PREPAREDNESS

AND

REPAIRABLE ITEM

MANAGEMENT

Linking Logistics and Air Power

Michelle Maclean

Published by
Air Power Studies Centre
RAAF Base Fairbairn
Canberra
1994

ISBN 0 642 20028 9

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National Library of Australia
Cataloguing-in-Publication entry

Maclean, Michelle.
Preparedness and repairable item management: linking logistics and air power.

Bibliography.
Index
ISBN 0 642 20028 9.

1. Australia. Royal Australian Air Force. Operational readiness. 2. Australia. Royal Australian Air Force - Equipment - Maintenance and repair. 3. Logistics. I. Australia. Royal Australian Air Force. Air Power Studies Centre. II. Title. (Series: Fellowship paper (Australia. Royal Australian Air Force. Air Power Studies Centre);5).

358.40994

Designed by Defence Publications

Published and distributed by:
Air Power Studies Centre
RAAF Base FAIRBAIRN
Canberra, ACT, 2600
AUSTRALIA. Telephone (06) 267 6458

Printed by Union Offset Co. Pty Ltd, Canberra

ACKNOWLEDGMENTS

I would like to express my sincere appreciation to the many people from the Defence community who have assisted in the research and preparation of this book. Numerous people granted interviews during the year and provided valuable written material. For your time and keen interest in the issues surrounding preparedness and logistics I thank you all.

I am particularly grateful for the support provided by the staff at the Air Power Studies Centre in 1993. Notably, Wing Commander Greg Donaldson provided valuable guidance and encouragement throughout the year. Particular thanks also to Leading Aircraftswoman Sharon Wilton and Corporal Andy Morgan for preparation of diagrams; and to my thorough proof readers, Squadron Leader Mark Kelton, Group Captain Gary Waters, and Wing Commander Al Curr.

I pass my sincere appreciation also to Squadron Leader Steve Secker, who is always enthusiastic about Repairable Item management, and reviewed my work prior to publication.

Finally, a heartfelt vote of thanks to my husband, Don, for his constant faith in my abilities.

ABSTRACT

This book was prepared at the Air Power Studies Centre as a Chief of Air Staff's Air Power Fellowship in 1993. The fellowship scheme commenced in 1990, and aims to develop awareness and foster understanding of air power in the Australian context. The aim of this fellowship was to identify opportunities to improve RAAF preparedness through Repairable Item (RI) management, and to recommend means of pursuing these opportunities.

The author has researched the development of the RI system, and investigated the process of preparedness assessment. Starting with fundamental concepts of logistics, RI management, and preparedness doctrine, the book proceeds to examine analysis of RI requirements undertaken in recent preparedness studies. Flaws in study methodologies are identified, particularly with regard to sustainability and logistics analysis.

An altered approach to preparedness assessment has been recommended, based on improved understanding of both the operational environment, particularly in contingency, and logistics support systems. Central to this approach is the teaming of operational staff and logisticians to jointly develop an understanding of the contingency environment and its implications for logistics. A further theme is the need to complement the calculation of preparedness resource requirements with ongoing development of the RI system.

Systems thinking is recommended as an appropriate philosophical basis for ongoing RI system review and development. Systems thinking perspectives are applied to provide insight to the analytical weaknesses of past RI system studies, and the potential contribution of the system dynamics methodology to facilitate a systems thinking approach to RI management is examined.

A series of opportunities are identified to improve RAAF preparedness through RI management, and specific recommendations made for the pursuit of these opportunities. Recommendations have implications for directorates at Headquarters Logistics Command, Weapon System Logistics Management Squadrons, and the Directorate of Logistics Policy at Air Force Office. Additionally, they are relevant to the cooperation of Headquarters Logistics Command and Air Headquarters Australia, and subordinate FEGs/units, in preparedness assessment activity.

Keywords: *logistics, logistics modelling, preparedness, readiness,* repairable item, repairable item management, sustainability, system dynamics, systems thinking

TABLE OF CONTENTS

CHAPTER THREE - REPAIRABLE ITEM MANAGEMENT

CHAPTER FOUR - DEVELOPMENT OF RI MANAGEMENT

CHAPTER FIVE - RI MANAGEMENT OPPORTUNITIES AND ISSUES

CHAPTER SIX - INTRODUCTION TO PREPAREDNESS

CHAPTER SEVEN - PREPAREDNESS STUDIES

CHAPTER EIGHT - PREPAREDNESS IMPLICATIONS FOR RI MANAGEMENT

CHAPTER 9 - SYSTEMS THINKING USING SYSTEM DYNAMICS

CHAPTER 10 - SYSTEM DYNAMICS AND RI MANAGEMENT

CHAPTER ELEVEN - CONCLUSION AND RECOMMENDATIONS - RI MANAGEMENT AND PREPAREDNESS

ANNEXES:

LIST OF FIGURES AND TABLES

CHAPTER TWO

CHAPTER THREE

CHAPTER FIVE

CHAPTER SIX

CHAPTER SEVEN

CHAPTER EIGHT

CHAPTER NINE

CHAPTER TEN

ANNEX A

ANNEX B

ANNEX C

ANNEX D

ANNEX E

ABBREVIATIONS

AAT	Asset Availability Target
AATARS	Aircraft Availability Tracking and Reporting System
ACPP	Air Command Preparedness Project
ACAUST	Air Commander Australia
AD	Aircraft Depot
ADF	Australian Defence Force
ADFP	Australian Defence Force Publication
ADT	Administrative Delay Time
AFO	Air Force Office
AFO WP	Air Force Office Working Party
AFTI	Air Force Temporary Instruction
AHQAUST	Air Headquarters Australia
$\mathbf{A_{it}}$	Item Availability Target
$\mathbf{A_o}$	Operational Availability
AL	Activity Level
AMP	Annual Maintenance Plan
AOC	Air Officer Commanding
AOG	Aircraft Operationally Grounded
APL	Authorised Parts List
AUTOPROC	Automated Procurement
BDS	Break Down Spares
BOA	Basis of Assessment
BPR	Biannual Preparedness Report
CAMM	Computer Aided Maintenance Management
CDF	Chief of the Defence Force
CFU	Carried Forward Unserviceability
CLOG	Controller of Logistics
CORD	CDF Operational Readiness Directive
CPD	CDF's Directive on Preparedness
CSB	Central Studies Branch
CSP	Commercial Support Plan
DECOR	Depot Control and Reporting system
DI(AF)	Defence Instruction (Air Force)
DILP	Directorate of Integrated Logistics Processes
DLD	Directorate of Logistics Development
DLDP	Directorate of Logistics Development and Planning
DLIS	Directorate of Logistics Information Services
DLM	Depot Level Maintenance
DLPD	Directorate of Logistics Procedures Development
DLQPE	Directorate of Logistics Quality, Planning, and Evaluation
DLRP	Defence Logistics Redevelopment Project
DLSPG	Defence Logistics Strategic Planning Guide
DM	Deeper Maintenance

DMMS	Directorate of Major Maintenance Services
DMP	Director of Maintenance Policy
FAK	Fly Away Kit
FE	Force Element
FEG	Force Element Group
FELSA	Front End Logistics Support Analysis
FES	Force Expansion Study
FMECA	Failure Modes, Effects, and Criticality Analysis
HQADF	Headquarters Australian Defence Force
HQLC	Headquarters Logistics Command
HQSC	Headquarters Support Command
HQTC	Headquarters Training Command
ILM	Integrated Level Maintenance
ILS	Integrated Logistics Support
JO	Job Order
LC	Logistics Command
LCC	Life Cycle Cost(ing)
LDT	Logistics Delay Time
LG	Logistics Group
LIMSG	Logistics Information Management Steering Group
LIMSP	Logistics Information Management Strategic Planning
LOAS	List of Authorised Spares
LOG	Logistics
LOGENG	Logistics Engineer
LOGEVAL	Logistics Evaluation
LOGCAS	Logistics Capability Assessment
LRI	Line Replaceable Item
LRU	Line Replaceable Unit
LSA	Logistics Support Analysis
LSAR	Logistics Support Analysis Record
MAARS	Maintenance Activity Analysis and Reporting System
MATRIARC	Multi-Echelon Analysis Technique for Repairable Item Availability and Requirements Computation
MDT	Maintenance Downtime
MEA	Maintenance Engineering Analysis
METRIC	Multi-Echelon Technique for Recoverable Item Control
MIL-STD	Military Standard
MLOC	Minimum Level of Capability
MMI	Maintenance Managed Item
MRPII	Manufacturing Resource Planning
MRU	Manpower Required in Uniform
MSI	Maintenance Supply Item

MTBM	Mean Time Between Maintenance
MTTR	Mean Time To Repair
MUE	MSI Unit Entitlement
NSN	Nato Stock Number
OLM	Operating Level Maintenance
OLOC	Operational Level of Capability
OM	Operating Maintenance
OPUS9	Optimum Utilisation of Spares, Version 9
OVP	Operational Viability Period
P&TSGWG	Procedures & Training Steering Group Working Group
PAT	Process Action Team
PATTRIC	Poisson Availability Target Technique for Repairable Item Computation
PE	Prime Equipment
PLOC	Present Level of Capability
PMB	Program Management and Budgeting
POL	Priority Output List
POM	Purchase Order Maintenance
PREPEVAL	Preparedness Evaluation
QMIN	Minimum Quantity
QPL	Pipeline Quantity
R&M	Reliability and Maintainability
RAAF	Royal Australian Air Force
RAAFQ	RAAF Quality
RAAFSUP	RAAF Supply computing system
RAF	Royal Air Force
RI	Repairable Item
RIAAMS	RI Asset Availability Monitoring System
RIMS	Repairable Item Management System
RLA	Repair Level Analysis
ROAMS	Repair and Overhaul Automated Management System
SERLEV	Servicing Level
SD	System Dynamics
SG	Support Group
SOPP	Staff Officer Plans and Procedures
SOPSL	Staff Officer Project Support and Logistics
SORO	Staff Officer Repair and Overhaul
SORODB	Staff Office Repair and Overhaul Data Base
SP	Sustainability Period
SRLM	Strike Reconnaissance Logistics Management
SRU	Shop-Replaceable Unit

SSRP	Supply Systems Redevelopment Project
SYSENG	Systems Engineer
TAT	Turnaround Time
TECH	Technical
TFLM	Tactical Fighter Logistics Management
TMP	Technical Maintenance Plan
TQM	Total Quality Management
UE	Unit Entitlement
UNDA	Urgency of Need Designator A
UR	Usage Rate
USAF	United States Air Force
WRSK	War Readiness Spares Kit
WSLM	Weapon System Logistics Management

CHAPTER ONE

INTRODUCTION

BACKGROUND

In 1989 a common methodology was introduced for the specification and assessment of preparedness across the Australian Defence Force (ADF). The adoption of this formal framework poses significant challenges for RAAF logistics. Logistics objectives, assumptions, processes, and performance must be critically examined, and the links between logistics and air power explored within this framework. In short, the RAAF has entered a new period which demands disciplined thought about logistics and preparedness.

Headquarters Logistics Command (HQLC) has participated in several ADF and RAAF preparedness studies, the most significant being the Headquarters ADF Force Expansion Study and the Air Command Preparedness Project. These preparedness studies have been conducted in a period of ongoing philosophical and organisational change in the RAAF logistics environment. The need to more closely align logistics activity with preparedness requirements has prompted many of these changes, while some are mandates driven by other considerations, which are pre-dominantly efficiency-based. High priority changes include the integration of logistics functions and implementation of Integrated Logistics Support, formation of Weapon Systems Logistics Management Squadrons and their relocation to operational bases, and the Commercial Support Program. The current logistics challenge is to implement these changes in a manner which aligns with the ADF preparedness framework and enhances RAAF preparedness.

One significant logistics activity which must be re-examined in light of current challenges is Repairable Item (RI) management. An RI is an aircraft sub-assembly[1] which is removed upon failure and repaired. Upon return to a serviceable state an RI can be re-fitted to an aircraft when required. An adequate supply of serviceable RIs is essential to support air operations.

Considerable effort has been expended studying and reviewing the RI management system over the past decade. This reflects its significant impact upon preparedness, and the high level of resources committed to RI management. Despite this effort, many fundamental

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1 RIs do exist for a range of non-aircraft parent equipment; however this paper focuses on aircraft RIs.

questions regarding RI management and preparedness remain unanswered.

AIM

The aim of this paper is to identify opportunities to improve RAAF preparedness through RI management and to recommend means of pursuing these opportunities.

At another level, this paper is intended to promote greater understanding of the role of logistics in support of air power, and to stimulate debate amongst and between logisticians and operational staff on this issue. Logisticians in particular are encouraged to participate in further disciplined analysis of the links between air power and logistics.

The material presented in this paper should challenge prevalent assumptions and perceptions regarding RI management, and encourage people in the logistics system to contribute to its development with greater knowledge of both preparedness and RI management.

METHODOLOGY

Information for this paper was gathered from a variety of sources. The main sources used were:

a. file review at HQLC and Air Force Office;

b. literature review using the Defence Information Services Network (DISNET) and academic libraries, predominantly the Australian Defence Force Academy library;

c. interviews with staff located at Headquarters Australian Defence Force, Air Force Office, HQLC, Air Headquarters Australia, units at RAAF Bases Amberley and Williamtown, and RAAF Representative Officer QANTAS; and

d. a range of defence and civilian courses conducted during 1993.[2]

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2 These courses included (a) Integrated Logistic Support Course conducted by the Department of Defence Acquisition and Logistics Organisation, Project Management Education and Training Section (b) RAAF Reliability Management Course conducted by the Directorate of Materiel Logistics Requirements - Air Force (c)Workshop in Systems Thinking with *IThink*™ presented at the Australian Defence Force Academy by Keith Linard. Additionally, informal training on the OPUS9 RI Spares Assessment model was provided by staff at Staff Officer Project Support and Logistics, HQLC.

Quantitative methods are not used to analyse information gathered. The analytical approach has been to introduce basic aspects of both RI management and preparedness, including discussion of their development, and to explore their relationship from fundamental principles.

A systems thinking paradigm has been adopted. The system dynamics methodology is introduced as a means of facilitating systems thinking. Techniques from this methodology have been applied to elements of the RI management system to demonstrate its potential contribution to system development.

LIMITATIONS

In order to produce an unclassified paper, classified aspects of preparedness policy and studies have not been discussed. This has restricted discussion of various aspects of these topics to a conceptual level.

The RI management system spans several organisational boundaries, both internal and external to the RAAF, and consists of a multitude of activities. Given the breadth of this system, all aspects could not be discussed in equal detail. Emphasis is given to those aspects of most relevance to the preparedness issues raised. Further, time and resource limitations[3] necessitated a restricted scope. Of note, the following aspects are excluded from analysis:

a. non-aircraft RIs, although some of the principles and findings may be equally applicable to aircraft and non-aircraft RIs;

b. weapon system acquisition activities; and

c. detailed examination of infrastructure and defence industry issues.[4]

PAPER STRUCTURE

This paper contains eleven chapters, the first of which is the introduction. The body of the paper can be divided into three broad parts: logistics and RI management, preparedness, and systems thinking.

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3 Although having access to the advice and expertise of several people, this fellowship paper is the product of one person's work over a twelve month period.

4 This issue has significant implications for sustainability, and would probably justify a further twelve month fellowship.

Chapters Two to Five introduce logistics and RI management. Chapter Two introduces the current RAAF logistics environment, the logistics mission, and the implementation of integrated logistics support and weapon system logistics management. Fundamental aspects of RI management are discussed at Chapter Three, including relevant definitions and system objectives. Those familiar with RI management may care to skim or ignore the overview of RI management processes at Annex A. The development of RI management over the past decade is examined in Chapter Four, supported by more detailed discussion at Annex B for those with a keen interest in this subject. Based on material introduced to this point, current RI management opportunities and issues are identified in Chapter Five.

An overview of preparedness doctrine and policy is provided at Chapter Six, which readers with relevant current knowledge may choose to skim. Recent preparedness studies are analysed in Chapter Seven. The Wrigley Review, Air Command Preparedness Project, and Force Expansion Study are examined, with an emphasis on the assessment of RI resource requirements undertaken as part of these studies. Chapter Eight considers preparedness implications for RI management. It highlights the dangers inherent in the approach of calculating RI requirements taken by the RAAF to preparedness and RI management, and argues for a broader approach to system development.

Systems thinking and system dynamics are introduced in Chapter Nine. In Chapter Ten the potential application of systems thinking to RI management using the system dynamics methodology is explored. Insights are provided to the shortcomings of methodologies previously applied to RI management review, and rationale provided for the use of system dynamics. This is supported by analysis of elements of the RI management system using system dynamics techniques in Annexes C to E.

Finally, in Chapter Eleven major themes are drawn from the body of the paper, and significant opportunities to improve RAAF preparedness through RI management are summarised.

A Note on Technical Aspects

This paper is written with a wide readership in mind. Although some technical logistics aspects are discussed, underlying concepts have been introduced to enable the non-logistician to follow discussion. Readers who possess logistics knowledge may find it useful to refresh their knowledge of these concepts.

CHAPTER TWO

THE LOGISTICS ENVIRONMENT

INTRODUCTION

The RAAF logistics environment has undergone considerable change in recent years. Two significant elements of this change are Integrated Logistics Support (ILS) and Weapon Systems Logistics Management (WSLM). As interest in ILS gained momentum during the 1980s, so did recognition of the need to consider the supportability of a weapon system in terms of a range of factors. These factors include reliability and maintainability. During the same period, plans were developed for the adoption of a logistics support structure orientated to the physical structure of weapon systems. This structure is underpinned by the WSLM concept.

The adoption of ILS and WSLM concepts facilitates the focus of logistics activities on Australian Defence Force (ADF) preparedness requirements. This focus is embodied in the stated mission of logistics in the ADF.

Aim and Scope

The aim of this chapter is to introduce ILS and WSLM. Following a brief introduction to RAAF logistics, the philosophy and practice of ILS will be introduced. The WSLM concept, and rationale for its adoption, are then outlined.

This chapter assists in placing RI management into the context of RAAF logistics, as discussed at Chapter Three. It also facilitates examination of the issues currently facing RI management, as covered in Chapter Five.

RAAF LOGISTICS

Definition of RAAF Logistics

The broad ADF definition of logistics is 'the science of planning and carrying out the movement and maintenance of forces'.[1] This comprehensive definition comprises the four aspects of:

a. design and development, acquisition, storage, movement, distribution, maintenance, evacuation and disposition of materiel;

b. movement, evacuation, and hospitalisation of personnel;

c. acquisition or construction, maintenance, operation and disposition of facilities; and

d. acquisition or furnishing of services.

This definition encompasses the broad range of activities which are grouped under the banner of logistics.

Logistics Mission

The mission of logistics in the RAAF is 'to provide the effective and efficient logistics support needed for the RAAF to meet endorsed readiness and sustainability objectives'.[2] Preparedness encompasses readiness and sustainability. Hence, this mission clearly focuses logistics activity, including RI management, on preparedness.[3]

1 ADFP 101 (A), *Australian Joint Services Glossary*, p L-11.

2 Adapted from Department of Defence Logistics Division, *Defence Logistics Strategic Planning Guide* (DLSPG), 1991, p 29. An alternative mission statement is provided at DI(AF)AAP 1000, *RAAF Air Power Manual*, Air Power Studies Centre, Canberra, 1990. The Air Power Manual states the mission of RAAF logistics as 'to enable and sustain air operations' (p 209). This is consistent with the DLSPG which proceeds to specify 'air operations' as those endorsed by policy through the Chief of Defence Force's Preparedness directive, as introduced at Chapter Six.

3 Detailed examination of preparedness doctrine is contained in Chapter Six.

INTEGRATED LOGISTICS SUPPORT (ILS)

Technological advances have increased the complexity of military weapon systems. Accordingly, there has been an escalated interest in comprehensive logistics support throughout the life of a weapon system. These support aspects are intrinsically linked to each other, both within, and across, each phase of a weapon system life cycle. Furthermore, strong links exist between logistics supportability and the system design parameters of reliability and maintainability. Such interdependency makes it necessary to consider provision of logistics support as an integrated discipline aimed at cost effectively meeting military preparedness requirements.

The application of ILS to Defence logistics is endorsed in the Defence Logistics Strategic Planning Guide, first published in 1990. The RAAF embraced ILS in the early 1990s, publishing initial policy guidance to this effect in December 1991.[4]

ILS Definition and Key Concepts

The endorsed RAAF definition of ILS is 'a disciplined and iterative approach to the management and conduct of activities necessary to satisfy weapon system preparedness requirements at minimum Life Cycle Cost by:

a. causing logistics support considerations to influence weapon system design requirements;

b. defining logistics support requirements that are optimally related to the design, and optimising the logistics support required by the design consistent with preparedness requirements;

c. acquiring the required logistics support; and

d. providing the required logistics support during the in-service phase'.[5]

A number of significant concepts are incorporated in this ILS definition, and encapsulated in Figure 2-1. Logistics support must be considered in conjunction with the weapon system design parameters of reliability and maintainability (R&M). In concert, these factors largely determine the operational availability of a weapon system, hence heavily influence operational preparedness. Design and supportability must be optimally related to each other through the application of trade-off

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4 DI(AF)LOG 5-1, *Application of Integrated Logistics Support in the RAAF*, Issue No 14/91, 6 December 1991.

5 Ibid, para 4.

analysis. Additonally, design and supportability should be driven by preparedness requirements, not vice-versa. The aim of this consideration is to meet operational performance objectives whilst minimising the total cost of acquiring and supporting a weapon system. In summary, the objective of ILS is to provide cost effective logistics support to meet preparedness requirements throughout the weapon system life cycle.

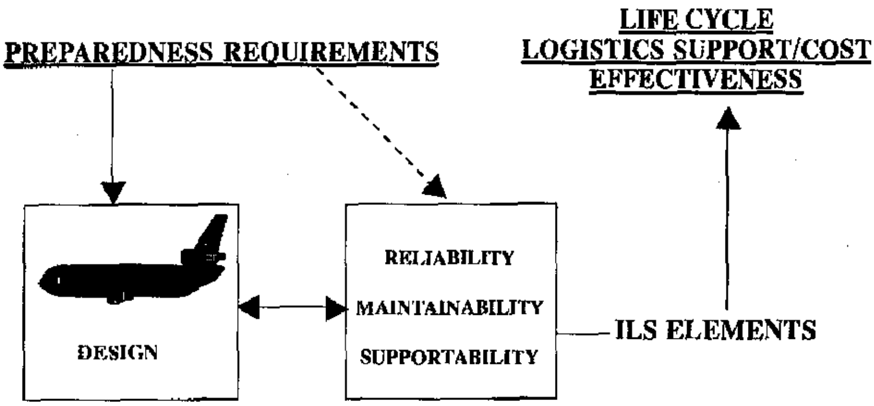

Figure 2-1. Key ILS Concepts[6]

The Weapon System Life Cycle

The RAAF divides the weapon system life cycle into four phases, as shown at Figure 2-2. It is important that the ILS methodology is applied throughout the entire life cycle. Early ILS application is critical to minimise Life Cycle Cost (LCC). The majority of decisions affecting LCC are made during the concept phase, with the specification of R&M requirements being particularly important.[7]

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6 Based on Project Management Education and Training, Department of Defence, Acquisition and Logistics Organisation, Integrated Logistics Course Notes, February 1993, p 1-1.

7 DI(AF)AAP 5102.002, *RAAF Integrated Logistics Support Manual*, Sect 1 Chap 3, para 307.

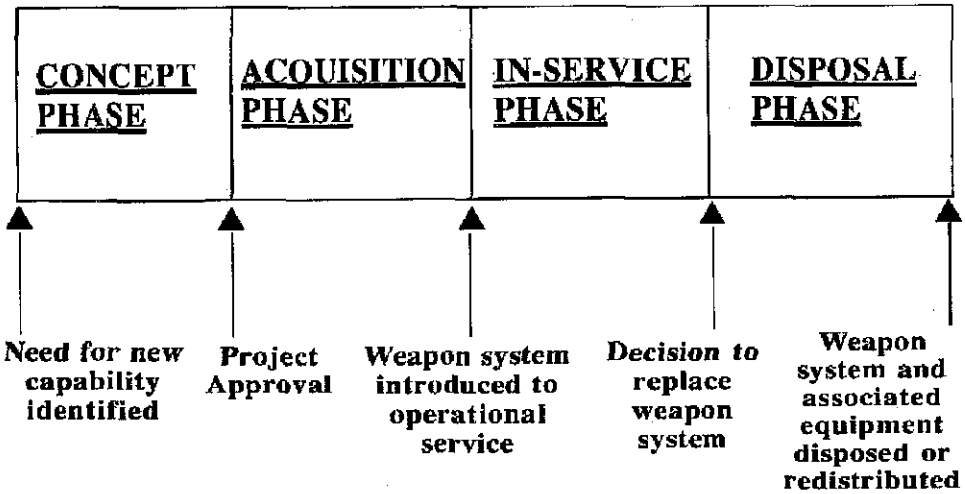

Figure 2-2. Weapon System Life Cycle

ILS Elements

The RAAF identifies ten ILS elements. The first of these, ILS Management, provides the focus for ensuring the cost-effective integration of the other nine ILS elements, shown at Figure 2-3. As all elements (other than ILS Management) are inherently linked to each other, informed trade-off decisions are required to produce an optimal mix of investment in each activity.

ILS Tools and Techniques

Logistics Support Analysis. Logistics Support Analysis (LSA) is the primary method of integrating logistics support throughout the life cycle of the weapon system. LSA is the application of analytical techniques to achieve the first two objectives of ILS, as previously defined. It is undertaken utilising a standard methodology in a structured, iterative manner. Use of computerised LSA tools is necessary given the complexity of the physical structure of weapon systems and the logistics support environment. To fulfil this need, the RAAF is acquiring a suite of such tools via the CAPLOG project, managed by Staff Officer Project Support and Logistics (SOPSL-LC). OPUS9, the RI spares assessment model, is the first of these tools to be introduced.

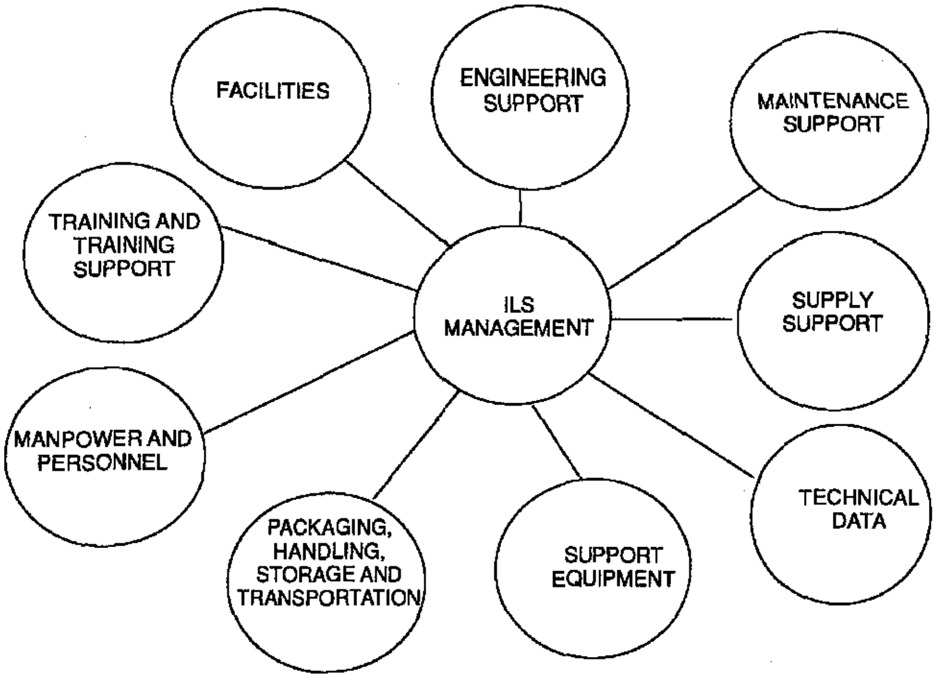

Figure 2-3. ILS Elements

<u>Conduct of LSA in Acquisition Programs.</u> LSA 'is to be applied to all weapon system acquisition programs'.[8] Front End Logistics Analysis (FELSA), the first stage of LSA, is performed during the concept phase. FELSA is 'aimed at establishing broad logistics support parameters such as Reliability and Maintainability at a system/sub-system level and an estimate of logistics support LCC'.[9] The second phase of LSA, conducted during the acquisition phase, 'is aimed at developing detailed logistics support requirements while influencing the design at lower levels to achieve preparedness requirements'.[10] At this stage, techniques are applied to analyse maintenance requirements derived from R&M design features. All maintenance tasks are identified and detailed to provide input to various models used to aid activities such as spares assessment and Life Cycle Costing.[11] Design changes or trade-offs in weapon system performance, cost or logistics support requirements may occur as a result of these activities.

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8 DI(AF)LOG 5-5, *Conduct of Logistics Support Analysis in the RAAF*, Issue No 34/92, dated 24 Aug 92, para 7.

9 DI(AF)AAP 5102.002, op cit, Sect 2, Chap 11, para 1104.

10 Loc cit.

11 For a more comprehensive discussion of LSA processes see DI(AF)AAP 5102.002.

In-Service Conduct of LSA. Once the weapon system enters the in-service phase, LSA must be performed by the Weapon System Logistics Manager. This manager applies in-service LSA to assess and influence modifications to the weapon system design.[12] Additionally, in-service LSA can be conducted to re-optimise logistics resources and infrastructure if necessary. This will be required if enduring changes to the weapon system operating profile occur, or logistics performance alters from that assumed during the acquisition phase.

The Logistics Support Analysis Record. The results of LSA are stored in a Logistics Support Analysis Record (LSAR). The LSAR is a data base that will be maintained throughout the weapon system's life to aid logistics support. Where it is cost-effective, LSARs will also be 'retrospectively constructed for existing weapon systems'.[13]

Life Cycle Costing. The LCC of a weapon system is the sum of all direct costs incurred in the operation and maintenance of the weapon system over its entire life cycle. Life cycle costing is aimed at monitoring, reducing, and controlling costs throughout the life cycle. It requires the structured collection and analysis of LCC data, and application of computerised LCC models.[14]

Logistics Capability Assessment (LOGCAS). LOGCAS is the quantitative analysis of the preparedness (or capability) of a weapon system with a given operating profile as a function of the availability and distribution of logistics resources. Changes in operational profiles or preparedness requirements may represent a short-term surge. Where surge occurs, LOGCAS tools can be used to assess operational outcomes given specified logistics resources and infrastructure.

ILS and WSLM

During concept and acquisition phases of the weapon system life cycle, management of ILS is the responsibility of a dedicated equipment acquisition project team. The in-service ILS management for each weapon system will be performed by the relevant WSLM Squadron.

The ILS philosophy and the WSLM concept are complementary in many ways. Decisions to adopt both were made in response to shared concerns regarding integration of logistics functions to meet weapon system preparedness requirements. The structural reorganisation undertaken to implement the WSLM concept lays the foundation for introduction of the ILS philosophy and the tools for in-service weapon system management.

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12 DI(AF)LOG 5-1, op cit, Annex D.

13 DI(AF)LOG 5-5, op cit, para 7.

14 Defence policy on life cycle costing is contained at DI(G)LOG 03-4 [DI(AF)LOG 5-11], *Defence Policy on Life Cycle Costing.*

WEAPON SYSTEM LOGISTICS MANAGEMENT

Rationale for WSLM Adoption

Hargreaves Review. Prior to 1980, Headquarters Support Command (HQSC)[15] had a functionally segregated approach to logistics management. HQSC was restructured in 1980/81 based on the review by Air Commodore R.A. Hargreaves, who was tasked with 'developing approved proposals for an integrated logistics capability within HQSC'.[16] Logistics Branch was formed, and a weapon system focus initiated by combining certain elements of supply and maintenance management into Support Groups (SGs).

Remaining Deficiencies. Despite ongoing organisational and procedural refinement during the 1980s further integration proved difficult. The need to fully apply WSLM was driven by a number of deficiencies which continued to undermine logistics support in the late 1980s. They were:

a. the need to specifically create an integrating team to address major weapon system difficulties, indicating that personnel did not routinely integrate across the organisation;

b. an inconsistent application of priorities to weapon systems across functional activities;

c. a bias to reactive, rather than proactive, management;

d. the difficulty of aggregating and optimising costs by weapon system, as required by Program Management and Budgeting (PMB); and

e. an inability to readily identify the impact on weapon system supportability of proposed changes in resources, operations, and contingency planning.[17]

ILS tools provide capabilities relevant to the latter two requirements. In the absence of an organisational structure and ethos focussed on both preparedness and management of weapon systems, the

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15 HQSC was responsible for both logistics and training support functions. In 1989/90 those functions were divided between the newly formed Headquarters Logistics Command (HQLC) and Headquarters Training Command (HQTC).

16 Air Commodore R.A. Hargreaves (HQSC Reorganisation Project Officer) assisted by Wing Commander R.T. Orr and Wing Commander B. Curran, *Corporate Logistics Support Objectives For the RAAF*, November 1981, p 14.

17 Factors identified in Air Commodore W.J. Belton, *Briefing on Implementation of Enhanced Weapon System Logistics Management*, November 1990, p 2.

remaining inefficiencies could not be addressed, and effective application of ILS tools would have proved highly difficult.

The WSLM Concept

Physical Build Hierarchy Focus. The WSLM concept is multi-faceted. It has the prime objective of integrating logistics support functions on a weapon system basis. At the heart of WSLM is the orientation of the physical build hierarchy of weapon systems, in terms of both organisational structure and management focus.

Structural Aspects. Key maintenance, engineering, and supply functions have been grouped into WSLM Squadrons and assigned to support specific weapon systems. Decentralisation has also been pursued through the relocation of WSLM Squadrons to operational bases. Each WSLM Squadron is independently structured, with varying degrees of functional integration reflected in their internal organisation. For instance, the core of the Strike Reconnaissance Logistics Management (SRLM) Squadron is three integrated teams containing engineering support, RI managers, and Break Down Spares inventory managers. Each team focuses on particular sub-systems within the weapon system (eg, avionics, airframe). In contrast, Tactical Fighter Logistics Management (TFLM) Squadron has established a central RI pipeline management cell. The rationale for establishment of this cell is to retain and lever the expertise which the RAAF has acquired in pipeline management. This decision follows a similar logic to that applied in selecting a number of generic functions to remain centralised at HQLC in order to maintain engineering or maintenance expertise.

