mark Cassidy for his help in the initial stages of the research, and Squadron Leader Ken Henderson for his help in reviewing interview questions.

My deepest gratitude goes to my wife Sue who has put up with 16 months of neglect and impatience. I appreciate the way she has acted as both mother and father to our boys over that period of time. I am looking forward to getting to know my family again.

John D. Eckel

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Abstract

The purpose of this research was to evaluate the suitability of the United States Air Force (USAF), Network Repair level Analysis (NRLA) model as the primary Repair Level Analysis (RLA) tool for the Royal Australian Air Force (RAAF). The research documents existing RAAF and USAF RLA procedures, identifies drawbacks of the present method of RAAF RLA, establishes the improvements offered by NRLA over existing RAAF RLA methods, and identifies possible sources of data for both existing and NRLA based RAAF RLA.

RAAF and USAF RLA procedures were documented through a review of orders and instructions, and informal interviews with repair level analysts. Drawbacks of existing RAAF procedures were then determined through formal interviews with RAAF analysts and reviews of correspondence on previous RLA projects.

A comparison of the USAF and RAAF procedures showed that a NRLA based RLA offered improvements over existing methods of RAAF RLA. Therefore, the final stage of the research identified possible sources of data to support NRLA based RAAF RLA.

The major finding of this research was that regardless of which RLA procedure the RAAF uses, data collection is a

major constraint. In a first attempt to address this data problem possible sources of data for both existing and NRLA based RAAF RLA have been identified in this thesis. Further study is required to confirm these sources, and to identify methods for extracting and adjusting data from these sources to meet RLA input requirements.

Two recommendations are made:

a. that NRLA not be introduced to the RAAF until data collection difficulties have been resolved, and

b. the RAAF use of NRLA be limited to the analysis of complex components or sub systems where its strength in allocating support equipment costs and sensitivity analysis will contribute to a better quality RLA.

AN EVALUATION OF THE UNITED STATES AIR FORCE NETWORK REPAIR LEVEL ANALYSIS MODEL AS A TOOL FOR ROYAL AUSTRALIAN AIR FORCE REPAIR LEVEL ANALYSIS

I. Introduction

Overview

This chapter provides the necessary background to understand the perceived shortcomings of existing Royal Australian Air Force (RAAF) Repair Level Analysis (RLA) methods, and how the United States Air Force (USAF) Network Repair Level Analysis (NRLA) model may address those shortcomings.

The specific research problem will be explained and the research objective and more specific research questions will be described. The chapter will conclude with an explanation of the limitations and potential benefits of this research.

Background

When a new weapon system is acquired by the RAAF, decisions must be made on the repair philosophy for components in the system. A component can be discarded on failure, or repaired at one of three levels of maintenance: the operational level, intermediate level, or depot level.

Operational level maintenance is the simplest form of maintenance and is usually performed by the squadron operating the weapon system. Operational level maintenance is characterized as requiring a small range of support equipment and a limited use of workshop facilities (8:7). An example of operational level maintenance would be the removal of an unserviceable radio and replacement of a serviceable radio in an aircraft.

Intermediate level maintenance is the next higher level of maintenance and usually supports several operational units. This level of maintenance requires a wider range of support equipment and facilities then the operational level (8:7). An example of intermediate level maintenance would be the testing of an unserviceable radio set to determine which circuit card in the set was unserviceable and replacing that card with a new one.

Depot level maintenance is the highest level of maintenance and usually supports several intermediate units. Depot level maintenance requires a wide range of special and general support equipment and facilities (8:7). An example of depot level maintenance would be the testing and repair of an unserviceable circuit card from an aircraft radio system.

The process of determining whether a component should be repaired or not, and, if repaired, at what level, is known as Repair Level Analysis (RLA). The formal definition of RLA in the RAAF is:

> The process of analyzing the economics of repair and the economic allocation of maintenance workload between

available service and contractor maintenance facilities. (18:1108)

As an example of how the "economics of repair" are calculated in the RLA process, consider the repair of a particular aircraft component. This component could be repaired at either four operational squadrons, two intermediate maintenance squadrons, or one aircraft depot. For simplicity, assume equal failure rates at each squadron, that the repair of the component requires unique support equipment (SE), and that the costs of the SE and the component do not change for the life of the aircraft. The cost of a "discard on failure" policy would be:

(cost/item) * (expected life of aircraft (L)) * (failures / year) (1)

The cost of any repair alternative would be:

[(spares cost/year) * (L)] + (# repair sites * SE cost / repair unit) + (additional component cost to cover resupply pipeline) (2)

For a "repair at operational unit" policy the number of repair sites would be 4 and the pipeline resupply costs would be 0. Assuming that the intermediate maintenance squadrons are remote from the operational units, for a "repair at intermediate unit" policy the pipeline resupply costs would be more significant but the number of repair sites would be reduced to 2. For a "repair at depot policy" pipeline costs would be greater then that for the intermediate alternative, but the number of repair sites would be reduced to one. The "economics of repair" process would then select the repair level where the life cycle costs were the lowest.

Although the general concept of RLA seems simple, difficulties arise when trying to allocate the proper SE and pipeline costs for each of the different repair alternatives. This is especially so for complex systems involving many Line Replaceable Units (LRUs) and Shop Replaceable Units (SRUs).

An example of a LRU would be circuit card from a radio system. A faulty card could be detected with the use of test equipment and replaced with another on the aircraft line. An example of an SRU would be an electronic component on the circuit card. The detection and repair of a faulty component on a circuit card is usually done in the workshop and requires special support equipment.

If, in the above example, the radio test equipment is used to detect several different faulty LRUs, how is the cost of that test equipment apportioned between the different LRUs for RLA calculations? How are the spares pipeline costs for LRUs to be related to the pipeline costs for their respective SRUs? Should LRUs be treated separately from their SRUs in RLA calculations, or should LRUs and their SRUs be treated as an integrated package? Considerations such as these have necessitated the development of standardized RLA policies and procedures by both the RAAF and USAF.

Figure 1 shows the branches of the RAAF that are responsible for RLA. The Directorate of Maintenance Planning - Air Force (DMP-AF), is located at Defence Central Headquarters Canberra, and is responsible for developing RAAF RLA policy (10:1). DMP-AF provides advice to the Chief of the Air Staff (CAS), through the Assistant Chief of the Air Staff - Engineering (ACAS-ENG). CAS implements RLA policy through the Air Officer Commanding Support Command, located in Melbourne. Ultimately, Capital Projects Division (CAPROJ) in Support Command is responsible for conducting RLA.

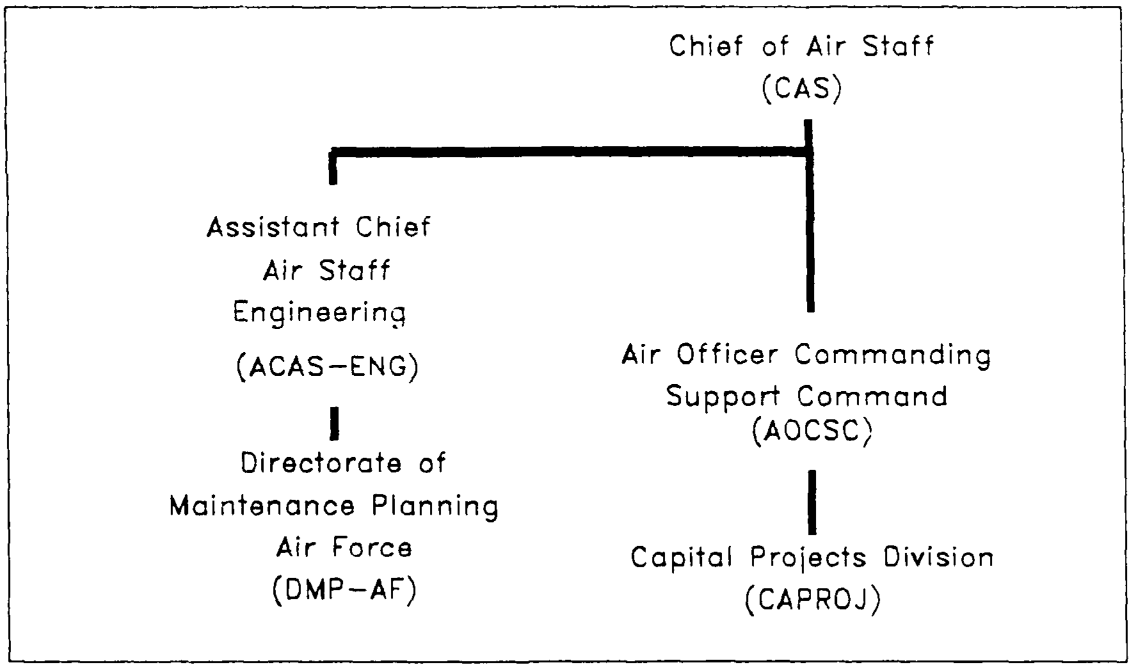

Figure 1. RAAF Organizations responsible for RLA

Historically, the RAAF has purchased existing weapon systems that have been operated for several years by overseas

Services such as the USAF and United States Navy (USN). Accordingly, the RAAF has been limited to evaluating repair level decisions previously established by those Services, or their contractors, and then modifying them to align with RAAF support and organizational requirements (7:703). This approach has both constrained and assisted the RAAF. The RAAF has been constrained because the existing weapon system maintenance manuals, spares availability and support structures are consistent with the overseas Service philosophy and not necessarily with the RAAF. The RAAF has been assisted because information is already available on the cost effectiveness of repair levels established by the overseas Service (18:2134).

Guidance on RAAF RLA procedures, including the use of foreign source data is given in RAAF Headquarters Support Command Logistic Instructions. The instructions identify specific cost elements to be considered in RAAF RLA including: training, ground support equipment, and inventory costs (18:213E1).

However, RAAF RLA analysts involved in recent analyses found that instructions on how to calculate specific cost elements were too broad. This meant that interpretations and costs varied widely between analysts (19:1, 20). In other words, the RAAF has no standardized quantitative means whereby RLA cost data are analyzed.

In addition to the cost factors, political and strategic constraints on RLA decisions in Australia are different than those used by other Services. For instance, the RAAF has a policy of developing a system of support to optimize in-country maintenance capabilities up to the depot level (9:1). This is necessary because of the remoteness of Australia from overseas design and manufacturing centers.

The RLA performed by the RAAF may differ from previous analyses performed by other Services due to strategic reasons. In this way an item that may have been classified as "throwaway" by the USAF because of ease of replacement from an in-country manufacturer, may be specified as repairable by the RAAF so that "... repair and maintenance skills can be developed or maintained by the RAAF or in Australian industry" (18:21310).

DMP-AF and CAPROJ both have expressed concern about the way RLA is currently being conducted in the RAAF (21, 5:1, 19:1-3). At present RLA is conducted using a broad set of procedures developed in 1981. These procedures suggest strategic considerations for RLA. However, as mentioned earlier, while the economic factors to be considered have been provided, the individual repair level analyst must use personal judgement to select weights and values for cost factors when performing the RLA calculations.

Present methods of RAAF RLA for complex equipment or sub systems have been described as a mixture of engineering judgement and black magic (17:1). A more scientific approach to RLA is required to reduce the RAAF's reliance on the individual analysts experience (5:1). Additionally, existing RAAF RLA procedures do not allow for indenture, that is the relationship and interaction of repair decisions for SRUs and LRUs (5:1).

In an effort to make RAAF RLA procedures more quantitative, DMP-AF initiated an investigation into the feasibility of using the USAF Network Repair Level Analysis (NRLA) model to perform RAAF RLA. The USAF NRLA model is a comprehensive, computerized, RLA model that provides for the systematic analysis and calculation of alternative repair level costs.

The DMP-AF investigation concerned two areas, the general suitability of NRLA to the RAAF environment, and the suitability of existing RAAF maintenance and supply databases to meet NRLA input requirements (20:1, 1:2). The latter area is currently being investigated by Computer Services Division in Canberra. The former area was the impetus for this thesis.

The Problem

The USAF NRLA model was perceived by DMP-AF as an approach that may provide a more scientific means of Repair

Level Analysis (20:1). However, there has been no formal investigation of what improvements NRLA offers over existing RAAF RLA methods. Furthermore, NRLA was designed for use in the USAF environment, to compliment other USAF maintenance procedures and databases, and no compatibility studies of NRLA in the RAAF environment have been performed.

Therefore, an investigation of NRLA's potential benefits and compatibility with existing RAAF RLA methods was required. The intent of this study was to determine if the NRLA approach offered any improvement over existing RAAF procedures and if NRLA was compatible with existing RAAF maintenance procedures and data sources.

Research Objective

The objective of this research was to evaluate the suitability of the USAF Network Repair Level Analysis model as the primary Repair Level Analysis tool for the Royal Australian Air Force.

Research Questions

To accomplish the research objective three research questions were addressed:

Research Question 1. How does the RAAF perform Repair Level Analysis? This was determined by answering the more specific investigative questions:

1a. What is the RAAF policy on RLA?; and

1b. How is the RAAF conducting RLA in practice?

Research Question 2. How does the USAF perform RLA using the NRLA model? This was determined by addressing the investigative questions:

2a. What is the USAF policy on RLA?; and

2b. How does the USAF use NRLA in practice?

Research Question 3. Should the RAAF use NRLA to perform RLA? This was determined by answering the investigative questions:

3a. What is not being done that should be done in RAAF RLA?;

3b. Does NRLA based RLA offer any improvement over existing RAAF RLA procedures?; and

3b. Is the data required for a NRLA based RLA available from existing RAAF data sources?

Limitations

The USAF conducts both design oriented and provision oriented RLA. The USAF describes design oriented RLA as part of "... a goal to evolve a design that considers the economics of support, stating alternatives and producing an economical life cycle cost profile" (14:1). Provision oriented RLA occurs after the initial design process.