Management Focus. A weapon system physical build structure can be viewed in terms of an item-importance hierarchy, as at Figure 2-4.[18] In general terms, the most 'important' components in terms of direct impact on aircraft availability are those spares which can be replaced directly on the aircraft. These are known as Line Replaceable Items (LRIs), or Line Replaceable Units (LRUs), and include many RIs. Of decreasing significance, in terms of both direct impact on availability and resource consumption, are items that require repair off-aircraft at maintenance venues. Components of repairable spares, known as Break Down Spares (BDS), are generally lowest in the hierarchy. The management implications of this hierarchy may be summarised as follows:

> "If you have serviceable stocks of the line replacement spares...then you have the capability to directly affect the readiness, availability and surge

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18 A number of variations on this hierarchy can be found in different sources. The particular classifications placed at each level of the hierarchy depend on the context within which the hierarchy is placed, and the purpose for which it is presented.

> capacity of weapon systems. In contrast, BDS are time lagged away from the direct support of operations having first to be fitted and tested in a LRI...To summarise the position, although there is little separation in the importance of serviceable holdings of spares in our current (ie, 1989) inventory management methods, there is a physical criticality hierarchy in aircraft spares to logistic performance and this must be used in establishing more operationally orientated inventory management methods."[19]

Hence, one of the aims of WSLM is to refocus inventory management and procedural effort from the lower to higher levels of this hierarchy.

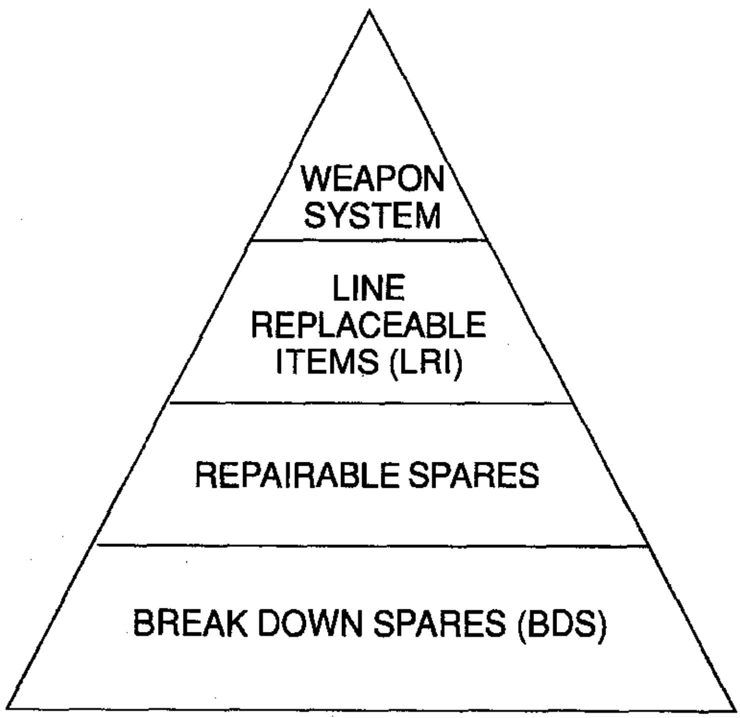

Figure 2-4. Item-Importance Hierarchy[20]

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19 Group Captain G.N. Chandler, *The Logistic Branch Way Ahead, A System Fully Orientated to the Build Hierarchy of Weapon Systems*, AL3, 13 July 1989, p 2.

20 Ibid, Annex A.

Supplementary WSLM Features. A number of supplementary features are commonly cited as elements of WSLM. These are:

a. a significant proportion of weapon system logistics support funding is controlled by a single authority, the Commanding Officer of the WSLM Squadron;

b. multi-skilling of team members;

c. flatter management structure and devolution of responsibility and authority;

d. application of RAAFQ and strategic planning techniques;

e. matrix management; and

f. emphasis on customer focus, with specific customers being a function of the weapon system supported by the WSLM Squadron.[21]

CONCLUSION

The mission of logistics in the RAAF is clearly focused on meeting preparedness objectives. ILS and WSLM have been implemented to create a functionally integrated logistics environment conducive to meeting this mission.

Concurrent implementation of ILS and WSLM is challenging logisticians to adopt new paradigms. It demands an altered conceptual appreciation of their role. Notably, logisticians require a clearer understanding of the links between the operational environment and the logistics system.

ILS philosophy stresses the need to optimally relate weapon system design and supportability. The prime objective of ILS is to meet preparedness requirements at minimum LCC. ILS tools, to be introduced to the RAAF, will provide an enhanced capability to link logistics resource planning and activity to operational requirements.

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21 Both Strike Reconnaissance and Tactical Fighter Logistics Management Squadrons list these elements as integral to the WSLM approach. See *SRLMSQN Concept Paper*, 501WG/4360/27/4 Pt1 (62), 24 November 1992, and Squadron Leader Ian Whish-Wilson, *Weapon Systems Logistics Management (WSLM) Tactical Fighter Logistics Management Squadron*, in *The Logbook*, Issue No 3, June, 1993, pp 16-17.

The essence of the WSLM concept is the orientation of the physical build hierarchy of weapon systems. To strengthen this orientation, previously isolated functional entities have been collocated in WSLM Squadrons. Within WSLM Squadrons, functional integration has proceeded further through the formation of small, multi-functional teams who support specified weapon system sub-systems. Application of ILS tools, and maintenance and use of a common LSAR, have the potential to greatly enhance the effectiveness of such integrated teams.

CHAPTER THREE

REPAIRABLE ITEM MANAGEMENT

INTRODUCTION

Repairable Item (RI) management incorporates a wide range of logistics activities which are conducted by a variety of RAAF and external agencies. Due to its broad scope, differing perceptions exist on its nature and objectives. The views of individuals on this matter are often shaped by those aspects of RI management with which they are familiar, and by their functional background. Hence, prior to discussing RI management issues within the current logistics and preparedness frameworks, it is important to clarify some basic aspects.

Aim and Scope

The aim of this chapter is to discuss the nature and objectives of RI management in the RAAF. Additionally, its links to ILS are examined. This places RI management within the context of the logistics environment, as discussed at Chapter Two.

THE NATURE OF RI MANAGEMENT

What is a Repairable Item?

An RI is a class of sub-assembly of prime equipment (PE). For the purposes of this paper, that PE is an aircraft. A sub-assembly is classified as an RI if it is more cost-effective over the aircraft life to maintain the item rather than discard it on failure and purchase a replacement. Hence, RIs are economically repairable. A clear, consistent definition of the term 'repairable item' beyond this point is difficult to identify.

The terminology associated with RI management is often a source of confusion. Three alternate terms are commonly used in reference to RIs. These terms are sometimes used incorrectly, and are often assumed to be interchangeable. This reflects the functional separatism which has characterised RAAF logistics in the past. These terms are:

a. Maintenance Managed Item (MMI) -'a technical item for which data is collected to satisfy one or more maintenance requirements';[1]

b. Maintenance Supply Item (MSI) -'a technical item of which the normal usage, except for the replacement of wastage, is met by the process of repair or overhaul of existing items';[2] and

c. Repairable Item (RI) - an item 'whose resupply normally centres on maintenance processes formally authorised by the RAAF to be carried out at nominated venues.'[3]

The first definition, MMI, is the broadest, and reflects an engineering functional perspective. In practice the second definition, MSI, is applied to items for which the PATTRIC[4] spares assessment model is used. Hence, items with relatively high annual wastage are excluded.[5] The MSI definition has a distinct supply functional perspective. To add to the confusion over terminology, MSIs are further classified as being either 'rotable' or 'repairable'. The distinction between the two is that rotables are 'normally capable of being repaired or reworked an unlimited number of times', and repairables only a 'limited number of times.'[6] The final definition, RI, is contained in current RI management policy, DI(AF)LOG 2-2. It is tailored to the management of maintenance pipelines, and excludes items otherwise suitable for classification as an RI for which maintenance pipelines have not been established. A common misperception is that there is a hierarchical relationship between the three terms, with RIs a subset of MSIs, which are in turn a subset of MMIs.[7]

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1 DI(AF)AAP 7001.031, *Technical Maintenance Plan Manual*, para 212.

2 JSP101, *Australian Joint Services Glossary*, p M-3.

3 DI(AF)LOG 2-2, *Repairable Item Management*, Issue No 1/91, 1 June 1991, para 4.

4 The Poisson Availability Target Technique for Repairable Item Computation (PATTRIC) spares assessment model is introduced at Annex A. All annexes are presented at the rear of the book.

5 A 1991 review of asset availability targets by HQLC members, including representatives from all Support Groups and Directorate of Major Maintenance Services, listed the following as criteria which an RI need satisfy in order to be modelled on PATTRIC: a. Arising Rate > 2 per annum over last two years, b. Average Quantity in Pipeline > 1 per annum, and c. Average Wastage < 1 per annum over last three years. *Repairable Item (RI) Management - Asset Availability Targets (AATs)*, SGA2/4300/18/1 Pt2 (4), 13 December 1991, para 2.

6 JSP(AS)101, op cit, p M-3.

7 Analysis in this paragraph reflects ideas contained in a presentation by Squadron Leader S. Secker at RAAF Base Williamtown on 3 September 1993.

The basic terminology presented above needs to be simplified to align with the more integrated logistics structure and philosophy which the RAAF has adopted. The DI(AF)LOG 2-2 definition of 'RI' reflects the pipeline management focus of current RI management policy.

What is RI Management?

RI management, as defined in DI(AF) LOG 2-2, is 'a system of processes and responsibilities whose objective is to provide satisfactory PE availability by ensuring that RI pipelines can and do function efficiently.'[8] This definition distinguishes the 'RI management system' from the physical infrastructure of the RI system. The infrastrucutre consists of the permanent installations, such as maintenance venues and warehouses, which can be utilised to achieve the objectives of RI management, and the physical activities performed by staff within such installations. The RI Management system contains the policies and decision making activities which utilise these installations and staff to achieve specified management objectives. This distinction is represented in Figure 3-1 by the containment of the 'RI management system' and the 'physical infrastructure' within the broader 'RI System'.

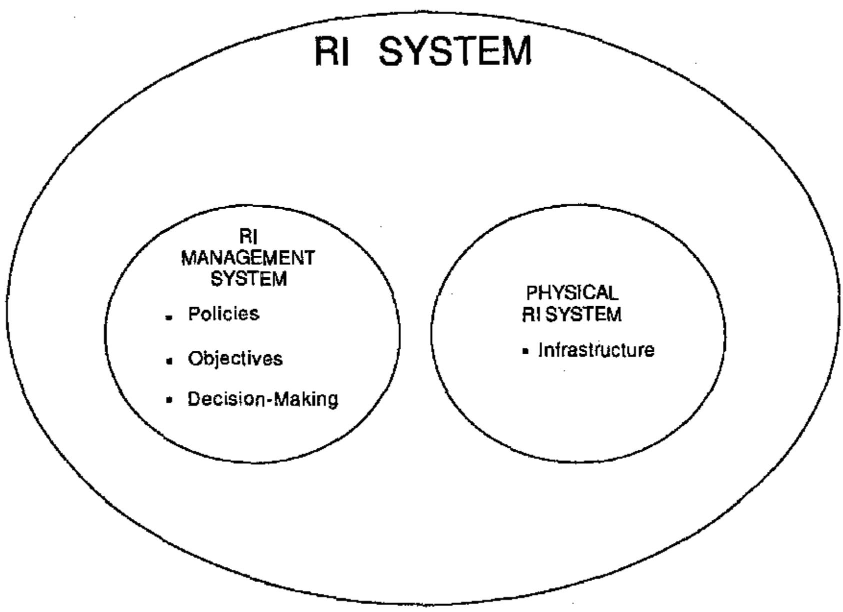

Figure 3-1: The RI System[9]

8 DI(AF)LOG 2-2, op cit, para 6.

9 My thanks to Wing Commander Greg Donaldson for his assistance in formulating this concept and diagram.

DI(AF)LOG 2-2 defines the 'central purpose' of 'the RI Management system' as 'to set up, maintain and operate maintenance pipelines.'[10] Thus, RI management is concerned with the establishment and functioning of RI pipelines to meet a PE availability objective. Although it could be argued that the scope of RI management must be broader if preparedness objectives are to be met, it is important to appreciate the concept and nature of RI pipelines.

RI Pipelines

Pipeline Definition. The term 'pipeline' is used in a number of contexts in logistics, and is commonly associated with a quantity of stock flowing through an inventory system.[11] DI(AF)LOG 2-2 describes an RI *maintenance* pipeline as follows:

> "On becoming unserviceable, RIs are said to enter maintenance pipelines. A typical pipeline provides for maintenance as appropriate, transfer of serviceable RIs to holding stores, and eventual return to end users for fitment to PE (or other higher assemblies) when needed."[12]

This description of an RI maintenance pipeline can be depicted as an apparently straightforward concept, as shown at Figure 3-2. However, on closer consideration it is not clear where the pipeline begins - is it the point at which the RI becomes unserviceable while in use, the moment it is removed from the aircraft, or some other point? Similarly, at what point is the serviceable RI considered to have been returned to end users - when it is located in a base warehouse or squadron store, or when it is actually being fitted to a PE? While these questions may seem trivial, they have a practical relevance in defining the extent of RI management, the functions which it is considered to incorporate, and the performance measures used.[13]

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10 Ibid, para 3.

11 For instance, Craig C. Sherbrooke uses 'the term 'pipeline' to denote the random variable for the number of units of an item in repair at a site or being resupplied to the site from a higher echelon' in *Optimal Inventory Modelling of Systems - Multi-Echelon Techniques*, John Wiley & Sons, New York, 1992, p 14. The American Production and Inventory Control Society (APICS) also defines pipelines in terms of stock, in T.F. Wallace and J.R. Dougherty, *APICS Dictionary*, APICS, Falls Church, 1987, p 22.

12 DI(AF)LOG 2-2, op cit, para 2.

13 This point is discussed further in the context of implications of preparedness for RI management at Chapter Eight, p 8-10 - 8-11.

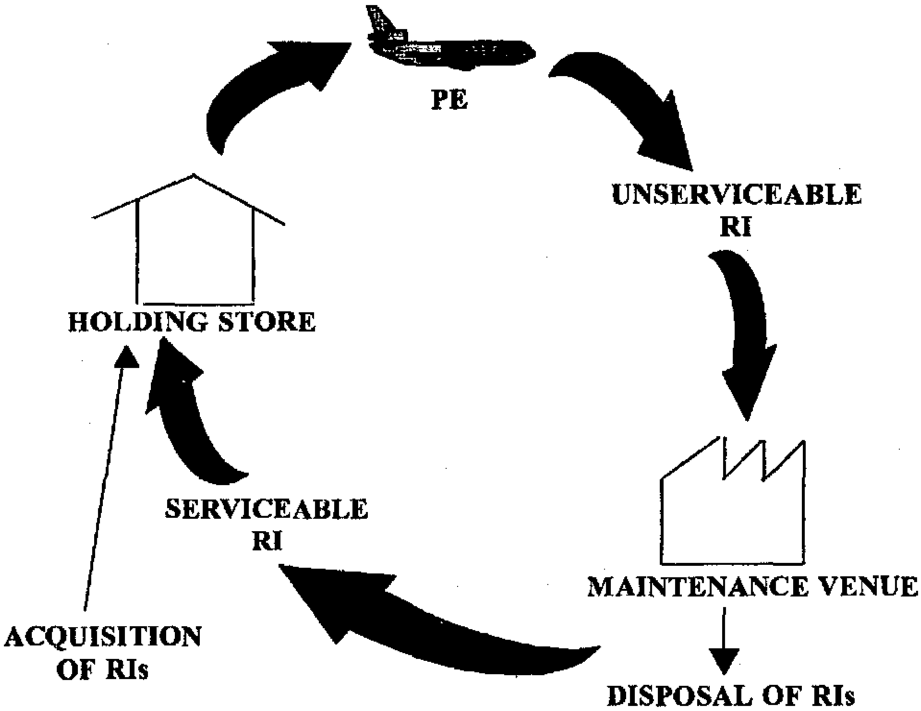

Figure 3-2. Generalised RI Pipeline

<u>RI Pipelines in Practice</u>. The perception that RAAF RI pipelines are complex, and have indeed proven quite difficult to manage, can be attributed to a number of factors. Pipeline performance is the result of the interaction of processes performed in different organisational domains. RIs cross multiple organisational boundaries within the pipeline. As each organisational entity controls its section of the pipeline, the management of the total pipeline is fragmented. Thus, pipeline performance is adversely affected by the multiplicity of separate decisions, and the array of personnel who administer each section. The general perception of system complexity reflects the lack of understanding of dynamic pipeline behaviour and its key drivers.

RI Management Processes and Controls

An overview of key RI management processes and controls is provided at Annex A. This overview illustrates the broad scope of activities and large number of RAAF and external agencies which constitute, and impact upon, RI system behaviour and performance. Considered within the integrated logistics environment, the 'RI management system' is less distinct, and somewhat broader than suggested by the endorsed RAAF definition. In particular, activities which directly affect RI reliability and maintainability have been associated with RI management less readily than spares assessment and maintenance planning activities. It is important to recognise that the scope of the system is broader than the activities performed to physically manipulate RIs through the pipeline.

RI MANAGEMENT OBJECTIVES

PE Availability

The stated RI management objective of 'satisfactory PE availability'[14] requires examination in order to determine what the term means and how it might be applied to RI management. The term 'aircraft availability' is defined in DI(AF)AAP 7001.038-1, RAAF Aircraft Maintenance Philosophy and Policy, as the 'proportion of time that an aircraft is available to carry out its designated function.'[15]

The definition of 'designated function' is implied by the method used to measure aircraft availability. The daily serviceability status of each RAAF aircraft is recorded at 0930 hours each day.[16] An aircraft is considered serviceable if it is 'airworthy, not due for scheduled maintenance, and can be made ready to perform any of the roles programmed for the units' operations for the succeeding 24 hours.'[17] If an aircraft satisfies these three criteria it is considered 'available to carry out its designated function.'[18] The latter of these criteria suggests a link between aircraft availability and operational requirements (to be discussed later).

14 DI(AF)LOG 2-2, op cit, para 4.
15 DI(AF)AAP 7001.038-1, *RAAF Aircraft Maintenance Philosophy and Policy* (Third Edition), Date of Issue: 1Sep83, para 110.
16 Guidance for recording and reporting of serviceability status is contained in DI(AF)TECH 5-14, *Monthly Maintenance Report*.
17 Ibid, Appendix 1 to Annex A.
18 Loc cit.

Operational Availability

A number of different concepts of availability exist.[19] Of these, Operational Availability (A_O) is closest to the RAAF definition of aircraft availability. A_O is also commonly used as a measure of logistics performance, and as a target in logistics models.

A_O is defined as 'the probability that a system or equipment, when used under stated conditions in an actual operational environment, will operate satisfactorily when called upon.'[20] A_O is commonly expressed as:

$$A_o = \frac{\text{SYSTEM UPTIME}}{\text{UPTIME + DOWNTIME}}$$

Clearly, A_O will be maximised when downtime is minimised and uptime is maximised. Thus, it is important to understand the key drivers of both uptime and downtime in order to improve the performance of the RI system.

Uptime. Mean Time Between Maintenance (MTBM) is the average period of time between maintenance arisings (unscheduled and scheduled). It is a function of both the reliability designed into the PE and its sub-assemblies, and maintenance policy, which determines the frequency and content of scheduled maintenance activities.

Downtime. Maintenance Downtime (MDT) is composed of three main factors:

a. Mean Time to Repair (MTTR) - actual time spent performing maintenance actions on the PE or RIs (colloquially known as 'spanner time'). A key determinant of MTTR is maintainability, which pertains to 'ease, accuracy, safety and economy in the performance of maintenance actions'.[21]

b. Logistics Delay Time (LDT) - time spent waiting for resources such as spares, test equipment, transportation or facilities to become available in order to proceed with maintenance.

c. Administrative Delay Time (ADT) - delay time associated with administrative processes such as notification of failure, consulting manuals, or processing paperwork.

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19 For an introduction to other concepts of availability including Inherent Availability and Achieved Availability see B. Blanchard, *Logistics Engineering and Management* (Third Edition), Prentice-Hall, New Jersey, 1986, pp 64-65.

20 Ibid, p 65.

21 Ibid, p 15.

The A_o equation can thus be restated as:

$$A_o = \frac{MTBM}{MTBM + MDT}$$

Strategies to improve A_o must seek the optimum balance between high MTBM and low MDT. For instance, pursuit of reduced MTTR in isolation may lower the quality of maintenance, thus increasing item failure rate, and lowering MTBM. The ILS emphasis on joint analysis of reliability, maintainability, and supportability throughout the weapon system life cycle reflects the need to make such trade-offs.

Measurement of A_o. While A_o is physically measurable, it is not currently monitored by the RAAF in accordance with the above definition. The daily aircraft serviceability status measurement provides a snapshot of the proportion of each RAAF aircraft fleet which is serviceable. It has been criticised primarily because it provides only a serviceability snapshot rather than recording availability over a time continuum.[22] However, its predominant flaw, from the perspective of operational preparedness, is the failure to incorporate mission capability. A further significant measurement flaw is the failure to express A_o in terms of probabilities. The distribution around the mean for MTBM and MDT can vary significantly, and is not represented in a single point measurement.

Mission Capability

Operational availability is not sufficient to meet preparedness requirements. A mission capable aircraft must *also* be fitted with all of the systems required to effect the mission. These critical systems must remain operable for the period necessary to achieve the mission objectives. Thus, mission reliability[23] is a key element of mission capability. The importance of mission capability is emphasised in RAAF Maintenance Policy for Technical Equipment, DI(AF)LOG 2-1. It states:

> "The mission of maintenance is to support operational preparedness...The critical factor to mission success is the sustained ability to provide mission capable and ready equipment at the time and place it is needed."[24]

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22 See, for instance, Squadron Leader M.W. Cornwall, Squadron Leader G.D. Evans, Squadron Leader C.G. Wheaton, and Flight Lieutenant G.C. Saunders, *A Study of RAAF Aircraft Availability and Cost Factors*, DLDP AF91/7557 Pt1 (13), 17 September 1991, pp 11-12.

23 Mission reliability is 'the probability that the aircraft will be able to perform a given mission without any failures or defects that will have an operational effect.' DI(AF)AAP.0038-1, op cit, para 106.

24 DI(AF)LOG 2-1, *Maintenance Policy for Technical Equipment*, para 1.

Despite its importance, mission capability is not utilised as a logistics performance measurement, nor incorporated in a disciplined way into the majority of logistics activities and decision-making.

Aircraft Availability Tracking and Reporting System (AATARS)

The AATARS system is being developed to overcome the deficiencies of the current aircraft availability measurement methodology.[25] It is a computer-assisted system which is used to record aircraft status over elapsed time; each change in aircraft status being reported to this system.

AATARS aircraft status categories include 'Fully Mission Capable' and 'Limited Mission Capable'. These categories relate capability directly to the unit roles promulgated in the annual Chief of Defence Force's Directive on Preparedness (CPD). An operational aircraft will be considered fully mission capable 'subject to receiving before-flight servicing and being capable of performing all roles promulgated in' the CPD.[26]

Mission reliability will not be monitored using AATARS. However, staff in the Directorate of Logistics Planning, Quality and Evaluation (DLQPE-LC) are investigating the use of aircrew flight reporting to close this gap.[27]

RI Availability

While PE availability is the stated objective of RI management, it is not currently utilised as an in-service RI management target. For example, the performance objective used in in-service spares assessment is an RI item availability target (A_{it}) of 97%-98%.[28] The RAAF uses the PATTRIC spares assessment model which considers each RI in isolation rather than as part of the overall weapon system build structure.

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25 AATARS is being trialed at 492 Squadron. Implementation across the RAAF is currently planned for February 1994. Interview, Squadron Leader D. McDonald, DLQPE, 13 October 1993.

26 *AATARS User Manual*, Issue No 1/92, 12 May 92, p 1. The term 'CPD' has been substituted for the superseded 'CORD' (CDF's Operational Readiness Directive). This development is outlined in Chapter Six, where the CPD is discussed more fully.

27 Interview, Squadron Leader D. McDonald, op cit.

28 The 97% figure is given by Group Captain (Ret) J.E. Townsend, *Interim Report on a Study into Aspects of Repairable Item Determination and Control*, 13 August 1990, para 14. 98% is the figure suggested in *Process Action Team Interim Report - Review of the Depot Level Maintenance Process for Aircraft Repairable Items*, SRO4/4600/3/PROCEDURE Pt5 (10).

Consequently, the link between individual A_{it} and overall PE availability is not considered in current in-service RI spares assessment.[29] Additionally, systems to monitor achieved A_{it} are not in place.

ILS tools will assist evaluation of the impact of RI management decisions on Operational Availability. Notably, OPUS9, the spares assessment model which will replace PATTRIC, links A_{it} and A_o.[30]

Subordinate Objectives

The performance targets most commonly used in RI management are actually subordinate to RI availability, and are derived from the spares assessment activity. These targets are the Unit Entitlement (UE) figure calculated from spares assessment, and the pipeline turnaround time (TAT) assumed in this calculation.

Unit Entitlement Targets. The availability of RIs is generally monitored against a Unit Entitlement (UE). UE is the quantity of assets assigned to a unit, depot or contractor to meet operational requirements and maintenance commitments for a defined maintenance policy. In practice, UE is most commonly set for MSIs (known as MUE - MSI Unit Entitlement). The MUE is based on output from PATTRIC, plus a number of management allowances. As availability targets are lacking for many non-PATTRIC modelled RIs,[31] this target is not comprehensively applied.

Pipeline TAT Objective. Two of the constituent elements of TAT are specified as pipeline performance targets in DI(AF)LOG 2-2 - Time to Make Serviceable (equivalent to MTTR), and processing/shipping time. However, overall TAT is not broken into constituent elements during spares assessment and the activities to be included in the processing/shipping time element are not clearly specified. Hence, targets cannot readily be established for these elements. Also, as data on achieved processing/shipping time is not readily available, this target cannot be monitored.

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29 A method of linking A_o and A_{it} in project spares assessment is outlined in DI(AF)AAP 7001.042-1, *RAAF Maintenance System for Technical Equipment*, Annex A to Chapter 6. However, 'in practice this process is thwarted by lack of valid data to support such an analysis, and by the influence of other quite separate project considerations.'(ibid, p 6A-10) Further, the standard Ait applied to in-service RIs 'is based on RAAF research into actual availabilities being achieved in the fleet at the time PATTRIC was introduced' (ibid, p 6A-11), and does not consider the A_o/A_{it} link.

30 OPUS9 is introduced at Annex A.

31 As at December 1991 asset availability targets had been assigned to only approximately 50% of DLM maintained RIs across all RAAF aircraft types. Data from DLQPE performance monitoring database.

The TAT used in spares assessment is actually based on historical performance rather than target performance. The higher the historical TAT, the greater the recommended UE. Consequently, problems contributing to poor pipeline performance can be masked through increasing the number of spare assets. The need to set TAT as a matter of policy is incorporated in DI(AF)LOG 2-2, but is yet to be implemented.

Broader RI Objectives

UE and pipeline TAT targets are inadequate to meet the objectives of A_0 and mission capability. These targets are derived from the RI spares assessment process, which is not currently linked to aircraft availability requirements. Safety or mission criticality are also not considered during spares assessment.[32] Further, the higher profile which ILS has given RI reliability and maintainability in the acquisition phase of the weapon system life cycle is not yet reflected in the in-service phase. DI(AF)LOG 2-2 assigns R&M a role in problem analysis and corrective action, rather than establishing R&M targets as in-service objectives in their own right.

ILS AND RI MANAGEMENT

The conceptual link between ILS and RI management is summarised at Figure 3-3.

Baseline assumptions, judgements and data regarding the weapon system design, operating environment, and logistics support infrastructure are input to LSA. LSA is then performed to convert preparedness objectives into statements of logistics resource requirements. Output from this process must be supplemented with information on the logistics infrastructure, such as maintenance venue capability and capacity, to support the establishment of RI pipelines.

Once pipelines are established, they are managed by RI. To meet preparedness objectives within given resources, in-service pipeline performance and RI reliability must be at least as good as that assumed during initial LSA. Where all of the resources recommended by LSA are not procured (eg, due to financial constraints), preparedness requirements will only be met through compensatory in-service performance in excess of that incorporated in calculations.

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32 *Identification and management of mission critical RIs is examined further at Chapters Seven and Eight.*

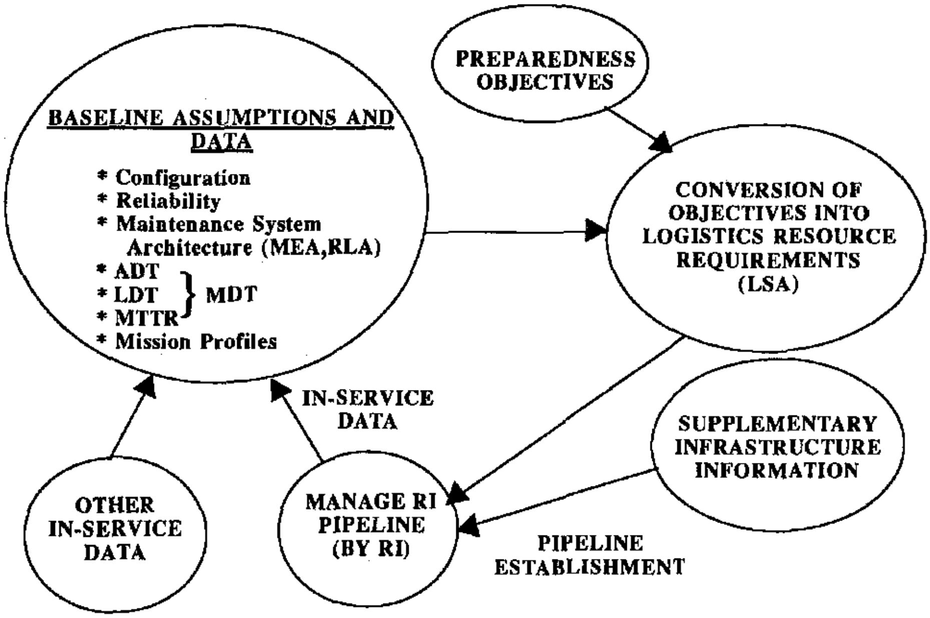

Figure 3-3. ILS/RI Management Links[33]

There is a need for ongoing review of in-service data against the baseline used to establish the logistics support requirements. This is necessary to establish RI and RI pipeline performance, and to review the logistics resource mix and infrastructure should preparedness objectives alter.

CONCLUSION

A wide range of activities is necessary to manage RIs throughout the weapon system life cycle. Of these, RI management is currently focused upon pipeline management. For example, the definition of 'RI' in current policy specifies the existence of pipelines, and pipeline TAT is one of the key objectives actually applied in RI management. However, the range of processes which directly affect system performance suggests that the pipeline management emphasis is too restrictive.

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33 My thanks to Wing Commander Greg Donaldson for his assistance in development of Figure 3-3. With regard to acronyms in Figure 3-3, MDT (Maintenance Downtime) elements are outlined at page 3-6. MEA (Maintenance Engineering Analysis) and RLA (Repair Level Analysis) are introduced at Annex A, p A-1.

The adoption of an expanded RI management perspective would align with the integrated RAAF logistics structure and philosophy. Two important steps toward this are the statement of a simpler, more generic definition of 'RI', and active management of in-service RI reliability and maintainability.

Additionally, broader RI management objectives should be specified, and performance measured against these. Operational availability and mission capability must be monitored and incorporated into decision-making in order to link logistics activities to preparedness requirements. The AATARS system is being developed in response to this need. It will soon enable measurement of A_0 over elapsed time, which can be utilised in decision making using ILS tools such as OPUS9. However, a means of monitoring mission reliability is yet to be devised.

CHAPTER FOUR

DEVELOPMENT OF RI MANAGEMENT

INTRODUCTION

RI management has been the subject of considerable debate over the past decade. This reflects its significant impact upon preparedness, and the high level of resources committed to it annually. Numerous reviews, conducted at various organisational levels, have examined a range of RI management issues including terminology, relationship to preparedness, and procedural effectiveness and efficiency. These reviews, and the debate which they generated, provide insight into the development of RI management.

Aim and Scope

The aim of this chapter is to examine major themes in the development of RI management over the past decade. These themes are drawn from written records of reviews, conferences and meetings conducted during this period. However, discussion of relevant preparedness studies is presented in a later chapter.[1]

OVERVIEW OF DEVELOPMENT

A number of key RI management reviews and studies conducted since the mid-1980s are examined at Annex B. While it is not a comprehensive discussion of all the issues raised, it does convey the ethos of the period, highlights the most significant problems identified, and discusses organisational responses to the issues covered. Major themes have been distilled from Annex B, and are discussed in this chapter.

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1 It is appropriate to introduce preparedness doctrine and policy (Chapter Six) prior to discussing preparedness studies (Chapter Seven).

SYSTEM DESCRIPTION AND ANALYSIS

Fragmentation

Numerous attempts have been made to describe and analyse the RI system at a macro level. This has proven difficult due to the perceived complexity of the system and differences between authorised and practised procedures.[2] An Air Force Office (AFO) Working Party, formed in 1985 to review and redesign the RI Management system, provided the following description:

> "The overall system is a complex interlacing of engineering, supply and maintenance management systems. There is no overview of the system, and operatives tend to learn only the process they are doing. Thus each process involves a new learning process without an appreciation of role within the total system. In addition, no single appointment or functional authority has been identified with responsibility for appreciating that total role and its responsibility for executing that total role."[3]

This gives the impression of a fragmented, poorly coordinated system, whose performance is subject to the actions and decisions of individuals operating in different organisational domains, with differing objectives.

Additionally, distinct differences existed between the management of Depot Level Maintenance (DLM) and Intermediate and Operating Levels of Maintenance (ILM and OLM respectively). Management procedures for ILM and OLM were particularly ill-defined. The recent reduction of the number of maintenance levels to two, Deeper Maintenance (DM) and Operating Maintenance (OM), has not yet eliminated this disparity. Most ILM has been incorporated into the DM category, and a mixture of previous DLM and ILM processes is now applied to DM management.

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2 As noted, for instance, by the 1985 Air Force Office Working Party (Annex B, p B-3) and a 1990 DLM Process Action Team (Annex B, p B-15).

3 *DMP-AF/DSPOL-AF Repairable Item Working Party Preliminary Report*, Enclosure 1 to AF85/22923 Pt1 (35), September 1985, para 18.

Analytical Techniques

System redesign has been inhibited by the limitations of analytical techniques and tools utilised by reviewers. In 1985 the Director of Maintenance Policy commissioned the development of a model to assist the AFO Working Party in the analysis of system behaviour and policy design. A discrete simulation model requiring validation was presented in 1986.[4] Unfortunately, this model was not developed further due to data and manpower shortfalls. Neither the alternate model applied nor later RAAFQ analysis have fully supported the intention of applying a systems-based approach, as discussed in Chapter Ten.

RI MANAGEMENT POLICY

Principles

During the mid to late 1980s, the major RI issue tackled at policy level was the design of a more coherent system which would enable RI item availability targets (A_{it}) to be met. A key principle adopted was the assignment of overall responsibility for achievement of RI availability to a 'circuit manager', complemented by assignment of subordinate responsibilities to managers throughout the system. The establishment of objectives subordinate to A_{it}, and relevant performance measurement, were seen as integral to improved system control. These principles are incorporated in current RI management policy, which was eventually published in 1989.

DI(AF)LOG 2-2

Support Groups (SGs) at HQLC were assigned a monitoring, coordinating and troubleshooting role over the RI system. However, limitations to the resource control and authority of SGs made it difficult for them to exercise overall system coordination.

A framework for the longer term development of the RI management system was contained in DI(AF)LOG2-2 by providing 'policy hooks for a number of initiatives.'[5] Many of these initiatives depend upon the development of information and support systems. Shortfalls in current support systems are a significant impediment to policy implementation, as noted in 1991 by Air Commodore P.G. Newton, then Director General of Logistics Operations, who stated:

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4 Squadron Leader M. Gaspert, BE, MSc, *Simulation of RAAF Repairable Item Circuit*, Thesis, School of Engineering, Gippsland Institute of Advanced Education, September 1986.

5 Group Captain C. Hingston, AF88/28674, *Repairable Item Management*, 8 December 1989, para 2.

> "Many of the essential information and support systems to achieve this goal (ie, DI(AF)LOG 2-2 implementation) are either not in place or have not been fully defined; consequently, the current extent of RI management falls short of that expected."[6]

Amongst the critical support capabilities currently lacking is the ability to actually monitor performance against RI A_{it} and subordinate objectives, as discussed in Chapter Three.

INFORMATION MANAGEMENT

Deficiencies

Inadequate data visibility and poorly integrated information management are significant problems throughout the RAAF logistics system. These deficiencies were described in the 1992 RAAF Logistics Information Management Strategic Planning (LIMSP) project report as follows:

> "Systems are fragmented, difficult to maintain, difficult to change...Users are having trouble with data integration, integrity and connectivity."[7]

RAAFSUP and CAMM, the RAAF's major supply and maintenance information management systems respectively, do not share data or functional interfaces. Consequently, they often contain contradictory data regarding a specific RI. At a more fundamental level, the two systems have a different view of RIs and BDS. For instance, RAAFSUP uses Nato Stock Numbers (NSNs) to identify assets, and CAMM uses Part Numbers.

Poor visibility of RI locations is another significant problem. Notably, logistics managers lack data on RI location and status when in transportation, at civilian contractor and overseas maintenance locations. Without this visibility an RI cannot be tracked throughout a pipeline. This deficiency retards system monitoring and control.

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6 Air Commodore P.G. Newton, Director General Logistics Operations, DGLOGOPS-LC 109/91, *Repairable Item Management*, 12 April 1991, para 4.

7 Nolan, Norton & Co., *RAAF Logistics Information Management Strategic Planning Project - Phase III Report, Volume I*, 3 December 1992, p 18. Nolan, Norton & Co. were contracted to assist the RAAF to develop a strategic plan for RAAF logistics information management during 1992.

Logistics Information Management Strategic Planning (LIMSP)

While improved functionality will be provided through the Supply Systems Redevelopment Project (SSRP) and CAMM2, concern has been expressed that 'RAAF Logistics is not effectively driving current information management initiatives to support the overall business process.'[8] This problem has been recognised by the Directorate of Logistics Information Services (DLIS), who sponsored the LIMSP study, and have formed the Logistics Information Management Steering Group (LIMSG) to implement many of its recommendations.[9] A key component of their strategy is the integration of engineering, maintenance, and supply transaction systems and databases, with a common delivery framework to the end user. LSAR and common logistics data definitions warrant an important role within this strategy.

Business Process Redesign

One of the critical factors identified for the successful implementation of the LIMSP strategies is business process redesign. The purpose of process redesign is 'to clarify and refine the need for existing processes and consequently for systems support.'[10] To develop information management systems without evaluating and redesigning business processes could lock in current processes. As these were developed prior to functional integration, existing functional barriers and inefficiencies could be perpetuated. To reduce this risk, projects following on from LIMSP will be managed by a business process owner, not a computing system manager.[11]

PROCEDURAL DEVELOPMENT

Ongoing Improvement

A number of specific RI procedures have been subject to ongoing review and development, notably maintenance planning, RI spares assessment and BDS assessment. Procedural improvement has been pursued in all of these areas, but with mixed results. Often, problem identification has been simpler than the design and implementation of improvement strategies.

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8 Ibid, p 24.

9 An initial implementation step is the tasking of KPMG Management Consultants to conduct a preliminary strategic inventory management design study. This will be known as the Strategic Inventory Decision Environment (STRIDE) study.

10 Nolan, Norton & Co., op cit, p 54.

11 For instance, STRIDE will be managed by the Directorate of Logistics Development, not DLIS.

For example, fundamental flaws in the PATTRIC RI spares assessment model were identified in 1985, but a suitable replacement, OPUS9, was not selected until 1990. Furthermore, OPUS9 implementation will be protracted over a number of years because of the need to provide training and construct the databases required for input to the model.

A second example is the difficulty of relating BDS requirements to parent RIs in spares assessment and maintenance scheduling activities. This difficulty reflects inadequate integration of relevant information systems, and control of procedures by separate functional groups. The recent co-location of relevant functional entities in WSLM Squadrons, and current redevelopment of RAAF logistics information management systems, present opportunities to overcome this challenge.

RAAFQ

One means by which procedural improvement has been pursued is through the application of RAAFQ.[12] A project led by Staff Officer Repair and Overhaul (SORO) to progressively 'review manageable segments'[13] of the RI circuit did result in some improvements, for example in contractor performance monitoring and maintenance planning. However, the project was curtailed due to the competing priorities of the HQLC restructure and the subsequent transfer of procedural responsibilities to WSLM Squadrons.

RAAFQ reviews have demonstrated the feasibility of procedural improvement at a sub-system level. However, segmented review of a system demands a reasonable understanding of the total system in order to wisely select elements for review, and to avoid sub-optimal improvement.

RELIABILITY MANAGEMENT

RI management debate has focused upon RI circuits or pipelines. In terms of A_0, improvement effort has concentrated on the control and reduction of MDT elements of Logistics and Administrative Delay. A complementary approach to improving A_0 is to reduce MTBM. This can be achieved through scheduled maintenance policy or reliability improvement.

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12 RAAF Quality (RAAFQ) is the RAAF's adaptation of Total Quality Management (TQM).

13 *RAAF Quality - Process Action Teams in SLSPTO Branch*, SORO 4014/2/1 (10), 29 March 1990, para 2.

Maintenance schedules are reviewed through the ongoing Maintenance Engineering Analysis (MEA) program. However, the impact of scheduled maintenance on A_0 is not analysed. This is attributable to both the lack of appropriate analytical tools and functional isolation of MEA within HQLC. The proposed assignment of MEA responsibility to WSLM Squadrons is conducive to the utilisation of OPUS9 in this role.[14]

Currently there is no systematic application of RI reliability improvement to increase RI availability. Only when significant performance degradation occurs is action taken to improve RI reliability. Rather than responding to degradation, a proactive reliability management program should be possible. However, attempts to implement such a program have floundered through data availability and manipulation problems, and the pressure of competing daily tasks.[15]

Functional integration is increasing awareness of the impact of reliability and maintainability on weapon system and RI availability. An R&M Centre of Expertise has been created in the Directorate of Material, Air Force Office, to assist R&M management in the acquisition phase of the weapon system life cycle. A corresponding in-service R&M focus is yet to be developed at HQLC or in WSLM Squadrons.

PERFORMANCE MEASUREMENT

Performance measurement has not been conducted at the RI system level. Rather, individual managers have monitored the performance of activities under their control in accordance with locally-determined objectives. Hence, performance measurement has been inconsistently applied across the system.

SORO[16] conducted the most comprehensive performance measurement to date, although this considered only DLM-maintained RIs. From 1990 to 1992 SORO tracked the availability of RIs, by weapon system, against asset availability targets (AAT). This activity highlighted the incomplete application of availability targets to RIs,[17] and the practical difficulties of availability monitoring. Single point AATs were derived from the spares assessment computation. This computation incorporates

14 Reassignment of MEA responsibility from HQLC (AIRREG3) to individual WSLM Squadrons is being considered as part of the 1993/94 HQLC restructure. The redistribution of personnel to perform this process is a matter of ongoing debate at the time of writing.

15 Two such attempts are outlined at Annex B, pp B-17 - B-19.

16 SORO was subsequently renamed the Directorate of Major Maintenance Services (DMMS).

17 As at December 1991 availability targets were assigned to approximately 50% of DLM-maintained RIs across all RAAF aircraft types (data from DLQPE performance monitoring database).

process variation, and identifies required buffer stocks. Hence, it is possible that availability could lie above or below the AAT, yet remain within acceptable process control limits.

A statement of requirement was written at HQLC in 1992 for an RI Asset Availability Monitoring System (RIAAMS). This system was to apply process control limits to AATs. RIAAMS was not subsequently developed, partly because it was unclear whether it would provide a more timely indicator of availability shortfalls than the current priority demand mechanism.[18]

CONCLUSION

The RI system has frequently been described as fragmented, poorly coordinated, and complex. Policy has been developed in an attempt to overcome this fragmentation. However, it has proven difficult to coordinate activity across functional barriers towards the attainment of RI availability objectives. For example, in 1989 HQLC Support Groups (SGs) were assigned responsibility for system coordination. At this time the logistics organisation remained functionally segregated. Consequently, the SGs lacked the necessary authority and resource control to fulfil this role.

Besides functional segregation, numerous factors have limited the development of RI management. These include a lack of data integration and other information management deficiencies, an imbalanced focus on pipeline management, and inconsistent performance measurement. Whilst progress has been made in both policy development and specific procedural aspects, such barriers have restricted the extent of improvement. These barriers will only be removed through long term initiatives such as the LIMSP project.

A more subtle barrier to system development is the limitations of the analytical techniques utilised by system reviewers. The manner in which these techniques have inhibited understanding of dynamic system behaviour and restricted system redesign is discussed in a later chapter.

18 The main indicator of availability shortfalls used by RI pipeline managers is the number of high priority (UNDA/AOG) demands placed for RIs.

CHAPTER FIVE

RI MANAGEMENT OPPORTUNITIES AND ISSUES

INTRODUCTION

In many ways RI management has reached an exciting period in its development. The implementation of the WSLM concept has created an environment conducive to challenging existing logistics practices. A significantly different organisational structure now exists to that which was in place when existing RI management policy and processes were implemented and evolved. This change alone is sufficient basis for re-examination of fundamental aspects of RI management. ILS tenets provide important guidance on the role of logistics in the RAAF, while ILS tools will equip logisticians with the capability to more readily assess the impact of decisions upon operational preparedness. Hence, an integrated logistics environment provides new opportunities to tackle many of the limitations to system development discussed in the previous chapter. Conversely, it also introduces a series of new challenges.

Aim and Scope

The aim of this chapter is to discuss current RI management opportunities and issues. This discussion is pitched at the macro, or system, level. Hence, the many localised opportunities and issues which exist are not examined here.

OPPORTUNITIES

Key changes in the RAAF logistics environment over the past decade and forces now driving change are summarised at Figure 5-1. These include mandates upon RAAF logistics, plus organisational strategies implemented in response to recognition of the need for change. The most significant of these are:

a. Commercial Support Program (CSP)- requiring the RAAF to competitively tender against commercial organisations across a range of non-core activities concentrated in the logistics field;

b. Program Management and Budgeting (PMB)- a resource management framework requiring aggregation and optimisation of costs by weapon system; and

c. Preparedness objectives.

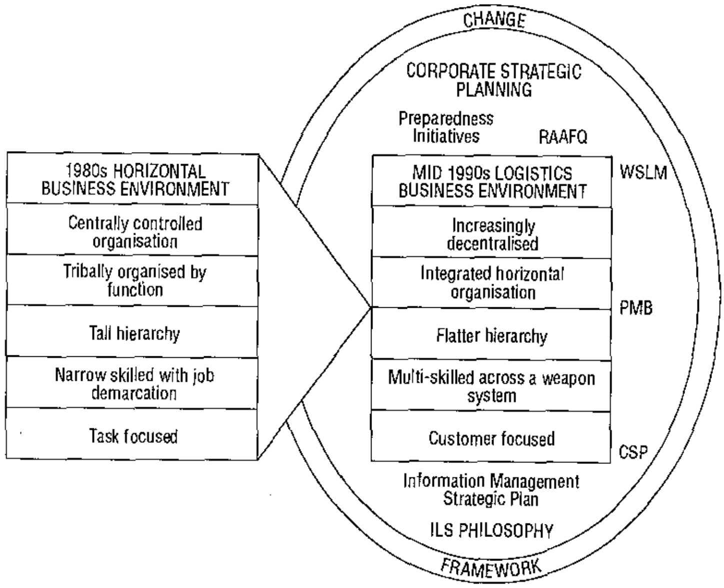

Figure 5-1. Changing RAAF Logistics Environment[1]

In terms of RI management, the environment shown at Figure 5-1 possesses many features conducive to system redesign. The increased focus on preparedness includes:

a. WSLM Squadrons having control of a larger number of the RI management activities and resources than previous organisational entities. In conjunction with Staff Officer Plans and Procedures (SOPP),[2] they are increasingly being perceived as an identifiable RI management process owner. Together these agencies now bear prime responsibility for system development.

b. The location of WSLM Squadrons on operational bases to provide physical proximity to operational customers and an increased range of RI pipeline elements.

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1 Some of the ideas used in developing this diagram were taken from Nolan, Norton & Co., RAAF *Logistics Information Management Strategic Planning Project - Phase III Report*, Volume 1, 3 December 1992, p 12.

2 SOPP responsibilities will be passed to a new appointment within the Directorate of Logistics Development which is to be created as a result of the 1993 HQLC structure review. The point is that there will be a readily identifiable appointment with responsibility for RI management procedural development within HQLC.

c. Collocation of a range of functional entities within WSLM Squadrons to provide the opportunity for enhanced functional coordination and the establishment of a broader perspective on RI management.

d. Ongoing introduction of the ILS philosophy, tools, and LSAR to support more integrated, operationally-oriented logistics business practices.

e. An information management strategic plan which emphasises business process redesign, and will improve data integration.

f. RAAF work study practitioners and increasing RAAFQ experience amongst logisticians as a source of process improvement skill.

CONSOLIDATION ISSUES

A number of the changes introduced above have taken place within the past two years. Consequently, effort is required to ensure their consolidation, raising the issues discussed below.

Application of ILS Tools

Initial training and labour investment is required to apply ILS tools and develop LSARs for new and selected in-service weapon systems. Additionally, strategies are required to make best use of improved data and models. Centralised management and application of some tools by HQLC may seem justifiable on the basis of the level of expertise needed to fully utilise them and interpret results. However, the development of such expertise within each WSLM Squadron would increase understanding of the ILS philosophy and engender a mindset more attuned to preparedness.

Information Management

The LIMSP study established a strategic plan to drive the integration of logistics transaction systems and databases. Historically, information management has limited the development of RI management. There is no guarantee that information systems currently under development will not lock the RAAF into existing business practices. Some of these are not well suited to the new logistics environment. Timely system review and redesign are essential if business processes are to shape information systems, and not vice-versa.

Procedural Diversity

Authorised RI management procedures are currently being collected within a single Defence Instruction by SOPP staff. These, in conjunction with a core WSLM procedural manual, will form the basis of common procedures across decentralised WSLM Squadrons. Each WSLM Squadron will be able to further develop separate procedures, and application of procedures will be subject to self-audit. The strategy is based on 'skinny' common procedures, with SOPP in an advisory role to WSLM Squadrons.[3]

Scope exists for procedural diversity between WSLM Squadrons. Allowing diversity aligns with the semi-autonomy and devolution of responsibility associated with the WSLM concept. However, it does introduce risks such as reduced interoperability and decreased transfer of expertise between WSLM Squadrons. Inconsistent performance reporting, and disparate demands on information management systems, with the potential to undermine the integration of these systems, need to be considered as other risk factors.

Supplier Management and Infrastructure Development

A significant element of RAAF maintenance work is performed by industry, with CSP increasing that proportion. While the weapon system focus has simplified lines of communication between RAAF logisticians and operational staff, it has the potential to complicate relationships with civilian maintenance contractors. There remains a need to exercise centralised control over supplier management, as argued in a paper by Wing Commander G.D. McDougall, who contends that:

> "effective and efficient supplier management...requires an overview of ALL RAAF maintenance requirements to ensure that capability and capacity are available for all WSLMs, either in-house or in industry and that sub-optimisation does not occur as a result of internecine activities between the WSLMs."[4]

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3 Based on comments made by Group Captain C. Russell, Director of Integrated Logistics Procedures, Interview, 17 February 1993.

4 Wing Commander G.D. McDougall, *Maintenance Management Post MATLOG, "Effective Supplier Management", "Effective Venue and Infrastructure Management"*, V3.1, 20 September 1992, p 5.

Infrastructure development to meet strategic requirements must be based upon well coordinated supplier management. The rationale for this link is presented by Wing Commander McDougall, who summarises his theme as:

> "infrastructure development for the RAAF (and ADF), together with the requirement to balance workloads at venues and provide an overall capability and capacity management plan which will achieve effectiveness and efficiency whilst balancing strategic requirements."[5]

This responsibility will be adopted by the Directorate of Logistics Development (DLD), established as a result of the 1993 review of HQLC organisational structure. DLD will seek to strengthen supplier partnerships as a key element of infrastructure development.

SYSTEM DEVELOPMENT ISSUES

Current Status

Some progress has been made over the past ten years toward the design of a more coherent, better coordinated RI system. Similarly, the need to improve a range of procedures and R&M management has been recognised. However, system improvement has been erratic due to factors including inadequate information management, and a narrow focus on specific functional elements of the system.

The behaviour of the system as a whole remains poorly understood. Many individuals are unaware of their role within, and impact upon, the larger system. In this sense, the system remains quite fragmented. This situation is reflected in a minute written in August 1993 outlining an RI Management education program for consideration by Director General Logistics Operations at HQLC:

> "In his base visits as LG8 MSI assessor, SGT White has discovered that most base staff have no concept of the total RI pipeline and their importance in it."[6]

Functional integration provides a basis from which to address the ongoing problem of fragmentation of the RI system. It also provides the opportunity to overcome the historic limitation of a narrow pipeline focus in system improvement activities.

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5 Ibid, p 17.

6 Squadron Leader D.C. Leaney, LG8C, *Repairable Item Management Education*, , LG8/4301/6/1 Pt2 (20)9 August 1993, para 3.

An interesting imperative to greater efficiency is the reduced quantity of spare RIs recommended by the OPUS9 spares assessment model.[7] Given that an excess of RIs may mask wasteful practices which increase pipeline TAT, the prospect of fewer RIs within pipelines can be viewed as an opportunity rather than a problem.

Training and Awareness

Procedural training and strategies to improve the awareness of individuals of their role within the total RI system are currently being developed. One education and training program being jointly developed by DMMS and LG8 aims to improve both procedural knowledge and 'RI pipeline awareness'[8] of relevant RAAF members. It will emphasise the correct use of the current system and the contribution of pipeline TAT to RI availability. A complementary strategy being developed by DLQPE is the use of a computerised simulation model to facilitate a conceptual appreciation of the system at WSLM level. This model will be used in RAAFQ training activities.

While training is important to system improvement, system fragmentation will not be overcome through education alone.

System Behaviour and System Design

The perception that RI management is complex highlights the need to improve understanding of dynamic behaviour of the system as a whole. Such understanding is fundamental to successful development of a coherent, coordinated RI system. It is also necessary to ensure effective guidance of local procedural development and RAAFQ-based improvement initiatives.

The value of a systems paradigm to RI management improvement is gradually gaining support. A '*total systems review*...that considers all the processes and interdependencies of agencies involved in the RI process as elements of a total system,'[9] was formally proposed by TFLMSQN in July 1993. Based on interviews conducted with staff at WSLM Squadrons and HQLC throughout 1993, the concept of a systems-based approach is widely supported.

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7 OPUS9 sensitivity analysis conducted by Staff Office Project Support and Logistics (SOPSL) staff indicates that even varying individual inputs up to a magnitude of two will still yield reduced recommended buy quantity against comparable PATTRIC computation. SOPSL interview, 5 April 1993. Although this comparison ignores the impact of financial constraint on actual quantity purchased, it does suggest that the RI management system will need to become more efficient.

8 Loc cit.

9 Wing Commander J.A. Longrigg, CO TFLMSQN, *Repairable Items (RIs) Repaired by Civilian Contractors*, TFLM/4005/1/RIM1 Pt1 (17), 28 July 1993, para 2.

However, the systems paradigm and supporting methodologies are not well understood. Additionally, the distinction between the concepts of system improvement and system design are often poorly appreciated. Whereas improvement carries the connotation that the structure and underlying assumptions of the system are set, system design involves questioning the assumptions on which the old structure and processes have been built. System design also requires the specification of more appropriate assumptions - assumptions which should flow from the mission of the system. For RI management, this means that the implications of meeting preparedness objectives, as per the logistics mission, must be considered and used as the basis for system design.

CONCLUSION

Changes in the logistics environment over the past decade have created opportunities to challenge many RI management issues outstanding from the 1980s. They have also introduced a series of new issues requiring attention.

Significant consolidation issues include the application of ILS tools and development of information management within a framework of business process redesign. Additionally, decentralisation of many logistics responsibilities to WSLM Squadrons is accompanied by risks associated with both procedural diversity and infrastructure development, the latter being particularly significant to preparedness.

Consolidation of such changes will enable system development issues to be tackled. Despite increased functional integration, the RI system remains quite fragmented. Planned training programs have the potential to improve system performance within existing policy and procedures. More significantly, the opportunity exists to engage in disciplined system redesign based on analysis of the implications of preparedness requirements for RI management. Basic assumptions and tenets of the systems should be drawn from this analysis, providing a preparedness-oriented foundation for system development.

The current logistics environment is conducive to not only improving existing logistics practices, but also challenging the fundamental assumptions underlying these practices. Recent changes in this environment bring to RI management both an imperative to translate weapons system preparedness requirements into logistics objectives, and a set of concepts and tools to assist in this task.

CHAPTER SIX

INTRODUCTION TO PREPAREDNESS

INTRODUCTION

The Australian Defence Force (ADF) exists for the defence of Australia. Its mission is to promote the security of Australia, and to protect its people and its interests. Military capability is the combination of force structure and preparedness through which a nation exercises combat power. Given the criticality of preparedness to the attainment of the ADF's objectives, preparedness considerations should play a dominant role in military thinking.

Since the late 1980s, considerable effort has been expended to develop a doctrinal and policy framework for ADF preparedness. A key development has been the issue of an annual Chief of Defence Force Directive on ADF Preparedness which specifies preparedness requirements against which all Force Elements (FEs) are required to report biannually.

Aim and Scope

The aim of this chapter is to introduce current ADF preparedness doctrine and policy. Ongoing development of policy guidance will also be discussed.

DEVELOPMENT OF PREPAREDNESS DOCTRINE

The Army, Navy, and Air Force have traditionally set and measured readiness in different ways. However, fundamental changes to ADF command and control arrangements in the mid-1980s removed direct operational responsibility from the Service Chiefs of Staff and highlighted the need to apply a consistent method of measuring readiness across all three services. In response to this requirement, the then CDF tasked Air Commodore I.M. Westmore with a review of ADF Operational Readiness in 1988.

In addition to assessing force readiness levels, Westmore proposed a framework of terms and concepts through which ADF readiness could be understood and developed. He also specified readiness objectives for promulgation in a CDF directive. The

Westmore Report formed the basis of current preparedness doctrine and led to the issue of the first CDF Operational Readiness Directive (CORD) in 1989.

Refinement of preparedness doctrine has continued in Headquarters Australian Defence Force (HQADF). Up until 1991, the doctrine was contained within the CORD. Relevant doctrine has now been separated from the annual CDF directive, and is included in Australian Defence Force Publication 4 (ADFP4).[1] ADFP4 is yet to be issued, although the first two chapters have been circulated under VCDF signature. These chapters introduce the three elements of mobilisation planning (mobilisation, force expansion and preparedness),[2] outline the general preparedness framework and terminology, and provide a doctrinal basis for further study of the issue of resource implications of preparedness. ADFP4 will be expanded to address the additional areas of legal issues, the mobilisation planning process, and responsibility for implementation.[3]

Additionally, the RAAF Air Power Manual (published in 1990) discusses aspects of preparedness as part of Air Power doctrine. Preparedness is one of the six imperatives[4] nominated in the Air Power Manual. Imperatives are specific doctrinal aspects to which the RAAF must devote attention to 'gain maximum military effectiveness from the use of the air.'[5]

Ongoing development of preparedness doctrine and policy is seen as a high priority by HQADF. This is due partly to the significance of preparedness considerations for the implementation of a number of current Defence programs. For instance, determination of Manpower Required in Uniform (MRU), to which preparedness requirements are an essential input, is necessary to progress both the Force Structure Review and Commercial Support Program.

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1 ADFP4 - Operations Series - *Mobilisation Planning*, July 1993.

2 Mobilisation is defined as (a) the act of preparing for war or other emergencies through assembling and organising national resources, and (b) the process by which the armed forces or part of them are brought to a state of readiness for war or other national emergency including assembling and organising personnel, supplies and materiel for active military service. Force expansion is the process by which the force-in-being is increased in size, capability or both, by the acquisition of additional trained personnel, equipment, facilities or other resources. Definitions from ADFP4, Glossary.

3 Interview - Lieutenant Colonel Hay, HQADF Development Division, 11 March 1993.

4 The six imperatives of air power are command, qualitative edge, attrition management, centre of gravity, timing, and preparedness. DI(AF)AAP 1000, *The Air Power Manual*, Air Power Studies Centre, Canberra, 1990, p 98.

5 Ibid, p 91.

Additionally, the 1992 Parliamentary Review of Stockholding and Sustainability in the Australian Defence Force[6] raised the profile of work on Reserve Stockholding policy. This policy has been under development in conjunction with preparedness doctrine since 1988.[7]

Mobilisation planning doctrine has a central role in guiding daily ADF activity. This role is summarised in ADFP4 as follows:

> "Mobilisation planning is a dynamic and evolving process influenced by changes to strategic circumstances, force development priorities and financial guidance. It is a fundamental and routine element of daily Defence planning which requires the coordinated efforts of operations, plans and logistic elements of the ADF."[8]

KEY ELEMENTS OF PREPAREDNESS DOCTRINE

Preparedness Defined

Preparedness denotes the ability of forces to undertake operations in a timely manner and sustain the activity involved in those operations. It is used to describe the combined outcome of readiness and sustainability. Readiness is the ability of designated forces to be committed to conduct specified operational roles and tasks within a nominated time at specific strengths and capabilities. Sustainability is the ability to support forces on operations.[9]

In combination with force structure,[10] preparedness provides the military capability through which a nation exercises combat power, as shown at Figure 6-1. Military capability is one instrument of policy available to Government to meet national

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6 Parliament of the Commonwealth of Australia Joint Committee on Foreign Affairs, Defence and Trade, *Stockholding and Sustainability in the Australian Defence Force*, AGPS, Canberra, December 1992. The Committee was tasked to (a) investigate and report on the adequacy and suitability of ADF stockholding policies and practice in a changing strategic environment, and (b) assess the effectiveness of the logistics system in meeting surge and sustainability objectives. It made sixteen recommendations, a number of which specified direction for ongoing preparedness policy development.

7 Westmore's terms of reference included consideration of integration of preparedness concepts with stockholding policy, reflecting the concurrent review of ADF stockholding policy undertaken by Major General Baker and Air-Vice Marshal Heggen. Subsequent policy development is contained in Logistics Strategic Planning Section, Defence Logistics Division, *ADF Reserve Stockholding Policy and Implementation Guide*, 1993.

8 ADFP4, op cit, para 102.

9 Definitions from ADFP4, Glossary.

10 Force structure 'refers to the size, organisation, and technical and operational characteristics of the force-in-being.' ADFP4, Glossary.

Figure 6-1. Preparedness Elements and Role

objectives; it can be used to complement and support 'activities conducted in the diplomatic, economic, social and commercial fields.'[11] Based on national objectives, the strategic environment, and the range of policy instruments available, the Government provides strategic guidance on national requirements for military capability. In this manner preparedness requirements are derived in a top-down fashion from national objectives.

Levels of Capability and Readiness Notice

Broadly speaking, preparedness requirements can be thought of in terms of levels of capability. The expense of maintaining forces at high levels of capability in peacetime cannot be justified. Hence, a mechanism is required to allocate limited resources between FEs to meet preparedness objectives.

The concept of readiness notice enables resource allocation. Each FE is 'kept at the minimum level of capability from which higher contingency operational capability can be reached within an appropriate time frame.'[12] Readiness notice is thus 'the specified time in which a unit or force element must be capable of being made ready to conduct specified operational roles and tasks.'[13]

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11 *ASP90 - Australia's Strategic Planning in the 1990s*, Departmental Publications, Canberra, 27 November 1989, p 3.

12 Logistics Strategic Planning Section, Defence Logistics Division, op cit, p 8.

13 ADFP4, op cit, Glossary.

Three levels of capability are identified within the readiness notice concept. They are:

a. Operational Level of Capability (OLOC) - that level of capability at which units or force elements have the necessary resources and are sufficiently trained to conduct specified operational roles and tasks,

b. Minimum Level of Capability (MLOC) - the minimum level from which units or force elements can achieve their operational level of capability within assigned readiness notice, and

c. Present Level of Capability (PLOC) - the level of capability of a unit or force element at any given time.[14]

Capability criteria at each level are specified in terms of equipment levels, equipment condition, personnel and training.

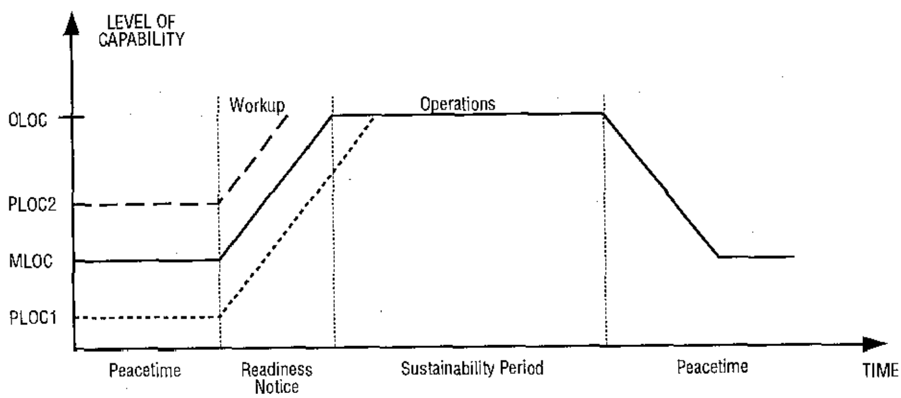

Figure 6-2. Levels of Capability[15]

14 Loc cit.
15 Source: Logistics Strategic Planning Section, Defence Logistics Division, op cit, p 9.

The relationship between these levels of capability and readiness notice is shown at Figure 6-2. If PLOC, which will fluctuate in practice, lies below MLOC (PLOC1) it is unlikely that the FE will be able to achieve OLOC within readiness notice. FEs whose PLOC exceeds MLOC (PLOC2) will be able to work up to OLOC with ease. However, allowing PLOC to permanently exceed MLOC represents allocation of unnecessary levels of resources towards maintaining peacetime capability. Once OLOC has been achieved, activity must be sustained at this level for the period known as the sustainability period (SP).

Preparedness Resources

ADFP4 specifies resources necessary to meet preparedness requirements, as shown at Figure 6-3. These resource categories are:

a. Minimum Resources - 'those required to maintain units or force elements at minimum level of capability'; comprising normal operating resources required by units for peacetime activity.

b. Workup Resources - 'those required to raise, within readiness notice, the capabilities of units or force elements to a level which would permit their deployment on, or commitment to operations.' That is, the resources used or employed to enable FEs to 'work up' from MLOC to OLOC within readiness notice.

c. Sustainability Resources - those required to sustain deployed or committed FEs in operations for the duration of the sustainability period.

d. Operational Viability Resources - a component of Sustainability Resources, but required to be held as part of readiness. These resources are required to maintain the FE for a period after deployment or commitment to operations without external support. They are generally required at the end of the readiness notice period, but may need to be provided earlier to enable logistic preparation for deployment.[16]

16 The last two paragraphs have drawn heavily on the 1993 Defence Logistics Division paper on ADF Reserve Stockholding Policy and Implementation Guidance, p 8.

PREPAREDNESS POLICY

Preparedness objectives are contained in annual CDF's Directive on Preparedness (CPD). The CORD was expanded in 1992 to include sustainability requirements and renamed the CPD. An incremental approach is taken to the development of the CPD. For instance, CPD94 is expected to reflect the advances in preparedness policy that are currently being developed.

The CPD is revised annually by HQADF Operations Division, Joint Plans Staff. It is developed in an iterative manner, with the involvement of Air Force Office on RAAF serials, with Air Headquarters Australia (AHQAUST) able to suggest modification or additional serials.