Only in very rare cases is an aircraft developed in Australia to a RAAF specification (7:702). Consequently, there is little need to consider that part of the USAF procedures dealing with design oriented RLA. The existing

RAAF RLA procedures deal with provision oriented RLA and this is the main concern of DMP-AF and CAPROJ staff (5:1,1:2). Therefore, this research was confined to the use of NRLA in USAF provision oriented RLA and its application to the RAAF.

The number of RAAF personnel involved in both the policy and implementation of RLA number less then ten, and they deal with only one or two major analyses a year. Therefore, there was no opportunity to do large surveys or look at large numbers of repair level analyses completed by different teams.

The research was limited to discussing RLA matters with individuals through telephone interviews, and validating the responses of those conducting RLA in CAPPROJ with the policy makers in DMP-AF.

The last investigative question required that the availability of data for NRLA based RAAF RLA be investigated. This was limited to identifying the parameters required for NRLA and possible sources of data. The mechanics of extracting information from the database and modifying it for input to NRLA will not be addressed as it is the subject of a separate investigation by DMP-AF.

Benefits of Research

This research documents existing RAAF and USAF RLA procedures, identifies drawbacks of the present method of RAAF RLA, establishes the improvements offered by NRLA over existing RAAF RLA methods, and identifies possible sources of data for both existing and NRLA based RAAF RLA.

The study shows that NRLA is applicable to the RAAF RLA environment in a limited capacity, provided reliable data can be obtained for the NRLA model. NRLA is shown to offer advantages in the allocation of support equipment costs between multi use components, and the conduct of sensitivity analysis.

In addition, because present RAAF RLA methods and their deficiencies have been well documented, this research provides a firm basis for further studies into alternative RLA procedures for the RAAF.

Summary

Repair Level Analysis is the process of analyzing the economics of repair and the economic allocation of maintenance workload between available service and contractor maintenance facilities (18:1108).

Several perceived drawbacks of existing methods of RAAF RLA have been identified:

a. the lack of specific instructions on calculating cost elements,

b. the lack of a professional and scientific approach which means that the outcome of an analysis depends heavily on the individual performing the analysis, and

c. that no allowance is made for indentured relationships between LRUs and SRUs in RLA calculations.

RAAF management has suggested that the USAF NRLA based approach to RLA could be used by the RAAF to overcome these three drawbacks. However, no objective study had been previously performed to document the benefits nor critically analyze the value of NRLA to the RAAF.

The objective of this research was to evaluate the suitability of the USAF NRLA model as the primary Repair Level Analysis tool for the Royal Australian Air Force.

Thesis Organization

The remainder of this thesis reviews the USAF NRLA and RAAF RLA procedures and documents the study's methodology and data analysis. Chapter II contains an explanation of USAF and RAAF RLA procedures. The various USAF RLA techniques are described, and specific details are provided on the assumptions and input requirements of the NRLA model. The mechanics of RAAF RLA techniques and sources of RLA data are also described.

Chapter III explains the methodology used in this research. The methodology includes a review of USAF and RAAF RLA procedures, a comparison of the procedures to highlight any similarities and differences, and the procedure for interviewing the RAAF RLA staff to determine if the advantages suggested by NRLA are suitable for the RAAF environment.

Comparative analysis of the RAAF and USAF RLA procedures, and the responses of RAAF RLA staff are included in chapter IV. The conclusions and recommendations made as a result of the study are contained in Chapter V.

II. Literature Review

Overview

This chapter provides a detailed explanation of USAF and RAAF RLA procedures. The various USAF RLA techniques are described and specific details are provided on the assumptions and data input requirements of the NRLA model. The mechanics of RAAF RLA techniques and sources of RLA data are also described.

USAF RLA Policy

> "The goal of the [USAF] RLA program is to establish equipment and component repair level decisions on an economical and effective basis that integrate design, operations, and logistics support characteristics" (15:1).

The USAF policy on RLA specifies two RLA programs, design oriented RLA and provision oriented RLA (15:1).

Design oriented RLA is the preliminary analysis that begins early in the acquisition program and continues through critical design review. Its goal is to evolve a design that considers the economics of support alternatives and produces an economical life cycle cost profile (15:1). It identifies: repair level constraints resulting from the system operational concept, specific design features that will improve reliability and maintainability and reduce repair and discard costs, and previous design problems on similar systems and items to avoid repeating them in new systems (15:2).

Provision oriented RLA begins after initial system design is complete (15:1). It involves the use of RLA models to determine the most economic levels of repair for system components (15:2). The analysis justifies recommended support equipment, spare and repair parts, technical documentation, facilities, and maintenance personnel requirements (15:2).

USAF RLA Models/Methods

There are several methods that can be used for RLA in the USAF. These methods are described in AFLC/AFSC pamphlet 800-4 and include: Cursory Discard Equations, Equal Cost Curves (ECC), Support Equipment/Pipeline Ratios, Marginal Analysis Repair Level Analysis (MARLA), Item Repair Level Analysis (IRLA), and Network Repair Level Analysis (NRLA) (14:1).

Cursory Discard Equations, Equal Cost Curves and Support Equipment/ Pipeline Ratios methods are screening procedures. They can be useful in determining initial repair versus discard decisions without the detailed analysis required by IRLA, MRLA or NRLA (14:10).

The Cursory Discard Equation approach determines the replacement cost and minimum support equipment, spares, and material cost for a component. If the replacement cost is less than the minimum combined cost of spares, support equipment and other material, then a discard on failure policy should be adopted (14:9).

If the initial assessment is for repair, and support equipment costs can be aggregated between a family of items, then an Equal Cost Curves approach can be used (14:9). Equal Cost Curves are based on historical information on the same or similar components.

Costs equations are developed for discard, depot, and intermediate repair alternatives in terms of variables such as cost per unit and expected repairs per month. The equations are set equal to each other and parameters are varied to develop a locus of points for discard equals intermediate, discard equals depot and intermediate equals depot repair costs. An example of a set of equal cost curves is shown at Figure 2. Plotting the estimated unit cost for a new component against the expected repairs per month for that component will give a point on the graph. The region that point falls into will specify the most economical repair policy for the component.

The final screening procedure that can be used is the Support Equipment/Pipeline Ratio procedure. This procedure compares the investment in establishing a depot repair pipeline and the cost of the required Support Equipment at intermediate level if items are not sent to the depot. If

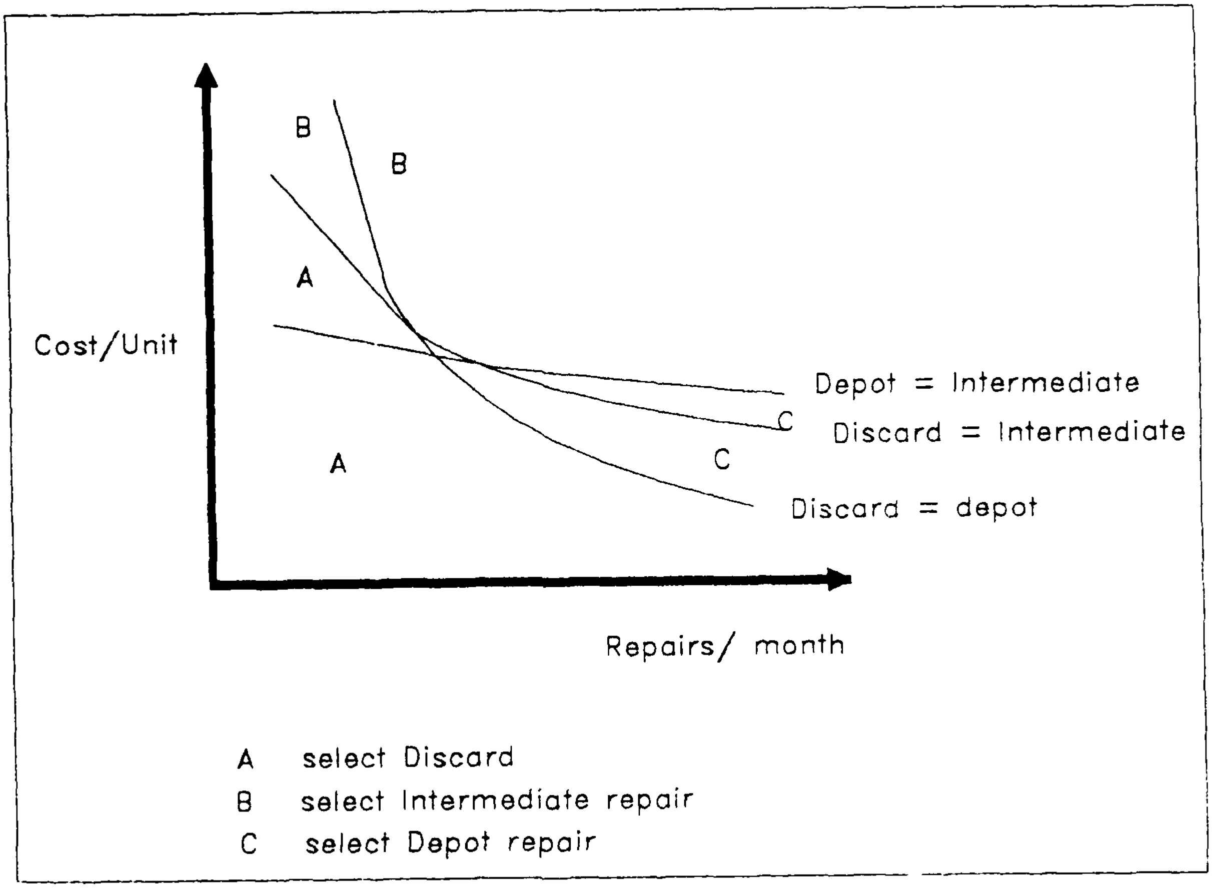

Figure 2. Equal Cost Curves (adapted from 14:10)

the pipeline cost is significantly less than the cost of the additional intermediate support equipment, than intermediate repair can be eliminated as an option in any further analysis. If the reverse is true, then depot repair can be eliminated from any further analysis (14:9).

A diagram of the screening process is shown in Figure 3. If screening procedures cannot be applied, or they produce inconclusive results, more detailed analysis involving MRLA, IRLA, or NRLA is required.

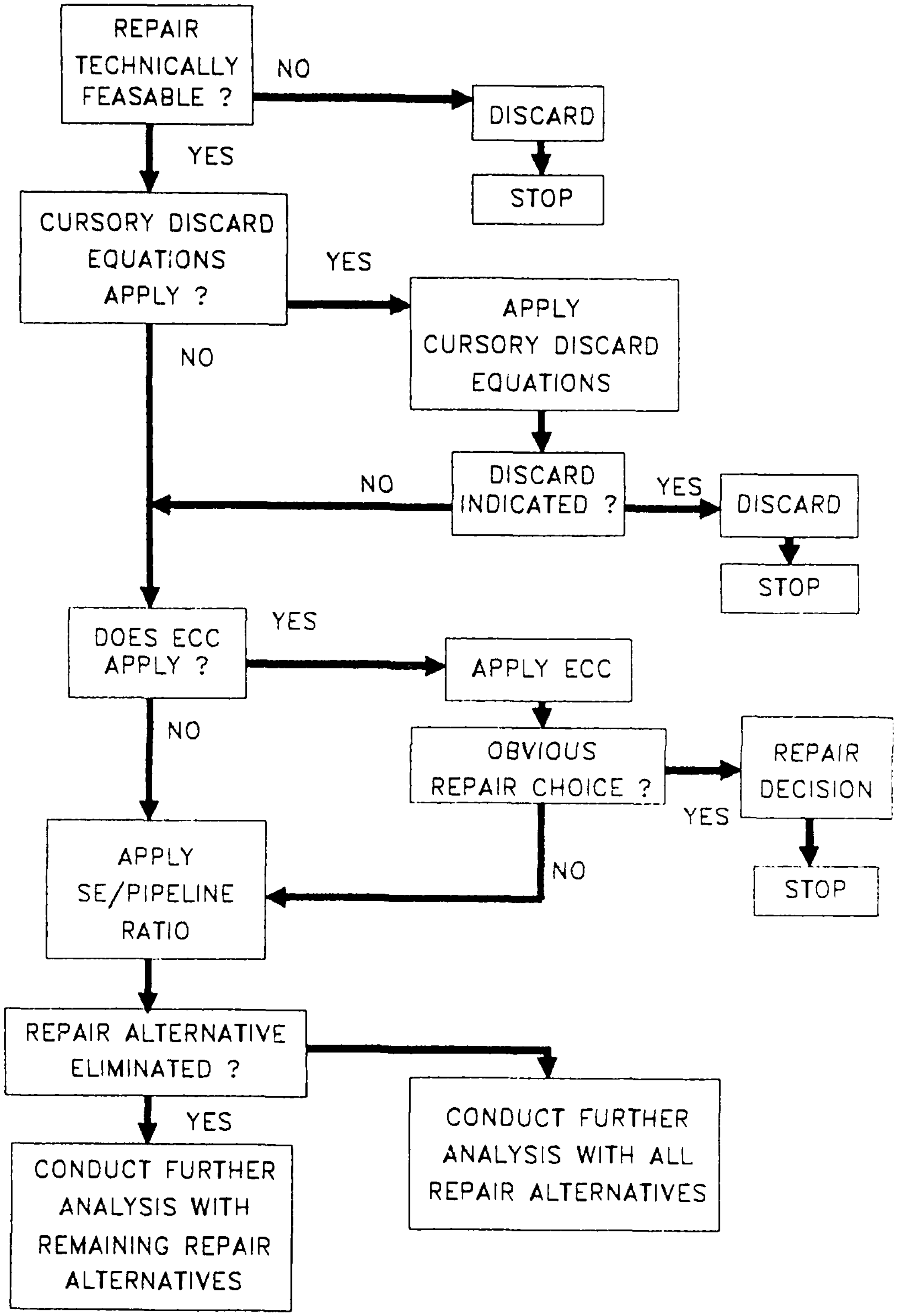

Figure 3. USAF RLA Screening Process (adapted from 14:7–11)

Marginal Analysis Repair Level Analysis (MARLA) is a means of making repair level decisions using marginal cost analysis to select repair levels (14:14). In MARLA costs are classified as either pipeline costs or support equipment costs. Repair level decisions are made on the basis of scrap costs versus pipeline costs plus support equipment costs (14:14). Decisions are made according to the following criteria:

$$(P_I + SE_I) < P_D \text{ and } (P_I + SE_I) < P_S \quad (3)$$

$$(P_D + SE_D) < P_I \text{ and } (P_D + SE_D) < P_S \quad (4)$$

$$P_S < P_I \text{ and } P_S < P_D \quad (5)$$

where:

P_S is the scrap cost.

P_I is the intermediate repair pipeline cost.

P_D is the depot repair pipeline cost.

SE_I is the intermediate support equipment cost.

SE_D is the depot support equipment cost.

If criterion (3) is satisfied, then intermediate repair should be chosen because the support equipment and pipeline costs for that alternative are less then the depot pipeline costs or discard on failure costs. If criterion (4) is satisfied, depot repair should be chosen because the costs for that alternative are less then the intermediate pipeline or discard costs. The discard alternative should be chosen if criterion (5) is met, where cost of discard is less then the depot or intermediate pipeline costs.

MARLA is similar to the Support Equipment/Pipeline approach with the exception that the various costs are investigated more fully to substantiate final decisions.

MARLA does not consider indenture, that is the relationship and interaction between LRUs and SRUs, when allocating support equipment costs. It assumes that support equipment costs are apportioned equally between LRUs and SRUs. For components or sub-assemblies where this assumption does not hold, the more complex IRLA technique should be used (14:15).

Intermediate Repair Level Analysis (IRLA) accommodates indenture levels. This requires that support equipment costs be allocated to LRUs and SRUs on the basis of actual usage. After allocating the support equipment costs, repair level decisions can be made using the same reasoning as the MARLA technique.

When using IRLA, support equipment costs attributable to each component at each level of indenture must be determined manually. In addition, LRUs and SRUs are examined on a "one at a time" basis, which can lead to contradictory results (14:13). For example, an SRU could be allocated to base level repair while an LRU that contains it could be allocated to depot level repair (14:13). The limitations of IRLA can be overcome by using the NRLA approach.

The Network Repair Level Analysis (NRLA) method is different from proration methods such as IRLA in that it avoids having to allocate costs to individual items. In NRLA the total cost of each Support Equipment item is structurally tied to each LRU and SRU which requires the SE (3:4).

In essence, NRLA models use life cycle costs together with LRU/SRU/SE interdependency relationships to construct a network representation of the repair level decision problem (3:1). Using a computer, the network representation can be solved to provide a system wide optimal repair solution rather than an individual component solution, as is the case with IRLA analysis (3:1).

The USAF recommends NRLA as the preferred method of conducting RLA in the USAF (14:12). This is because it uses the systems approach and can analyze a small system or subsystem in one iteration. NRLA also allows a variety of sensitivity analyses to be performed via simple instructions from the analyst.

However, in practice NRLA is only used for components and sub-assemblies which possess a complex relationship between SRUs and LRUs. This is to prevent the unnecessary use of computer and data collection time on components that could be accurately analyzed using the simpler RLA techniques described above (22).

Detailed NRLA Procedures

The USAF NRLA model is a FORTRAN based computer program that compares the cost of depot, intermediate, and discard repair level decisions. NRLA was developed on the Honeywell 635 computer; however, it has been successfully run on IBM hardware (2:1, 22). The model makes several assumptions including:

a. If one base sends a particular LRU or SRU to a depot for repair, then all bases send their repairables of that item to the same depot for repair. In other words, in the logistics system being modeled there is only one depot (3:2);

b. Base level maintenance data such as available work time per man, labor rate, and turn over rate are equal for all bases for and all types of repair (3:3);

c. Supply system data is constant for all SRUs and LRUs being analyzed. This means that order and shipping time from depot to each base is a constant for every item (3:3);

d. Only one set of technical data is purchased from the contractor, and duplication and distribution costs for additional sets of data are minor and assumed to be zero (3:3);

e. The model explicitly evaluates each type of LRU failure, however, SRUs are evaluated only in terms of the support equipment, repair skills and repair time required for their principle mode of failure (3:3); and

f. Depot level stocks of SRUs are computed on the basis of base level demands for SRUs, that is, to resupply bases when they send SRUs to the depot for repair. Therefore, the SRU calculations support a base remove and replace actions but not depot remove and replace actions (3:3).

The NRLA computer program uses two types of data input files. One file contains run specific information while the other contains program specific information which is unlikely to change from run to run (3:5). The NRLA run specific input data file contains information on the format of the output data and the type of sensitivity analysis required (3:30-35).

The program specific file contains records of information on weapons system data and options, maintenance system data, supply system data, support equipment data, LRU description, LRU failure modes, SRU data, and Support Equipment resource data. Appendix A contains details of the specific entries made in each of these data records.

Output from the NRLA model may contain any of the following: a summary of input data, alternative repair costs for LRUs and SRUs, recommended repair levels for LRUs and

SRUs, the expected cost of support equipment at intermediate and depot level for the system being analyzed, and any sensitivity analysis results (3:43). NRLA allows sensitivity analysis to be performed by varying LRU costs, LRU Mean Time Between Failure (MTBF), or Support Equipment costs by a fixed percentage (14:13).

Generally, Network Repair Level Analysis is performed by the contractor using the standard USAF NRLA computer program. The components or sub-systems to be analyzed by NRLA are usually specified by agreement between the USAF program manager and the contracting authority (22).

RAAF Repair Level Analysis Policy

Repair Level Analysis is conducted on behalf of the Directorate of Maintenance Planning - Air Force (DMP-AF) by Head Quarters Support Command (HQSC). However, repair level decisions do not become policy until approved by DMP-AF.

Repair level policies are issued as part of the Technical Maintenance Plan (TMP). Each aircraft type and major equipment system in the RAAF has a TMP. The TMP is issued by DMP-AF and specifies maintenance policy for all maintenance managed items of the parent equipment (11:1).

DMP-AF provides directions on general RLA principles rather than specifying particular models or mechanisms to be employed in performing a RLA. This allows HQSC considerable latitude in the way it conducts RLA. Even so, DMP-AF still maintains control over the RLA process in its role as the approving authority for any final repair level decisions.

DMP-AF specifies that RLA procedures are to involve a cost benefit analysis (7:407). The analysis should include facilities, spares items, support equipment, training, manpower, spares consumption, and shipping and handling costs (7:407).

The use of data from USAF NRLA and USN MIL-STD-1390B based RLA is permitted in RAAF RLA, provided the data is consistent with RAAF organizational and support requirements, and RAAF experience with similar items under similar operating conditions (7:703).

RLA policy also requires the analyst to state the range of circumstances for which a particular analysis is valid. This is necessary to ensure that long term support requirements and operational flexibility factors are considered in any calculations (7:407).

The broad policy guidelines on RLA provided by DMP-AF have been interpreted in HQSC Logistics Branch Instructions. In addition to policy interpretations, procedures for the conduct of RLA are also included.

HQSC recognizes that RLA on a particular aircraft or major equipment type is often performed by foreign services and contractors before the item is procured by the RAAF (18:1019).

The major benefit of using foreign source data in RLA analysis is that information on maintenance publications, support equipment requirements, and spares requirements are likely to be available (18:2134). However, analysts are warned that such data and subsequent repair level decisions are consistent with the foreign service's maintenance concepts and resources and not necessarily the RAAF's (18:2134).

This is consistent with the DMP-AF policy on allowing the use of foreign source data provided it is modified to suit the RAAF environment (7:703).

RAAF RLA Methods

Capital projects Division (CAPPROJ) within HQSC is responsible for conducting RLA in the RAAF. A flowchart of the RAAF RLA procedure used by CAPPROJ staff is shown in Figure 4. The procedure begins with a screening process that is limited to determining if a component is intrinsically repairable (18:2132). If it is not possible for a component to be repaired, the only repair policy that can be adopted is one of discard on failure. However, if a component can be repaired, current procedures call for a complete repair analysis to be conducted.

The first stage in a complete repair analysis involves gathering data on fourteen cost elements to be considered in repair level calculations. Initial or non recurring costs

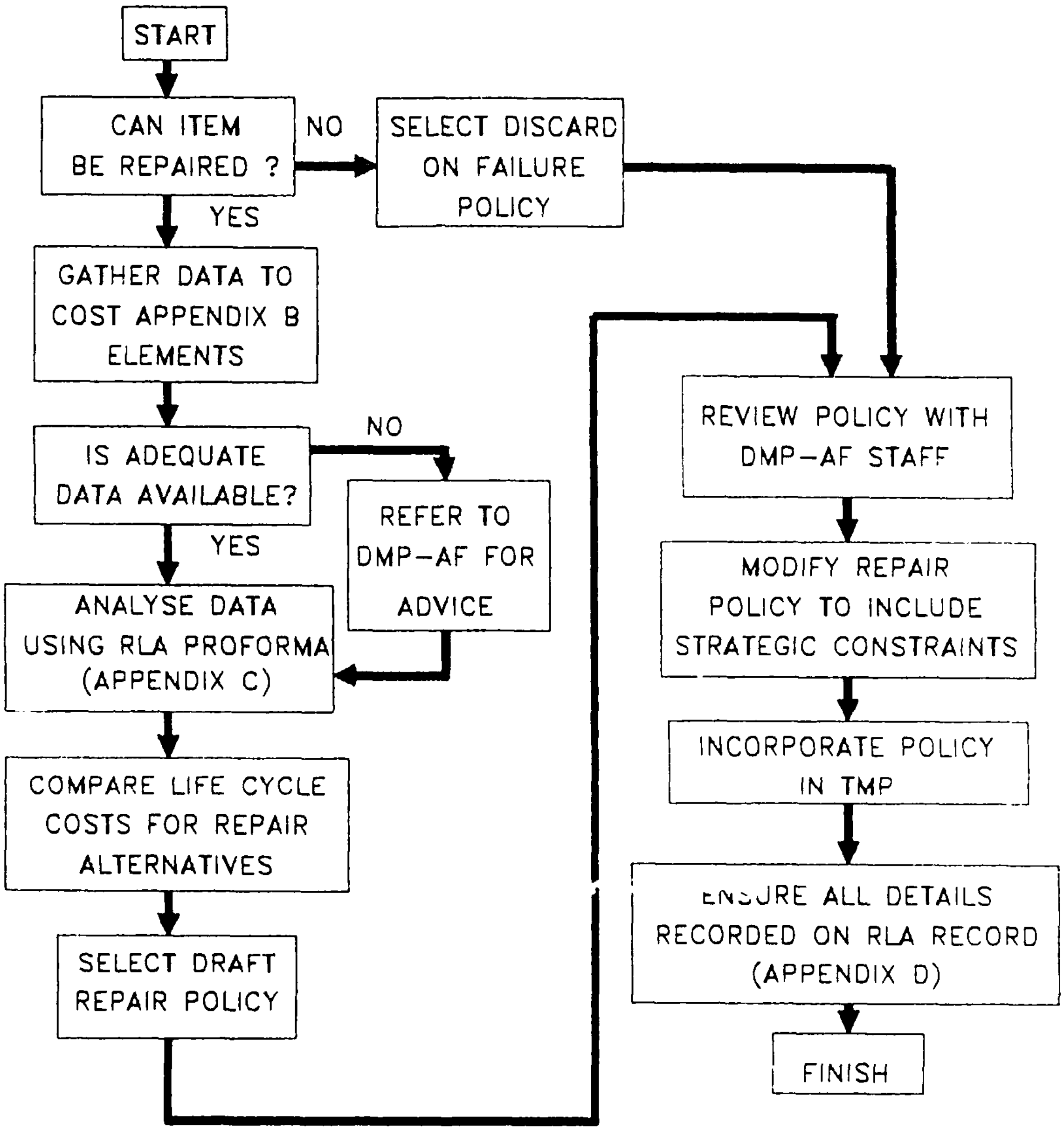

Figure 4 RAAF RLA Flowchart (adapted from 18:2131)

and follow on or recurring costs are calculated for each of these elements (18:1322). A list of these cost elements is shown in Appendix B. The appendix also includes the factors to be considered when calculating initial and follow on costs. For example, when considering the cost element of maintenance publications, initial costs would include: selection, validation, purchasing, cataloguing and manpower set up costs. Follow on costs would include configuration change and publication management manpower costs.

If there is insufficient data available to determine the value of a cost element, the matter is referred to DMP-AF. DMP-AF may authorize the removal of the element from RLA considerations, or, in conjunction with CAPPROJ personnel, determine an arbitrary value for the cost element (18:2132). The latter option relies on the experience of the individuals involved in the analysis (4).

The cost element data is analyzed using a cost comparison chart, which is shown in Appendix C. Each of the cost elements is listed together with the recurring and non recurring costs for alternative maintenance policies. Individual costs are then summed to give total life cycle costs for each alternative.

On the basis of life cycle costs a draft repair policy is chosen by CAPPROJ staff. DMP-AF and CAPPROJ then review the policy and, if necessary, modify it to reflect strategic considerations. The justification of a final repair policy is documented on a CAPPROJ RLA record proforma, which is shown at Appendix D.

The CAPPROJ approach to RLA is consistent with DMP-AF policy in that a range of costs is identified, a common baseline is used, the circumstances for which the analysis is valid is identified, and factors such as long term support requirements and operational flexibility are included.

The main tool used in support of the RLA process is the RAAF Procurement and Provisioning model (PATRIC). PATRIC allows spares requirements to be calculated for a given mean time between failure, rate of effort, and resupply pipeline. It provides useful information on the cost of spares support for the various levels of maintenance.