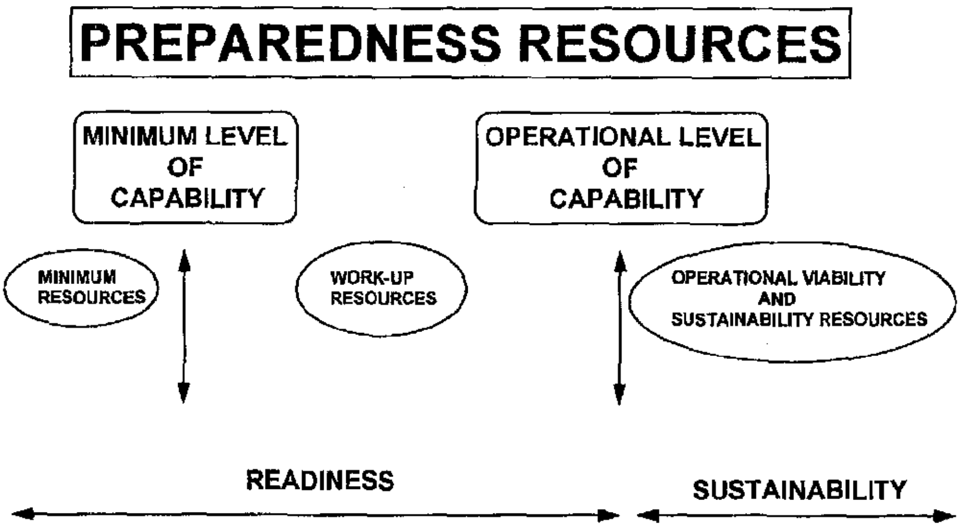

Figure 6-3. Preparedness Resources[17]

CPD Contents

The CPD specifies operational roles and tasks which each FE is required to perform, and the preparedness objectives to be met. The preparedness objectives for each FE are presented as annexes to

17 Source: ADFP4, op cit, Annex A to Chapter 2.

the CPD in serial format. Each serial may contain more than one role or task. Preparedness objectives are specified in terms of:

a. assets required (ie, FE, unit, or number of assets);

b. readiness notice;

c. operational role(s) and expected primary tasks;

d. OLOC criteria in terms of equipment on hand, equipment condition, manpower and training;

e. Operational Viability Period (OVP); and

f. Sustainability Period.

An indicative CPD format for a RAAF serial is shown at Figure 6-4.

SERIAL NUMBER	SECURITY CLASS	FEG(3)	FE(4)	NOTICE	ROLES/ TASKS	PREPAREDNESS RESOURCE	FMC(7)	FMC MLOC(8)
C 38	Unclas(1)	SRG(2)	3 RF111(3)	17 days	STRATINT (5)	Operational viability (6) 30 days Sustainability 180 days	4	3

Notes

(1) Unclassified (Example only)
(2) Strike Reconnaisance Group
(3) Force Element Group
(4) Force Element
(5) Strategic Intelligence
(6) Operational Viability Resources
(7) Number of fully mission capable crews needed
(8) Minimum number of fully mission capable crews from which FMC can be obtained within notice

Figure 6-4. Example of CPD Serial Format (RAAF)[18]

Preparedness Reporting

Reporting Cycle. Joint Commanders are required to submit to CDF, through their Service Chiefs of Staff, biannual reports on the state of preparedness for the periods ending 31 May and 30 November each year. These Biannual Preparedness Reports (BPRs) identify capability deficiencies against the CPD, analyse their consequences for ADF operations, describe action taken to rectify shortfalls, and

18 Source: Logistics Strategic Planning Section, Defence Logistics Division, op cit, p 11.

estimate the time necessary to regain directed levels of preparedness. Additionally, inability to meet preparedness objectives for serials with a readiness notice of 28 days or less are reported as they arise.

Links exist between preparedness reporting and a number of other reporting requirements. Notably, Program Performance Statements submitted to meet PMB requirements link annual activity and expenditures to the attainment of preparedness levels. This reflects the importance that resource management places on meeting preparedness levels.

Sustainability Reporting. Sustainability reporting was introduced with the May 1992 BPR. An open-ended, subjective sustainability reporting format exists. This is indicative of the difficulty of deriving sustainability objectives against which measurement can be performed during peacetime. It also reflects the need for further development of policy guidance on sustainability, as discussed below.

DEVELOPMENT OF FURTHER POLICY GUIDANCE

The CPD 'does not provide sufficiently detailed information on the likely nature of operational activities and hence the likely need for resources.'[19] In response to this, HQADF has been developing supplementary planning assumptions relating to requirements for concurrent activation of CPD serials, and activity levels and usage rates.

Activity Levels

Activity levels (ALs) 'refer to the tempo and intensity at which operations will take place,'[20] and are the basic determinants of resource requirements. Current thinking is that activity levels will be divided into four components: training (workup and continuation) and operations (security and combat).

Differing levels of confidence can be assigned to judgements made with regard to each of these components. For example, the security component will not involve the expenditure of weapons, and the length of activity will not be dependent on the level of enemy activity. This component is likely to represent a large part of the total ADF operational activity, and the resource costs can be predicted with some certainty. However, the combat component will involve

19 Ibid, p 13.
20 ADFP4, op cit, para 217.

expenditure of munitions, and the level of activity will be related to the level of enemy activity. Hence, this component is likely to represent the lesser part of total ADF operational activity, and a high degree of uncertainty will be ascribed to planning estimates.[21]

Although much of the guidance on ALs will be qualitative in nature, numeric activity indicators such as flying hours, or numbers of sorties in particular roles, will be of direct importance to logistics determinations.

Usage Rates

Usage rates are 'the levels of consumption of resources for defined activity levels over time.'[22] The usage rate for an item consists of first and second order components. First order usage rates can be computed, based on 'specific activity indicators, equipment reliability/maintainability/performance data and contingency support concepts.'[23] Demand for RIs and repair parts are based primarily on first order usage rates. Second order usage rates are those which cannot be computed from activity indicators. They relate principally to combat requirements, and are 'a matter for judgement, based on the more qualitative aspects of contingency activity level guidance and on operational concepts.'[24] Attrition of prime equipments and usage of munitions are examples of second order usage rates.

Reserve Stockholding Policy

Stockholding policy has recently been published in the 'ADF Reserve Stockholding Policy and Implementation Guide'. This guide outlines stockholding terminology, presents a reserve stock determination model, and provides guidance on the assessment of model inputs. It also assigns responsibilities for policy.

This policy differentiates between Operating and Reserve Stocks.[25] The purpose of Operating Stocks is to maintain MLOC as dictated by CPD objectives, while Reserve stocks cover requirements for Workup, Operational Viability and Sustainability.[26] Reserve

21 My thanks to Wing Commander M.W. Weir, Directorate of Air Force Plans, for clarification of current thinking on AL components.

22 ADFP4, op cit, para 217.

23 Logistics Strategic Planning Section, Defence Logistics Division, op cit, p 14.

24 Ibid, p 15.

25 Operating stocks are 'used or employed to maintain authorised peacetime levels of activity'. Reserve stocks 'are those stocks held in peacetime, over and above operating stock levels, to support possible future contingency operations.' Ibid, p 17

26 Ibid, p 19.

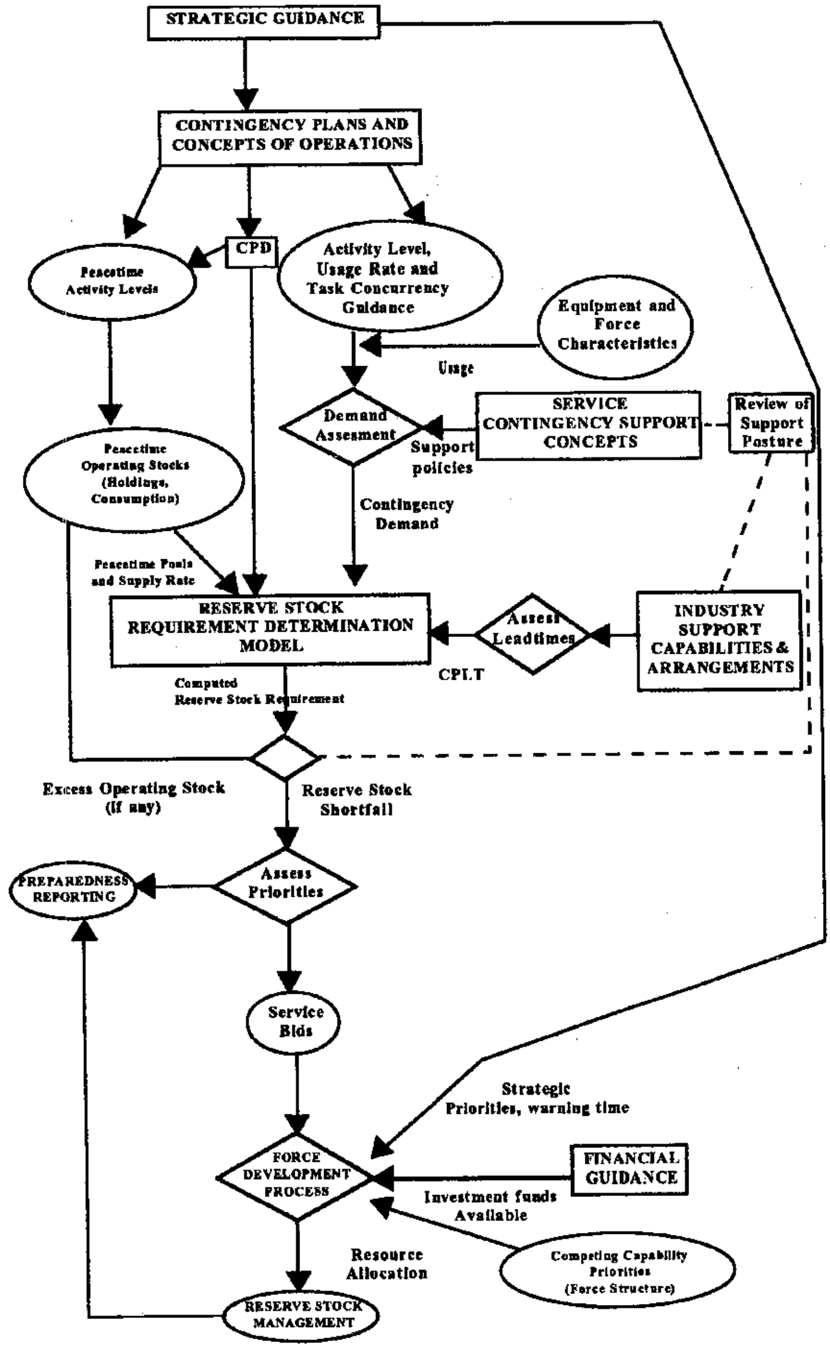

Figure 6-5. Framework for Stockholding Aspects of Preparedness Management[27]

27 Source: Logistics Strategic Planning Section, Defence Logistics Division, p 64.

stocks will be funded from capital, and are not expected to be consumed in peacetime. Hence, they should be maintained at authorised levels.

The overall logic underlying reserve stock requirements determination and resourcing is shown at Figure 6-5. Clearly, reserve stock resource levels are driven by strategic considerations, and reserve stock management is one part of wider preparedness management. The framework and model incorporate both assessment of demand for PE, RIs, and consumable items, and consideration of supply factors. These factors include the availability of peacetime operating stocks and assessment of contingency procurement leadtime which are based on factors such as industry support capabilities and arrangements.

CONCLUSION

Preparedness is essential to the attainment of the ADF's objectives. Hence, preparedness doctrine, which was implemented following the 1988 Westmore Report on operational readiness, has a central role in guiding daily ADF activity. Doctrine is continuing to evolve, and now incorporates some sustainability and significant resource management considerations.

Preparedness objectives are stated for each FE in terms of operational roles and the levels of capability necessary to fulfil those roles. Readiness notice, which has particular significance for resource management, is also specified in the CPD.

HQADF and Service Offices are responsible for development of doctrine and policy guidance. Their current emphasis is sustainability and the resource implications of preparedness. Further development is necessary to enable the derivation of logistics objectives from operational preparedness requirements. The need for this development is supported by the subjectivity and superficiality of sustainability reporting and logistics analysis in preparedness studies conducted to date. A number of these studies are examined in the following chapter.

CHAPTER SEVEN

PREPAREDNESS STUDIES

INTRODUCTION

In addition to ongoing reporting against the CPD, a number of studies on aspects of ADF and/or RAAF preparedness have been conducted in recent years. Prior to implementation of the Westmore recommendations, a sustainability study was conducted as part of the Wrigley Review. Two significant studies conducted since the Westmore Report are the Air Command Preparedness Project (ACPP) and the Force Expansion Study (FES). Each of these studies considers the impact of logistics upon preparedness. Review of these reports and associated working papers provide an insight to current thinking on RI management and preparedness.

Aim and Scope

The aim of this chapter is to discuss RI management analysis undertaken as part of recent preparedness reviews. Reviews considered are the Wrigley Review, ACPP, and FES.

WRIGLEY REVIEW

Defence Central Studies Branch (CSB) provided analytical input to the Surge[1] and Sustainability component of the 1989 Wrigley Review.[2] The aim of this component was to identify constraints on Australia's ability to counter military threats, and determine how civil infrastructure might be able to assist in removing or relaxing these constraints. Amongst potential constraints considered were maintenance manpower, spare parts and consumables.

Methodology. CSB applied a spreadsheet-based methodology, for which the RAAF provided data and information. Due to time constraints, many sweeping and simplified assumptions were made, including the omission of unscheduled maintenance as a

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1 Surge is the process by which military forces operate at higher than normal rates of effort for a limited period, in order to undertake operations or achieve specific objectives. JSP(AS) 4, p xiii.

2 The Wrigley Review examined the use of civil infrastructure in Australia's defence, and was published as 'The Defence Force and the Community: A Partnership in Australia's defence'.

constraint and the application of peacetime maintenance policy. The combined effect of these assumptions and the use of 'limited available data in a gross way'[3] produced inaccurate results.

RI Analysis. RI assets required to support various Rates of Effort (ROE) for nominated aircraft types were estimated by HQLC using the PATTRIC Spares Assessment model. However, the use of PATTRIC for this task was inappropriate, as this model is only applicable to a steady state[4] long term environment. It was also recognised that use of PATTRIC 'for short term surge does not produce reasonable answers, because other variables employed in the model will also change,'[5] particularly pipeline turnaround time (TAT). This approach was adopted due to the need to provide answers in a limited timeframe and the lack of more appropriate models.

AIR COMMAND PREPAREDNESS PROJECT (ACPP)

The ACPP was initiated at Air Headquarters Australia (AHQAUST) in 1990 by Air Commander Australia (ACAUST), then Air Vice-Marshal Gration. His purpose was to provide operational level direction for FEG preparedness in the short term, and influence longer term ADF preparedness outcomes from an informed position.[6]

ACPP Phase One

Methodology. The objective of ACPP Phase One was to develop operational level objectives from the CORD. This would enable improved assessment of Air Command readiness, and the development of assumptions on which to base sustainability assessment. CORD serials were analysed at FEG level under the guidance of an AHQAUST project officer. Supplementary assumptions and data were derived, including activity levels and usage rates. Equipment analysis was restricted to PE (ie, aircraft) and operational consumables. RI and Fly-Away Kit (FAK)[7] requirements were not addressed.

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3 M.F. Gilligan, Assistant Secretary Central Studies Branch, *Surge and Sustainability Study Results*, CSB79/89 SPFD89-22333,25 July 1989.

4 The PATTRIC model is discussed at Annex A. The nature of steady state and dynamic environments is discussed later in this chapter.

5 Air Commodore D.A. Tidd, Director General Technical Policy - Air Force, *Brief on Wrigley Review for Assistant Chief Engineering - Air Force*, 11 July 1989.

6 (Draft) *Air Commander Australia Directive on Air Command Preparedness*, APSC/31/AIR Pt1 (9), 24 October 1990, para 3.

7 An FAK is an air-transportable pack of items required to maintain aircraft in an operational role for a designated period when detached from the parent base. ADFP101, F-10.

Operational Preparedness Directives. As a result of Phase One, ACAUST issued a series of Operational Preparedness Directives to FEG Commanders in June 1992. These directives stipulate, by CORD serial, the expanded planning assumptions and readiness objectives. FEG Commanders were tasked to monitor and advise on the validity of the directives and to report routinely on deficiencies against PLOC and OLOC objectives.

Fly Away Kits. FEG commanders were also tasked to develop FAK listings to meet operational viability[8] requirements against each CORD serial. This is an important prerequisite for the identification of RI deficiencies. However, not all FEGs have addressed this requirement.

The experience of the USAF in the Gulf War using War Readiness Spares Kits (WRSK), the equivalent to RAAF FAKs, should be noted. WRSKs had been validated through *Coronet Warrior* exercises in which units were tasked with flying at wartime rates for 30 days without WRSK re-supply.[9] Even so, problems such as the initial shortage of kits in-theatre as a result of insufficient airlift resources were experienced with WRSK.[10] When airlift resources are at a premium, knowledge of which FAK items are most likely to affect operations is important.[11] While it is unlikely that the RAAF can afford to operate FEs at OLOC during peacetime specifically to validate FAKs, computer modelling[12] and peacetime exercise experience are viable proxies.

ACPP Phase Two

Objective. In June 1992 ACAUST invited HQLC to coordinate Phase Two of the ACPP, alternatively known as the HQLC Sustainability Study. The study objective was the 'quantification of

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8 The Operational Viability Period (OVP) was previously introduced as the period after deployment or commitment to operations in which external support will not be available to an FE. See Chapter Six, p 6-6.

9 *Desert Shield/Storm Logistics: Observations by US Military Personnel*, United States General Accounting Office, November 1991, p 27, cited in G. Waters, *Line Honours - Logistics Lessons of the Gulf War*, Air Power Studies Centre, Canberra, 1992, p 22.

10 Ibid, p 28, cited p 22.

11 Conversely, limiting FAK assets taken on deployment in order to reduce airlift resources utilised may prove to be a false economy. For example, during 1993 considerable effort was being expended to pre-position and recover resources prior to and following 82WG deployments in order to meet the limitation of peacetime deployment with a single C-130 in support.

12 OPUS9 can be used to recommend FAK composition to achieve maximum A_0 against constraints such as size or weight. Also, Logistics Capability Assessment (LOGCAS) modelling can be applied to FAK composition for specific operational scenarios. The RAAF does not currently possess a LOGCAS model appropriate to this task, but is evaluating alternatives with the aim of adopting one in the near future.

the non-manpower resource implications of preparedness and planning and provisioning of such resources.'[13] Planning data in Directives to FEG Commanders provides the basis for this analysis.

The HQLC project officer and working party interpreted the project requirements as determination of reserve stock requirements 'for all operational consumables and for a selected range of RIs and Break Down Spares' (BDS).[14] This study was conducted prior to the development of reserve stockholding policy and guidance.[15]

Operational Consumables. The methodology used and results of the study of operational consumables are beyond the scope of this paper. Interestingly, a response on operational consumables was provided by December 1992, while the March 1993 target for RI and BDS analysis was not met. This is perhaps indicative of the greater complexity of the latter.

RI Analysis. Deficiencies in RAAF logistics modelling capability impede the assessment of reserve RI stockholding requirements. The ACPP was seen as an 'opportunity to introduce and develop the logistics modelling processes' required to estimate 'logistics resources needed to meet defined operational capabilities.'[16] OPUS9 is being simultaneously implemented and utilised as the primary analytical tool to complete the study. To achieve this, selected staff in WSLM Squadrons have been trained to use OPUS9 and tasked to pursue the study on a weapon system basis.

Databases required to apply OPUS9 to a complete weapon system build structure require 'many man-years of work.'[17] Hence, a short list of problem RIs from each weapon system was derived for analysis in an attempt to meet the study deadline.

Methodology Limitations. The methodology adopted suffers several limitations. These relate to the selection of RIs to be analysed, flaws in the application of OPUS9 to a small RI set, and the validity of data input to OPUS9. Discussion of these limitations also highlights some of the problems inherent in the derivation of quantifiable logistics objectives from preparedness requirements, and the difficulty of performance measurement against these objectives.

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13 *Operational Preparedness Directives to FEG Commanders*, AHQ 7/34/AIR, 26 June 1992.

14 *Air Command Preparedness Project*, SOAE/4000/60/FES/1 (45), 10 August 1992, para 2.

15 Reserve stockholding policy and guidance was published by Logistics Strategic Planning Section, Defence Logistics Division, in 1993.

16 *Air Command Preparedness Project*, SOAE/4000/60/FES/1 (46), 18 August 1992.

17 Loc cit.

However, it must be stated at the outset that the approach adopted is pragmatic, does provide a valuable learning opportunity, and that OPUS9 is an improvement on other models currently available to the RAAF.

RI Selection. Selection of RIs for analysis was based on a list of potential candidates derived using an inventory stratification approach developed within the Directorate of Integrated Logistics Processes (DILP) in 1992.[18] Intended for use in an RI management improvement program, stratification was based on annual maintenance costs and peacetime RI supply shortfalls.[19]

The assumption underlying application of the latter criteria to the ACPP is that RIs in short supply during peacetime are most likely to impede achievement of OLOC. While a reasonable starting point, it overlooks the impact of altered patterns of use of aircraft sub-systems in contingency. This point was highlighted in guidance issued by Chief of Staff Logistics Command in December 1992, that 'the duty-cycle for many systems will change; those rarely used in peacetime will experience a high initial failure rate and may require higher spares holdings.'[20] ADF Reserve Stockholding policy stresses the need to assess changes in environmental conditions and operating tempo during contingency when computing first order usage rates.[21] Such guidance is supported by RAND research which found that 'parts that were never a problem (in peacetime) can suddenly become *showstoppers* because of environmental conditions, different usage patterns, or a change in quality.'[22]

A further significant criteria overlooked in ACPP Phase II is mission capability.[23] It is common practice to fly aircraft with certain systems in an unserviceable state. The shortage of an RI is one of the possible causes of 'Carried Forward Unserviceabilities' (CFUs) which, while acceptable from an airworthiness perspective, may undermine mission capability. The significance of a CFU to preparedness

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18 The DILP project is outlined at Annex B, p B-18.

19 Annual maintenance costs were measured by annual civilian contractor costs or RAAF technical labour hours. RI shortfalls were measured by high priority UNDA/AOG demand submissions.

20 *Impacts on Logistics Command Functions in a Contingency*, DCOE 4000/49/MRU Pt2 (9), 16 December 1992, Annex A para 5.

21 *ADF Reserve Stockholding Policy and Implementation Guidance*, Logistics Strategic Planning Section, Defence Logistics Division, 1993, p 41.

22 Marygail K. Brauner, Daniel A. Relles, and Lionel A. Galway, *Improving Naval Aviation Depot Responsiveness*, RAND, Santa Monica, 1992, p v.

23 Mission capability was introduced at Chapter Three, p 3-8. To be considered mission capable an aircraft must be available, and fitted with all systems required to achieve mission objectives. Additionally, these systems must remain operable for the period necessary to achieve mission objectives (ie, mission reliability).

depends upon whether the unserviceable sub-system is essential to achievement of a tasked mission. This is especially important with multi-role capability.

RI criticality is considered in Maintenance Engineering Analysis (MEA).[24] Operational Squadron staff assist system engineers to classify aircraft systems according to whether they are safety critical, mission critical, or non-critical. However, the award of a mission critical classification can be misleading; an item which is tentatively safety critical, but is backed up by full or partial redundancy, will actually be classified as mission critical in the MEA process.[25] Although the criticality classification logic may require review, it is obvious that identification of systems and RIs critical to CPD missions is feasible. Further, such classification is essential to reserve stock assessment,[26] and would have proven valuable in RI selection for ACPP analysis.

WSLM Squadron staff were encouraged to supplement the inventory stratification through 'liaison with FEG logistics staff'[27] to select RIs for analysis. However, no guidance was given on the criteria to be considered in deriving a valid list of RIs most likely to impede achievement and maintenance of OLOC.

OPUS9 Application. In ACPP analysis, OPUS9 is being applied as a replenishment spares assessment tool. Its objective is to optimise the quantity and distribution of RIs in relation to the performance criteria of operational availability at lowest life cycle cost. Unlike PATTRIC, which assesses each RI independently, OPUS9 will consider a set of RIs in relation to each other. When data on only a single RI is input to OPUS9, recommendations will not be optimal for the entire weapon system. A greater number of RIs analysed in the model will ensure that the recommendations will be closer to the optimal solution. ACPP analysis is based on a limited set of RIs for each weapon system. Analysis using data on a more complete RI set for each weapon system would provide increased accuracy in assessment of additional requirements to support the CPD.

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24 MEA includes the systematic evaluation of aircraft scheduled maintenance requirements. Information and decisions from MEA are used in preparation of aircraft servicing schedules and Technical Maintenance Plans. DI(AF)AAP 7001.038-2, para 103.

25 The logic underlying assignment of criticality ratings to systems is shown in the 'System Criticality Analysis Logic Flowchart' provided at Figure 3-2 of DI(AF)AAP 7001.038-2, op cit.

26 Service offices have been tasked to 'determine item essentiality/criticality classification for all reserve stock candidate requirements' as part of ongoing reserve stock policy development in Logistics Strategic Planning Section, Defence Logistics Division, op cit, p 69.

27 SOAE/4000/60/FES/1 (45), op cit.

Steady State and Dynamic Environments. The distinction between steady state and dynamic environments is important to logistics modelling. Consider Figure 7-1 which plots the utilisation of a weapon system over time in terms of Rate of Effort. During peacetime, Rate of Effort is relatively constant, with occasional fluctuations through the effects of deployments, fleet groundings or other events. The Rate of Effort rises during the work-up period to attain a higher ongoing level during contingency (the sustainability period). As with peacetime, the Rate of Effort will be punctuated by surges during contingency. From the modelling perspective, Figure 7-1 can be broken into regions of steady state behaviour (the 'flat' regions) and dynamic behaviour (the peaks and troughs). The analysis of steady state behaviour is best accomplished using deterministic models, while dynamic simulation models are more appropriate to dynamic behaviour.[28]

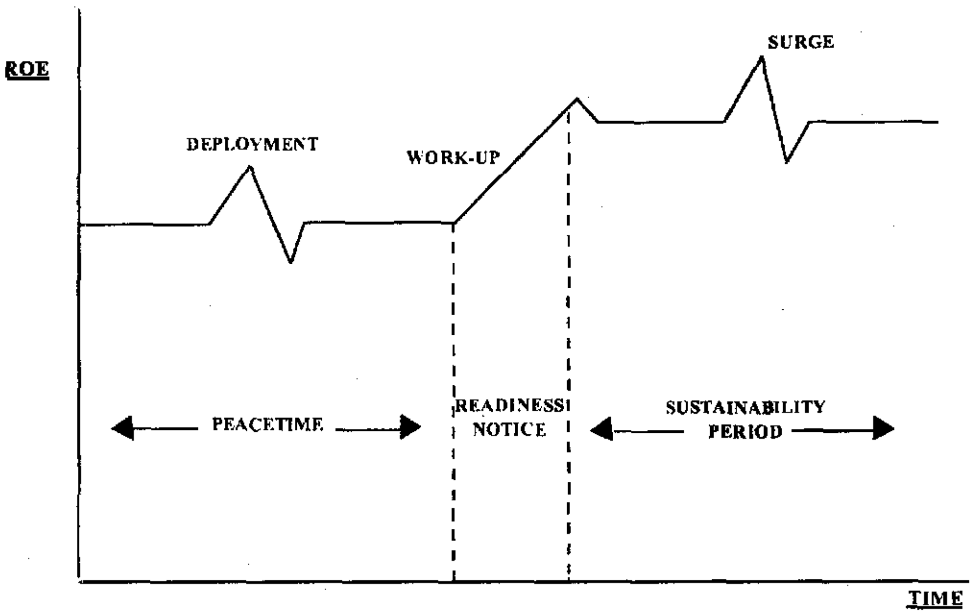

Figure 7-1. Steady State and Dynamic Behaviour[29]

OPUS9 as a Steady State Model. OPUS9 is a steady state model, and is therefore inappropriate to analysis of dynamic surge environments. OPUS9 could be applied once the surge activity has ceased and a steady-state environment is re-established, possibly at a

28 Paragraph based on Annex B to (Draft) DI(AF)LOG 5-8 *Logistics Capability Assessment*, December 1992.

29 Source: Loc cit.

higher ROE. However, it cannot be validly applied to the workup period and subsequent surge at contingency ROE. Dynamic LOGCAS models are needed for this purpose.

Input Parameters. The input parameters used in modelling must be accurate for operation of the logistics system at work-up and contingency ROE, not peacetime performance. Likely RI system performance at CPD ROEs has not been studied, and is not incorporated into the ACPP analysis.

Study Focus. By interpreting the ACPP's terms of reference as the calculation of reserve stockholding, HQLC analysts may have locked out other means of meeting surge demand for RIs. For example, it may be possible to decrease the time spent repairing RIs at contractors (MTTR) by increasing payment to cover the expense of shiftwork or hire of additional technicians. Additionally, RAAF CPD serials do not require the use of all FE platforms. During a contingency, cannibalisation will be another means by which the surge in demand for RIs can be met. Such quantifiable options were not considered.

THE FORCE EXPANSION STUDY (FES)

Aim

The FES, conducted in 1991/92, was a desktop analysis of the internal expansion process of the ADF to meet credible contingencies. The methodology was piloted using Maritime Patrol Group (Phase I), prior to being applied across the ADF. It aimed to identify chokepoints in the internal expansion process, and focussed on manpower, training, equipment and logistics activities.

Methodology

Phase II (FESII) was based on a specified Operational Order which, for the RAAF, ultimately matched that used in the ACPP. RAAF FES activity was coordinated by an Air Force Office (AFO) Working Group.

A key analytical tool was a Force Expansion Process flowchart, which was drafted by AFO and subsequently refined in conjunction with a HQLC working party. The flowchart displayed identified chokepoints and dependencies on external events, such as funding availability. A chokepoint is essentially any event in the expansion process which delays or prevents an FE from achieving OLOC within readiness notice, or sustaining operations at OLOC.

RI Pipelines

Handling and processing of RIs through maintenance pipelines was identified as a potential chokepoint in the force expansion process. Evaluation of alternatives to meet demand for RIs was more broadly based than ACPP analysis. As reflected on the RI Provisioning flowchart at Figure 7-2, alternative means of increasing availability were identified, including reduction of repair turnaround time (TAT) and asset redistribution. Possible strategies to reduce repair TAT were listed in a HQLC working document as:

a. industrial mobilisation,

b. reduce transit time to and from repair venues and spares suppliers,

c. blanket authorisation for evacuation/induction of repairs,

d. increase buys of Breakdown Spares,

e. approval of overtime/additional shifts,

f. expedite/waiver customs requirements, and

g. relocation of test equipment and personnel.[30]

Funding deficiencies, shortfall of information on maintenance venue capacity and capability, and industrial mobilisation were noted as potential chokepoints underlying some of these strategies.[31] This list was the result of 'relatively brief consideration of the questions involved,'[32] and the viability and impact of these strategies on maintenance pipelines was not analysed.

Clearly, RI circuits will require close management during a contingency. This is reflected in HQLC guidance that WSLM 'RI management staff will become heavily involved in speeding up both in-house and contractor repair circuits.'[33]

30 *Force Expansion Study*, SOAE/4000/60/FES/1 (10), 5 June 1992, p 13.
31 Ibid, p 13.
32 Ibid, para 2.
33 DCOE/4000/49/MRU Pt2 (9), op cit, Annex A, para 6.

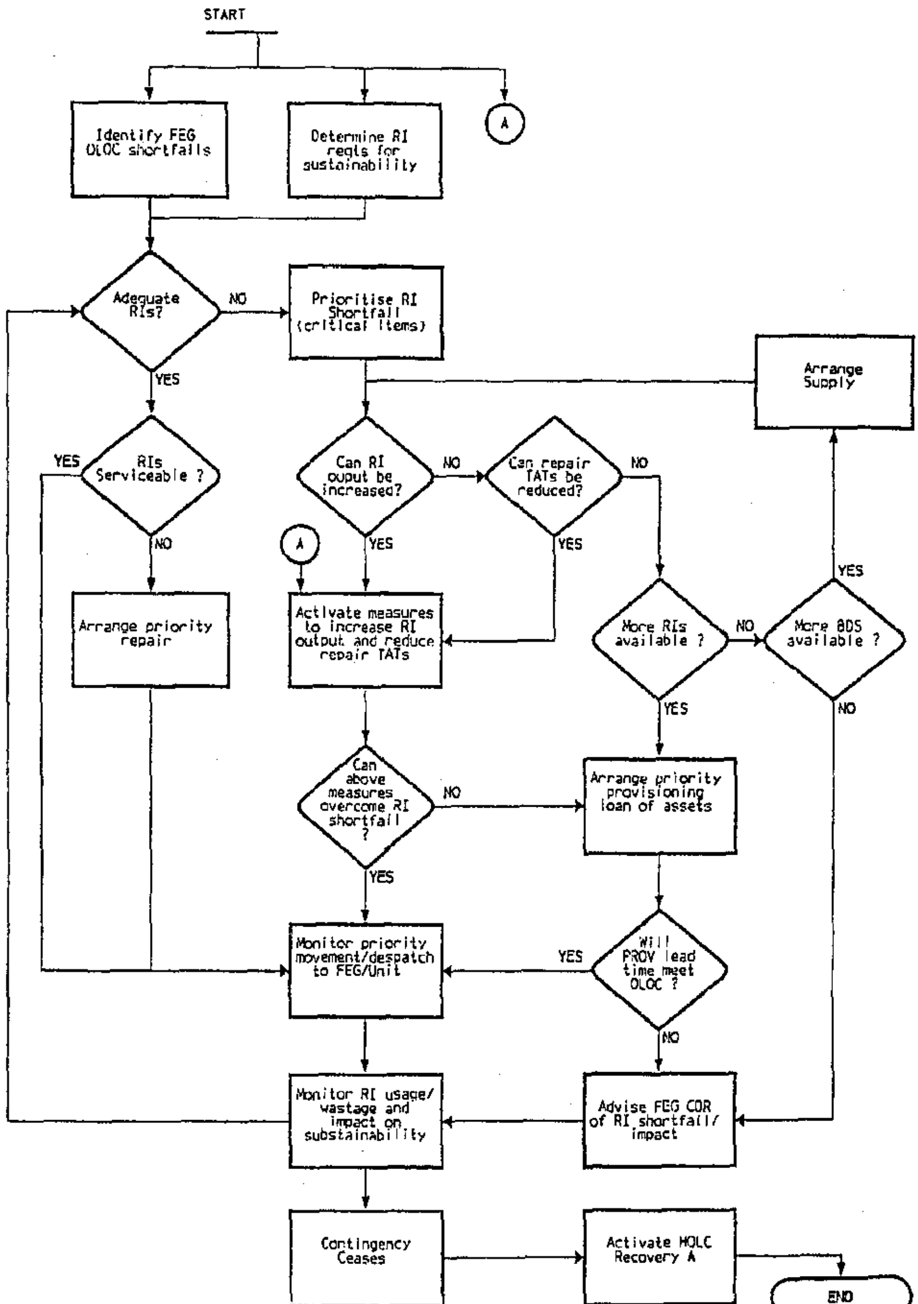

Figure 7-2. FES RI Provisioning Process Flowchart[33]

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33 Source: Ibid, p 11.