Another source of data that is useful, provided similar items are already in service, is the RAAF Maintenance Analysis and Reporting System (MAARS). MAARS can provide actual reliability, maintenance, and general logistics system data on components already in the RAAF maintenance system (6:3). In terms of the cost elements to be considered in RLA, this MAARS information is useful for calculating realistic maintenance manpower, spares, support equipment, transportation, packaging and handling costs.

Present RAAF RLA methods involve manual procedures and are based on the principles of marginal cost analysis (5:1).

While this appears to be adequate for simple components, problems arise when analyses relate to components with complex LRU/SRU/SE relationships.

The existing RAAF approach does not allow for indenture. RAAF procedures apportion Ground Support Equipment (GSE) costs equally against all LRUs that use the GSE, rather than basing costs on GSE utilization rates (5:1). Additionally, because of the manual approach to RLA, it would be difficult and time consuming to perform sensitivity analysis on RLA calculations.

Summary

The USAF RLA process consists of both screening procedures and detailed analysis procedures. The screening procedures use simple algorithms to make "obvious" repair level decisions for some system components. However, if the constraints of these procedures cannot be met, more detailed analysis is required.

In MARLA, costs are allocated as either repair or pipeline costs and repair decisions are made by comparing the cost to discard to the sum of pipeline and support costs. IRLA is similar to MARLA; however, indentured relationships between LRUs and SRUs are acknowledged and the cost of support equipment is allocated on the basis of actual use.

NRLA is the most complex method of RLA, it uses a systems approach and possesses the capacity to analyze a small system or subsystem in one iteration. NRLA allows the relationships between SRU's and LRU's to be modeled as a network. Support equipment costs are automatically attributed to SRUs and LRUs by NRLA on the basis of LRU/SRU/SE interdependency. Sensitivity analysis and changes to input data can be accommodated in NRLA by changing one or two data cards.

The CAPPROJ approach to RLA is consistent with DMP-AF policy in that a range of cost elements are identified, the circumstances for which an analysis is valid is recorded, and strategic constraints are considered in final policy deliberations.

The screening procedure in RAAF RLA is limited to determining if an item is intrinsically repairable. If a component is deemed repairable a standard form of marginal cost analysis is performed, regardless of the complexity of the component being analyzed.

The marginal analysis approach used by the RAAF does not allow for indenture when allocating support equipment costs, and for some cost elements there is a heavy reliance on the individuals performing the analysis to interpret and allocate cost data. In addition, because of the manual approach to RAAF RLA, it would be difficult and time consuming to perform sensitivity analysis on RLA calculations.

III. Methodology

Overview

The purpose of this research was to evaluate the suitability of the USAF Network Repair Level Analysis (NRLA) model as the primary Repair Level Analysis tool for the Royal Australian Air Force (RAAF). To achieve this objective the research was conducted in three phases.

In phase 1 of the research background material on RAAF and USAF RLA procedures were gathered. This was necessary to determine the context in which NRLA was used in USAF RLA, and provide background for subsequent studies on the impact of NRLA on RAAF RLA procedures.

There has been no formal research on RAAF and USAF RLA procedures. Consequently, the primary sources of information on the subject were RAAF and USAF orders, regulations, instructions, and pamphlets. Supplementary information was obtained through formal and informal interviews with RAAF analysts in DMP-AF and CAPPROJ, and USAF analysts at Wright-Patterson AFB, Ohio

In phase 2 of the research drawbacks of existing RAAF RLA methods were identified. The drawbacks were determined by reviewing critiques by analysts involved in recent RLA programs, as well as formal interviews with RAAF RLA practitioners and policy makers in DMP-AF and CAPPROJ.

In phase 3 of the research the suitability of USAF NRLA for RAAF RLA was evaluated. The strengths and weaknesses of NRLA and its use by the USAF were reviewed to determine if NRLA could be used to overcome the drawbacks of existing RAAF RLA procedures.

In the remainder of this chapter the specific aspects of the three research phases are discussed. First, the research questions identified in chapter I are restated. The relationship between each phase of research and the research questions is then described. Finally, the limitations, pre-testing and conduct of the formal interviews for this research are explained.

Specific Methodology

To accomplish the research objective three research questions were developed. More specific investigative questions were generated for each of the research questions. By answering the investigative questions information to answer the higher order research questions was obtained. The three research questions and their associated investigative questions were:

1. How does the RAAF perform Repair Level Analysis?
   - 1a. What is the RAAF policy on RLA?
   - 1b. How is the RAAF conducting RLA in practice?
2. How does the USAF perform RLA using the NRLA model?
   - 2a. What is the USAF policy on RLA?

2b. How does the USAF use NRLA in practice?

3. Should the RAAF use NRLA to perform RLA?

3a. What is not being done that should be done in RAAF RLA?

3b. Does NRLA based RLA offer any improvement over existing RAAF RLA procedures?

3b. Is the data required for a NRLA based RLA available from existing RAAF sources?

Research questions 1 and 2 were addressed in phase 1 of the research effort. Phase 2 of the research addressed investigative question 3a. Phase 3 of the research effort addressed investigative questions 3b and 3c. The specific methodology used to answer each of the research questions will be discussed next.

Research Question 1. How does the RAAF perform Repair Level Analysis?

The RAAF policy on RLA was determined by reviewing Defence Technical Instructions on the matter, and obtaining supplementary information through informal interviews with RLA policy makers in the Directorate of Maintenance Planning (DMP-AF), Headquarters - Australian Defence Force.

How the RAAF conducts RLA in practice was determined by reviewing work sheets and written procedures used in recent RLA applications. Formal interviews with RLA practitioners were also performed. The review concentrated on the analysis of BlackHawk aircraft components as that was the most recent, and therefore most current example of how the RAAF conducts RLA.

Research Question 2. How does the USAF perform Repair Level Analysis using the NRLA model?

Answering this question involved a similar methodology to that used for research question 1. USAF RLA policy was determined through a review of Air Force Logistic Command (AFLC) and Air Force Systems Command (AFSC) Pamphlets and instructions on the matter.

The use of NRLA in practice was determined through a review of NRLA handbooks and manuals, and examples of NRLA based analysis. Supplementary information on the mechanics of NRLA was obtained through informal interviews with the chief NRLA analyst in AFLC at Wright-Patterson AFB, Ohio.

Research Question 3. Should the RAAF use NRLA to perform Repair Level Analysis?

The first step in answering this question involved determining the drawbacks of the present RAAF RLA methods. The background material presented in chapter I and the review of RAAF and USAF RLA procedures presented in chapter II showed that the perceived drawbacks of RAAF RLA include:

a. the lack of specific instructions on how to calculate cost elements,

b. the lack of a professional and scientific approach which means that the outcome of an analysis depends heavily on the individual performing the analysis, and

c. that no allowance is made for indentured relationships between LRUs and SRUs in RLA calculations.

d. that any form of sensitivity analysis requires a complete rework of the RLA process.

To further investigate these perceived drawbacks of existing RAAF RLA methods, RLA policy makers and RLA practitioners were interviewed. The interview process is explained fully in a separate section later in this chapter.

After the drawbacks of RAAF RLA were confirmed and documented, NRLA based RLA procedures were investigated to determine if they could offer any improvements over existing methods. For example, one drawback of the RAAF system is that it does not allow for indentured relationships between SRUs and LRUs; NRLA does provide for this indenture.

The researcher found that NRLA did offer advantages over existing RAAF methods of RLA. Therefore, the next step was to investigate if NRLA data requirements could be satisfied from existing RAAF data sources. This was accomplished by matching the input requirements for NRLA (refer to Appendix A) with RAAF data availability. The sources of RAAF data which were investigated included the Computer Aided Maintenance Management System (CAMM), the Defence Supply Retail Management system (DSRMS), and the RAAF Procurement and Provisioning model (PATRIC).

NRLA data requirements that could not be met from existing RAAF sources were highlighted as factors limiting the introduction of NRLA to the RAAF. However, investigating alternative forms of data support was considered beyond the scope of this thesis.

Interview Limitations

The purpose of the formal interviews was to: verify that published RLA guidelines were being followed in practice, confirm the perceived drawbacks of RAAF RLA established in chapters I and II, and highlight any additional drawbacks of the present RLA procedures. Accordingly, those selected for interviews were required to have personal experience in the practical application of RLA or the development of RLA policy.

Seven people were interviewed. The relevant experience of these seven individuals is contained at Appendix E. Two of those interviewed were involved in the RLA policy area, and the other five performed RLA on the Blackhawk helicopter project. While a sample size of seven may appear small, it should be noted that:

a. there are only eight Repair Level Analysis positions established in CAPPROJ. At the time of the interviews, four of the eight people in those positions had no practical experience in RLA (a fifth analyst was interviewed at his follow-on posting), and

b. in DMP-AF there are only a maximum of two people actively involved with RLA policy. These two individuals also review the CAPPROJ RLA decisions.

The RLA experience of most of those interviewed was limited to the recent BlackHawk project. Although it would have been desirable to have respondents with both present and past RLA experience, it was not possible. This was because personnel with earlier RLA experience have moved to other positions or out of the RAAF two to three years ago, and would not be current on present RLA procedures. Nonetheless, general conclusions on RLA can be drawn from the comments of those interviewed because:

a. RLA principles and procedures are the same, no matter what aircraft or major system is being dealt with; and

b. the BlackHawk project was the last major RLA effort in the RAAF and as such the procedures used reflect the most current practical methods of RLA.

Because of the limited number of qualified people and the distance involved, the interviews were conducted by telephone. There are certain recognised limitations of telephone interviews. The two major limitations include: not all respondents may be available by telephone, and it is not possible to use illustrations to explain a point (16:171). In certain types of research these create true limitations, however, in this research all known respondents were reached by telephone, and all respondents had a working knowledge of RAAF RLA.

Interview Pre-Test

The initial set of interview questions is contained in Appendix F. These questions were tested during discussions with Squadron Leader K. Henderson. Squadron Leader Henderson has RLA experience on both the Squirrel and Blackhawk projects. As a result of this question pre-test, the original questionnaire was amended by:

a. reducing a three point response scale of unsatisfactory - satisfactory - very satisfactory to a two point response scale of satisfactory - unsatisfactory,

b. rewording Part 2 question 5 from "how do you describe the present method of comparing life cycle costs for repair alternatives?" to " How would you describe the mechanics of completing RLA once data has been collected?",

c. removing part 2 question 7 as it was an area where most respondents would not have any knowledge, and

d. removing the second question dealing with the experience required to conduct RLA as it was considered redundant.

The process of pre-testing the questions was limited to a single individual because of the small number of knowledgeable people available for interviews. Since there was little change to the original questionnaire, Squadron Leader Henderson's comments during the pre-test were included with other interview responses.

Interview Questions

The amended questionnaire, used in the formal interviews, is in Appendix G. The interviews were conducted by telephone in May 1989.

The first part of the interview dealt with procedural questions. The purpose was to check and validate the RAAF RLA process. Chapter II details how the RAAF should conduct RLA according to published procedures and guidelines. The first part of the interview therefore provided a means of checking whether these procedures were reflected in practice. The information obtained addressed investigative question 1b.

The second part of the interview elicited opinions on present RAAF RLA procedures. Figure 5 shows which interview questions related to which step(s) in the RLA process. Each question was asked in two stages. Initially respondents were asked to express an opinion about a particular aspect of RLA. A dichotomous satisfactory - not satisfactory response scale was used. This simple scale was preferred to a Lickert type scale, as the purpose of the questions was not to collect

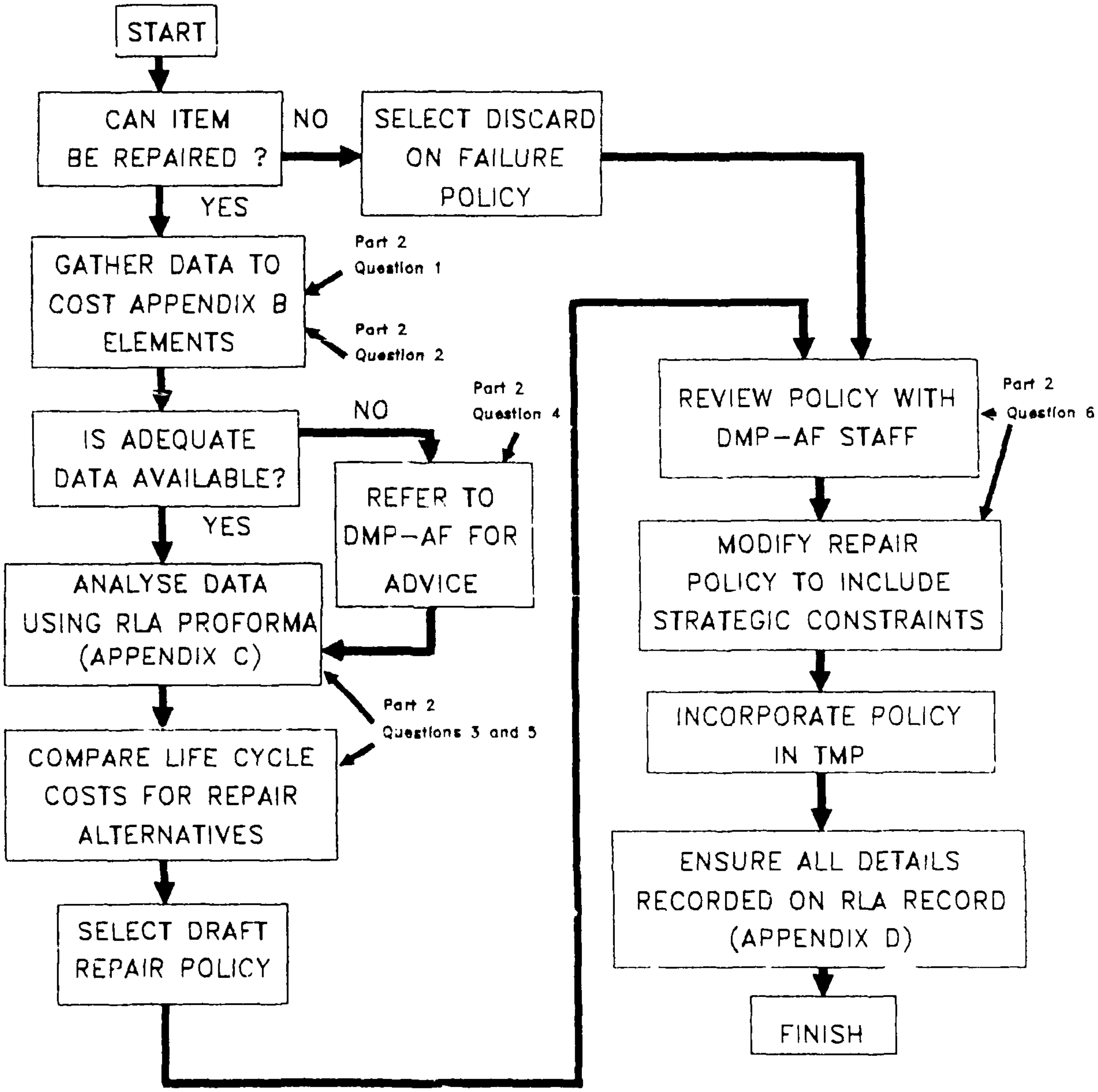

Figure 5. RAAF RLA Process with Interview Questions

data for statistical analysis, but rather to provide insight for the second stage of questioning, which involved clarifying 'why' respondents felt the way they did.