Sustainability Snapshot

The first sustainability snapshot was included in FESII to coincide with the May 1992 Biannual Preparedness Report (BPR). The snapshot considered BDS, operational consumables, and surge capacity limitations for deeper level RI circuits. The Directorate of Major Maintenance Services (DMMS) prepared a response on RI availability and circuits, in consultation with WSLM Squadron staff.

The impact of RI availability was assessed from a financial perspective. Where a CORD serial resulted in an increase in ROE over peacetime levels, a proportionate increase in funding requirements was assumed. DMMS acknowledged that additional RI maintenance work may require a 'disproportionate increase in funds due to a requirement to work overtime or additional shifts,'[35] but were unable to incorporate this into calculations as insufficient time was provided for 'proper analysis.'[36] Other factors omitted were distribution of assets, effect of operation from deployed locations, and engineering and modification aspects. In their own words, 'availability of RIs to sustain CORD requirements (was) subjectively assessed in the crudest rudimentary manner.'[37]

Maintenance venue surge capability was also superficially addressed. Factors which may affect surge capability were identified, as were longer-term issues such as the availability of spares and consumables, fixture constraints (eg, test benches, workshop space), and additional monetary compensation required to pay for increased contractor work.

The capacity of specific venues and pipelines was not addressed in the sustainability snapshot. However, the comment was made that 'a reasonable level of corporate knowledge exists within HQLC about the capability and capacity of various subcontractors within Australia.'[38] If such corporate knowledge exists, why was it not applied in the sustainability study? Information on capability and capacity is gathered annually from subcontractors and recorded at HQLC. However, it is perhaps too general to enable identification of pipelines lacking necessary expansion capacity.[39]

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35 *Force Expansion Study - Sustainability Snapshot*, SRO4 4000/35/FES (8), 14 July 1992, para 3.

36 Loc cit.

37 Ibid, para 1.

38 Ibid, Enclosure 2, para 4.

39 This statement is made with some caution. Both DMMS and the Directorate of Contracting Services (DCS) maintain records of subcontractor capability and capacity. I have not sighted these records. A number of interviewees suggested that much of the corporate knowledge on this subject is unrecorded, hence difficult to utilise in preparedness analysis. For this reason it is raised as an area of concern and potential improvement.

Review of sustainability comments included in recent RAAF BPRs show that there has been little development in methodology applied to sustainability assessment or specificity of information reported. The deficiencies in policy guidance, more immediate HQLC priorities, and inadequate use of modelling tools have all contributed to this situation.

FESII Follow-Up Action

Findings of FESII have been used at HQADF to guide ongoing policy development. However, RI pipeline surge limitations are not being specifically addressed in a coordinated manner.

ONGOING PREPAREDNESS DEVELOPMENTS

HQADF Activity

Doctrine. Development of preparedness doctrine continued with three additional chapters of ADFP4 being written during 1993.

CPD. The CPD review and reporting process is well established as the principal means by which preparedness requirements are determined and reported. Ongoing preparedness developments will be linked to the CPD framework.

Policy Papers. HQADF staff are currently working in conjunction with relevant Service offices to complete a series of papers aimed at providing increased guidance on sustainability and stockholding determination.

HQLC Activity

Restructuring. The ongoing formation and relocation of WSLM Squadrons to operating bases has been a HQLC priority throughout 1993. Restructuring on a weapon system basis will provide a greater focus of logistics on weapon systems generation, and is in part a structural response to preparedness requirements.

ILS Implementation. As discussed in Chapter Two, the Integrated Logistics Support (ILS) philosophy and ILS tools are currently being implemented by HQLC, as required by current ADF and RAAF logistics policy. ILS specifically recognises satisfaction of weapon system preparedness requirements as the objective of logistics activity. It also provides tools which seek to optimise logistics support and weapon system design in relation to this objective, at minimum life cycle cost. Within HQLC, Staff Officer Project Support and Logistics (SOPSL) is working to select a suite of ILS tools which will be implemented across HQLC to aid in-service weapon system logistics management.

ACPP Phase Two. Work on RI evaluation utilising OPUS9 for ACPP Phase Two is continuing, albeit slowly. Given the limitations of the methodology, as discussed in this chapter, study results will be of little value from a preparedness perspective.

CONCLUSION

Overall, RI management analysis performed as part of preparedness reviews has been superficial. Several common factors have limited the depth and utility of such analysis. These factors relate to organisational structure, policy guidance, tools, and assumptions and data.

Integration of logistics functions and formation of WSLM Squadrons has been a HQLC priority over the past two years. Additionally, the transfer of RI management responsibilities from SGs and DMMS to WSLM Squadrons has necessitated a period of adjustment and learning. Consequently, preparedness reviews have not been afforded as high a priority as desirable.

At the operational level, there has been limited cooperation between operational and logistics staff in assessing the impact of logistics upon preparedness. Close communication is necessary between WSLM Squadron and FEG staff to explore significant assumptions such as RI duty cycles in contingency.

Preparedness study methodologies were devised in the absence of policy guidance on sustainability. This contributed to the adoption of simplistic assumptions, which has undermined the validity and utility of some analysis, particularly ACPP Phase II. Notably, the differences between contingency and peacetime environments have been oversimplified, and mission criticality has been ignored.

Finally, the modelling tools available have not always been suited to the dynamic contingency environment. Even those which have had some utility, such as OPUS9, have not been appropriately applied.

WSLM Squadron relocation issues have been largely resolved, and HQADF has provided increased policy guidance on sustainability and stockholding. Under these conditions, the opportunity now exists to raise the priority of preparedness analysis, and apply the lessons of our experience in this area.

CHAPTER EIGHT

PREPAREDNESS IMPLICATIONS FOR RI MANAGEMENT

INTRODUCTION

Review of recent preparedness studies shows that the approach being taken in consideration of the logistics implications of ADF preparedness doctrine and policy is currently based on the calculation of resource requirements. Recent HQADF policy development and the ACPP both emphasise calculation of reserve stockholding requirements to support the preparedness objectives specified in the CPD. That is, these studies have emphasised the establishment of 'bottom line' logistics resources required to meet preparedness outcomes. This is largely achieved through the use of quantitative models. However, this approach has been taken with minimal consideration of the operational environment or of the way that support systems function. To be of practical value, calculation of resource requirements must occur within a broader framework of ongoing development of logistics systems such as the RI system.

Aim and Scope

The aim of this chapter is to discuss the limitations of calculating RI resource requirements with an inadequate understanding of the operational environment and logistics system, and the need to adopt a broader approach to RI system development. To illustrate the insights that are possible utilising a broader, non-quantitative methodology, several initiatives are identified which have the capability to more closely align RI management to preparedness requirements. Identification of these initiatives flows from material presented in previous chapters.

CALCULATION OF RI RESOURCE REQUIREMENTS

The adoption of Logistics Capability Assessment (LOGCAS) will reinforce the calculation of resource requirements undertaken in the ACPP. LOGCAS has been assessed within HQLC as:

> "a profound cultural change to the conduct of logistics in the RAAF because the focus on logistic capability

> assessment will bring more rigour to the decision making processes relevant to contingencies."[1]

However, the application of LOGCAS and other logistics models does not necessarily result in rigorous decision-making. The potential limitations of model-based resource calculation for assessment of preparedness implications are discussed below.

Judgements and Assumptions

Professional military judgement is applied in the development of CPD serials and assessment of activity levels derived from each serial. First order usage rates for RIs are computed from activity levels. This computation is relatively straightforward using RI spares assessment models. However, many assumptions are attached to the use of such models.

A model is a representation or approximation of reality. Thus, a model provides a simplified version of the operation of the logistics system (or sub-systems). Further, assumptions are often attached to the model's data inputs. Computation based on the modelling and data assumptions produce *probabilistic* outcomes which must be carefully interpreted. For instance, 'a judgement is necessary to set a target for the average level of aircraft serviceability which will ensure that variations below the average do not compromise the CPD number and notice.'[2]

Due to the features of the modelling process discussed above, it is dangerous to apply models without a clear understanding of the factors which affect their output. The main factors to be understood if model outputs are to be validly interpreted are:

a. the operational and logistics environments being modelled;

b. the mechanics of the model - how calculations are performed, inherent assumptions, and limitations; and

c. input data - data source, applicability to the scenario being modelled, and variability of input data.

At this stage in the development of RAAF logistics, considerable progress is required in all of these areas. For example, the impact of variation in the operational environment and altered support system parameters in contingency have not generally been considered in the logistics analyses performed in recent preparedness studies. Additionally,

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1 Squadron Leader D. Tramoundanis, *Logistics Capability Assessment - A Strategy for the Future*, DLQPE/123/5/5/Air (14), Enclosure 1, 18 December 1991, p 11.

2 Squadron Leader C. Wheaton, *Logistics Performance Measurement*, in *The Logbook*, Issue No. 3, June 1993, pp 37-39.

there is a clear need to train selected personnel in modelling techniques. This observation is supported by a 1992 RAAF visit report that evaluated the use of logistics models by overseas defence and civilian organisations. One of the conclusions of this report was that:

> "Personnel involved in modelling and logistics analysis require specialist skills and knowledge which are not adequately developed by existing (RAAF) training. A method of obtaining the required background is through completion of post-graduate degrees in operations research."[3]

Even where the factors affecting model outputs are clearly understood, the probabilistic nature of the computed 'solution' must be acknowledged. Importantly, input data will always be subject to some variability, hence it is not possible to derive deterministic model outputs. The modelled solution will lie within a range of likely outcomes. For this reason a confidence interval should be attached to model outputs. Additionally, relevant assumptions should be reported with model outputs, and their implications discussed.

Modelling Tools

Development of reserve stockholding policy will not immediately affect assessment of RI requirements to meet CPD objectives. Appropriate modelling tools are required to assist in ascertaining the resource requirements of this policy. As previously explained, OPUS9 may be unsuited to RI spares assessment and LOGCAS in the dynamic environment embodied in CPD serials. The RAAF's need for a dynamic LOGCAS capability has been under examination since the late 1980s. HQLC is currently seeking to acquire an RI LOGCAS model as one of a suite of ILS tools.[4] However, RI LOGCAS methodologies will take several years to implement, even with improved data availability from OPUS9 implementation.

Modelling and Operational Availability (A_O)

A_O is most commonly used in logistics models as a performance target against which resource requirements are optimised. As discussed in Chapter Two, A_O does not reflect mission capability, hence is inadequate when used in isolation as a measure of logistics capability against preparedness requirements.

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3 Wing Commander M.W. Cornwall and Wing Commander P.A. Szorenyi, *A Preliminary Evaluation of Selected Logistics Models*, DLDP AF91/36009 Pt 2 (97), 12 October 1992, p I.

4 This potential acquisition is being managed by Staff Officer Project Support and Logistics as part of the CAPLOG project, previously introduced at Chapter Two, p 2-5.

A second problem with the use of A_O is that it is a macro performance measure. Hence, A_O is the outcome of the interaction of a multitude of logistics sub-activities, as well as the inherent features of aircraft design. Supplementary performance data is necessary to determine the impact of each sub-activity upon A_O, and appropriate targets must be established for sub-activities. Analysis of performance against such targets will assist in improving the understanding of their interplay, provided sufficient knowledge of system behaviour exists to validly interpret data.

Input Data

Logistics modelling requires input data on both resource demand and supply factors. For preparedness assessment, such data should be pertinent to the contingency environment. ADF reserve stockholding guidance stresses 'that contingency demand is not able to be inferred directly from peacetime databases, which relate to peacetime support concepts, operating environments and equipment behaviour.'[5] Up to now, logistics input data utilised in preparedness studies has been based predominantly on peacetime data, not contingency data. However, a peacetime focus is not adequate in establishing logistics resource requirements.

Logisticians must team with operational staff to identify and appreciate the likely differences in operational environment and equipment use during contingency. For instance, the duty cycle times of specific systems on an aircraft for different missions may have a significant bearing on logistics support requirements in contingency. This approach is an extension of the Logistics Support Analysis (LSA) 'Use Study.'[6] LSA is central to implementation of ILS, and should be based on preparedness objectives specified in the CPD.

Similarly, contingency support concepts and logistics system behaviour should underlie data on supply parameters used in preparedness analysis, not peacetime concepts and performance data. ADF reserve stockholding policy identifies the possible variation of maintenance policies in contingency 'in terms of where and how often maintenance is to be performed and how it is to be managed.'[7] This will clearly alter repair turnaround time, which is a critical modelling input.

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5 Logistics Strategic Planning Section, Defence Logistics Division, *ADF Reserve Stockholding Policy and Implementation Guidance*, 1993, p 40.

6 MIL-STD-1388-1A, LSA, has been adopted by the RAAF for LSA implementation. It specifies tasks which may be included in conduct of a weapon system LSA. Task 201 is the Use Study. LSA and ILS are discussed at Chapter Two, pp. 2-3 - 2-7.

7 Logistics Strategic Planning Section, Defence Logistics Division, op cit, p 40.

The RAAF is yet to develop contingency maintenance policy. Such policy is needed to identify the assumptions underlying calculation of logistics resources against preparedness requirements.

Model Validation

Modelling of anticipated contingency scenarios is inherently predictive and probabilistic. Recognising this, the USAF have sought to validate LOGCAS models using exercises such as the *Coronet Warrior* series. These exercises comprise isolation of an operational squadron on a simulated surge for a thirty day period without RI resupply (equivalent to operating for a 30 day Operational Viability Period). Predictions of RI availability from LOGCAS models were usually found to be pessimistic, while the items limiting availability were accurately predicted.[8]

Variation in both demand and supply factors produces variability against quantitative predictions. Research conducted for the USAF by RAND indicates that logistics models poorly predict demand.[9] With regard to supply factors, Air Commodore D.A. Tidd suggested in a brief on the Wrigley Review for the Assistant Chief of Engineering that 'ingenuity, innovativeness and dedication to the cause generated a human factor difficult to apply in modelling,'[10] leading to higher than predicted supply of RIs in the *Coronet Warrior* exercises. This observation on human factors is reinforced by mission capable rates achieved by the USAF in the Gulf War, which consistently exceeded those attained in peacetime for all aircraft types. This result has been attributed partly to 'ingenuity on the part of ground crews to ensure maintenance, logistics and other sustainment functions work.'[11]

In conjunction with consideration of assumptions noted above, the USAF experience suggests that while logistics models are a potentially valuable decision support tool, quantitative outputs often need to be carefully interpreted and qualified.

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8 Ibid, p 8.

9 J.A. Stockfisch, *Linking Logistics and Operations: A Case Study of World War II Air Power*, RAND, Santa Monica, 1991, p 1.

10 Air Commodore D.A. Tidd, Director General Technical Policy - Air Force, *Brief on Wrigley Review for Assistant Chief of Engineering*, 11 July 1989.

11 G. Waters, *Logistics Observations from the Gulf War*, in G. Waters, *Line Honours. Logistics Lessons of the Gulf War*, Air Power Studies Centre, Canberra, 1992, p 20. Waters provides tabulated mission capability rates to support his comment.

A COMPLEMENTARY APPROACH - SYSTEM DEVELOPMENT

The risks of relying too heavily on logistics modelling to calculate resource requirements in preparedness analysis are apparent from the findings of a 1991 overseas visit by Air Vice-Marshal W.M. Collins, Air Officer Commanding (AOC) Logistics Command, and senior HQLC Officers, who discussed RI LOGCAS and the Gulf War experience with RAF and USAF counterparts. Following this discussion the AOC warned that:

> "The Command (ie, HQLC) needs to be careful about placing too much emphasis on the use of computer models that identify critical repairable items. The factors that greatly influenced readiness and sustainability (in the Gulf War) were much broader than critical RIs, eg. the adequacy of logistics communications, fuel and transport systems."[12]

In this statement, the AOC emphasises the systemic nature of logistics support. Logistics modelling and quantitative analysis do have an important role in preparedness analysis. However, this role lies within a broader approach to logistics system development. A sound understanding of system behaviour is essential to develop valid modelling assumptions and data. Further, modelling itself can provide insight into system behaviour and guidance of value to system development. Modelling in isolation from thinking about system behaviour and development is of limited value. Hence, the two are complementary activities in the consideration of preparedness implications for RI management.

An approach to system development must meet several criteria if it is to complement resource calculation. Specifically, this approach must:

a. enhance understanding of the logistics system;

b. enable implementation of changes which develop a system better able to support contingency operations;

c. guide the selection of models for resource quantification; and

d. support the appropriate application of these models.

In the remainder of this chapter, several considerations relevant to development of the RI system, given current ADF preparedness doctrine and policy, are discussed.

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12 *Report on the Overseas Visit of Air Vice-Marshal W.M. Collins, AM, Air Officer Commanding RAAF Logistics Command, 20Sep91-18Oct91*, pp 1-2.

Uncertainties of War

It has long been recognised that uncertainty permeates war and military operations. Strategic-political uncertainty, technological changes, and tactical change during a war all stress the logistics system. Amongst the uncertain events to which logistics managers may be required to adapt are technical modifications and introduction of new systems, new or unexpected enemy tactics, and use of a system for a mission other than what it was originally designed to perform.[13] It is conceivable that missions flown in a low level or escalated low level conflict in the defence of Australia will vary from those contained in the CPD, or that tactics will vary from those practiced in peacetime,[14] with unforeseen impacts on logistics support. The existence of such uncertainty strengthens the need to complement the calculation of logistics resource requirements with the attainment of deeper understanding of the logistics system, and ongoing development of a system whose behaviour and capabilities contribute to the fulfilment of preparedness objectives.

Doctrinal and Strategic Guidance on System Development

Guidance on development of the logistics system to meet preparedness requirements can be found in a variety of sources including the ADFP4, the Air Power Manual, and the Defence Logistics Strategic Planning Guide (DLSPG). The dominant theme in such guidance is that logistics must be focused on operational readiness and sustainability. The quantification of resource requirements is an element of this focus, being, for instance, one of the eight objectives specified in the DLSPG.

The DLSPG was developed to identify Defence-wide logistics priorities to be considered at Program Management level. The strategic planning objectives contained in the DLSPG, shown at Table 8-1, were derived from the ADF logistics mission 'to provide effective and efficient logistics support needed for the ADF to meet endorsed readiness and sustainability objectives'. Thus, these objectives represent an analysis of the logistics implications of preparedness at Program level. By their nature, these objectives are more specific than the doctrinal guidance contained in ADFP4 or the Air Power Manual.

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13 Stockfisch, op cit. Stockfisch provides a detailed examination of the impact of uncertainty upon logistics, drawing case studies from the application of Air Power in World War II.

14 Ibid, p vi. Stockfisch argues that in the periods between wars there is 'little realistic testing and hence useful knowledge of what a new weapon might actually accomplish in war and little opportunity to discover the best tactics that should govern its operational use.' War provides opportunity and incentive to develop improved tactics.

OBJECTIVE I	Relate logistics support directly to operational need
OBJECTIVE II	Identify and meet support targets that will achieve force element preparedness objectives
OBJECTIVE III	Apply the principles of integrated logistics support with emphasis on life cycle costing
OBJECTIVE IV	Improve and integrate logistics information systems for responsive decision support and better logistics performance
OBJECTIVE V	Improve military, industrial and civil logistics infrastructure
OBJECTIVE VI	Optimise the use of service personnel, defence civilians and contractors in providing logistics support
OBJECTIVE VII	Create a more flexible, motivated and productive logistics work force
OBJECTIVE VIII	Improve the quality and management of logistics operations

Table 8-1. Defence Logistics Strategic Planning Objectives[15]

Implementation of Guidance

The RAAF is actively working to implement a number of the DLSPG objectives, for instance through the Commercial Support Program (Objective VI) and ILS (Objective III). Implementation of some other objectives requires further analysis of their implications for particular logistics activities. Such analysis requires an appreciation of the fundamental assumptions underlying current policy and procedures, and identification of the key drivers of system behaviour. The appropriateness of these system features can then be examined against the implications derived from analysis of preparedness objectives.

In light of the overview of RI Management and discussion of preparedness in previous chapters, a number of specific observations can be made regarding fundamental changes needed to focus RI management more directly on preparedness.

15 Taken directly from Department of Defence, Logistics Division, *Defence Logistics Strategic Planning Guide*, Canberra, 1991.

RI Definition

A simpler, broader definition of the term 'repairable item' which is not based on a specific functional perspective should be adopted. This definition should not exclude those items subject to regular wastage, nor those for which an established maintenance pipeline does not exist. Such items may have as significant an impact on meeting preparedness requirements as items for which a maintenance pipeline is established. It may even be appropriate to include potentially repairable items for which a peacetime throwaway policy exists. If the risk exists that supply sources for such items will be inadequate in contingency, development of a contingency repair scheme is perhaps warranted.

A definition which meets these criteria is:

'a technical item for which demand may be met through repair.'

This definition includes all potentially repairable items in the RAAF inventory, hence sub-categories will be required for daily management purposes. The suggested sub-categories are:

a. Peacetime Repair Item - normal usage met through repair or overhaul in peacetime;

b. Contingency Repair Item - normal usage met through reprovisioning in peacetime, but contingency repair scheme exists; and

c. Provisioned Item - normal usage will be met through reprovisioning in peacetime or contingency.

RI Management Objectives

RI management objectives are presently stated in terms of item availability and pipeline TAT. Current policy and procedures encourage reduction of the pipeline TAT elements of ADT and LDT[16] as a system improvement strategy. However, operational availability is also driven by the Mean Time Between Maintenance (MTBM) and Mean Time To Repair (MTTR). These parameters are largely dependent on RI reliability and maintainability (R&M) characteristics. Hence, the specification of RI R&M objectives would complement existing TAT and availability objectives. It would also encourage more consistent use of R&M as leverage points in troubleshooting and corrective action by RI managers.

16 As introduced at Chapter Three, p 3-7, ADT is Administrative Delay Time and LDT is Logistics Delay Time.

Specific mission reliability objectives and a means of measuring performance against these are also necessary. One option is the increased use of on-aircraft monitoring and feedback from operational crews as measurement tools.

Linking Decisions to A_0

Many RI management decisions have the potential to affect A_0, yet this link is not evaluated when making those decisions. For example, the impact upon A_0 of alternative scheduled maintenance intervals is not currently evaluated during Maintenance Engineering Analysis (MEA).[17] One reason is that suitable tools have not always been available to support evaluation, although some ILS tools could now be used in this role. For instance, OPUS9 can be used to evaluate the impact of scheduled maintenance on A_0. Application of these tools will enable consideration of the impact upon A_0 when making decisions, in addition to other important current considerations such as airworthiness and safety.

The implementation of OPUS9 and other ILS tools in WSLM Squadrons will support assessment of the impact of RI management decisions upon A_0. Additionally, the education necessary to implement ILS tools will develop a mindset more attuned to linking logistics support with preparedness in WSLM Squadrons.

Mission Criticality and Inventory Stratification

Inventory stratification is used to classify items with similar management requirements. It also directs management attention to the most critical inventory items in terms of specific criteria. The RAAF is required to devise a method of identifying critical RIs to implement reserve stockholding policy.[18] Mission criticality should be a key consideration in any stratification scheme applied to RI management.

Pipeline Scope

Existing logistics information systems do not provide visibility of assets in all elements of RI pipelines.[19] An RI manager in a WSLM Squadron depends upon logistics systems such as CAMM, MAARS and

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17 MEA is introduced at Annex A, p A-1.

18 Logistics Strategic Planning Section, Defence Logistics Division, op cit, p 69. One of the reserve stockholding implementation requirements assigned to Service Offices is to 'determine item essentiality/criticality classification for all reserve stock candidate items.'

19 Information system deficiencies are discussed at Annex B, p B-11 and Chapter Four, pp 4-4 - 4-5.

RAAFSUP[20] to monitor pipeline activity. Hence, the pipeline scope applied in daily RI management is shaped by the data available from these information systems. Consequently, the pipeline is perceived to begin at (or after) the arrival of an unserviceable RI at a maintenance venue, and end at (or prior to) the return of a serviceable RI to a base warehouse.[21]

In addition to improving asset visibility within the pipeline, the prevalent perception of pipeline scope should be challenged. Pipeline boundaries should be extended to include all locations within the logistics system in which RIs may be stored or otherwise processed, such as at operational squadrons. Additionally, the potential use of on-aircraft monitoring has application beyond the assessment of mission reliability. If notification can be received on the ground during flight that a critical RI has failed, work can begin immediately to locate another RI with maintenance staff for replacement of the unserviceable item upon aircraft landing.[22] The time saved through advance notification of RI failures may be insignificant in peacetime compared to the total time an item will spend in a pipeline. However, it has potential value in contingency, although such a system may be inappropriate for covert operations where radio transmissions may reveal an aircraft's location.

Core Business and Infrastructure Development

The RI system incorporates a wide range of interdependent functions, most of which are performed or closely managed by the RAAF. Each of these functions should be identified and assessed to determine whether there is a strategic need for the RAAF to retain internal control, and whether expertise in these functions is available within Australian industry. This evaluation should consider not only specific maintenance processes where commercial capability and capacity is necessary, but also activities such as transport and storage, particularly of unserviceable RIs.

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20 CAMM (Computer Aided Maintenance Management) data on maintenance activity is utilised to produce management reports by MAARS (Maintenance Activity Analysis and Reporting System). RAAFSUP (RAAF Supply) supports the RAAF supply system.

21 The pipeline scope monitored by CAMM/MAARS and RAAFSUP vary as the two were developed to suit differing functional perspectives.

22 The potential for expanded use of on-aircraft monitoring was highlighted by Squadron Leader S. Secker, RAAFRO QANTAS, in a presentation at RAAF Base Williamtown on 3 September 1993. QANTAS has integrated this capability in its 747 and 767 aircraft. System performance is monitored in-flight, with information communicated via VHF or satellite to the aircraft destination and/or their Sydney control centre. This information is frequently used to locate spares around the world.

Preparedness Evaluation

Operational deployments and exercises are not currently utilised as an opportunity to assess logistics activities in a consistent and disciplined manner. Supply staff at AHQAUST have developed an assessment methodology known as PREPEVAL (Preparedness Evaluation) which has potential application to RI management. However, difficulty has been experienced in gaining the agreement of operational staff to the use of exercises to realistically test and assess the capabilities of the logistics system through PREPEVAL.[23] Given its significant potential contribution to logistics system development, HQLC staff should pursue its application in cooperation with AHQAUST.[24]

Further Analysis

The above observations are based on review of the existing RI system presented in Chapters Three to Five. The methodology used to derive these observations is a combination of examination of existing policy and procedural documentation, interviews, and analysis of past studies and debate on RI management.

Application of systems thinking using the system dynamics methodology has the potential to expand current understanding of system behaviour, and enable experimentation to design a system which better meets preparedness requirements. Thus, system dynamics is a potentially valuable element in an approach to system development which meets the criteria previously specified on page 8-6. This theme is explored in the following two chapters.

CONCLUSION

Policy development at HQADF is focused on providing further guidance on reserve stockholding and sustainability issues. The recent release of guidance on reserve stockholding policy provides a framework for computation of reserve stock requirements for resources subject to first order usage, including RIs and breakdown spares. This guidance in

23 A number of articles have been published in the *RAAF SUPPLY Journal* (now "The Logbook") on Logistics Evaluation (LOGEVAL), which preceded PREPEVAL. An introduction to relevant concepts and methodology is contained in Squadron Leader R.W. Reading, *Logistics Evaluation - "LOGEVAL" - Its Background and Future*, No. 20, March 1989, pp 37-39. The trial of LOGEVAL procedures at Stores Depots during exercise K89 is outlined by the same author in *Logistics Evaluation (LOGEVAL), "From Small Acorns Great Trees Grow"*, No. 23, December 1989, pp 29-31. Conduct of LOGEVAL at Base Squadron Darwin in Exercise Pitch Black 90 is discussed in Flying Officer M.H. Ockers, *Logeval Pitch Black 90 - A Learning Experience*, No. 27, December 1990, pp 40-43.

24 As the ACPP is an AHQAUST initiative to which HQLC has been invited to contribute, it may be a suitable vehicle for HQLC to pursue PREPEVAL implementation.

combination with the implementation of ILS tools, including a dynamic RI LOGCAS model, is likely to perpetuate an emphasis on calculation of RI resource requirements, as currently being undertaken in the ACPP. However, the reserve stockholding policy does provide guidance on the need to understand the contingency environment and logistics system prior to the conduct of modelling.

The use of logistics modelling will not automatically ensure valid calculation of the resource requirements needed to support preparedness objectives. To produce meaningful assessments, improved understanding of the operational environment, use of weapon systems and RIs, and logistics support concepts likely to exist in contingency are required. The clear statement of assumptions flowing from consideration of these factors will enable the derivation of more valid contingency data. This is currently hampered by the use of peacetime parameters as a basis for preparedness analysis. Limitations of the modelling process, specific models used, and input data variability must also be appreciated to validly apply and interpret model outputs. Although it is generally prohibitively expensive to activate CPD serials in peacetime, methods of validating planning decisions made on the basis of modelling and quantification should be sought.

The RAAF is undertaking calculation of RI resource requirements in preparedness assessment with inadequate understanding of the operational environment and logistics system. This assessment must occur within the broader framework of logistics system development. Improved understanding of the behaviour and key performance drivers of the RI system is essential to improve the quality and validity of logistics modelling. Conversely, logistics modelling can enhance knowledge of the system, and guide system development activity.

Without utilising modelling techniques, a number of initiatives have been identified which have the capability to align RI management more closely to preparedness requirements. The potential to gain further insight into system behaviour and design utilising systems thinking is explored in the remainder of this paper.

CHAPTER NINE

SYSTEMS THINKING USING SYSTEM DYNAMICS

INTRODUCTION

In Chapter Four a number of studies and reviews of RI management conducted over the past decade were introduced. In Chapter Seven the analysis of RI management conducted in recent preparedness studies was then examined. Despite the time and effort expended in an attempt to understand the RI system, identify system problems and underlying causes, and improve system design, some fundamental questions regarding RI management and preparedness remain unanswered. To date, the primary reason offered for this inability is the need to further develop aspects of preparedness policy, and implement appropriate quantitative analysis tools.

At a more fundamental level, there is inadequate understanding of the dynamic behaviour of the RI system to confidently assess its ability to meet the demands of credible contingencies. Chapter Eight argued that, in order to redesign the RI system, there is a need to assess the implications of preparedness for the system. Understanding of the behaviour of the current system in peacetime, and anticipated behaviour in contingency, is imperative to resolve the deficiencies of past analyses.

Systems thinking is being applied increasingly to human organisational systems (or 'social' systems) as a means of gaining insight into these systems' behaviour. It is also used in system design. The key to systems thinking is to examine the relationships between system components rather than study these components in isolation. The focus is on understanding behaviour of the system as a whole. The system dynamics methodology facilitates systems thinking.

Aim and Scope

The aim of this chapter is to outline systems thinking and the system dynamics methodology. The systems thinking perspective is introduced prior to discussing system dynamics. Some examples of the way in which system dynamics might be applied to RI management are presented.

SYSTEMS THINKING

Philosophical Approach

Systems thinking is a philosophical approach to problems which requires them to be viewed as a whole. The systems perspective requires the viewing of any particular problem in a macro, organisational context. It seeks to examine not only the objects (or components) of a system but, more importantly, the relationships between those objects. Adoption of the systems perspective requires a shift from the 'classical scientific paradigm (in which) it was believed that in any complex system the dynamics of the whole could be understood from the properties of the parts.' 'In the new paradigm, the relationship between the part and the whole is just the opposite. The properties of the parts can only be understood through the dynamics of the whole.'[1] Clearly, the emphasis of the system approach is on 'promoting holistic understanding rather than piecemeal solutions.'[2]

What is a System?

The concept of a system is not a twentieth century innovation. It can be traced back at least as far as Aristotle whose statement, 'the whole is more than the sum of the parts', is a valid definition of the basic systems concept.

Numerous definitions of the term system are found in current literature, all of which embody 'the idea of a set of elements connected together to form a whole, this showing properties which are properties of the whole rather than properties of its component parts.'[3] This is reflected in a commonly cited definition:

> "a set of objects together with relationships between the objects and between their attributes related to each other and to their environment to form a whole."[4]

Wolstenholme provides a definition which interprets the concept of a system from the perspective of the inquirer:

> "any combination of real world elements which together have a purpose and which form a set which is of interest to the inquirer."[5]

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1 Fritjof Capra, *Criteria of Systems Thinking*, in *Futures*, October 1985, pp 475-476.
2 Eric F. Wolstenholme, *System Enquiry. A System Dynamics Approach*, Wiley, Chichester, 1990, p1.
3 Peter Checkland, *Systems Thinking, Systems Practice*, Wiley, Chichester, 1981, p 3.
4 Schoderbek, et al, op cit, p 13.
5 Wolstenholme, op cit, p 1.

Hence, delineation of a system from its environment will often be determined by the inquirer on the basis of the goal, or system purpose, of interest to that inquirer. The maintenance pipeline emphasis evident in RI system review and 'improvement' over the past decade can be partly attributed to the narrowly stated objective of RI availability on which inquirers have focused.

Perspectives of Systems Thinking

Mental Models. Each of us possesses 'deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action.'[6] Despite the central importance of these *mental models* to our daily activities they are often unstated, and even unrecognised, by us.

Causality. When faced with a question of causality, such as 'What causes employee burnout?', most people respond with a list of factors, such as those at Figure 9-1. Thinking about causality in terms of a 'shopping' or 'laundry' list is a common form of mental model. The causal factors listed are assumed to exert their influence on the end result, or effect, independently of each other.

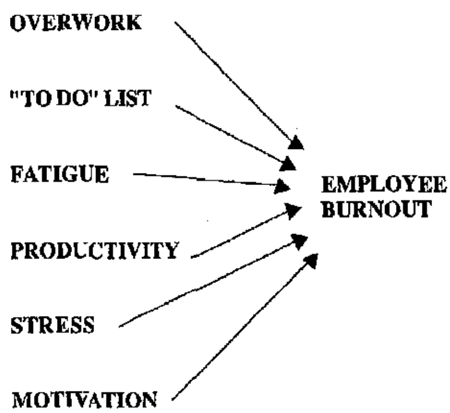

Figure 9-1. Employee Burnout - Laundry List Causality[7]

6 Peter M. Senge, *The Fifth Discipline. The Art and Practice of the Learning Organization*, Random House, Sydney, 1992, p 8.

7 Source: adapted from Keith Linard, *System Dynamics with ithink*™ Course Notes, Australian Defence Force Academy, August 1993.

Circular Causality. Adopting the systems perspective, the inter-relationships between the causal factors are considered. For instance, in response to a lengthening 'to do' list an employee may work additional hours, leading to fatigue which diminishes productivity. As productivity falls, tasks are added to the 'to do' list at a quicker rate than they can be completed, further increasing both overwork and stress. Continuing this analysis will lead to the development of a modified model - a web of inter-related and interdependent factors, such as that at Figure 9-2. Viewing the world in terms of circular relationships is central to the systems thinking perspective.

Figure 9-2. Employee Burnout - Circular Causality[8]

Time and Space. Cause and effect are not closely related in terms of time and space. For this reason it is necessary to step back from the detail of events which occur within a system. Spatially, the system must be viewed from a distance appropriate to identify and understand the web of relationships, rather than developing a detailed picture of the individual components of the system. In a temporal sense, the systems thinker focuses not on specific events which occur in a system, but on the pattern of events over time and, more importantly, on the system structure underlying these patterns.

Endogenous Perspective. While the impact of external forces is considered when analysing system performance, it is the impact of internal forces which are most closely scrutinised. Rather than viewing external factors as the *cause* of system behaviour, they are seen as *precipitators* of that behaviour. Responsibility for behaviour, or performance, rests within

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8 Loc cit.

the system. The organisation must contend with its external environment through the design of its systems. This is reflected in Coyle's description of system dynamics as:

> "*a method of analysing problems in which time is an* important factor, and which involves the study of how a system can be defended against, or made to benefit from, the shocks which fall upon it from the outside world"[9]

The organisation may not be able to control events in its environment. However, it can, through anticipation and appropriate design, prepare itself to meet, and even benefit from, such events. For example, the increase in flying activity and subsequent RI arising rate which could be expected in a range of contingency scenarios, is a 'shock' with which the RI system must be able to contend.

<u>Leverage and Complexity.</u> The principle of leverage suggests that 'small, well-focused actions can sometimes produce significant, enduring improvements, if they're in the right place.'[10] To contend with a difficult problem, points of high leverage should be identified. At such points a minimum of effort can lead to lasting, significant improvement.

While there is no standard method which can be applied to identify points of high leverage, the adoption of certain mental models makes their discovery more likely. For example, the RI system has often been described by those analysing it as 'complex'. The form of complexity being described has generally been that of *detail complexity,* characterised by a large number of variables. For instance, the 1985 Air Force Office RI Management Working Party (WP) conducted a telephone survey in order to document the RI 'systems in the field'. They 'discovered a great deal of detail about individual unit operations,'[11] leading them to present a system model in the diagrammatic format shown at Figure 9-3. In addition to focusing on detail, the WP model also represented the system in terms of a sequence of events. Their analysis excluded consideration of *dynamic complexity,* or complexity over time, 'where cause and effect are subtle, and where the effects over time of interventions are not obvious.'[12]

Senge could have been discussing the development of RAAF RI management when he explained that:

> "most *systems analyses* focus on detail complexity not dynamic complexity...In fact, sadly, for most people *systems thinking* means *fighting complexity with*

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9 R.G. Coyle, *Management System Dynamics*, Wiley, Chichester, 1977, p 2.

10 Senge, op cit, p 64.

11 *Repairable Item Management System Working Party Report*, AF85/22923 Pt1 (35), September 1985, para 12.

12 Senge, op cit, p 71.

complexity, devising increasingly *complex* (we should really say *detailed*) solutions to increasingly *complex* problems. In fact, this is the antithesis of real systems thinking."[13]

Seeking to understand dynamic complexity, rather than detail complexity, is one means of increasing the likelihood of identifying points of high leverage.

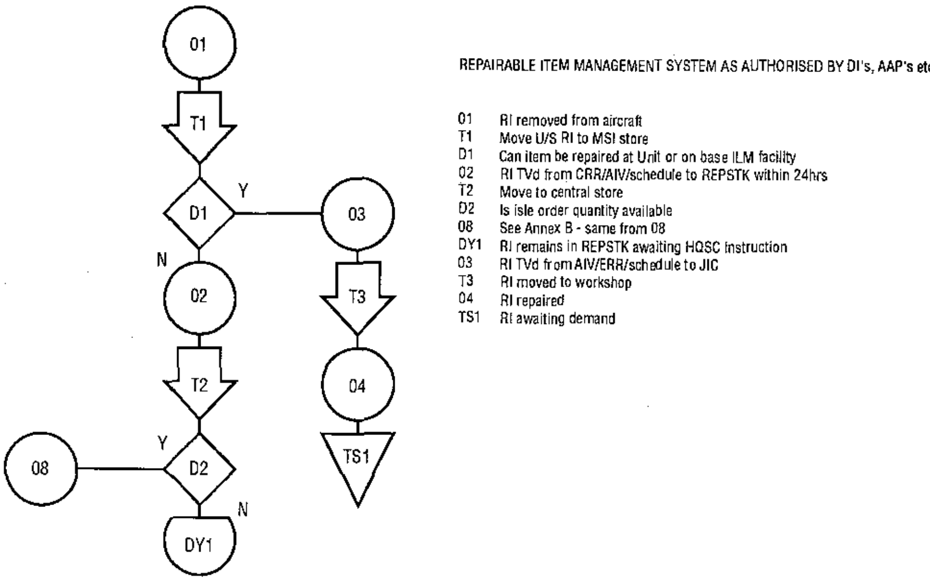

Figure 9-3. 1985 RI Management Working Party Model[14]

SYSTEM DYNAMICS

Development and Definition

System dynamics is a methodology for facilitating systems thinking. It was conceived and developed during the late 1950s at the Massachusetts Institute of Technology under Professor Jay Forrester. Initial applications were largely industrial, earning it the early title of *Industrial Dynamics*. It has subsequently been applied across a wide range of disciplines in individual studies varying in scope from intra-organisational to global. System dynamics developed from control engineering and cybernetics which focus on communication and control based on feedback.

13 Ibid, p 72.
14 Source: AF 85/22923 (35), op cit.

System dynamics is defined by Wolstenholme as:

"a rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organisational boundaries and strategies; which facilitates quantitative simulation modelling and analysis for the design of system structure and control."[15]

The system dynamics method is thus comprised of both qualitative and quantitative phases, which are normally undertaken sequentially as complementary stages of a single study or project. Figure 9-4 illustrates these phases and key techniques which may be utilised within each.

The Qualitative Phase

System Structure. One of the key tenets of system dynamics is that structure is a critical determinant of system behaviour. This reflects the endogenous systems thinking perspective that 'systems cause their own crises, not external forces or individuals' mistakes.'[16] The term structure 'means the basic interrelationships that control behaviour. In human systems, structure includes how people make decisions - the *operating policies* whereby we translate perceptions, goals, rules, and norms into actions.'[17]

Mental Models as a Data Source. These operating policies are not only those formally authorised and documented, but those incorporated in the mental models of the individuals making decisions within the system. It is for this reason that mental models are a rich source of data in the qualitative phase.

One of the aims of the qualitative phase is to take these imprecisely formed mental models and state them more clearly. From this process, underlying assumptions are specified and relationships flowing from these assumptions can be identified and examined. It is the task of the system analyst to facilitate the specification of mental models in this way through individual interviews or group discussion. Ongoing interaction between the analyst and key system players is an essential part of the system dynamics methodology. Through such interaction, the learning benefits of examining mental models are spread throughout the organisation.

The use of system dynamics techniques is discussed in the remainder of this chapter.

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15 Wolstenholme, op cit, p 3.
16 Senge, op cit, p 40.
17 Loc cit.

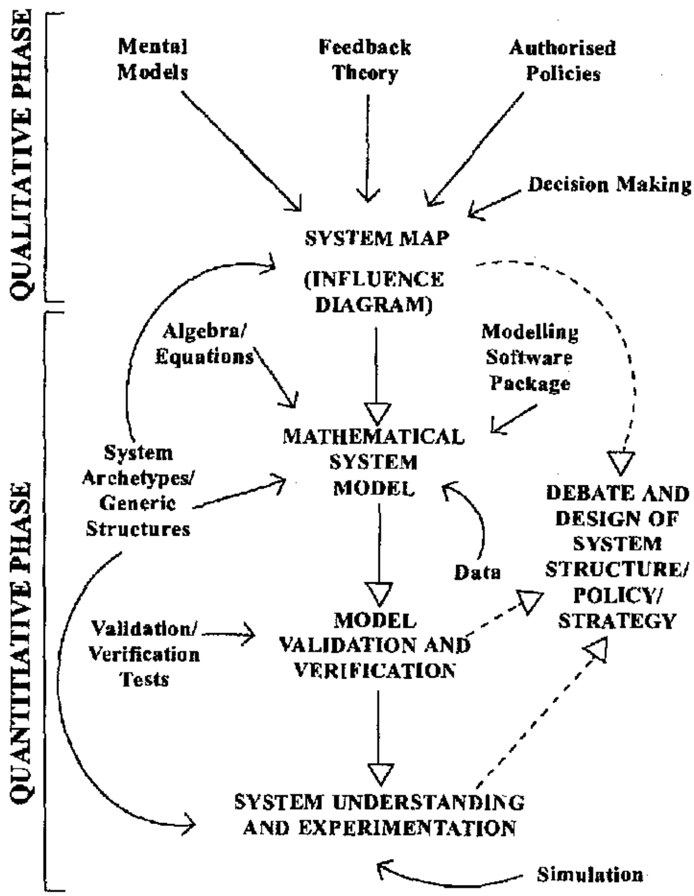


Figure 9-4. System Dynamics Methodology[18]

Influence Diagrams. The aim of the qualitative phase is to develop a system map. This map is a visual representation of the system constructed using feedback loops which are based on the concept of circular causality. These system maps are alternately known as influence diagrams or causal loop diagrams. The influence diagram shows major cause-and-effect links within a system, indicates the direction of the

18 Source: adapted from John D.W. Morecroft and Mark Pauch, *System Dynamics for Reasoning About Business Policy and Strategy*, System Dynamics Group, Massachusetts Institute of Technology, April 1986, p 13.

linkages, and identifies major feedback loops within the system. In effect, the influence diagram is a map of the underlying structure of the system, as contained in both endorsed operating policies and mental models.

Feedback Loops. In systems thinking, the concept of feedback denotes a flow of influence. An example of a feedback loop from the RI system is at Figure 9-5. The concept is that a change in the variable at the tail of an arrow influences the variable at the head of the arrow, causing it to change. This shows the cause-and-effect relationship, and direction of the linkage.[19]

For example, referring to Figure 9-5, an increase in the level of Unserviceable RIs at a maintenance workshop generates pressure to increase the rate at which RIs undergo repair. An increase in the RI repair rate will lead to an increase in the number of Serviceable RIs, and an increase in the number of Serviceable RIs will reduce the level of Unserviceable RIs.

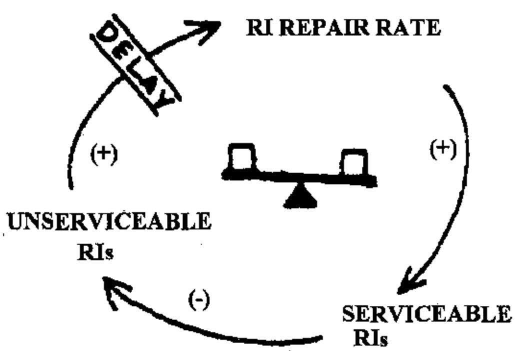


Figure 9-5. Feedback Loop Example

Balancing and Reinforcing Feedback. Two types of feedback processes exist - balancing and reinforcing. The feedback loop above shows a balancing feedback process. Balancing (or stabilising) feedback processes underlie goal-oriented behaviour, and are instrumental in system control. Balancing feedback attempts to maintain or meet a goal or target.

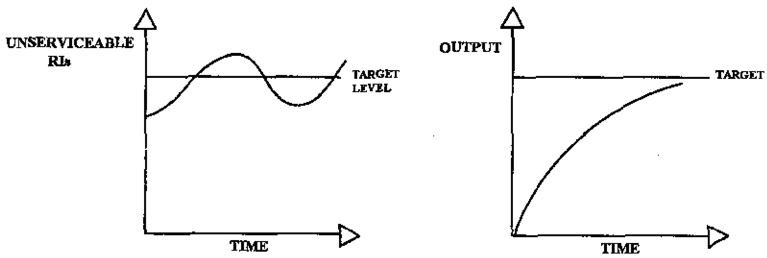
In the example at Figure 9-5, that target is a level (or backlog) of Unserviceable RIs in the workshop. This target may be either stated or implicit - for example, a level of unserviceable RIs with which the workshop

19 Explanation of the feedback loop concept based on Group Captain M.C. Coles, *A Cybernetics Framework for Aggregate Inventory Management in the Royal Australian Air Force*, a dissertation submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in the University of New South Wales, September 1990, p 118.

manager is intuitively 'comfortable'. If achievement against the target is plotted over time it will show a clear goal-seeking pattern, as at Figure 9-6(a).

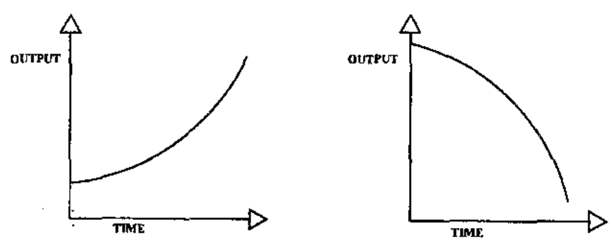
An alternate goal-seeking pattern is shown at Figure 9-6(b). In contrast, reinforcing (or amplifying) feedback processes underlie patterns of growth or accelerating decline, as shown at Figure 9-7.[20]

Delays. As cause and effect in systems are separated in time and space, delays exist in nearly all feedback processes. However, these delays are often unrecognised or not understood, and can lead to instability in systems. In the workshop example above, a delay exists between the increase in the level of Unserviceable RIs and the increase in RI repair rate



(a) Oscillating **(b) Approaching Target**

Figure 9-6. Balancing Feedback and Goal-Seeking Behaviour



(a) Accelerating Growth **(b) Accelerating Decline**

Figure 9-7. Reinforcing Feedback and Accelerating Behaviour

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20 Variations exist on the symbols and terminology applied to feedback diagrams. Balancing feedback loops are sometimes called 'negative', and reinforcing loops 'positive'. This terminology is based on the technique of multiplying directional signs contained in the feedback loop as a means of determining the nature of the feedback process. However, the inappropriate connotations of the term positive as something intrinsically desirable, and negative as something undesirable, have led to the more recent adoption of 'balancing' and 'reinforcing'. In this paper these are symbolised respectively by a beam balanced on a fulcrum and a snowball. Symbols adopted from Senge, op cit.

(marked by the small parallel lines crossing the arrow in Figure 9-5). This may be due to the use of a weekly production schedule cycle, which creates a lag of up to one week between an increase in unserviceable RIs and a corresponding rise in the RI repair rate. This delay contributes to fluctuation around the target level, as shown at Figure 9-6(a). Identification of influential delays is thus important to understanding system behaviour. Minimisation of feedback delays is a high leverage point for improving system performance.

Systems Archetypes. Certain common structures have been observed to recur in systems across a wide variety of fields including management. The utility of these generic templates, or archetypes, lies in the guidance which they provide in identifying points of high leverage in a system. Senge suggests that:

> "The purpose of the systems archetypes is to recondition our perceptions, so as to be more able to *see* structures at play, and to see the leverage in those structures. Once a systems archetype is identified, it will always suggest areas of high- and low-leverage change."[21]

Hence, having developed an influence diagram of the system, systems archetypes can be identified as an important step in generating debate regarding potential leverage points and desirable changes to system design. Researchers have identified approximately a dozen systems archetypes, three of which are presented and applied to the RI system at Annex C.

Benefits of the Qualitative Phase. Although the qualitative phase is most often seen as a precursor to the quantitative phase of the system dynamics method, it 'is often sufficient in itself to generate problem understanding and ideas for change.'[22] This is due to the explicit statement of mental models, enabling assumptions and perceptions to be challenged and re-evaluated, and also to the role of systems archetypes in guiding the search for leverage.

The Quantitative Phase

System Modelling. The quantitative phase is based on computer modelling and simulation, as shown in Figure 9-4. The system model is developed using either a simulation language, or a specialised software package. The availability of software packages which do not require

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21 *Senge, op cit, p 95.*

22 Eric F. Wolstenholme, *System Dynamics in Perspective*, in *Journal of Operational Research*, 1982, p 549.

mastery of a computing language, and are designed for use on a personal computer, have greatly increased the accessibility of system dynamics modelling.

An introduction to the *ithink*™ package is provided at Annex D to demonstrate the ease of use and functionality of such software.

Model Structure and Data. Development of a system dynamics model requires the mathematical description of relationships of significance to system behaviour. Relationships modelled include those identified during the qualitative phase. These relationships may be defined using equations or tabular and graphical input, and can be based on either data gathered from the system or estimates drawn from the mental models of those working within the system.

However, the modelling effort should not be driven by the search for actual system data. The purpose of modelling is not to provide precise quantitative 'answers', but to better understand system behaviour and support system development. 'In system dynamics the structure of the model is more important than the exact values of parameters and functions.'[23] In some cases data may simply be unavailable. For instance, the existence of *soft* variables, such as morale or motivation, may limit the degree of quantification possible. Such variables may be incorporated into a system dynamics model, and their impact on system behaviour explored. Sensitivity analysis can be utilised to guide data gathering and parameter specification to those relationships most critical to system behaviour.

Model Validation and Verification. 'Verification is usually defined as ensuring that the model runs as intended', while the purpose of validation is to determine whether 'adequate agreement exists between the entity being modelled and the model for its intended use.'[24] A variety of techniques may be utilised in this activity, ranging from face validity, where people knowledgeable about the system are asked whether the model is a reasonable representation of the system, to modular software testing techniques.[25]

It is critical to involve those who will be using the model in validation and verification. Such involvement provides another opportunity to review the assumptions underlying model structure, and also tends to enhance the confidence which these people have in the model.

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23 J.D. Lebel, *System Dynamics*, in F.E. Cellier (editor), *Progress in Modelling and Simulation*, London: Academic Press, 1982, pp 119-158.

24 R.G. Sargent, *Verification and Validation of Simulation Models*, in F.E. Cellier (editor), op cit, pp 158-167.

25 The interested reader is referred to Sargent, ibid, as a starting point for further guidance on verification and validation.

Generic Structures. Having developed confidence in the model, it is commonly used in two main ways. As with the qualitative phase, generic structures can be identified within the quantitative model as a means of understanding the feedback shaping system behaviour, and generating debate on changes to system design and policy. The second application of the model is simulation.

Simulation. Simulation is the process of using a quantitative model to imitate some aspect of the behaviour of a system over time. Once a system dynamics model has been defined, simulation is performed by successive rounds of calculation of the mathematical relationships embodied in the model, reflecting the passing of time. This is achieved most readily and accurately using a computer.

Simulation is an essential element of model verification and validation. The dynamic behaviour of the system as modelled can be compared to known historical system performance data. Reasons for discrepancies can be investigated, and changes made to improve model validity.

Simulation and Experimentation. Simulation can also be used as a 'what if' tool. The impact of changes in variables, assumptions underlying relationships within the model, and structural changes can all be assessed using simulation. Used in this manner, simulation is a valuable system redesign tool. It provides a 'safe' laboratory environment in which to experiment with changes to system structure and policy. The compression of time and space in a simulation experiment facilitates understanding of the impact of cause-and-effect relationships which are spread across time and space in the real world.

Simulation and Mental Models. System dynamics practitioners argue that the strengths of computer simulation and mental models are complementary. In applying computer simulation to systems, it has been found that behaviour is often counter-intuitive. This suggests that many systems are complex beyond the capacity of intuition and mental models. Forrester states the case as follows:

> "The most important difference between the properly conceived computer model and the mental model is in the ability to determine the dynamic consequences when the assumptions within the model interact with one another. The human mind is not adapted to sensing correctly the consequences of a mental model. The mental model may be correct in structure and assumptions, but even so, the human mind ... is most

apt to draw the wrong conclusions. There is no doubt about the digital computer routinely and accurately tracing through the statements of behaviour for individual points in the model system."[26]

Together, the system dynamics qualitative phase, in which mental models are made specific, and the quantitative phase, in which these models are utilised in simulation experiments, utilise the complementary strengths of mental models and computers.

CONCLUSION

The essence of systems thinking is viewing problems as a whole. The dynamics of a system can only be understood through the relationships of the parts of that system to one another.

Systems thinking challenges predominant mental models of the world, and requires a paradigm shift. Linear thinking about causality must be replaced with circular thinking, and the focus on events shifted to a search for patterns over time, and the structure underlying those patterns. Systems thinking views the external environment only as a precipitator of system behaviour, and the internal system structure as the cause of that behaviour.

System dynamics has been developed to facilitate the understanding of dynamic system behaviour using a systems thinking perspective. It emphasises identification of the structure which generates system behaviour, where structure includes decision making processes.

The mental models of individuals working within a system are a valuable source of data used to develop system maps in the qualitative phase of system dynamics. These system maps, or influence diagrams, illustrate flows of influence between variables within the system. These flows form feedback loops which can be analysed to develop understanding of system behaviour. Recurring generic feedback templates, known as systems archetypes, aid in the identification of high leverage points within the system. At such points effort can be focused to produce significant, enduring improvements.

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26 Jay W. Forrester, *Counterintuitive Behaviour of Social System*, p 2, in *Technology Review*, Volume 73, number 3, January 1971, pp 1-16.

During the quantitative phase, system structure is modelled mathematically. This is most readily achieved using a specialised software package. Computerised simulation of the model can be used to both improve understanding of current system dynamic behaviour, and experiment with redesign of system structure and policy.

Although still under significant development, the system dynamics methodology has been utilised to apply a systems thinking perspective in a wide range of disciplines and organisations. Recently, the methodology has been applied within the ADF. Its potential application to RI management is discussed in the following chapter.

CHAPTER TEN

SYSTEM DYNAMICS AND RI MANAGEMENT

INTRODUCTION

System dynamics was introduced in Chapter Nine as a methodology for applying systems thinking. This methodology has been developed to facilitate the understanding of dynamic system behaviour, and to aid in system design.

System fragmentation is a recurring theme in RI management studies and reviews conducted over the past decade. RI pipelines cross several organisational boundaries, and their performance is subject to decisions made within these disparate domains. The system has often been described as complex, which is understandable given the prevalent analytical focus on events and detail.

Examination of methodologies used in past reviews from a system dynamics perspective reveals several common deficiencies. The limitations of these methodologies help to explain the difficulty experienced in understanding dynamic system behaviour. The application of system dynamics to RI management development has the potential to enhance system understanding, and to make a valuable contribution to the design of a system better able to meet its mission of supporting endorsed ADF preparedness objectives.

Aim and Scope

The aim of this chapter is to propose the application of the system dynamics methodology to the RI system. A brief introduction will be given to known applications of this methodology, including its use by the ADF and in the field of RAAF logistics. Following this, limitations of previous RI management reviews are discussed from a system dynamics perspective. Finally, rationale is presented for the use of system dynamics as a central element of RI system development in the near future.

SYSTEM DYNAMICS APPLICATIONS

A Multi-Disciplinary Methodology

The system dynamics concepts and tools are generalised to the extent that they have been applied across a diverse range of disciplines including ecology and the environment, energy and resources, education, human resource management, health and medicine, societal dynamics, transportation, industry, information systems, economic growth, and geography.[1] Australian government bodies known to be applying System Dynamics include the Australian Taxation Office and Medicare.

ADF Applications

A recent interest in the application of system dynamics by the ADF has been fostered largely through the Australian Defence Force Academy, albeit on a small scale at this stage.[2] For example, a System Dynamics model of the Australian Regular Army General Service Officer Stream, submitted as a thesis in October 1992,[3] has spurred the development of a more comprehensive personnel system model by the Directorate of Army Personnel. Additionally, a model of Defence Force Structure was developed in 1990 to assist the Army Force Structure Review Team.[4] More recently, Wing Commander Greg Donaldson has been investigating the use of System Dynamics for air power modelling and simulation at the RAAF Air Power Studies Centre.[5]

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1 An extensive bibliography of applications can be found in J.D. Lebel, *System Dynamics*, in F.E. Cellier (editor), *Progress in Modelling and Simulation*, Academic Press, London, 1982, pp 119-158.

2 Keith Linard from the Department of Civil and Maritime Engineering at the University of New South Wales (Australian Defence Force Academy) has been instrumental in fostering ADF interest in System Dynamics.

3 Jason Y. Markham, *A System Dynamics Model of the Australian Regular Army General Service Officer Stream*, Department of Civil and Maritime Engineering, University College, The University of New South Wales, Australian Defence Force Academy, Canberra, October 1990.

4 Author unknown, *Stella Systems Dynamics Modelling of Defence Force Structure*.

5 See Greg Donaldson, *Combat Modelling in the RAAF*, Paper No. 19, Air Power Studies Centre, Canberra, November 1993.

RAAF Logistics. The only known application of system dynamics to RAAF logistics is an aggregate inventory management framework developed by Group Captain M.C. Coles in 1990 in fulfilment of a doctorate degree.[6] The model excludes RI management.

Although system dynamics has been applied to the USAF Reparable Asset System,[7] only a limited element of the methodology has been applied to the RAAF RI system. A partial influence diagram of the system was developed by staff at the Directorate of Integrated Logistics Processes (DILP) to aid in development of their 1992 RI management improvement project. A quantitative model was not developed, nor was the diagram subsequently utilised in the project.[8]

SYSTEM DYNAMICS INSIGHTS ON PREVIOUS REVIEWS

System Boundaries

Although some previous studies have claimed to review the 'RI system', most have adopted narrow system boundaries. Consider, for instance, the conceptual model developed by the 1985-1987 Air Force Office Working Party (AFO WP) as a policy design aid (presented and examined at Annex B, Figure B-2). This static conceptual model represented the system as a set of generic activities performed across a range of organisational domains.

However, a narrow RI circuit boundary was delineated in the model, which excluded flight line maintenance, activity internal to repair facilities, and reprovisioning activity. The AFO WP objective was 'to identify a (RI) management system which ensures that target

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6 Group Captain M.C. Coles, *A Cybernetics Framework for Aggregate Inventory Management in the Royal Australian Air Force,* a dissertation submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in the University of New South Wales, September 1990.

7 Reference is made to a number of papers outlining System Dynamics analysis of the USAF Reparable Asset System in Captain B.M. Kettner, Captain W.M. Wheatley, and Major D.K. Peterson, *Redefining Before Refining: The USAF Reparable Item Pipeline*, in *Air Force Journal of Logistics*, Fall 1992, pp 5-11. Most of these applications have been performed to meet Master of Science thesis requirements at the US Air Force Institute of Technology. The Reparable Asset System is the USAF version of the RI management system.

8 The 1992 DILP-LC Project is discussed at Annex B, pp B-18 - B-19. Group Captain M.C. Coles was Director of Integrated Logistics Processes when the influence diagram was developed. The use of this technique reflected his use of it in completing the previously cited doctorate on Aggregate Inventory Management in the RAAF.

item availabilities are met.'[9] Each of the activities excluded from the conceptual RI circuit clearly has an impact on the achievement of RI item availability. Thus, the model boundaries were too narrow to support policy design to meet the AFO WP objective.

The impact of a narrow system boundary is summarised by Schoderbek et al as follows:

> "Perhaps the failure to adequately solve many organizational and institutional problems may be the tendency to concentrate on too restricted a system. What should be regarded as but a subsystem is taken as the system, with the result that the significant interrelationships of the system with other subsystems are either overlooked or completely ignored."[10]

System Segmentation.

In other reviews the system has been deliberately segmented. Notably, when tasked to coordinate a RAAFQ review of RI management in the early 1990s, Group Captain K.J. Cairns, then Staff Officer Repair and Overhaul, decided 'to select important and manageable segments of the overall task and lead the Process Action Teams (PATs)[11] progressively through them until completion.'[12] The division of the system for review made the task more 'manageable' not only in terms of time and resources, but also in terms of the range of system elements and interactions which PAT members would need to consider at any one time.

Focus on Events

The systems thinker examines the pattern of events in a system over time, and the structure underlying those patterns. Events in themselves are regarded simply as snapshots of activity which provide very little insight into dynamic system behaviour.

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9 *Repairable Item Management Party Progress Report*, Enclosure 1 to AF85/22923 Pt1 (51), 30 April 1986, para 2a.

10 Peter P. Schoderbek, Charles G. Schoderbek, and Asterios G. Kefalas, *Management Systems. Conceptual Considerations*, Fourth Edition, Irwin, Boston, 1990, p 53.

11 PATs are cross-functional teams formed to review nominated process(es) which cross functional boundaries. The team members are assigned to the PAT on a part time basis, and utilise RAAFQ methodology. RAAFQ is the RAAF's adaptation of Total Quality Management (TQM).

12 *RAAF Quality - Process Action Teams in SLSPTO Branch*, SORO 4014/2/1 (19), 29 March 1990, para 2.

Techniques which focus on events have been commonly utilised in RI management review. These techniques include lists and flowcharts. The sequential listing of activities, or events, conducted as an RI travels around pipelines, was used by the AFO WP, as shown at Figure 9-3. With the adoption of RAAFQ, flowcharts have tended to replace lists as the predominant means of representing events within the RI system. The Force Expansion Study also utilised a flowchart based methodology.

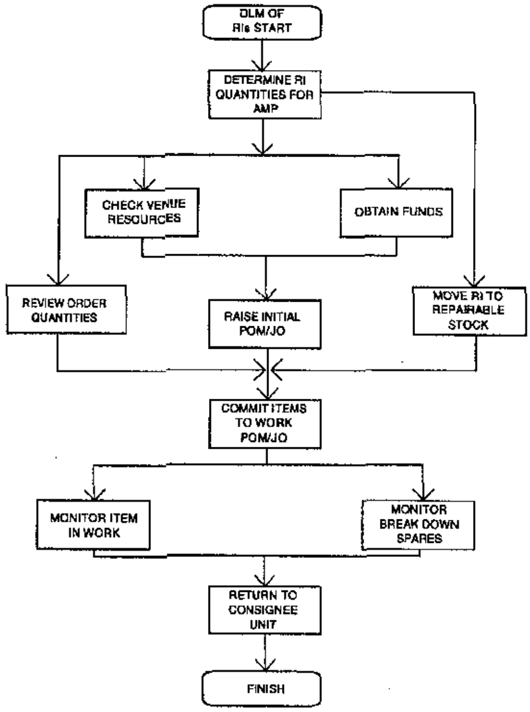

Figure 10-1. Sample Flowchart - DLM Pipeline of Repairable Items[13]

Feedback Analysis

The flows represented on flowcharts such as Figure 10-1 are generally physical flows of an RI or resource, a series of sequential events, or flows of documented or computerised information. Flows of influence are not explicitly captured in flowcharts, hence feedback analysis is not readily supported using this tool. Representation of feedback is a critical step to understanding system behaviour using the System Dynamics methodology. On the one known occasion in

13 Source: *Process Action Team Interim Report. Review of the Depot Level Maintenance Process for Aircraft Repairable Items*, SRO4/4600/PROC Pt5 (10), October 1990, Annex B.

which influence diagramming was used to represent the RI system, by DILP in 1992, it played a limited role in the subsequent study. For instance, the diagram was not reviewed to re-examine underlying assumptions as the study progressed.

A RAAFQ tool known as a 'fishbone diagram', or cause-and-effect diagram, has been used in some reviews. The fishbone diagram groups causal factors contributing to a problem and presents them as shown at Figure 10-2. No attempt is made to examine the relationships between causal factors. The fishbone diagram is simply a list of causal factors which does not support feedback analysis. It represents a 'shopping list' mental model of causality.

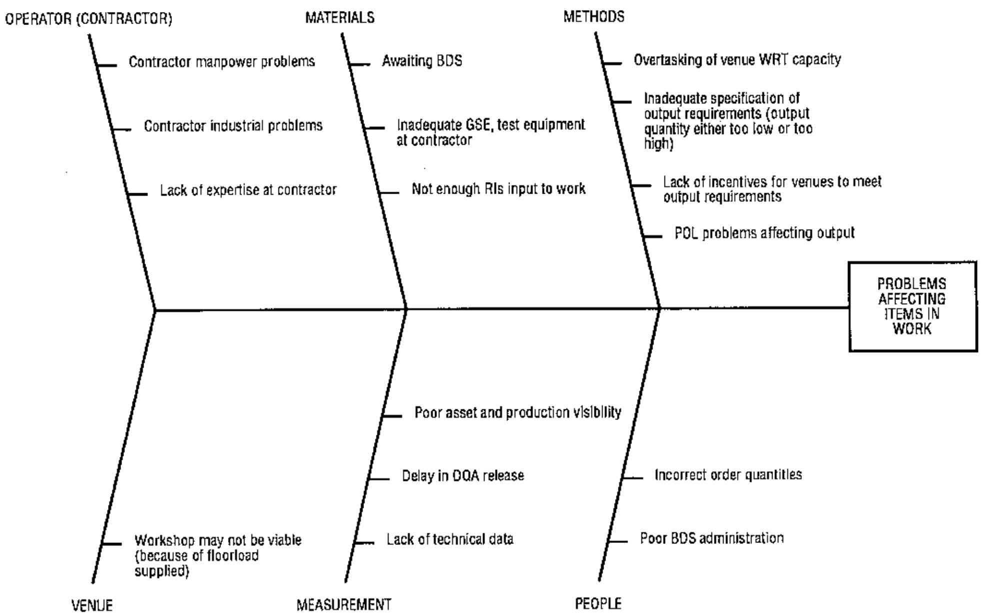

Figure 10-2. Sample Fishbone Diagram[14]

System Structure

The under-utilisation of feedback analysis reflects the predominant perception that system structure is physical by nature. A number of studies have commented in general terms on aspects of the perceptions and norms of people working within the RI system. However, none has explicitly examined the role of such perceptions and norms in decision making within the system. System dynamics views these elements as an integral part of system structure.