For example, to Part 2 question 4, "How would you describe your discussions with DMP-AF when trying to resolve data collection inadequacies?"; a respondent's response of "not satisfactory" in itself is not meaningful. However, by asking why it is not satisfactory, opinions on the inadequacies (or strengths) of the present system were obtained.

In addition to general questions on RAAF RLA procedures, Part 2 contained a specific question on allocating support equipment costs (Part 2 question 2). In chapter I RAAF management's perception that existing procedures are not adequate for allocating support equipment costs was highlighted. The purpose of the question was to confirm if there are any practical problems in allocating support equipment costs using present RAAF RLA methods.

Part 2 of the questionnaire also contains a specific question on conducting sensitivity analysis in the RAAF. In chapter II the ease of using NRLA in the USAF for sensitivity analysis was highlighted. The purpose of this question was to determine if it is difficult to perform sensitivity analysis using existing RAAF RLA methods.

The information obtained from Part 2 of the interview addressed investigative questions 3a and 3b.

In Chapter I, RAAF management's expectation that NRLA would provide a more scientific approach to RLA was highlighted. The belief was that a more scientific approach would mean less reliance on the experience and expertise of the individual doing the analysis.

The purpose of the third part of the interview was to gain expert opinion on how scientific or quantitative the present RAAF RLA methods are in terms of expertise required to do an analysis. This information was used later to compare the RAAF approach with the scientific rigor offered by NRLA.

The information obtained from part 3 of the interview addressed investigative questions 3a and 3b.

Summary

The purpose of this chapter was to explain the methodology that was used to answer the research questions posed in chapter I. Methods used to investigate the three research questions included:

a. reviews of RAAF and USAF orders and instructions,

b. informal interviews with RAAF and USAF repair level analysts, and

c. formal telephone interviews with RAAF analysts.

IV. Findings and Analysis

Overview

This chapter reports the findings of this research and provides an analysis of data collected in support of the research. The results of the interview process are summarized first. This interview data is then combined with background material from chapter II to address the thesis research questions.

Interview Questions

The interview questions are listed at Appendix G. A list of those interviewed and their relevant experience is contained at Appendix E. All those interviewed had a working knowledge of the RAAF RLA process. The interviews dealt with questions on general RLA procedures, respondent's personal opinions of present methods, and opinions about the scientific rigor of RLA procedures. Detailed interview responses are contained in Appendix H.

Procedural Questions. The purpose of the procedural questions was to confirm if RAAF RLA guidelines were being followed in practice. The interview results are summarized below.

Repair level analysts decide if a component is intrinsically repairable or not through the application of common sense, and where applicable, USDoD Source, Maintenance and Recoverability (SMR) codes. SMR codes provide information on the maintenance level and repair action for a component as determined by the USDoD (12:3).

Common sense is used to make the obvious decisions such as nuts and bolts being non repairable. SMR codes are used for guidance if the decision to repair is likely to require special support equipment and facilities.

A SMR coding of "repairable" would indicate that support equipment had been developed for a component, and that alternative repair level actions should be investigated by the RLA analyst. On the other hand, a SMR coding of "expendable" would make it unlikely that specialist support equipment had been developed. This would favor a "discard on failure" policy for the RAAF because of the limited resources available to develop the required support equipment in Australia.

The cost elements considered by RAAF analysts are listed in Appendix B. On the BlackHawk project, individual analysts were first asked to determine their own standard cost figures. The analysts were then bought together as a group and a standard cost for each element was obtained by consensus.

This approach was effective, in that it provided a forum for discussing the accuracy of cost data and provided a means of setting standard costs for applicable elements prior to the RLA process. This approach was also necessary, as existing RLA instructions do not provide any information on the sources of cost element data, or the standardization of such data.

Where applicable, RAAF analysts used repair level decisions by overseas Services as a starting point for RAAF RLA. For example, if an item had been annotated as depot repairable, the analyst knew that support equipment existed or that it was being developed to service the component.

In addition, analysts have used USDoD Logistics Support Analysis (LSA) data as the basis for developing standardized cost elements. The USDoD requires LSA to be conducted on all acquisitions of major equipment. LSA provides cost data on maintenance, supply, and other support requirements (13:10).

However, analysts are aware the LSA data cannot always be directly applied to RAAF RLA. For example, USDoD publication costs usually include the cost of initial development and production. The cost to the RAAF would not include any development costs, but would include costs of changes in the publications to meet RAAF maintenance practices.

Even if reliable overseas information is available, full costing of each alternative is still conducted to determine the most economical approach from the RAAF point of view. For instance, a component that is repaired at a depot in the

USA may be more economical to repair at an intermediate workshop in Australia, or alternatively the low number of arisings in Australia may make it more economical to send components to the USA for repair.

Opinions of Present Methods. The purpose of the questions dealing with opinions of present methods was to determine the strengths or weaknesses of the present method of RLA. Comments made in that part of the interview are summarized below.

Generally, the analysts interviewed were satisfied with the consensus approach to determining standardized cost figures. However, they expressed concern over the accuracy and the sources of data used to determine the estimates. For example, initial publication costs varied in price depending on the source of the data. In addition, inventory cataloging costs had no identifiable source at all. In both cases a standardized 'best guess' was determined by the analysts rather than basing the cost on some source of reliable data.

The proper allocation of support equipment costs seems to be a particular problem for analysts. In the initial RLA on the BlackHawk, the full cost of support equipment was logged against each item that required the support equipment. Later, this was changed so that support equipment costs were apportioned between all of the items using the test equipment.

Even so, respondents expressed concern over apportioning the costs of new support equipment as well as the costing of new component usage of existing support equipment. They found it difficult to properly attribute costs based on support equipment usage, especially where parent assemblies and sub assemblies used the same test equipment.

CAPPROJ analysts interviewed did not appear to have been required to conduct formal sensitivity analysis. Even so, DMP-AF staff have said that in recent times the need for sensitivity analysis has increased as "what if" questions associated with civil versus military maintenance of major components are investigated.

Those interviewed believed that any sort of sensitivity or "what if" type of analysis would be time consuming. This is because RAAF RLA is largely a manual process and changing any input parameter would require the whole RLA process to be repeated.

Although published guidelines indicate that problems in determining accurate cost elements should be resolved with DMP-AF, in reality, CAPPROJ sorts out the problems themselves and documents this for DMP-AF to review at the end of the RLA process after a final repair policy is recommended.

The RLA experts interviewed were generally satisfied with the mechanics of the RAAF RLA process, after cost elements were determined. For simple components that do not require proportional allocation of support equipment costs, the present methods of RAAF RLA were considered adequate.

The procedures and forms used to perform RAAF RLA are identical to those outlined in chapter II. The only variation is the use of a DBASE® computer program to automate the summation of the various maintenance alternative life cycle costs.

Complaints about the present procedure for determining alternative life cycle costs included the need to run the provisioning model PATRIC for each maintenance alternative. Each PATRIC run takes several hours to set up and complete. This is a time consuming task.

The repair level analysts surveyed expressed little difficulty in dealing with DMP-AF staff when maintenance policies were being reviewed. Generally, questions from DMP-AF dealt with the assumptions used for establishing the cost estimates. In most cases, DMP-AF accepted CAPPROJ cost estimates as soon as further explanation was provided.

Scientific Rigor of Present Methods. The purpose of the third part of the interview was to gain expert opinion on how scientific or quantitative the present RLA method is. This data will be used later to compare with the scientific rigor offered by NRLA. The assumption here is that a more quantitative approach would involve less reliance on the experience or qualifications of the individual performing the analysis.

There was disagreement between the respondents over the degree of experience required to conduct RAAF RLA. Some argued that all that was required was enthusiasm and a background in the applicable aircraft or trade.

Others argued that in addition to having the right background, experience in spares assessing or staff work in the repair and overhaul area would be an advantage. When RLA cost elements were being standardized there appeared to be a heavy reliance on those individuals with experience in those areas of HQSC. The assumption here suggests that people with such experience would be better able to identify and pursue data sources for RAAF RLA cost inputs.

Research Questions

The information gathered in the interview process and the literature review will now be used to address each of the three research questions.

Research Question 1. How does the RAAF perform Repair Level Analysis?

A review of the worksheets completed by RLA analysts on the recent Blackhawk helicopter project revealed that the procedures contained in HQSC branch instructions are being followed in practice. A random selection of airframe, engine and avionic component repair level analysis work sheets were analyzed. All used the performas suggested in the instructions and all appeared to consider the relevant cost factors in their analysis.

Interviews with repair level analysts confirmed that, in almost all cases, theory was being followed in practice, as outlined in Figure 4 of chapter II. The only exception to the published procedure was that cost data collection problems were resolved within CAPPROJ rather than being referred to DMP-AF for resolution. This procedure does not circumvent DMP-AF authority, as the validity of cost estimates can, and is, questioned by DMP-AF during the review phase of the RLA process. Therefore the intent, if not the letter of the HQSC branch instruction is being followed.

> Research Question 2. How does the USAF perform Repair Level Analysis using the Network Repair Level Analysis model?

The USAF RLA process consists of both screening procedures and detailed analysis procedures. The screening procedures use simple algorithms to make "obvious" repair level decisions for some system components. However, if the assumptions of these procedures cannot be met, more detailed analysis is performed.

The first level of detailed analysis is Marginal Repair Level Analysis (MRLA). In MARLA, costs are allocated as either repair or pipeline costs and repair decisions are made by comparing the cost "to discard" to the sum of pipeline and support costs.

The next level of analysis is Item Repair Level Analysis (IRLA). IRLA is similar to MARLA; however, indentured relationships between LRUs and SRUs are acknowledged and the cost of support equipment is allocated on the basis of actual use.

Network Repair Level Analysis (NRLA) is the most complex method of USAF RLA, it uses a systems approach and provides the capacity to analyze a small system or sub system in one iteration.

The USAF regards NRLA as the preferred method of conducting RLA (15:12). However, in practice, NRLA is only used for components and sub-assemblies which possess a complex relationship between SRUs and LRUs. This procedure prevents the unnecessary use of computer, and data collection time for components that could be accurately analyzed using the simpler RLA techniques described above (22).

In practice, NRLA is usually conducted by the contractor using data obtained from the applicable aircraft LSA. Because NRLA is computer based and the information is available in the required format, the background of those performing NRLA can be varied (22). Aircraft trade or spares assessing experience is not necessary. All that is required is the ability to take the applicable LSA data and enter it into the NRLA model.

NRLA uses life cycle costs together with LRU/SRU/SE interdependency relationships to construct a network representation of the repair level decision problem (3:1). Support equipment costs are automatically attributed to SRUs and LRUs by NRLA on the basis of LRU/SRU/SE interdependency. There is no need to manually attribute support equipment costs to each component in the system being analyzed.

Additionally, sensitivity analysis and changes to input data can be accommodated in NRLA by simply changing one or two data cards.

> Research Question 3. Should the RAAF use the USAF Network Repair Level Analysis model to perform Repair Level Analysis?

The RAAF RLA analysts interviewed reported that published RLA procedures and guidelines were easy to follow. However, they believed that the orders were not specific enough on how to gather data and determine specific cost elements. As a result, analysts initially had to rely on their personal experience to determine costs. This meant that interpretations and costs varied widely between analysts.

As a result of their experience on the Blackhawk RLA, analysts have suggested a way of tightening up existing RLA procedures. During the interview stage of this research, and in earlier written comments on the Blackhawk RLA process, analysts have suggested that at the start of the RLA process:

a. the importance of each cost element to each repair alternative should be determined, and

b. standardized costs for each element should be specified (19:1).

For example, training costs for throw away, overseas and contractor maintenance alternatives were regarded as nil for the Blackhawk project and the standard recurring cost of training for other alternatives was specified as $50 per hour (19:A2).

Analysts in the Blackhawk program reported that if they had information on standardized costs and the applicability of the various cost elements to repair alternatives at the beginning of the RLA process, they would have cut the time spent on RLA by more than 50% (19:2).

However, as discussed earlier in this chapter, for particular cost elements such as publication and inventory costs for example, there are problems in either identifying sources for the data or having the data in the right form in which to develop standardized costs.

Other drawbacks of existing RAAF RLA procedures identified in the interview process include difficulties in allocating support equipment costs to allow for LRU/SRU interdependencies, and the need to completely rework the RLA of a component when conducting sensitivity analysis.