14 Source: ibid, Annex I.

Simulation.

Simulation has not been used to examine RI system behaviour or experiment with alternative system structure and policies. Reliance on the human mind has contributed to the limited understanding of system behaviour currently possessed. The potential benefit of simulation was recognised by Group Captain P.J. Rusbridge, Director of Maintenance Policy, in 1985, when he sponsored the development of a discrete event simulation model to support policy design by the AFO WP. However, despite considerable development, the model was never completed nor applied by the AFO WP.[15]

RAAFQ and System Dynamics

From a systems thinking perspective, RAAFQ tools such as flowcharts and fishbone diagrams have some limitations, as discussed above. However, RAAFQ tools have been successfully utilised in RI management process improvement,[16] and have the potential to contribute to further improvement. This potential may be more extensively realised if RAAFQ is combined with System Dynamics.

The strengths of the RAAFQ/TQM methodology can be viewed as complementary to those of System Dynamics. While RAAFQ is well suited to learning and improvement at the *technical* level, the strength of System Dynamics lies at the *conceptual* level. This theme is explored in an article by Daniel H. Kim, who defines these two levels as follows:

> "Learning at the *operational* level (which can be equated to the RAAF's technical level) entails changing behaviors or methods of doing things in order to improve the performance of a particular system. It can involve physical changes in a machine setting, procedural changes in a production step, or a psychological change in worker's attitude about his/her job. Learning at the *conceptual* level means changing one's mental models about how the world

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15 The model was developed in 1986 by Squadron Leader (now Wing Commander) M.E. Gaspert in partial fulfilment of requirements for a Graduate Diploma in Engineering Maintenance Management. It is introduced at Annex B, p B-5. The only known application of the model was to a local management problem at RAAF Base Amberley by Wing Commander Gaspert when posted to 482 Maintenance Squadron.

16 The achievements of two RAAFQ teams which reviewed RI system processes are discussed at Annex B, pp B-15 - B-16.

looks. It includes changes in the way one thinks about a problem by reframing it in a different context and exploring the implications."[17]

Kim suggests that while system dynamics is well suited to 'the process of gaining a more systemic view' of the organisation, it lacks 'simple tools that can be used at the technical level to actually make the improvements that are indicated by a system dynamics study.'[18] In contrast, TQM offers a set of well-defined tools which are readily applied at the technical level. If the two can be utilised in an integrated manner, organisations will be 'able to identify high leverage points' in a system '*and* act on them.'[19]

SYSTEMS DYNAMICS AND FUTURE RI MANAGEMENT DEVELOPMENT

The Need to Understand Dynamic System Behaviour

RI Management development over the past decade was discussed at Chapter Four, with a more detailed analysis at Annex B. It was noted that many studies and reviews of RI management have been conducted at a variety of levels.

Despite ongoing examination of the RI system, some fundamental questions regarding system behaviour and preparedness cannot be readily answered, as was discussed at Chapter Seven. For instance, the Force Expansion Study (FES) identified handling and processing of RIs through maintenance pipelines as a potential force expansion chokepoint. However, analysis of the specific physical or policy limitations on pipeline activity were discussed in very general terms, and potential improvement strategies only superficially analysed at HQLC.

It has been suggested in this paper that a poor understanding of the dynamic behaviour of the RI system is one of the factors contributing to the superficiality of current preparedness assessments of RI management. In the previous section, system dynamics concepts were utilised to develop insight into the limitations

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17 Daniel H. Kim, *Total Quality and System Dynamics: Complementary Approaches to Organizational Learning*, MIT Sloan School of Management, 1990, p 2.

18 Ibid, p 7.

19 Ibid, p 9. Kim presents an 'organizational intervention model' showing the integration of TQM and System Dynamics methodologies. Unfortunately, he provides little practical advice on how to integrate the tools of the two methodologies, suggesting that a 'common library' of system dynamics tools 'which managers can apply relatively quickly to their own systemic issues' must first be developed. Recent work to develop a range of systems archetypes, as discussed in Chapter Seven and at Annex C, provide one such tool.

of some of the RI management reviews conducted over the past decade. These limitations have contributed to the perception of system complexity and difficulty in understanding dynamic system behaviour. Indeed, the RI system does appear complex when the analytical focus is on events and detail within the system. However, there has been no structured consideration of the dynamic complexity of the system.

Adoption of systems thinking and application of the system dynamics methodology have the potential to significantly improve understanding of dynamic behaviour of the RI system. A sample system dynamics model of the RI system is presented at Annex E to illustrate this potential. Although of limited scope, development of this sample model shows how concepts embodied in RI system feedback loops may be translated into a quantitative model, which can then be used to simulate system behaviour.

Interestingly, this model also demonstrates the discovery of counter-intuitive system behaviour through simulation. A key concept underlying the model is that as the level of unserviceable RI inventory in a maintenance workshop rises, pressure is created which results in lower quality of maintenance work. It was hypothesised that lower maintenance quality has a significant impact on the RI failure rate. After verifying that the model behaved as was intended, system behaviour was explored using simulation. Contrary to the modellers expectations, this showed that although lower maintenance quality did have an impact on the RI failure rate, it was negligible in comparison with the influence of flying hours.[20]

Overcoming Fragmentation

The RI system contains a wide range of activities performed in different organisational domains throughout the weapon system life cycle. The system has often been described as fragmented. It contains many cause-and-effect relationships which are separated by time and space. As noted by Wing Commander Warnecke, Staff Officer Plans and Procedures (SOPP) at HQLC, in 1992:

> "There are no simple solutions (to RI management development) because there are too many variables, there are too many *many-to-many* relationships."[21]

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20 As the model was not validated it cannot be assumed that this observation on system behaviour is valid for the real world. This model has been developed only to illustrate the potential applicaion of system dynamics to the RI system. Simulation results are reported at Annex E.

21 Wing Commander D. Warnecke, *Selected Writings on Repairable Item (RI) Management*, SOPP/4300/5/9/3, 8 January 1992, para 1.

System dynamics has been developed for application to systems exhibiting this feature. It focuses on identification of causal relationships throughout the system. Through simulation, time and space are compressed in order to understand how those relationships generate system behaviour.

Another common observation is that individuals working within the RI system lack an appreciation of their role in, and impact upon, the broader system. This is seen to contribute to isolated, sub-optimal decision making by those individuals. System dynamics seeks the involvement of individuals throughout the system in the development and application of both influence diagrams and system models. The specification of these individuals' mental models of the system encourages them to review the assumptions which they currently hold. In a group forum this has the potential to foster communication and engender shared appreciation of the broader RI system.[22]

Consistency with RAAF Logistics Environment

Increased functional integration is a key strategic thrust in the current RAAF logistics environment. The implementation of WSLM and ILS both reflect this thrust. Integration means 'to bring together (parts) into a whole.'[23] This aligns closely with the central tenet of systems thinking, the viewing of problems as a whole. Thus, the philosophical approach of system dynamics is consistent with that underlying ILS in particular.

A Means of Overcoming Inexperience

Evidence exists of a growing recognition of the need to apply a systems paradigm in the RAAF logistics environment, and specifically to RI management. As previously noted, a '*total systems review*...that considers all the process and interdependencies of agencies involved in the RI process as elements of a total *system*'[24]

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22 A more sophisticated extension of system dynamics is the development of *microworlds*, or *learning laboratories*. These are managerial 'practice fields', where computer simulation technology is utilised to 'allow groups to reflect on, expose, test, and improve the mental models upon which they rely in facing difficult problems.' Peter M. Senge, *The Fifth Discipline*, Random House, Sydney, p 315. Senge devotes a chapter to discussion of the nature and utility of microworlds.

23 *The Concise Macquarie Dictionary*, Doubleday, Sydney, 1982, p 645.

24 Wing Commander J.A. Longrigg, *Repairable Items (RIs) Repaired by Civilian Contractors*, TFLM/4005/1/RIM 1 Pt1 (17), 28 July 1993, para 2.

was proposed in July 1993. The current SOPP has stated his intention of coordinating such a review in 1994.[25]

Discussion of the limitations of methodologies previously applied in RI management reviews highlighted a lack of conceptual understanding and practical application of systems thinking amongst RAAF logisticians. This view is supported in a recent paper published by a senior officer in the Directorate of Logistics Quality, Planning and Evaluation (DLQPE). One of the conclusions of this paper is 'that there has been only limited appreciation (in HQLC) to this point of the nature of systems, their relationship to organisations and, more particularly, to *organisational* performance.'[26]

Hence, a challenge exists to overcome inexperience and unfamiliarity with systems thinking in order to fulfil the desire to adopt a systems perspective on RAAF logistics. The system dynamics methodology has been developed to facilitate systems thinking. It is intuitively appealing, and requires little specialised knowledge. System dynamics could readily be applied in the proposed HQLC 1994 RI system review. This review presents an opportunity to apply systems thinking to RI management for the first time, and has the potential to significantly affect RI management development into the future.

CONCLUSION

The application of system dynamics across a wide range of disciplines over the past forty years reflects its utility in understanding and designing systems in an increasingly interdependent and complex world. Recently it has been used on a limited scale by the ADF, with interest being fostered through the Australian Defence Force Academy.

The systems thinking paradigm has rarely been applied in RI management review and development. The only element of the system dynamics methodology to be utilised is the limited application of influence diagramming by DILP in 1992. Examination of previous RI management reviews from a system dynamics perspective highlights a number of limitations. Some of these limitations pertain to RAAFQ tools, which are well suited to learning and improvement at the technical level, but lack strength at the conceptual level. The system

25 SOPP will be absorbed into the newly created Directorate of Logistics Development (DLD) at HQLC by this time. At this stage, the current incumbent, Wing Commander R. Brown, will proceed to DLD with responsibility for RI management development.

26 Wing Commander C.W.K. Tankey, *A Discussion Paper on Key Result Areas, Plans & Measures - An Exercise in Systems Thinking*, under cover of DLQPE 123/3/2/AIR/2, 24 August 1993, para 30.

dynamics methodology has complementary strengths and weaknesses to RAAFQ. Hence, integrated application of the two methodologies has the potential to enhance system development.

There is a need to improve understanding of the dynamic behaviour of the RI system in order to develop it to better meet preparedness requirements. The system dynamics methodology can meet this need. It is well suited to exploring the multiple cause-and-effect relationships underlying the behaviour of a system which is commonly perceived as fragmented. Furthermore, with its emphasis on understanding of systems as a whole, it aligns with the increased integration of functions in the RAAF logistics environment.

While the need to apply systems thinking to RAAF logistics, particularly RI management, is being gradually recognised, RAAF logisticians lack conceptual understanding and practical skill in its application. Use of a methodology which engenders systems thinking and guides application of its tenets is a means of overcoming the gap between the desire to apply systems thinking and current inexperience. Use of the system dynamics methodology in the proposed 1994 HQLC RI system review is recommended.

CHAPTER ELEVEN

CONCLUSION AND RECOMMENDATIONS - RI MANAGEMENT AND PREPAREDNESS

INTRODUCTION

The topic of RI management and preparedness has been examined in this paper by firstly introducing RI management, discussing its development, and identifying current RI management opportunities and issues within the logistics environment. Next, preparedness doctrine and policy were outlined, and recent preparedness studies discussed, with an emphasis on analysis of RI management undertaken as part of these studies. Chapter Eight brought these two strands of analysis together. Limitations of the current emphasis upon calculation of resource requirements in preparedness studies were discussed. It was argued that a broader approach to logistics system development is necessary. Finally, system dynamics was presented as a methodology with the potential to facilitate a systems thinking approach to understanding and developing the RI system.

Many issues have been discussed in this paper, with a number of recurring themes emerging. From this discussion, a clear response may now be formulated to the aim of the paper, to identify opportunities to improve RAAF preparedness through RI management and to recommend means of pursing these opportunities.

Aim and Scope

The aim of this chapter is to respond specifically to the paper's aim, based on analysis in preceding chapters. Major opportunities to improve RAAF preparedness through RI management are summarised, and a strategy for pursuing opportunities is outlined.

CONCLUSIONS - OPPORTUNITIES

Both ADF preparedness doctrine and policy and the RAAF logistics environment have undergone significant and exciting change in the past five years. A consistent preparedness framework has been introduced to the ADF, and concepts developed to enable disciplined thought about logistics and preparedness. At the same time, philosophical and organisational changes in RAAF logistics have been implemented to improve functional integration and achieve a weapon system logistics management focus. As several of these changes begin to mature, the opportunity exists to shift priority from implementation of the changes themselves to building upon them to improve preparedness.

The lessons of the past provide useful guidance in developing a strategy to improve RAAF preparedness in the future. Two significant sources of lessons presented in this paper are the development of RI management over the past decade, and recent preparedness studies.

In considering these lessons and the other opportunities identified below, the mission of RAAF logistics in support of endorsed readiness and sustainability objectives should be borne in mind. RI management is a key element of RAAF logistics which, through its impact on the operational availability and mission capability of aircraft, significantly affects preparedness. Hence, opportunities to improve the effectiveness and efficiency of RI management are also, in general, opportunities to improve RAAF preparedness.

Lessons from RI Management Development

Lessons from RI management development can be divided into two categories - those regarding the RI system, and those concerning analytical techniques applied to study the system. Significant lessons in the former category include the following:

a. Functional separatism undermines the coordination of activity across the RI system to attain RI management objectives. Functional integration should be pursued, including the development of integrated procedures, application of coherent performance objectives and measurement, and use of common terminology to discuss RIs and RI management.

b. Functional integration requires that individuals working in distinct elements of the RI system are aware of their role in, and impact upon, activity and decisions in other parts of that system. To develop this awareness it is essential to provide training based on a systems thinking approach.

c. Logistics information management systems must possess connectivity and data integration to support management of the RI system, which is broad in scope and composed of a diverse range of activities. These systems must provide visibility of RIs throughout maintenance pipelines to enable daily monitoring of RI status and performance measurement.

d. The broad scope of the RI system must be acknowledged and fully managed. Focus on a narrowly defined pipeline has restricted the identification of performance improvement opportunities and excluded important considerations from management decision-making.[1]

The dynamic behaviour of the physical RI system is poorly understood, despite the numerous RI management reviews and studies conducted over the past decade. This is partly due to the limitations of the analytical techniques used in these studies. From the systems thinking perspective, major flaws of these techniques are:

a. the delineation of narrow system boundaries, with the result that important interrelationships affecting system behaviour have been overlooked;

b. focus on events, and consequently on detail complexity, rather than on the pattern of events over time and the structure underlying those events, or dynamic complexity;

c. lack of feedback analysis to identify cause-and-effect relationships separated by time and space in the system; and

d. poor use of mental models as a data source.[2]

<u>Lessons from Preparedness Evaluation</u>

Discussion of the Force Expansion Study and Air Command Preparedness Project highlighted several lessons regarding preparedness evaluation methodology and deficiencies in the knowledge of operational environment and logistics support systems. Primary lessons from preparedness evaluation are:

a. Calculation of resource requirements to support preparedness objectives using logistics models will not provide valid output in the absence of a sound understanding of the contingency operational environment and logistics support systems.

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1 These lessons are summarised from discussion at Chapter Four.
2 These flaws are discussed further in Chapter Ten.

b. Modelling tools must suit the scenario being modelled, and must be applied appropriately. In particular, modellers must be well trained and should understand the assumptions and limitations inherent in the model. Also, the validity and variability of input data must be considered when interpreting model outputs.

c. Model outputs must be validated and complemented through the evaluation of logistics system performance during operational exercises.

d. Calculation of resource requirements as a means of preparedness assessment must be complemented by an appropriate system development strategy.

e. Logisticians must team with operational staff to jointly develop an understanding of the contingency environment and its implications for logistics.

f. Knowledge on maintenance venue capability and capacity should be detailed and recorded to enable the identification of RI pipelines most likely to become chokepoints in the force expansion process. This activity should be undertaken to facilitate ongoing strategic development of RI system infrastructure.[3]

Preparedness Policy Development

Publication of ADF reserve stockholding policy and implementation guidance in late 1993[4] provides an appropriate opportunity for HQLC to revise its approach to preparedness evaluation. In particular, the opportunity exists to consider the lessons learnt from the ACPP and to modify the methodology being applied in this project.

WSLM Squadron Establishment

Functional integration within WSLM Squadrons, and their establishment at operational bases, have progressed adequately in a number of cases for preparedness assessment to be given a higher management priority. The WSLM Squadron weapon system focus and location close to operational staff at major air bases provide a focal point for preparedness evaluation and improvement.

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3 These lessons are taken from discussion at Chapters Seven and Eight.

4 Reserve stockholding policy and implementation guidance are introduced at Chapter Six, p 6-10.

ILS Tools

The ACPP has provided the opportunity for WSLM Squadron staff to gain some experience with OPUS9. Further ILS tools will be introduced through the CAPLOG project in the near future.[5] These tools are decision-making aids which have the potential to enhance the capability of logisticians to evaluate the impact of RI management decisions on operational effectiveness. The in-service ILS implementation strategy must maximise this capability.

Training Strategy

A procedural RI training course has been developed and a computerised simulation model is currently being built to facilitate conceptual appreciation of the RI system.[6] A training strategy based on these initiatives has the potential to reduce system fragmentation and isolated decision-making.

LIMSP

The plan produced by the Logistics Information Management Strategic Plan (LIMSP)[7] study stresses the criticality of business process redesign as a pre-requisite to information management development. Business process owners will manage information management projects pursued under LIMSP.

RI System Study

The Directorate of Logistics Development (DLD) at HQLC plans to conduct a further RI system review in 1994. The desire to apply a systems thinking approach will guide selection of the study methodology.[8] The first major opportunity provided by this study is to conduct business process redesign as a precursor to information management development under LIMSP. The second major opportunity is to apply a methodology which facilitates systems thinking and advances a systemic view of RI management.

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5 CAPLOG is introduced at Chapter Two, p 2-5.

6 See Chapter Five, pp 5-5 - 5-6.

7 LIMSP is introduced at Chapter Four, p 4-5.

8 The intention to conduct a 'total systems review' of the RI system in 1994 is introduced at Chapter Ten, p 10-10.

System Dynamics

The system dynamics methodology facilitates systems thinking. The methodology has been applied to a range of systems from a variety of disciplines to aid in understanding the behaviour of dynamically complex systems, and as a system design tool. It offers complementary strengths to RAAFQ, which is increasingly being applied to the RI system at a localised level. Further, system dynamics has been used within the ADF in recent years, albeit on a small scale, and relevant expertise in its application is available at the Australian Defence Force Academy.[9]

RECOMMENDATIONS - PURSUING OPPORTUNITIES

Strategies recommended to pursue the range of opportunities which exist to improve RAAF preparedness through RI management fall into two categories. The first of these is the assignment of responsibilities to a number of HQLC directorates and WSLM Squadrons, with the aim of focusing ongoing management activity on preparedness. The second is the completion of specific tasks of finite duration, including the 1994 DLD RI system review. Each of these is discussed below, and recommendations are also made for further research topics of relevance to RI management and preparedness.

Directorate of Logistics Development[10]

WSLM Squadron establishment at operational bases has decentralised daily RI management. Certain RI management activities cross WSLM Squadron boundaries and require sharing of common resource pools. This necessitates centralised coordination of some activities and strategic guidance to WSLM Squadrons on RI management issues. DLD is positioned to adopt the role of coordinating system development and providing strategic guidance.

The following recommendations for DLD responsibilities are made:

a. To coordinate system development - to provide mechanisms for maintaining necessary procedural commonality across WSLM Squadrons, to assess the implications of proposed WSLM Squadron procedural improvements upon the broader RI system, and to coordinate and conduct RI system-level review and development activity.

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9 System dynamics is introduced in Chapter Nine, and its potential application to the RI system is examined in Chapter Ten.

10 Recommendations on assignment of organisational responsibilities have not considered staffing implications.

b. To cooperate with the Directorate of Logistics Quality, Planning and Evaluation (DLQPE) to ensure that system development and preparedness evaluation are linked.

c. To coordinate RI management training, with an emphasis on WSLM Squadron staff.

d. To monitor RI maintenance venue capability and capacity and to provide guidance on infrastructure development to meet strategic requirements. Evaluation of infrastructure to meet preparedness reporting requirements lies within this role.

Directorate of Logistics Quality, Planning, and Evaluation (DLQPE)

Preparedness assessment should be regarded as a form of logistics performance measurement which is performed on a regular basis, as required for submission of Biannual Preparedness Reports (BPRs) against the CPD objectives. Preparedness assessment should also provide input to logistics planning activity. Thus, coordination of preparedness assessment and development of assessment methodology is an appropriate extension of the current role of DLQPE in logistics planning and evaluation for HQLC and subordinate units.

The following recommendations for DLQPE responsibilities are made:

a. To develop a methodology for the identification of logistics resource shortfalls against CPD serials, as required in Biannual Preparedness Reports (BPRs), and for other preparedness studies. This role should be performed in conjunction with modelling specialists from Staff Office Project Support and Logistics (SOPSL), and relevant WSLM Squadron members.

b. To guide the implementation of such methodologies in WSLM Squadrons.

c. To provide administrative coordination of HQLC BPRs and responses to other preparedness studies.

d. To cooperate with DLD to ensure that preparedness assessment and system development activities are linked.

WSLM Squadrons

WSLM Squadrons now have primary responsibility for daily RI management, and must coordinate all RI system activity in support of a specific weapon system. To enable WSLM Squadrons to consolidate functional integration and incorporate the evaluation of operational effectiveness into daily-decision making, it is necessary that they possess ILS tools, and are trained in their use and the underlying ILS philosophy. This should be pursued through the CAPLOG project. It may be appropriate to establish a specialist analytical cell in each WSLM Squadron, including civilian staff positions, to develop and retain ILS expertise. This expertise will also be necessary to enable the WSLM Squadrons to conduct preparedness assessment relevant to the weapon systems which they support.

The following recommendations for WSLM Squadron responsibilities are made:

a. To develop RI management procedures and engage in system development activities in consultation with DLD.

b. To identify logistics shortfalls against CPD serials for relevant weapon systems to meet the BPR requirements.

c. To conduct preparedness assessment to meet other preparedness study requirements.

d. To team with operational staff at relevant Force Element Groups to jointly study the contingency operational environment and develop an understanding of its implications for logistics activity. This is an essential pre-requisite to the conduct of preparedness assessment, and would be an ongoing joint activity.

Preparedness Assessment Methodology

Responsibility for preparedness assessment methodology and coordination should be transferred to DLQPE as soon as possible. In conjunction with relevant members of WSLM Squadrons and SOPSL staff, DLQPE staff should consider ADF reserve stockholding policy and guidance, and lessons learned on preparedness assessment methodology from recent preparedness studies, particularly the Air Command Preparedness Project. This knowledge can be used to perform a number of tasks.

The following recommendations for preparedness assessment methodology tasks to be undertaken by DLQPE are made:

a. Facilitate implementation of teaming between WSLM Squadrons and Force Element Groups/Operational Wings to study the operational environment and implications for logistics.

b. Develop a methodology to identify and report logistics shortfalls against CPD serials in BPRs.

c. Modify ACPP methodology to overcome identified shortfalls, accepting that it may take several years to complete this project properly.

d. Identify how PREPEVAL, performed during operational exercises to realistically assess the capabilities of the logistics system, could be used as an adjunct to desktop studies such as the ACPP.[11] Following this, approach Air Commander Australia, through the Air Officer Commanding Logistics Command, to gain agreement to implement PREPEVAL.

Training

The current strategy of providing detailed procedural training to WSLM Squadron members, supplemented by general RI system awareness for people employed in other RI system activities should be pursued. It would be useful for the latter courses to be delivered on operational bases, possibly by WSLM Squadron staff, to a cross-functional group. These awareness sections could then be used to generate ongoing working relationships across the RI system and to initiate procedural improvement activities.

The following recommendations for training tasks to be undertaken by DLD are made:

a. continue to develop RI management training courses; and

b. coordinate implementation of RI management training in 1994.

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11 PREPEVAL was introduced at Chapter Eight, p 8-12.

System Dynamics

The following recommendation for DLQPE investigation of the system dynamics methodology is made:

> In conjunction with the Directorate of RAAFQ at Air Force Office, investigate the potential for the system dynamics methodology to be applied to the development of logistics systems as a complementary methodology to RAAFQ.

Policy

RI Management policy, DI(AF)LOG 2-2, requires revision. The term RI management requires redefinition to remove the narrow focus on pipeline management. The broader scope of the RI system should be emphasised, including the application of in-service reliability and maintainability objectives.

The following recommendation for policy development by the Directorate of Logistics Policy, Air Force Office, is made:

> Revise RI management policy, DI(AF)LOG 2-2, taking cognisance of the findings of this paper and the 1994 DLD RI system review.

HQLC 1994 RI System Review

The system dynamics methodology should be applied in the 1994 RI system review. The methodology should be used at the conceptual level to challenge fundamental assumptions regarding system behaviour, to improve understanding of dynamic system behaviour, and to aid in system design. Expertise at the Australian Defence Force Academy could be utilised to guide DLD in its application of the methodology and/or provide appropriate training.

This review should consider the implications of preparedness requirements for the RI system. In particular, the impact of all RI management changes proposed in the review upon the capability of the system to support contingency operations should be assessed.

As LIMSP recognises business process redesign as a critical factor in information management development, it is appropriate that this review makes recommendations on information management. Guidance should be sought from the Logistics Information Management Steering Group (LIMSG) when formulating study terms of reference.

The following recommendations for the DLD 1994 RI system review are made:

a. apply the system dynamics methodology;

b. consider the implications of preparedness requirements for the RI system; and

c. seek guidance from the LIMSG to formulate appropriate terms of reference regarding logistics information management.

Further Research

Associated topics which warrant further research are:

a. strategic infrastructure and defence industry development to meet RI requirements; and

b. preparedness and logistics in the weapon system acquisition phase.

ANNEX A

RI MANAGEMENT PROCESSES AND CONTROLS

INTRODUCTION

This annex contains a brief introduction to the maintenance policy, management processes and controls which shape the RI system. The broad scope of activities and large number of agencies which constitute the RI system are clearly illustrated.

Both RI management and general RAAF maintenance policy and management are in a state of transition due to functional integration, the Commercial Support Program (CSP), and Program Management and Budgeting (PMB). Consequently, published and practised RI processes and controls are undergoing considerable change. However, in some instances the two do not align. Variation also exists between management practices used by different WSLM Squadrons and maintenance venues. An explanation of both old and new approaches is given where it improves understanding of the other sections of this paper, or illustrates the extent and impact of current change. Otherwise, discussion aligns with current policy as promulgated in DI(AF)LOG 2-1, RAAF Maintenance Policy, DI(AF)LOG 2-2, Repairable Item Management, and complementary policy and procedural instructions.

MAINTENANCE POLICY

Maintenance Analysis

Maintenance planning begins in the acquisition project phase of a weapon system life cycle, and is now conducted using the Logistic Support Analysis (LSA) process. Following the identification of failure modes, Maintenance Engineering Analysis (MEA) is used to identify maintenance required to cost-effectively achieve operational requirements. Repair level analysis (RLA) is then performed to select appropriate maintenance processes and venues. Through these processes an item will be designated an RI. These analyses may also be performed in-service.

Technical Maintenance Plans (TMPs)

A TMP is promulgated for a PE and its Maintenance Managed Items (MMIs). The TMP contains the authorised maintenance processes, intervals (for scheduled maintenance), and venue specified during RLA. Unscheduled arisings are forwarded to authorised repair facilities in accordance with the TMP, dependent on the level of maintenance required.

Maintenance Levels and Servicing Levels

Maintenance Levels. The term 'level of maintenance' is used to describe both the complexity of maintenance activity and the necessary repair venue capability. Prior to 1991, the RAAF maintenance organisation was divided into three levels - Operating Level Maintenance (OLM), Intermediate Level Maintenance (ILM), and Depot Level Maintenance (DLM). The complexity of maintenance activities, requirement for specialised facilities, and length of the logistic pipeline increases through these levels. With the introduction of CSP, the need arose to delineate core from non-core RAAF functions, resulting in the adoption of two maintenance levels. These are Operational Maintenance (OM) which is largely a core activity, and Deeper Maintenance (DM) which is non-core. The primary task of OM is mission generation, while the focus of DM is asset preservation. Generally, ILM and DLM tasks have been transferred to DM under the new scheme.

Servicing Levels (SERLEVs). A SERLEV is a management code applied to control the movement of RIs. SERLEVs are applied to each RI on RAAFSUP (RAAF Supply computing system) to automate the production of paperwork directing the evacuation of RIs through the supply system to appropriate maintenance venues. The assignment of a SERLEV to an RI is dependent on the highest level of maintenance to which it is subject, and whether it is included in the Annual Maintenance Plan (AMP). SERLEV assignment, both prior to and following the adoption of two maintenance levels, is shown at Table A-1.

Examination of this SERLEV schema identifies the use of an AMP for maintenance planning as a distinguishing feature of DLM management. In conjunction with the general location of DLM venues remote from operational squadrons, this produced two distinct generic RI pipelines - the

SERLEV	MAINTENANCE RESPONSIBILITY (OLD SCHEMA)	MAINTENANCE RESPONSIBILITY (NEW SCHEMA-Draft)
A	OLM/ILM Facility nominated in TMP	Unit operating equipment, as nominated in TMP
B	RAAF DLM, as programmed in AMP	RAAF DM, as programmed in AMP
C	Contractor DLM, as programmed in AMP	Contractor DM, as programmed in AMP
D-L	ILM Squadron nominated in TMP	DM facility nominated in TMP, where items are not programmed in AMP (L unassigned)
X	Maintenance facility not determined and/or management visibility required - automatic evacuation inhibited	Overseas maintenance facility - automatic evacuation inhibited
Y	Managed by RI manager - excluded from automatic evacuation	Unchanged
Z	RI to he returned to stockholding, not maintenance facility determined or temporarily isolated from repair cycle	No maintenance facility determined or temporarily isolated from repair cycle

Table A-1. SERLEV Assignment

minor pipeline (OLM/ILM), and major pipeline (DLM). The adoption of OM and DM levels has removed this direct association. It has also resulted in some application of DLM management procedures to items previously managed as ILM, as indicated by the possible reassignment of RIs from SERLEV D-L (previously ILM) to SERLEV B.[1]

RI SPARES ASSESSMENT

Spares assessment is the process of determining the required level of investment in pipeline and buffer spares to meet RI item availability targets (A_{it}) consistent with PE availability requirements. Computerised modelling tools are used to perform spares assessment computation. Computation is performed by optimising the quantity of spares to be purchased against a performance constraint, such as maximisation of operational availability within a given budget.

Computation

Key data requirements for spares assessment computation relate to the weapon system operational concept and Rate Of Effort, RI reliability characteristics, maintenance policy, and logistics infrastructure, including repair turnaround time (TAT). Key outputs are:

a. the expected average quantity of RIs in the pipeline (QPL) and minimum buffer quantity needed to achieve A_{it},

b. total minimum quantity (QMIN) assessed for procurement, and

c. intended distribution of assets procured.

Models

Since 1981 the RAAF has used the PATTRIC (Poisson Availability Target Technique for Repairable Item Computation) spares assessment model. The limitations of this model have been recognised since the mid 1980s, and it is currently being replaced with the OPUS9 (OPtimum Utilisation of Spares Version 9) model. The brief comparison of PATTRIC and OPUS9 at Appendix

1 For instance, a number of SERLEV F RIs have been programmed on the AMP by Strike Reconnaissance Logistics Management Squadron. As the new SERLEVs are yet to be applied, local handling procedures have been derived to circumvent the programmed RAAFSUP procedures which were designed for the three-tiered maintenance system.

One highlights the increasing sophistication, data requirements, and utility of spares assessment.

Management Allowances

In addition to the spares assessment computation, RIs may be required to meet management allowances. These include Test Bench Allowance to support maintenance testing and Deployment Allowance to meet operational requirements on deployment remote from base.

Unit Entitlement

Management allowances are combined with the computed asset distribution to establish a Unit Entitlement (UE) for each operating and maintenance unit. UEs are most commonly applied to MSIs. The MUE (MSI Unit Entitlement) is a key RI management control parameter. For example, it is used in both asset replenishment and maintenance planning activities.

RI PROCUREMENT

RI procurement occurs in both the acquisition and in-service life cycle phases. In-service procurement is necessary to meet RI wastage or changes in the assessment inputs (eg, degraded RI reliability or maintainability characteristics or pipeline TAT performance). The quantity assessed for procurement will not always be purchased, notably due to budgetary limitations. Where such a management adjustment is made, exception management techniques may be needed to ensure that required item availability is met.

BREAK DOWN SPARES PROVISIONING

The availability of adequate break down spares (BDS), or RI piece parts, is a key factor affecting RI repair time and availability. BDS management is supported by RAAFSUP, which is not interfaced with maintenance management information systems. Historically, BDS assessment and provisioning have been poorly related to maintenance policies and programs. The recent adoption of a weapon system build hierarchy focus, and improvement in supporting information systems, will enable the adoption of more appropriate BDS management practices.

MAINTENANCE PLANNING

Purpose

Maintenance planning involves the forecasting of maintenance arisings and planned workload to meet asset serviceability targets (in the form of UE). The purpose of such planning is to ensure the availability of resources (such as finance, BDS, maintenance technicians and facilities) needed to support the maintenance program. The planning technique and intervals used are dependent on the RI SERLEV and local conditions, including scale of maintenance resources.

Annual Maintenance Planning

Planning for SERLEV B and C RIs (previously DLM management) is conducted using an annual cycle based on preparation of an AMP, released each July. The AMP details, by maintenance venue, the quantity of each RI to be input to work in the forthcoming financial year in order to meet serviceable asset targets derived from UE. Work listed on the AMP is authorised by the release of Job Orders (JO) or Purchase Orders Maintenance (POM). Unserviceable RIs are committed to a JO or POM throughout the year, until the authorised quantity is attained. RI managers, now located in WSLM Squadrons, monitor performance against the AMP and amend it as necessary.