In summary, what is not being done that should be done in RAAF RLA is:

a. identifying where data can be obtained to develop standardized cost elements,

b. manipulating data from existing sources to make it suitable for developing standardized cost elements,

c. developing better methods for allocating support equipment costs between multi use items, and

d. developing easier ways to perform sensitivity analysis.

Establishing what is not being done that should be done in RAAF RLA was the first step in answering research question 3. The second step was to determine what improvements NRLA offered over existing RAAF procedures. The final step was to determine if NRLA data requirements could be satisfied from existing RAAF resources.

The NRLA approach does offer improvements over the existing methods of RAAF RLA in allocating support equipment costs, and performing sensitivity analysis.

Present RAAF RLA methods allocate support equipment costs manually on the basis of component usage. Furthermore, because cost allocations are done on a component by component basis, there is no means of systematically taking into account system wide SRU/LRU interdependencies.

On the other hand, NRLA allows the relationships between SRU's and LRU's to be modeled as a network. Support equipment costs are automatically attributed to SRUs and LRUs by NRLA on the basis of LRU/SRU/SE interdependency. NRLA provides a system wide optimal repair solution rather than an individual component solution as is the case with existing RAAF procedures.

A standard NRLA output can contain an initial solution and several different sensitivity analyses for a complex component or subsystem. Furthermore, sensitivity analysis and changes to input data can be accommodated by changing one or two data cards. In contrast, conducting sensitivity analysis using RAAF RLA procedures requires the entire manual process to be repeated, as if a new component was being evaluated.

If NRLA is to be used by the RAAF to improve RLA in the areas of support equipment allocation and sensitivity analysis, NRLA data input requirements must be satisfied (refer Appendix A). In the USDoD such data is readily available, as it is required under the provision of USDoD LSA (13:3). However, as has been discussed earlier in this chapter, in Australia, RLA data is not as readily available.

Interviews with RAAF analysts and correspondence on recent RAAF RLA programs reveal that there are problems with identifying sources of RLA data, and where sources are available, manipulating the data to get it into an acceptable form to determine standardized cost elements. Furthermore, although USDoD data is used by RAAF analysts to aid in the RLA process, the analysts have noted that the data must be modified to reflect the RAAF environment.

The RAAF analysts interviewed indicated that if these data collection problems could be overcome, the existing method of RAAF RLA would be adequate for analyzing simple components. In addition, individuals would not be required to seek out and interpret cost element data as part of the RLA process.

Developing an expert system to satisfy the data requirements of RAAF RLA is the subject of a separate study (20:1). Accordingly, the mechanics of extracting information from specified sources and modifying it for input to NRLA or the existing method of RAAF RLA has not been investigated. Although such an investigation is beyond the scope of this research, a brief survey of the possible sources of data for RAAF NRLA based RLA is provided in Table 1.

The first column in the table lists the data input requirements for NRLA, ndensed form. It is based on the detailed NRLA input requ ments contained at Appendix A.

Table 1: NRLA - RAAF RLA - Data Sources

Condensed NRLA Requirements (1)	RAAF RLA (2) Requirements	Possible Sources
1. Weapon's System a. End use requirements b. Operations requirements c. Sensitivity analysis requirements (3)	RAAF RLA Record	RAAF Operational Requirement.
2. Maintenance System a. Manhour costs b. Manhour capacity c. Turnover rates	Maintenance Manpower	Staff Officer Repair and Overhaul (SORO); Director of Costing; Director of Postings Airmen (DPA).
3. Supply System a. Inventory management b. Lead times c. Packaging and handling d. Transportation costs	Inventory Management; Transport, Packaging, Handling; Standards	Head Quarters Support Command Support Groups (HQSC-SG).
4. Support Equipment a. support equipment requirements/ costs b. availability of existing equipment c. facilities cost	Support Equipment; Facilities; Software	Manufacturer; Department of Administrative Services; HQSC - AEENG6; User unit
5. LRU Data a. LRU description b. LRU removal/ repair times c. MTBF data d. General support requirements	RLA record Tooling	Manufacturer; SORO; HQSC - AEENG6;

Table 1: NRLA - RAAF RLA - Data Sources (Continued)

Condensed NRLA Requirements (1)	RAAF RLA (2) Requirements	Possible Sources
6. LRU Data a. SRU description b. Types of failure c. Parts required to repair d. personnel required to repair e. training required to repair f. technical publications req'd	RAAF RLA record; Spares, Consumables; Training; Maintenance Publication Costs; Maintenance Manpower.	Manufacturer; HQSC-SG; HQSC- Ground Training HQSC- Publications Director of Costing; SORO; DPA;
7. SRU Failure Mode a. Types of failure b. Associated SRU c. Parts required to repair d. personnel required to repair e. training required to repair f. technical publications req'd	RAAF RLA record; Spares, Consumables; Training; Maintenance Publication Costs; Maintenance Manpower.	Manufacturer; HQSC-SG; HQSC- Ground Training HQSC- Publications Director of Costing; SORO; DPA;
8. LRU/SRU/SE Cross Reference a. Relationship between LRU, SRU and SE (3)	-	Manufacturer
-	Data Process Support (4); Engineering Mnagemnt (4)	Computer Services Division; Director of Costing.

Notes:

1. see Appendix A for complete listing of NRLA input requirements.
2. see Appendices B,C, and D for more detail on RAAF RLA input requirements.
3. preliminary survey shows no apparent equivalent data input requirement for RAAF RLA.
4. preliminary survey shows no apparent equivalent data input requirement for NRLA.

Column 2 lists the input requirements for the existing RAAF RLA procedures as they relate to the NRLA inputs. Detailed RAAF RLA input requirements are specified in Appendices B and D.

There is not an unique one-to-one relationship between NRLA and RAAF RLA data requirements, as NRLA is more comprehensive and, therefore, requires more detailed inputs than RAAF RLA. However, Table 1 does show that similar factors are considered in both methods of RLA, only the level of detail and input combinations differ.

Column 3 of the Table 1 identifies possible sources of RAAF data for the various RLA inputs. These sources represent preliminary contacts and any refinement or detailing of the sources should be the subject of future investigation. As stated previously, the mechanics of extracting and modifying data for use in NRLA or RAAF RLA is beyond the scope of this study. It should be noted that, in addition to the sources listed, modified LSA data from equivalent USDoD major equipment and aircraft could be used to determine RLA costs.

If data input requirements for the existing RAAF RLA procedures and NRLA based procedures can be resolved, the RAAF can:

a. use the existing RAAF procedures for analysis of simple components, and

b. use NRLA for more complex components or subsystems where allocating support equipment costs or conducting sensitivity analysis is important.

Summary

An analysis of the data collected in this research shows that there are four major problems with the present RAAF RLA methods. These include:

a. identifying where data can be obtained to determine standardized cost elements;

b. manipulating data from existing sources to make it suitable for developing standardized cost elements;

c. developing better methods for allocating support equipment costs between multi use items; and

d. developing easier ways to perform sensitivity analysis.

NRLA can address the latter two problems, provided NRLA data input requirements can be satisfied. To improve existing RLA methods or successfully introduce a NRLA based RLA, data specification and sourcing difficulties must be solved.

The mechanics of extracting information from cata sources and modifying it for input to NRLA or the existing method of RAAF RLA has not been investigated and is beyond the scope of this research. However, the researcher has provided a survey of the possible sources of data for RAAF NRLA based RLA at Table 1.

Conclusions and recommendations made as a result of this research are contained in the following chapter.

V. Conclusions and Recommendations

Overview

The purpose of this research was to evaluate the suitability of NRLA as the primary Repair Level Analysis tool for the RAAF.

DMP-AF and CAPPROJ are concerned about the way RLA is currently being conducted in the RAAF (21, 5:1, 19:1-3). At present RLA is conducted using a broad set of procedures developed in 1981. RAAF RLA for complex equipment or sub systems is described as a mixture of engineering judgement and black magic (17:1). RAAF management's belief is that NRLA would provide:

a. a more scientific approach to RLA and thus reduce the RAAF's reliance on the individual analyst's experience, and

b. a means of accommodating SRU/LRU indenture when allocating support equipment costs (5:1).

The research process began with the documentation of existing RAAF and USAF RLA procedures. This was achieved by reviewing orders and instructions on RLA and confirming published information through informal interviews with repair level analysts. Drawbacks of existing RAAF procedures were then determined through formal interviews with RAAF analysts and reviews of correspondence on previous RLA projects.

The next step was to ascertain if NRLA based RAAF RLA could overcome some of the drawbacks of present RAAF RLA procedures. NRLA was found to offer improvements over existing methods of RAAF RLA. Therefore, the final stage of the research identified possible sources of data to support NRLA based RAAF RLA.

Conclusions

As a result of the research four conclusions can be made. First, the research confirmed RAAF management's belief that existing methods of RAAF RLA do not adequately address LRU/SRU indenture when allocating support equipment costs. The belief that there is a heavy reliance on individual analyst's experience was also confirmed. Analysts are relied upon to:

a. identify where data can be obtained to develop standardized cost elements, and

b. manipulate data from existing sources to make it suitable for developing standardized cost elements.

Second, existing RAAF RLA methods make it difficult and time consuming to conduct any form of sensitivity analysis. For each variation from the original case, the entire manual RLA process has to be repeated, as if a new component was being evaluated.

Third, a NRLA based RLA would offer improvements over existing RAAF RLA methods in the areas of allocating support equipment costs between indentured items, and sensitivity analysis. This is because:

a. RAAF RLA requires the manual allocation of support equipment costs, with no means of systematically accounting for SRU/LRU interdependencies. In contrast, NRLA allows the relationships between SRU's and LRU's to be modeled as a network. Support equipment costs are automatically attributed to SRUs and LRUs by NRLA on the basis of LRU/SRU/SE interdependency. NRLA therefore provides a system-wide optimal repair solution rather than an individual component solution as is the case with existing RAAF procedures. This makes it particularly useful for analyzing complex components or sub assemblies; and

b. A standard NRLA output can contain a specific solution and several different sensitivity analysis for a complex component or sub system. Further sensitivity analysis and changes to input data can be accommodated by changing one or two data cards.

Fourth, although NRLA offers improvements over existing RAAF procedures, it is at a cost of greater data dependence. The RAAF already has difficulties satisfying data requirements for existing RLA procedures. NRLA data requirements are more comprehensive than RAAF RLA data requirements (refer to Appendices A and B). Therefore, it would be more difficult to satisfy NRLA data needs. If NRLA was introduced to the RAAF using current data collection and cost estimation procedures, there would be greater rather than less reliance on the experience of individual analysts. This is because the comprehensive data input requirements of NRLA would require more effort and expertise by the analysts to identify, collect, and manipulate data for input cost estimation.

If current data collection and cost estimation procedures could be improved, the existing RAAF RLA procedure would be suitable for simple components, and a NRLA based RLA could be used to effectively analyze complex components, or sub systems.

Recommendations

This research has established that RAAF RLA requires improvements, and that NRLA can provide some of those improvements. However, regardless of which RLA procedure the RAAF uses, data collection is a major constraint. To address data collection difficulties and the introduction of NRLA it is recommended that:

a. Data sources for existing RAAF RLA and NRLA based RLA be identified and documented. Table 1 in chapter IV details possible sources of data for existing RAAF and NRLA based RLA. However, further investigation is required,

b. Data sources be required to produce data in an acceptable form for RLA input. USDoD LSA data requirements may provide a useful reference to develop the proper data elements for RLA cost elements,

c. Only after appropriate data sources and data formats are available should NRLA be introduced to the RAAF, and

d. NRLA's use in the RAAF should be limited to the analysis of complex components or sub systems where it's strength in allocating support equipment costs and sensitivity analysis will contribute to a better quality RLA. With improved data collection procedures, existing RAAF RLA methods should be preferred for the analysis of simple components.

It is the author's studied opinion that the use of NRLA can improve the effectiveness of RAAF RLA in the analysis of complex components and sub systems. However, before NRLA can be introduced to the RAAF data collection and cost estimation problems must be addressed.

Appendix A: NRLA Input Data Requirements

1. **Weapon System Data**

   a. End item name.

   b. Number of bases.

   c. Fraction of number of systems deployed overseas.

   d. Operational life of system in years.

   e. Number of systems at each base.

   f. Operating hours per month.

   g. Cost of developing support equipment for the system (in $1000).

   h. Type of sensitivity analysis required.

   i. Range information for sensitivity analysis.

2. **Maintenance System Data**

   a. Available work time per month for an intermediate maintenance man (manhours/month).

   b. Hourly rate for intermediate level maintenance man ($/hour).

   c. Available work time per month for a depot level maintenance man (manhours/month).

   d. Hourly rate for depot level maintenance men ($/hour).

   e. Annual turnover rate at intermediate level.

   f. Annual turnover rate at depot level.

3. Supply System Data

a. Initial management cost to introduce a new item to the inventory system.

b. Recurring management cost to maintain an item in the wholesale inventory system.

c. Annual management cost to maintain an item in the base level supply system ($/item/year).

d. Time between initial order for an item and the receipt of that item at a continental base (months).

e. Time between initial order for an item and the receipt of that item at an overseas base.

f. Cost of packing for shipment to continental bases ($/pound).

g. Cost of packing for shipment to overseas bases ($/pound).

h. Ratio of packed weight to item weight for continental shipments.

i. Ratio of packed weight to item weight for overseas shipments.

j. Shipping rate to continental locations ($/pound).

k. Shipping rate to overseas locations ($/pound).

l. Cost per original page of technical data produced by the contractor to support item repairs ($/page). (Note: does not include reproduction and distribution costs).

4. Support Equipment Data

a. Support equipment identification number that identifies the general category that the support equipment falls into.

b. Support equipment name.

c. Cost per unit of the support equipment ($/unit).

d. Annual maintenance and operating costs to support one unit of the support equipment ($/year).

e. Number of existing units of support equipment per location (for common support equipment only).

f. Average in-use time for each of the existing support equipment units (hours/month).

g. Expected time that a unit of support equipment will be available for item repairs (hours/month).

h. Cost of new facilities or environmental controls required for the support equipment ($).

5. Line Replaceable Unit (LRU) data

a. LRU identifier.

b. LRU name.

c. Number of LRUs per end item.

d. Cost of one unit of the LRU ($/unit).

e. Weight of the LRU (pounds).

f. Ratio of end LRU operating hours to end item operating hours.

g. Elapsed time between removal of a failed LRU at a continental base until that item could become a serviceable spare in depot stock (month).

h. Elapsed time between removal of a failed LRU at an overseas base until that item could become a serviceable spare in depot stock (months).

i. Elapsed time between removal of a failed LRU at a base until it could become a serviceable spare in base stock (months).

j. Fraction of LRU failures that could be repaired at the organizational level (on equipment maintenance).

k. Total number of kinds of general purpose support equipment resources required at both depot and intermediate level for LRU repair.

l. Mean time between failures for the LRU in its operating environment.

6. LRU Failure Mode Data

a. LRU identifier.

b. Failure mode identifier (different number for each type of failure).

c. Frequency of this type of failure (from b.) as a fraction of all failures for an LRU.

d. SRU identifier for the SRU associated with the specified LRU failure mode.

e. SRU name.

f. Number of new parts or assemblies required for the repair.

g. Number of standard parts (i.e., parts already in the inventory system) required for the base inventory if the LRU is base repaired.

h. Cost of all non-reparable assemblies and parts required for repair of specified failure mode ($).

i. Weight of non reparable parts required (pounds).

j. Minimum number of depot maintenance personnel to be trained for repair task (optional entry).

k. Minimum number of base maintenance personnel to be trained for repair task (optional entry).

l. Number of maintenance manhours required for depot level repair (manhours/item).

m. Number of maintenance manhours required for base level repair (manhours/item).

n. Maintenance training time required to teach the skills for repair (weeks).

o. Material and instruction costs for the required training ($/week/person).

p. Number of pages of technical data required for the repair task (pages/repair).

q. Total number of special support equipment resources required.

r. Forced LRU failure mode decision (optional allows comparisons to be made).

s. Number of hours the support equipment is required to aid in the repair of the specified failure mode (hours/repair).

7. Shop Replaceable Unit (SRU) Data

a. SRU identifier.

b. Unit cost of SRU ($/unit).

c. Weight of SRU (pounds/SRU).

d. Cost of parts and assemblies used in SRU repair ($/SRU repair).

e. Weight of parts and assemblies used in repair (pounds).

f. Number of new parts and assemblies used (No./SRU repair).

g. Number of standard parts required for repair of SRU.

h. Number of technical pages required for repair.

i. Number of kinds of support equipment resources used in repair.

j. Elapsed time between removal of failed SRU from an LRU at a continental base until it repaired and ready to be shipped (months).

k. Elapsed time between removal of failed SRU from an LRU at an overseas base until it repaired and ready to be shipped (months).

l. Elapsed time between removal of failed SRU from an LRU at a base until it repaired at the base and ready for use (months).

m. Time required to repair at depot (hours).

n. Time required to repair at base (hours).

o. Number of persons to be trained at depot to repair SRU (optional).

p. Number of persons to be trained at base to repair SRU (optional).

q. Time taken to train repairman (weeks).

r. Material and Instruction costs to train repairman ($/person/week).

s. Forced SRU decisions (see item 6-r on forced LRU decisions).

t. Number of hours of support equipment required to repair SRU (hours/repair).

8. LRU/SRU/SE Cross Reference Table

The purpose of this data record is to specify the relationship between the system LRUs, SRUs and support equipment. This is achieved by cross referencing LRU and SRU system identifiers entered in earlier records, and matching them with failure modes and support equipment resource numbers, also entered earlier.

Adapted from 3:15-25

Appendix B: <u>RAAF RLA Cost Elements</u>

Cost Element	Initial Cost Considerations	Follow on Cost Considerations
1. Maintenance Publications	. Selection . Validation . Purchasing . Cataloguing . Manpower	. Configuration Amendments . Manpower
2. Training	. Finite	. Finite
3. Maintenance Manpower	. Negligible	. Finite
4. Support Equipment	. Selection . Purchasing . Distribution . Installation . Testing	. Maintenance cost including Calibration and contractor support
5. Tooling	. Selection . Purchasing	. Maintenance . Wastage
6. Spares	. Selection . Data Gathering . Purchasing . Computation	. Wastage . Storage . Distribution . Transportation
7. Consumable Repair Parts	. Selection . Purchasing . Computation . Ordering . Management Coding . Life of Type ?	. Replenishment . Holding Costs . Depreciation
8. Software	. Selection . Purchasing	. Configuration Management . Maintenance
9. Facilities	. Space Allocation . Proportion . Finite Cost	. Maintenance . Finite Cost
10. Transportation Packaging and Handling	. Finite Cost	. Transportation costs for maintenance

11.	Standardization	. Effort to Standardize	. Support of Standard Items
12.	Data Processing Support	. Cost of project support	. Cost of on going data maintenance . Large and Finite
13.	Inventory Management	. Item entry control	. Finite . Disposal costs
14.	Engineering Management	. Finite	. Finite

Source: 18:6213H2

Appendix C: CAPPROJ RLA Cost Comparison Chart

Cost Elements (refer appendix B)	Dicard Level NR	R	Depot Level NR	R	Inter Level NR	R	Oper Level NR	R	Over-Seas NR	R	Con-tract NR	R
1. Maintenance Publications												
2. Training												
3. Maintenance Manpower												
4. Support Equipment												
5. Tooling												
6. Spares												
7. Consumable Repair Parts												
8. Software												
9. Facilities												
10. Transport Packaging an Handling												
11. Standards												
12. Data Process Support												
13. Inventory Management												
14. Engineering Management												
TOTALS												
TOTAL LIFE CYCLE COSTS												

Source (18:6213J1)

Appendix D: CAPPROJ RLA Record

This certificate records the CAPROJ RLA solution at Project Transition within the Project .... for TMP reference ....

Overview Conclusion	Project Officer Comments
Consideration has been given to life cycle costing and strategic implications.	
Maintenance levels (including repair levels) and allocations of maintenance activities to venues appear consistent with the manufacturer's recommendations.	
The maintenance policy is/is not based more on strategic considerations than economic factors.	
The maintenance policy is/is not based on management of similar items already in service.	

Date

CAPROJ Project Officer

Technical Management Code			1. Item Name		
2. True Mfr Name			3. True Mfr Reference No		
4. NHA Reference No		5. True Mfr Code		6. QTY/End Item	
7. Price			8. Construction		
Unit Cost	Break QTY	Unit Cost at Break	Modular		Integral
9. Item Code			10. Expected Lives		
System	LRU	Module/Part	MTBUR		MTBSR
11. Maintenance Factor			12. Condemnation Factor		
Oper	Inter	Depot/Cont	13. SMR Code		14. Manhr REP/OH
15. Item Description:					
16. Description of Maintenance to be accomplished:					

17.	RAAF Maintenance concept which guides maintenance policy formulation:
18.	RAAF maintenance policy to which spares assessing began:
19.	RAAF maintenance policy at Project Transition:
20.	Confidence in cost factors accuracy for RLA:
21.	Explanation of strategic factors causing override of an Economic Solution (if any):
22.	Additional RLA reference Material:

Enclosures: 1. CAPROJ RLA Cost Comparison

2. PATTRIC Print out (if applicable)

Source: 18:6213G1

Appendix E: Interview Respondents

1. Wing Commander S. Lang, 3AD (formerly of CAPROJ), Author of Headquarters Support Command Logistic Branch Instructions on Repair Level Analysis.

2. Squadron Leader K. Henderson, HQSC-AIRENG2 (formerly of CAPROJ), manager of the RLA team for the BlackHawk and Squirrel projects.

3. Flight Lieutenant G. Breen, DMP-AF, responsible for reviewing BlackHawk repair policy at the Headquarters Defence Force Level.

4. Warrant Officer W. Sparrow (CAPROJ), repair level analyst on the BlackHawk project.

5. Sergeant P. Walde (CAPROJ), repair level analyst on the BlackHawk project.

6. Sergeant P. Rackley (CAPROJ), repair level analyst on the BlackHawk project.

7. Corporal S. O'Donoghue (CAPROJ) repair level analyst on the BlackHawk project.

Appendix F: Initial Interview Questions

Introductory Remarks.

Hello I am Squadron Leader John Eckel, I am calling from the USA where I am doing the graduate logistics course. For my thesis I am investigating repair level analysis procedures for the RAAF. I understand that you are (have been) involved in RLA and wonder if I can take some of your time to answer some questions about the way RAAF does RLA? I will be talking to a number of people involved in RLA and while I will list you as a respondent I will not attribute any comments directly to you. Under these conditions would you object if I recorded this conversation so as I do not have to take notes while talking?

Part 1 - Procedural Questions

The first set of questions I will ask you deals with the procedures and guidelines for RAAF RLA as published in Support Command Logistics Instructions. My purpose is to see if guidelines are followed in practice, and to fill in some of the gaps left by the instructions.

1. The first stage in the RAAF RLA process involves determining if an item is intrinsicly repairable. How do you decide if an item is repairable or not?

2. Certain Costs must be gathered to perform RLA, how do you gather these costs?

3. If for some reason accurate cost data for RLA calculations can not be obtained, how do you resolve the matter?

4. If an overseas Service has already determined a repair policy for a component being considered by the RAAF, how does this influence the RLA process?

5. How do you modify an overseas maintenance policy to meet RAAF requirements?

Part 2 - Opinions of Present Methods

The purpose of the next set of questions is to get your opinion on the procedures that are used for RAAF RLA. Again

I remind you comments will not be attributed directly to you. For each question I want you to give me your general impression (e.g. not satisfactory, satisfactory, very satisfactory). From there we will discuss the reasons behind your response.

1. How would you describe the present methods of gathering cost element data for the RLA process?

1	2	3
Not satisfactory	Satisfactory	Very satisfactory

Comments:

2. In particular, how would you describe the present method of allocating support equipment costs to components?

1	2	3
Not satisfactory	Satisfactory	Very satisfactory

Comments:

3. How would you describe the present method of conducting sensitivity analysis?

1	2	3
Not satisfactory	Satisfactory	Very satisfactory

Comments:

4. How would you describe your discussions with DMP-AF when you are trying to resolve data collection inadequacies (if any) in the RLA process?

1	2	3
Not satisfactory	Satisfactory	Very satisfactory

Comments:

5. How would you describe the present method of comparing life cycle costs for repair alternatives?

1	2	3
Not satisfactory	Satisfactory	Very satisfactory

Comments:

6. How would you describe your discussions with DMP-AF staff when draft maintenance policies are being reviewed?

1	2	3
Not satisfactory	Satisfactory	Very satisfactory

Comments:

7. How would you describe the procedures for finalizing maintenance policy in a TMP?

1	2	3
Not satisfactory	Satisfactory	Very satisfactory

Comments:

Part 3 - Scientific Rigor of RLA Procedures

I want to finish off the interview by asking you some questions about the experience required of an individual to successfully perform RLA in the RAAF.

1. How important is it that someone with the right background does RLA?

1	2	3
Not Important	Important	Very Important

Comments:

2. What would be the impact of an inexperienced individual performing RLA?

1	2	3
Negligible	Minor Problem	Major Problem

Comments:

<u>Concluding Remarks</u>

Thankyou for your co-operation, if you are interested in the findings of my thesis please contact me at DMP-AF (MP1A) any time after November 1989.

Appendix G: Final Interview Questions

Introductory Remarks.

Hello I am Squadron Leader John Eckel, I am calling from the USA where I am doing the graduate logistics course. For my thesis I am investigating repair level analysis procedures for the RAAF. I understand that you are (have been) involved in RLA and wonder if I can take some of your time to answer some questions about the way RAAF does RLA? I will be talking to a number of people involved in RLA and while I will list you as a respondent I will not attribute any comments directly to you. Under these conditions would you object if I recorded this conversation so as I do not have to take notes while talking?

Part 1 - Procedural Questions

The first set of questions I will ask you deals with the procedures and guidelines for RAAF RLA as published in Support Command Logistics Instructions. My purpose is to see if guidelines are followed in practice, and to fill in some of the gaps left by the instructions.

1. The first stage in the RAAF RLA process involves determining if an item is intrinsicly repairable. How do you decide if an item is repairable or not?

2. Certain Costs must be gathered to perform RLA, how do you gather these costs?

3. If for some reason accurate cost data for RLA calculations can not be obtained, how do you resolve the matter?

4. If an overseas Service has already determined a repair policy for a component being considered by the RAAF, how does this influence the RLA process?

5. How do you modify an overseas repair policy to meet RAAF requirements?

Part 2 - Opinions of Present Methods

The purpose of the next set of questions is to get your opinion on the procedures that are used for RAAF RLA. Again I remind you comments will not be attributed directly to you.

For each question I want you to give me your general impression (e.g. not satisfactory, satisfactory). From there we will discuss the reasons behind your response.

1. How would you describe the present methods of gathering cost element data for the RLA process?

1	2
Not Satisfactory	Satisfactory

Comments:

2. In particular, how would you describe the present method of allocating support equipment costs to components?

1	2
Not satisfactory	Satisfactory

Comments:

3. How would you describe the present method of conducting sensitivity analysis?

1	2
Not satisfactory	Satisfactory

Comments:

4. How would you describe your discussions with DMP-AF when you are trying to resolve data collection inadequacies (if any) in the RLA process?

1	2
Not satisfactory	Satisfactory

Comments:

5. How would you describe the machanics of completing the RLA process once cost data has been collected?

1	2
Not satisfactory	Satisfactory

Comments:

6. How would you describe your discussions with DMP-AF staff when draft maintenance policies are being reviewed?

1	2
Not satisfactory	Satisfactory

Comments:

Part 3 - Scientific Rigor of RLA Procedures

I want to finish off the interview by asking you some questions about the experience required of an individual to successfully perform RLA in the RAAF.

1. How important is it that someone with the right background does RLA?

1	2
Not Important	Important

Comments:

Concluding Remarks

Thank you for your co-operation, if you are interested in the findings of my thesis please contact me at DMP-AF (MP1A) any time after November 1989.

Appendix H: Detailed Interview Responses

Detailed responses to the questionnaire contained in Appendix G are shown below. The responses quoted are largely in the words of the respondents, only minor amendments have been made to improve the readability of the comments. Where two or more individuals made the same response to a question only a single representative quote has been listed. Editorial comments have been included in parentheses [].

Part 1 - Procedural Questions

1. The first stage in the RAAF RLA process involves determining if an item is intrinsically repairable. How do you decide if an item is repairable or not?

"Well it is pretty much common sense, something like an aircraft bolt is obviously not repairable."

"For most components it is obvious if something can be repaired or not, for example an aircraft windscreen is either serviceable or not, you cannot 'repair' a crazed windscreen."

"Usually you can use common sense to decide if something is repairable or not. However, in some instances, especially where we think a part would require a lot of infrastructure or specialist test equipment support, we look at what the USA has decided. The US military have SMR codes that can tell you if an item is to be 'repaired on failure' or discarded. If the US have annotated an item as 'discard' then its likely development of support equipment and infrastructure is too costly and we would probably adopt a 'discard on failure' policy too."

"I am not sure I understand your question, its usually obvious if a component is repairable or not. In fact, most times I think you decide on that almost subconscientiously."

2. Certain costs must be gathered to perform RLA, how do you gather these costs?

"In the BlackHawk case we first gathered cost data individually. Then after some time we had a meeting and went through each of the elements and decided through group discussion what the value of each of the elements was going to be for the BlackHawk RLA."

"We were lucky that some people in the section had been posted in from SORO [Staff Officer Repair and Overhaul] and other areas of HQSC, they knew where to go to find some of the cost data we needed or at least provide an educated guess of costs if the data was not available."

"We all had a go at trying to determine cost elements and then met as a group to arrive at a consensus cost for each element. There are no actual instructions on where to go to get cost element data."

"Some of us had contacts in SORO, others knew where to go in SOPUBS [Staff Officer Publications]; we all did our best to track down the cost data and then met as a group to determine final cost element values before completing the RLA on the BlackHawk."

"During the BlackHawk RLA we gained access to LSA data prepared for the US military. The LSA data filled in some of the gaps as far as cost data was concerned, but we had to be wary of using it. For example, USDoD publication costs usually include the cost of initial development and production. The cost to the RAAF would not include any development costs, but would include costs of changes in the publications to meet RAAF maintenance practices.

3. If for some reason accurate cost data for RLA calculations can not be obtained, how do you resolve the matter?

"Having accurate cost data was a problem.. We used meetings between analysts to try an determine 'consensus' values for cost elements... We sorted out cost data problems within the Capital Project area."

"Determining the value cost elements was done with Capital Projects, any problems were resolved by us [CAPROJ]. DMP-AF have the opportunity to question our choice of costs when they review the recommended RLA decision from HQSC."

"I [DMP-AF representative] have had trouble sometimes trying to work out how they [CAPROJ] have determined some cost element values and expected number of arisings. We usually do not hear from CAPPROJ until they provide their RLA recommendation and supporting documentation."

"We usually sorted out any data problems we had in-house. Accuracy was sometimes a problem in terms of having the right sort of data on which to base cost element estimates. The matter was resolved by developing a consensus value for cost elements through group meetings."

4. If an overseas Service has already determined a repair policy for a component being considered by the RAAF, how does this influence the RLA process?

"We have a close look at what overseas Services have done. In particular, we make use of LSA data that is available from the US military."

"Although Overseas experience is a useful starting point, it is unwise to apply it directly to Australia. Full costing of each alternative should still be conducted to determine the most economical approach from the RAAF point of view. For instance, a component that is repaired at a depot in the USA may be more economical to repair at an intermediate workshop in Australia, or alternatively the low number of arisings in Australia may make it more economical to send components to the USA for repair."

"Overseas policy has an impact in two areas. First if they have decided that a component should be discarded on failure because of low replacement cost but high servicing cost then we most likely will adopt the same policy. Second, the data used to arrive at an overseas repair policy may be useful in determining a RAAF maintenance policy."

5. How do you modify an overseas repair policy to meet RAAF requirements?

"As I have mentioned, we sometimes take LSA data from the US military, make sure the costs relate to the RAAF, or modify the costs so that they do, and then use that data in part of the RLA calculations [see response Part 1 question 2]."

"We do not actually modify policy, it is more like taking the information [data] they used to arrive at their policy and modifying it to suit our analysis."

"This question seems similar to the last one; I do not think we take the overseas policy and modify it, rather we look at how they arrived at that decision (if we can get the data) and see if that is applicable to the RAAF."

Part 2 - Opinions of Present Methods

1. How would you describe the present methods of gathering cost element data for the RLA process?

Not Satisfactory - 2 Satisfactory - 5

"I think you have to be wary of some of the figures that analysts come up with. Often we [RAAF] have this attitude that we can do it better and cheaper than other countries; sometimes this results in costs and failure rate estimates being too optimistic."

"The method of collecting and evaluating data for cost elements is not ideal, [method is described in response to Part 1, question 2], but I think it's the best and most consistent way of doing things under existing conditions."

"I think the procedure we used of going out individually to get cost data, and then meeting as a group to decide what data to use in the RLA was a good way of making sure all available sources of data were investigated."

"I was happy enough about how we determined cost element data, but I would have liked to have some sort of documented procedure telling me where I should go to get the data and what form that data should be in. Sometimes we could identify where the data should come from, but they would not have kept details of the information we wanted."

"We had meetings to try and determine the right value for cost elements in the BlackHawk analysis. We did the best we could, but had some problems. For example, initial publication costs varied in price depending on the source of the data. Inventory cataloging costs had no identifiable source at all. In both cases a standardized 'best guess' was made because there was not an identifiable reliable data."

2. In particular, how would you describe the present method of allocating support equipment costs to components?

Not satisfactory - 7 Satisfactory - 0

"I do not think we do a good job of allocating support equipment costs. For complex components we are really guessing at the allocation of costs on the basis of support equipment usage."

"Not only are we having problems allocating costs between components using new support equipment, but we are having trouble allocating proportional use of existing ground support equipment for new components."

"When we started BlackHawk RLA we used to allocate the entire cost of the support equipment to each and every component using it. Then we got a bit wiser and now attempt to allocate cost on the basis of usage. This is difficult though, especially when you have a complex piece of kit with many sub components [LRU/SRU], all of which use the same piece of test equipment."

"I am still not too sure about how to go about allocating support equipment costs to new components. If the support equipment already exists, we have to try and work out the time it can be used for servicing the new component, if there is enough time available to meet servicing needs, and the cost that should be given to the component for its share of support equipment use. If new support equipment is to be purchased, the cost of usage per component serviced has to be worked out for RLA calculations. All of this is hard to do, with the data available, it is like crystal balling."

3. How would you describe the present method of conducting sensitivity analysis?

Not Satisfactory - 3 Satisfactory - 0

Note: some of the respondents were not aware of the term sensitivity analysis. However, they did comment on procedures employed to answer 'what if' type questions. All responses were noted; however, only those who understood the term sensitivity analysis had their satisfactory/unsatisfactory responses recorded.

"Sensitivity analysis was limited to running variations on the PATRIC model and crunching the numbers using the normal RLA manual process. There were no shortcuts, varying one parameter still required the whole RLA process to be repeated, the same as if we were looking at a new component for the first time."

"I do not think we do any sensitivity analysis, at least I do not think any one asked us to. If we had to answer 'what if' questions [meaning of 'what if' questions explained by interviewer], I think we would have to redo the analysis from scratch."

"I am not sure that we are doing sensitivity analysis but soon we will be redoing some major components from the

BlackHawk RLA; any changes in the data for that will cause us to redo the entire analysis for the component concerned."

"We [DMP-AF] do not normally task CAPROJ with doing sensitivity analysis, the present RLA procedures make it vary time consuming and we do not think they have the staff or time to handle it. For sensitive components, for example allocation of BlackHawk gearboxes to civilian or military depots, we sometimes try and do an 'ad hoc' form of sensitivity analysis here [DMP-AF]. In recent times the need for sensitivity analysis has increased as 'what if' questions about civil versus military maintenance of major components are investigated."

"If sensitivity analysis means adjusting different inputs to see what the output changes to, then we do not do that here [CAPPROJ]."

4. How would you describe your discussions with DMP-AF when you are trying to resolve data collection inadequacies (if any) in the RLA process?

Not satisfactory - 0 Satisfactory - 6

<u>Note:</u> *one of the respondents did not answer this question as he had not had any direct dealings with DMP-AF.*

"Sometimes they [DMP-AF] ask us to look at RLA of components again *in light of new information on contractor* versus military support, especially if there is some question over military versus civilian repair facilities being established. To do this we have to virtually redo the whole RLA."

"They [DMP-AF] sometimes question us over the figures we have chosen for cost elements in RLA calculations. But usually after we have provided additional information they [DMP-AF] are happy about what we have done."

"Every now and then DMP question some of the assumptions we have used for calculating cost element or failure rate figures. Usually all they want is some more information on why we did what we did and once we supply that they are happy.

"I do not think we have any problems with DMP, they ask us for more information and we give it to them."

5. How would you describe the mechanics of completing the RLA process once cost data has been collected?

Not satisfactory - 2 Satisfactory - 5

"Once the cost elements have been decided upon the mechanics of calculating life cycle costs for the various repair alternatives are pretty simple. We follow the HQSC instructions very closely."

"HQSC instructions are easy to follow when calculating alternative repair costs. A DBASE[R] program is used to automate the adding up of cost elements for the different repair alternatives."

"Recently we have been asked to do some 'what if' calculations to do with the BlackHawk transmission, The manual procedures mean we have to do the recalculations from the start. It is the same amount of work as if we were looking at a new component. This is not so bad for simple components where costs are straight forward, but for complex components or sub systems it is a tedious process."

"The mechanics of the RLA process, after the cost elements have been determined, are easy to complete.... What takes up time is the need to run PATRIC for each repair alternative [operational, depot, intermediate] to get spares requirements and cost data. Obviously, the more complex the component or system, the more time it takes."

"The problem with [RAAF] RLA is not the process that occurs after the cost elements have been determined; its with getting those cost elements in the first place. If the data problems could be solved, the existing procedures would be fine for determining RLA for simple components. More complex components would still be a bit tricky because of the support equipment cost problem, but simple components could be accurately analyzed."

6. How would you describe your discussions with DMP-AF staff when draft maintenance policies are being reviewed?

Not satisfactory - 0 Satisfactory - 6

Note: one of the respondents did not answer this question as he had not had any direct dealings with DMP-AF.

"Sometimes there is a bit of discussion regarding the way we determined some cost element figures, but this is usually sorted out amicably."

"The review of draft maintenance policies is usually the only time we talk to DMP about RLA other then the original RLA specifications they provide us with. Usually their only inquiries are about the assumptions we have made in RLA calculations. We are usually happy to talk to each other."

"Sometimes we discuss our reasons for assigning cost element figures or failure rates for particular components. As I said before, they ask for more justification and we provide it, that usually makes everybody happy."

"I think DMP and CAPPROJ get on well together as far as sorting out any problems with RLA. I think we both realize there are limitations with the present system and that CAPPROJ is doing the best job that it can."

Part 3 - Scientific Rigor of RLA Procedures

1. How important is it that someone with the right background does RLA?

Not Important - 3 Important - 4

"Provided a person has the right trade background, and enthusiasm and belief in the task, he will be a good analyst."

"It was important to have people in the group with previous experience in HQSC, especially those with spares assessing or SORO experience. This is because they knew where to go to track down cost data."

"To do BlackHawk RLA you would have to have helicopter experience to be familiar with the terminology and the components you might come across. It is also handy, but not essential, to have some HQSC experience to know where to go to track down cost element data. Mind you, provided a few of the analysts have HQSC experience they can find the data on behalf of the rest of the group."

"We had troops straight from the unit and troops with HQSC experience working on the BlackHawk RLA. The ones that did the best seemed to be the ones that were the most enthusiastic whether they had HQSC experience or not."

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Vita

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This research evaluates the suitability of the United States Air Force (USAF), Network Repair level Analysis (NRLA) model as the primary Repair Level Analysis (RLA) tool for the Royal Australian Air Force (RAAF). The research documents existing RAAF and USAF RLA procedures, identifies drawbacks of the present method of RAAF RLA, establishes the improvements offered by NRLA over existing RAAF RLA methods, and identifies possible sources of data for both existing and NRLA based RAAF RLA.

RAAF and USAF RLA procedures were documented through a review of orders and instructions, and informal interviews with repair level analysts. Drawbacks of existing RAAF procedures were then determined through formal interviews with RAAF analysts and reviews of correspondence on previous RLA projects.

A comparison of the USAF and RAAF procedures showed that a NRLA based RLA offered improvements over existing methods of RAAF RLA. Therefore, the final stage of the research identified possible sources of data to support NRLA based RAAF RLA.

The major finding of this research was that regardless of which RLA procedure the RAAF uses, data collection is a major constraint. In a first attempt to address this data problem possible sources of data for both existing and NRLA based RAAF RLA have been identified in this thesis. Further study is required to confirm these sources, and to identify methods for extracting and adjusting data from these sources to meet RLA input requirements.

Two recommendations are made:

a. that NRLA not be introduced to the RAAF until data collection difficulties have been resolved, and

b. the RAAF use of NRLA be limited to the analysis of complex components or sub systems where its strength in allocating support equipment costs and sensitivity analysis will contribute to a better quality RLA.