Scheduling

Maintenance scheduling is conducted at venue level in order to meet the maintenance plan. It requires the consideration of a range of factors including facility capacity, short term resource availability (eg, manpower, BDS), viable job batching, and serviceable asset holdings. Ongoing prioritisation is necessary to ensure that limited maintenance venue capacity is assigned to those RIs requiring achievement of lower TAT in order to satisfy availability requirements. The scheduling technique applied is determined by the venue, with the guidance of a monthly Priority Output List (POL) prepared by the WSLM Squadron for SERLEV B and C items.

STORAGE AND HANDLING

Storage

The storage location of both serviceable and unserviceable RIs impacts upon the length of the logistic pipeline, hence upon TAT and asset availability. With the closure of RAAF Stores Depots, RIs are stored in two primary locations - MSI stores located at or near operating squadrons, and central base warehouses. MSI stores are managed by the operating squadron or a maintenance venue, while warehouses are managed by local supply squadrons. MSI store holdings are based upon the UE of the squadron and/or maintenance venue which they serve. Serviceable holdings above this are held in base warehouses. Repairable stock of SERLEV B and C RIs surplus to authorised AMP quantities are also held in base warehouses.

Handling

The involvement of multiple operational, maintenance, and storage sites necessitates considerable transport, handling, and packaging of RIs, both within Australia, and to overseas venues.

RELIABILITY AND MAINTAINABILITY

Reliability and maintainability (R&M) are design parameters which are determined primarily by decisions taken during the project phase of the weapon system life cycle. Logistics Engineers (LOGENGs)[2] are responsible for continuous review of RI R&M in-service, and achievement of cost-effective improvement in these parameters. LOGENGs utilise the manual Defect Reporting System to identify candidates for modification and reliability improvement. This activity most commonly occurs in response to performance degradation identified at Unit level.

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2 Previously known as System Engineers, SYSENGs.

PERFORMANCE MONITORING AND IMPROVEMENT

Performance Targets

Performance targets are an essential system control mechanism. During the recent HQLC restructure, overall responsibility for coordinating and monitoring the RI system shifted from Support Groups at HQLC to WSLM Squadrons. However, because the RI system involves managers from a range of organisational domains, performance targets are set at sub-system levels for individual managers to utilise. Specification and promulgation of these targets have not been coherent.

Current policy provides for performance monitoring initiatives based on enhanced information management. Key performance targets will be based on data utilised or produced in the spares assessment process. These targets will aim to meet item availability requirements by ensuring that actual performance is at least as good as was assumed during spares assessment. Hence, it is important that target data is input to assessment computations, not historical performance figures - a criterion yet to be implemented.

Problem Analysis and Corrective Action

WSLM Squadron RI pipeline managers are responsible for identifying RIs for which serviceable assets are inadequate, and coordinating problem analysis and corrective action. A range of potential causes of poor pipeline performance must be considered. Any of the processes outlined above may hold the key to improvement, and a flexible, comprehensive analysis is required. The ability to 'trade-off' investment and performance in the RI system versus other logistics activities using ILS tools further complicates the improvement process.

INFORMATION SYSTEMS

The availability of information is the key to many of the processes outlined above. The need to track the movement of RIs using a distributed database recording all data required by managers throughout the system has been recognised for a number of years. It is unclear whether this need will be met through the development of CAMM2 (Computer Aided Maintenance Management, Version 2) and its interfaces with other systems currently under development. In the interim, a range of isolated information systems including CAMM, MAARS (Maintenance And Analysis Reporting System), DECOR (DEpot COntrol and Reporting system), RAAFSUP (RAAF Supply system), and SORODB (Staff Office Repair and Overhaul Data Base) are utilised to perform and manage a variety of the processes outlined above.

<u>Appendix:</u>

1. Comparison of PATTRIC and OPUS9 RI Spares Assessment Models

APPENDIX ONE TO ANNEX A

COMPARISON OF PATTRIC AND OPUS9 RI SPARES ASSESSMENT MODELS

BACKGROUND

Role of RI Spares Assessment Modelling

The general role of RI spares assessment models is to optimise the quantity of spare RIs required to support a weapon system in relation to a defined performance constraint. This constraint is most commonly maximisation of operational availability within a given budget or minimisation of the cost of achieving a given operational availability. Earlier models were subject to several limitations which required the adoption of simpler performance constraints, often minimisation of backorders. Many modern models can perform additional roles, including evaluation of alternate logistics support structures, and Logistics Capability Assessment (LOGCAS), which is introduced in Chapter Two.

RAAF Development

The RAAF has been using RI spares assessment modelling since 1968. Given the lack of computer support at this time, the LANDAU model allowed very simple manual spares assessment.[1] With the increased availability of mini-computers in the 1970s, the RAAF recognised the potential to adopt a more accurate model. Use of METRIC (Multi-Echelon Technique for Recoverable Item Control), developed by the Rand Corporation in 1966, created a desire to develop an in-house model. This model was to be applicable to the RAAF's small aircraft inventories, and easier to use.[2] The PATTRIC model was subsequently developed, and has been in use since 1981 for both project and in-service RI spares assessment.

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1 Details of the LANDAU model, developed for the RAAF by the Aeronautical Research Laboratory, are contained at ARL Aerodynamics Note 305, *Spares Assessing For Repairable Items*, September 1968.

2 *Follow-On Evaluation of the ROSAM, ACIM and OPUS9 Models for use as Repairable Item Spares Assessing and LOGCAS Models in the RAAF*, DLDP AF90/26924, 26 June 1991, pp 1-3.

POISSON AVAILABILITY TARGET TECHNIQUE FOR REPAIRABLE ITEM COMPUTATION (PATTRIC)

Role

PATTRIC is used solely as a spares assessment model.

Objective

The function of PATTRIC is to calculate the optimum quantity and distribution of spare RIs to achieve an item availability target (A_{it}). The A_{it} is specified in terms of minimising backorders and has been typically set at 0.98 by the RAAF. PATTRIC uses a Poisson distribution to describe the quantity of RIs in the repair pipeline, as shown at Figure A-1-1.

Inputs and Outputs

Key inputs to PATTRIC computation are aircraft Rate of Effort (ROE), item reliability characteristics, and repair turn around times (TATs). Key outputs of the PATTRIC computation are:

a. the minimum quantity of assets that need to be procured to meet the support objective (QMIN);

b. expected average quantity in the pipeline (QPL), and minimum buffer quantity needed to achieve Ait; and

c. intended distribution of assets procured.

Limitations

A review of the PATTRIC model in 1985[3] identified a fundamental flaw in the way in which the model links aircraft availability to RI availability. Of significance is the fact that PATTRIC assesses each RI in isolation from the total weapon system build structure. Additionally, the Poisson distribution is an inferior representation of RI demand patterns which display high

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3 *Repairable Item Requirements Determination and Availability Modelling, Review of the PATTRIC Methodology 1984/85*, AF85/21185,21 June 1985.

variability. PATTRIC is also limited to a single-echelon, single-indenture evaluation,[4] and fails to consider RI cost.

Probability of Quantity 'Q' in Major and Minor Pipelines

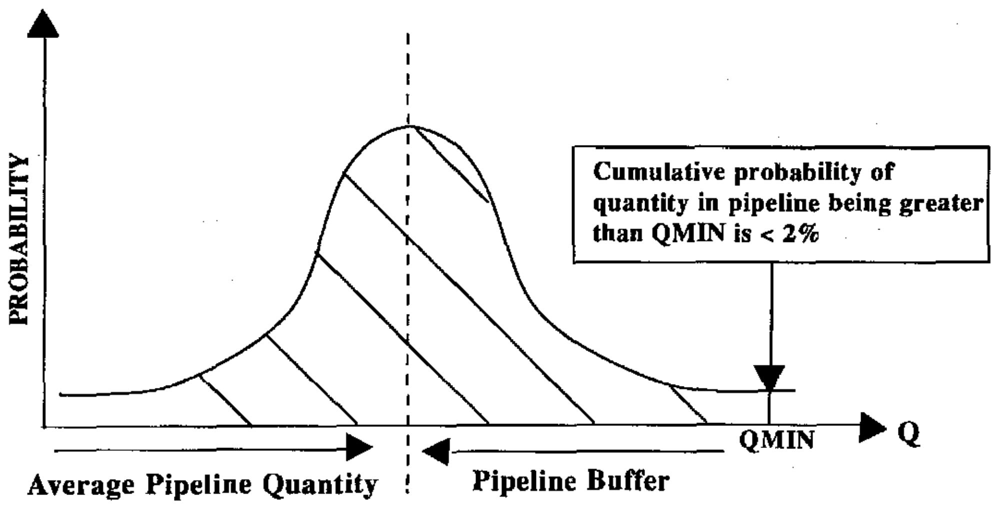

Figure A-1-1. PATTRIC Model of Pipeline Quantity Distribution[5]

OPTIMUM UTILISATION OF SPARES VERSION 9 (OPUS9)

Replacement of PATTRIC

Following recognition of the inadequacies of PATTRIC, a functional description was written for a model to be developed in-house - Multi-echelon Analysis Technique for Repairable Item Availability and Requirements Computation (MATRIARC). MATRIARC development was disrupted through the personnel posting cycle and a shortage of technical resources. By 1990 several commercial models were available which surpassed the MATRIARC functional specification. OPUS9 was selected as most suited to RAAF needs.

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4 A single echelon model can simulate the logistics system with only one level of maintenance and/or stockholding. A single indenture model does not recognise the interdependence of LRUs (Line Replaceable Units - components typically removed from aircraft at the flight line) and SRUs (Shop Replaceable Units - sub-components of LRUs, typically removed at maintenance workshop level).

5 Annex A to SRO4/4600/3/PROC Pt5 (10), October 1990.

Role

OPUS9 can be utilised in a number of roles. In the spares assessment role it an be applied to a range of problem types including initial or replenishment procurement, optimal reallocation of a given spares assortment, or reallocation followed by optimal replenishment. Other applications of OPUS9 include steady-state LOGCAS and limited Life Cycle Costing.

Objective

OPUS9 can optimise the quantity of spares against a variety of performance constraints, as described in the introductory paragraph of this appendix.

Inputs and Outputs

Considerable input data is required to utilise the multi-echelon, multi-indenture features of OPUS9. This includes data on the aircraft structure, operational profiles, and logistics support system, and will be managed using a Logistics Support Analysis Record (LSAR) for the weapon system. The initial compilation of the LSAR will occur during weapon system acquisition, or in-service for selected weapon systems already operated by the RAAF. However, the initial construction of LSARs, or compilation of other appropriate OPUS9 input data, is a labour-intensive task. Consequently, OPUS9 implementation will be protracted over a number of years.

In the spares assessment role, output data includes recommended quantity of spares and distribution as well as ranking of proposed purchases in cost-effectiveness order.

Advantages over PATTRIC

The advantages of OPUS9 over PATTRIC are that it:

a. uses a Compound Poisson model, which more accurately represents RI demand patterns than the PATTRIC simple Poisson model;

b. considers the weapon system as an interactive set of RIs with associated purchase costs, enabling recommendation of the most cost-effective mix of spares for all RIs within a weapon system to obtain specified weapon system availability;

c. can model complex multi-echelon support organisations, and recommend spares storage locations to achieve optimal systems availability;

d. can be used to determine fly away kit[6] quantities using dollar, weight, or volume as a controlling parameter for optimisation; and

e. can readily support studies involving trade offs between alternative support structures and repair and stocking policies.[7]

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6 A fly away kit is an air-transportable pack of items required to maintain aircraft in an operational role for a designated period when detached from the parent base. ADFP101, p F-10.

7 Derived from *The Suitability of OPUS9 to the SRLMSQN*, Enclosure 1 to 501WG/4520/2/2/1 (10), 11 March 1993, para 3.

ANNEX B

DEVELOPMENT OF RI MANAGEMENT IN THE RAAF

INTRODUCTION

This annex examines a number of key RI management reviews and studies conducted since the mid-1980s. Significant problems identified in the reviews and organisational responses to these are discussed. This material provides a background against which the potential impact of functional integration and other changes in the contemporary logistics environment are discussed in Chapter Two.

RI MANAGEMENT PHILOSOPHY

The Watson Paper

The 1984 Watson Paper embodied RI thinking in the early 1980s, when Group Captain Watson was the Staff Officer Repair and Overhaul (SORO) at HQSC.[1] Watson was concerned to 'create a framework for managing technical items'[2] through redefinition of RI management terms and concepts. The proposed philosophy embodied a shift away from classification of technical items on the basis of provisioning methodology and technical features towards classification on the basis of management processes applied to the items.

Procedures and Training Steering Group (P&TSG) RI Working Group

The P&TSG Working Group (P&TSGWG) was formed at Headquarters Support Command to investigate the philosophy of RI management. At that time the term RI was applied to any item which could theoretically be repaired once unserviceable. Items for which demand was met through maintenance were classified as RIs.

The investigations of the P&TSGWG 'revealed...a lack of well enunciated management philosophy for RIs.'[3]

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1 SORO was subsequently retitled the Directorate of Major Maintenance Services, DMMS.

2 Group Captain B. Watson, SORO, *Repairable Item Management*, SORO 2501/11/17/TECH Pt1 (35), 28 November 1984.

3 *Report of P&TSG Working Group (WG) Repairable Item Management*, Enclosure 1 to SORO 4000/49/1/2 (13), 1986, para 1.

Technical Inventory Classification. The WG sought to rationalise terms used to describe the technical inventory as the basis of a management philosophy. They favoured the adoption of a simple classification system; if an item was subject to maintenance management, it would be known as a Maintenance Managed Item (MMI). The purpose of this classification was to bring 'responsibility for and the execution of the resupply function...(for the first time) into sharp focus.'[4] This would reinforce the Watson proposal for classification of technical items according to management processes. While the simplified classification, shown at Figure B-1, was not adopted, some of the principles derived from it have been influential in policy development.

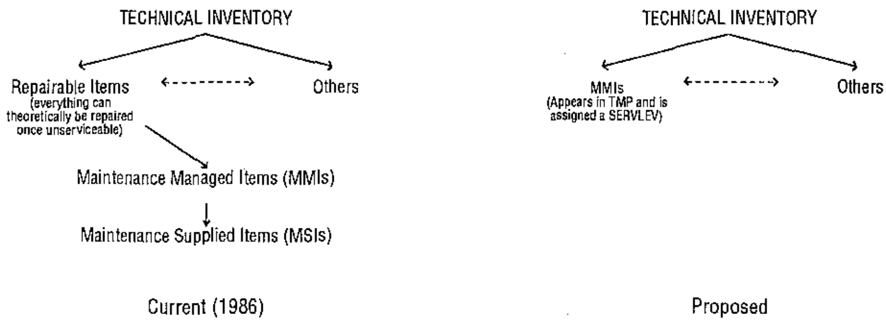

Figure B-1. Proposed Technical Inventory Classification[5]

Principles of RI Management. Building on the proposed technical inventory classification, the P&TSGWG proposed a set of principles which expressed a philosophy of RI (or, as they termed it, MMI) management. Amongst these principles were:

a. The use of Servicing Levels (SERLEVs)[6] to clearly distinguish RIs from other technical items; and

b. Recording of RI spares assessment inputs and outputs on a Basis of Assessment (BOA) document, with the BOA used to set RI availability targets.

While these principles were not radical, the application of availability targets to all MMIs had only recently entered the RI debate. Implementation of the WG's proposals would require considerable expansion of the RIMS computer[7] on which PATTRIC spares assessment

4 Ibid, para 8.
5 SORO 400/49/1/2/ (13), op cit, Enclosure 1.
6 The use of SERLEVs in RI management is introduced at Annex A, p A-2.
7 The RIMS (Repairable Item Management System) micro-computer was located at SORO. All PATTRIC calculations were executed by SORO staff.

calculations were performed. The resource intensiveness of this activity proved a key impediment to adoption.[8] However, the principle of using the BOA in setting performance targets has been incorporated into current RI management policy.

POLICY DEVELOPMENT - AIR FORCE OFFICE WORKING PARTY

Working Party Objective

A joint Air Force Office Working Party (AFO WP) was formed by the Directorates of Maintenance Policy and Supply Policy in July 1985 with the objective 'to identify a (RI) management system which ensures that target item availabilities are met.'[9] The target task completion time of six months, however, became two and a half years. During this time, the following reports were published by the AFO WP:

a. September 1985 - first report, which discussed current RI management, identified inadequacies, and ascribed principles to be applied in redevelopment of RI management;

b. April 1986 - second report, which defined a model of an RI management system for use as a benchmark in development of a new system, and described two options to meet system requirements; and

c. November 1987 - final report, which made recommendations on RI management procedures and system structure.

First Report

System Description. The AFO WP experienced difficulty in describing the RI system. An 'authorized system' was documented from official publications. However, the AFO WP found 'significant differences between the published RI management system and the system being followed in the field.'[10] Even their description of the authorised system could not 'be claimed to be 100% accurate as conflict was discovered between various publications.'[11]

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8 SORO noted that application of a SERLEV to all MMIs would increase the number of RIs by 70%. *Minutes of the Workshop on Repairable Item Management held at No 1SD on 9-10 November 1987*, SSPT 4360/4/4/1 (19),para 4.

9 *Repairable Item Management Party Progress Report,* Enclosure 1 to AF85/22923 Pt1 (51), 30 April 1986, para 2a.

10 *DMP-AF/DSPOL-AF Repairable Item Working Party Preliminary Report*, Enclosure 1 to AF85/22923 Pt1 (35) ,September 1985, para 34b.

11 Ibid, para 10.

The predominant impression of the RI system contained in this report is that of unnecessary complexity and fragmentation. This impression was summarised as follows:

> "The overall system is a complex interlacing of engineering, supply and maintenance management systems. There is no overview of the system, and operatives tend to learn only the process they are doing. Thus each process involves a new learning process without an appreciation of role within the total system. In addition, no single appointment or functional authority has been identified with responsibility for appreciating that total role and its responsibility for executing that total role."[12]

System Inadequacies. The lack of performance targets and inadequate data to monitor asset availability were identified as significant system inadequacies. Further deficiencies identified included:

a. administrative delays;

b. logistics shortfalls, such as the lack of repair parts or manpower at repair venues; and

c. information system limitations.

Principles. As with the P&TSGWG, the AFO WP proposed the achievement of target item availability as a fundamental principle to be applied in system redevelopment. They also stressed the design of a simpler system.

Assignment of overall responsibility for achievement of RI availability, supplemented by assignment of subordinate responsibilities within the system, was proposed as the key to a simpler system. Assignment of responsibilities was an attempt to counter the fragmentation seen as inherent in an RI system. RI management had been shaped by an amalgam of independently developed engineering, supply, and maintenance policies and procedures, rather than being purposefully designed as a coherent system.

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12 Ibid, para 18.

Second Report

System Model Development. The AFO WP sought to develop a generic model which could be used to benchmark a revised RI system. In August 1985 Group Captain P.J. Rusbridge, then Director of Maintenance Policy (DMP), requested the assistance of Mr Robert Jones, a lecturer at the University of New South Wales School of Civil Engineering, in this quest. The objective of the model was:

> "to simulate a standard RAAF RI circuit such that the Working Party can assess the effects that varying certain exogenous variables will have on the performance of the circuit. The simulation should...be flexible enough to permit the Working Party to make major changes; and subsequently to simulate their effects."[13]

Hence, the model was to be both an aid to understanding system behaviour and a policy design tool.

Discrete Event Simulation Model. Mr Jones undertook preliminary development of a discrete event simulation model which was further developed by Squadron Leader M. Gaspert as an academic thesis.[14] The program for the model was written in PASCAL and designed for implementation on a micro computer. The model represents the RI management system as two major elements, the repairable workshop and the stores system. A stream of RI maintenance jobs is fed into the system by an arisings generator. Each system element contains a series of 'nodes' representing maintenance activities, RI queues, store holdings, unsatisfied demands for RIs, and a range of decision points governing routing of RIs through the system. The model also incorporates RI wastage and reprovisioning activity. The nodes can be configured in any combination, providing the flexibility to analyse alternate system structures and policy. Performance statistics which can be reported are delays to demand satisfaction, queuing time throughout the system, and average TAT.

Further Model Development. When passed to DMP in September 1986, the model required validation and further development of the supply circuit elements. Unfortunately, this work was not completed due to data and manpower shortfalls.[15]

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13 *Letter from Group Captain P.J. Rusbridge to Mr Robert Jones*, AF85/22923 Pt 1 (48), 25 October 1985.

14 Squadron Leader Michael Gaspert, BE, MSc, *Simulation of RAAF Repairable Item Circuit*, Thesis, School of Engineering, Gippsland Institute of Advanced Education, September 1986.

15 Problems noted by GPCAPT P.J. Rusbridge in loose, undated minute to DGTP-AF and CAFTS, *RI Circuit Management*.

The Working Party Model. An alternate model was developed and used by the AFO WP. It consisted of verbal description supplemented by a high level conceptual flowchart, shown at Figure B-2, and detailed tables which identified responsibility for tasks within the system. The model was based on the principle of assigning overall responsibility for the achievement of RI availability targets (A_{it}s). This was to be pursued through the concept of circuit management.

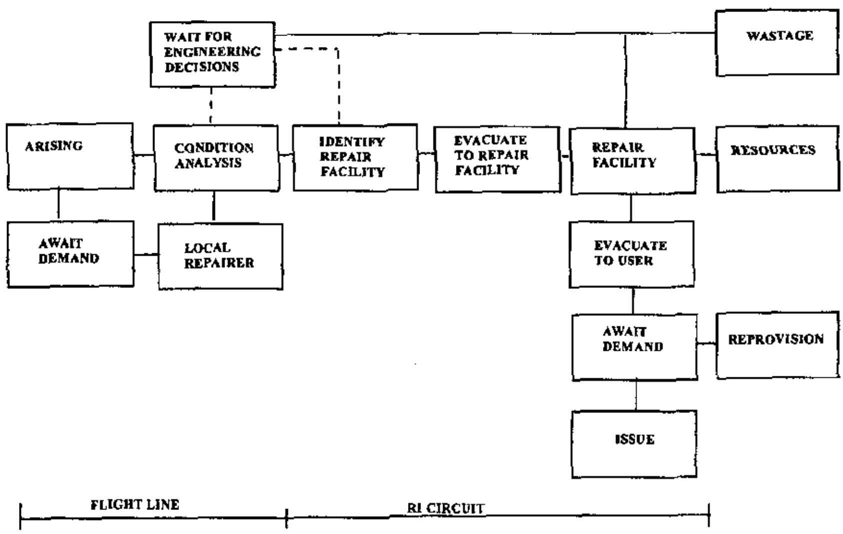

Figure B-2. Conceptual RI System Model[16]

The system was defined in terms of 'the circuit or circuits existing within the (system) boundary and over which the RI (circuit) manager must assert control, authority and responsibility.'[17] The proposed RI circuit manager would be responsible to ensure that RIs moved around the repair circuit, and to coordinate activity to ensure that target A_{it}s were met.

The model's inherent inflexibility for the development and evaluation of alternative policies was its major failing.

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16 Enclosure 1 to AF/22923 Pt1 (51), op cit, Annex A.
17 Ibid, para 13.

<u>System Boundary</u>. Figure B-2 shows the proposed system boundary. Elements excluded from the 'RI Circuit' model were:

a. Flight line maintenance;

b. Repair Facility - from commencement of survey and inspection of unserviceable RI to the point at which Quality Assurance acceptance has been performed (civilian maintenance venue) or trade supervisor has declared the RI serviceable (Service venue); and

c. Reprovisioning - wastage and replenishment activity.

Clearly, all of the activities beyond the proposed boundary of the RI circuit have a significant influence on system behaviour and the achievement of RI A_{it}. The model represents only part of the total RI system. Consequently, the model does not meet the stated aim of being 'unconstrained' in the sense that it showed a system 'necessary and sufficient to meet the stated aims of the circuit.'[18] This limitation was not stated by the WP.

<u>Model Deficiencies</u>. Although the attempt to adopt a systems-based approach to RI management is admirable, the model failed to incorporate key aspects of systems thinking. Notably, the identification of causality between elements of the system (feedback loops) which underlie system behaviour was not achieved. The weaknesses of this modelling approach and the implications of the systems thinking for RI management are examined in Chapter Ten.

<u>The Third and Final Report</u>

Due to staff shortages, the AFO WP was inactive for a period following the issue of the second report. Additionally, the authors of the final report differed from those of the first two. In reviewing the progress of the original WP, they noted a mixed response to the circuit management proposal. They expressed concern over potential clashes of authority between the circuit manager and other managers within the system, and a lack of detail regarding procedures and support systems.

<u>A Revised Circuit Management Proposal</u>. The final report noted the distinct differences of DLM management to OLM and ILM. For instance, it was observed that 'for OLM and ILM facilities, the RI management organization is so ill-defined as to be almost non-existent.'[19]

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18 Ibid, para 8.

19 *Repairable Item Management in the RAAF*, AF85/22923 Pt 2 (21), 12 November 1987, para 18.

The retention of existing DLM management responsibility at SORO was recommended, with appointment of an RI ILM manager (RIIM) to 'coordinate and oversee all RI processes within...OLM and ILM facilities'[20] at a base.

Procedural Changes. Annual Maintenance Plans (AMP) were already used to coordinate DLM workload and manage resources. Formal requirement of a similar planning activity at ILM level was recommended. Additionally, performance targets were examined at length, laying the foundations for adoption of serviceable RI asset levels and TAT as key targets derived from availability requirements.

Draft Policy. The WP's recommendations were encapsulated in draft DI(AF)TECH 3-20, released in November 1987. The draft described the circuit management concept and organisation. It specified the performance targets of TAT and 100% availability of RIs on demand at user locations. ADP (Automated Data Processing) requirements to support performance measurement were also detailed.

While the broad circuit management concept was generally accepted, the sentiment of Headquarters Support Command (HQSC) was that the draft policy attempted to prescribe implementation processes (a HQSC responsibility), and was repetitive of other policy instructions.[21] Headquarters Operational Command (now Air Headquarters Australia) agreed that the draft was overly prescriptive, and felt that the circuit manager duties would be too intensive for a secondary appointment, as had been proposed.[22] An over-riding concern was that 'without new data systems, reorganizing the management would not provide any improvements'.[23]

Review of the draft policy was agreed following lengthy debate at a high level RI Management Workshop in November 1987.

DI(AF)LOG 2-2, Repairable Item Management

Two years later, in December 1989, a more comprehensive RI management policy was released as an Air Force Temporary Instruction[24], and subsequently incorporated into the Logistics DI series as DI(AF)LOG 2-2.

Some of the recommendations of the earlier WP were applied, in particular the assignment of both distributed responsibilities within the system and an overall system coordinator. Support Groups (SGs) at HQLC

20 Ibid, para 26.
21 Consolidated Views on DI(AF) TECH 3-20, Loose undated file note on DEVM 4012/2/1 Pt 2.
22 HQOC 3040/8/Tech Pt 4 (41).
23 SSPT 4360/4/4/1 (19), ibid, para 21.
24 AFTI Tech 9/89 and the identical AFTI Sup 1/89.

were assigned a system monitoring, coordinating and troubleshooting role. Interestingly, this attempt to overcome the fragmentation within the system was seen by some as 'institutionalis(ing) that fragmented management rather than unifying it.'[25]

The policy also incorporated a management control strategy in the form of targets, monitoring and performance feedback. Guidance was provided for the development of appropriate measurement and information systems to support this strategy.

Long Term RI Management Objectives. The scope of the new policy was much broader than the proposed DI(AF)TECH 3-20. It included 'policy *hooks* for a number of initiatives'[26] arising from subsequent review. These initiatives reflected many of the concerns and issues discussed in the remainder of this annex, and include:

a. TATs determined as a matter of policy, rather than based on actual in-service achievement (supporting the use of TAT as a performance target);

b. repair-program-based provisioning and maintenance-policy-based assessing (the 'Manufacturing Resource Planning' approach);

c. maintenance planning at all maintenance levels; and

d. facilitation of the requirements of RI management in the development of information systems.[27]

The use of policy instructions to set long term objectives demands ongoing amendment to retain currency of those objectives in a changing logistics environment. Since current policy was written, the logistics environment has altered through significant changes such as functional integration, Weapon System Logistics Management (WSLM), and the Commercial Support Program. Hence, the longer term objectives contained within DI(AF)LOG 2-2 require revision.

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25 Group Captain P.J. Rusbridge, *RI Management*, AF86/8952, 23 December 1989, para 3.

26 Group Captain C. Hingston, *Repairable Item Management*, AF88/28674, 8 December 1989, para 2.

27 Loc cit.

1987 RI MANAGEMENT WORKSHOP

Workshop Purpose

Senior logistics managers from HQSC and RAAF maintenance venues met in November 1987 to discuss a series of RI Management issues. The need for such a gathering reflects the difficulty of coordinating the efforts of the large number of parties involved in RI management. In opening the meeting, the Controller of Logistics (CLOG) 'highlighted the need for an awareness at all levels of the various initiatives and activities being undertaken in relation to RIs'.[28] He also stressed the 'need to pull RI management together ... with a clear policy'.[29]

Brief examination of issues discussed at the workshop highlights the concerns of the period. Additionally, review of progress in each of these areas is indicative of both the improvements made over the last five years and areas of ongoing concern.

Planning Basis.

Discussion of planning focused on the transition of a weapon system from acquisition project to in-service phases of the life cycle. There was consensus that project planning information should be recorded and utilised as a basis for in-service logistics support. The 'importance of an operational plan as a basis to Logistic Support Planning'[30] was recognised, suggesting the need to link logistics activities to preparedness requirements. While the transfer of project data to the running system is currently being addressed through the adoption of Integrated Logistics Support, preparedness implications for RI management are yet to be adequately addressed, as discussed in Chapter Eight.

RI Circuit Management and Review.

Unit Entitlements. In addition to discussion of draft policy, a range of ongoing procedural concerns were raised at the meeting. The role of Unit Entitlements (UEs) and management of serviceable holdings of RIs against UEs generated debate. In response to ambiguity on this issue, guidance on UEs was included in DI(AF)LOG 2-2.[31]

Asset Visibility. The problem of incomplete RI asset visibility at operational squadrons and within the pipeline has been more difficult and expensive to overcome. The RAAF is currently unable to track RIs

28 SSPT 4360/4/4/1 (19), op cit, para 1.
29 Loc cit.
30 Ibid, para 9.
31 DI(AF)LOG 2-2, *Repairable Item Management*, Issue No 1/91, 1 June 1991, para 25.

throughout the entire pipeline, in particular being unable to monitor assets in the transportation element of the pipeline. Long term improvement is being pursued through information systems development. However, it is unclear whether systems currently being developed will significantly alter asset visibility, as discussed below.

CAMM/MAARS. The MAARS[32] database is the major source of information on maintenance activity for all items listed in Technical Maintenance Plans (TMPs). Data is collected automatically for equipment managed using the Computer Aided Maintenance Management (CAMM) system, and manually for other items.

MAARS input forms contain a number of fields of potential value for assessing pipeline performance, but many are non-mandatory. Additionally, MAARS measures TAT from the time that a Maintenance Arising Advice (EE435 M1) is raised by the unit operating the RI at time of failure to the time that RI is certified as serviceable on a Maintenance Completion Advice (EE435 M2) by the maintenance unit. Hence, the average TAT for a particular pipeline excludes significant transportation, packaging, and handling activities.

CAMM2, which is scheduled to replace CAMM and MAARS by 1996, will be interfaced to a range of other RAAF and ADF logistic databases. This should improve asset visibility and data accessibility. It should also provide a more comprehensive and flexible performance measurement capability, although the depth of pipeline TAT data is yet to be determined.[33]

SORO Data Base 2 (SORODB2). SORODB2 is a repair and overhaul management system which was designed for DLM management. It was developed largely in response to a 1988 audit review of DLM which traced numerous management deficiencies to inadequate and fragmented information management.[34]

The original SORODB2 functional specifications were quite comprehensive and were based in part on the ROAMS (Repair & Overhaul Automated Management System) specification, conceived in the late 1970s. ROAMS was never developed through lack of manpower and ongoing enhancement of an existing mini-computer within SORO.

Due to limited funding, SORODB2 development has been restricted to a core functionality which will support maintenance planning, order creation, production control, contract update, and file transfer from RAAFSUP. The initial specification included improved tracking of RIs

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32 MAARS - Maintenance Activity Analysis and Reporting System.

33 Interview, Squadron Leader G. Wadham, CAMM2 Project Manager, 23 March 1993.

34 *The ACENG-AF Sponsored Audit into Management of Repairable Item Depot Level Maintenance*, August 1988.

through DLM pipelines which have been largely foregone in the core system.

Breakdown Spares (BDS)

Delays. A general perception existed that poor BDS availability was contributing to RI maintenance delays. One of the identified causes, lengthy BDS transport leadtimes from Stores Depots, will be minimised through the closure of Stores Depots and forward positioning of technical spares under the Defence Logistics Redevelopment Program (DLRP).[35] However, spares delays remain a commonly perceived cause of delay to maintenance.

BDS Assessing Workload. In a 1990 report on RI performance Warrant Officer L.L. Fox noted 'the sheer volume of work involved in BDS assessing.'[36] In response to this workload, the AUTOPROC (Automated Procurement) system is being developed and refined to reduce time to progress BDS buys and, for low cost items, allow procurement with minimal intervention.[37]

Relating BDS to MMIs. A further challenge is that of relating BDS requirements to parent MMIs in both assessing and maintenance scheduling activities. Despite an increased weapon system orientation at HQLC during the 1980s, a 'considerable proportion of piece parts procurement was still managed on commodity lines'[38] in the early 1990s. While the functional entities which perform RI management and BDS assessment are now collocated in WSLM Squadrons, improved tools are needed to link the two activities.

It was envisaged in the late 1980s that 'LOAS[39] development (would) allow usage forecasts of BDS to be directly and consistently linked to forecast arisings of MMI, as well as allowing managers to group all spares deficiencies for the one MMI.'[40] This development has not proceeded, with LOAS to be subsumed in the Standard Defence Supply System (SDSS) as an Authorised Parts List (APL). SDSS, which will replace RAAFSUP,[41] is based on several modules of the MIMS computer package,

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35 As part of DLRP a Defence National Storage and Distribution Centre (DNSDC) is being constructed. It will be used to store bulky and less frequently demanded items, which could include some RIs. Hence, the word 'minimised' has been used in this sentence rather than 'eliminated'.

36 Warrant Officer L.L. Fox, DLPD, *Report on RI Performance (CT4 Aircraft as an Example)*, 26 March 1990, para 22.

37 AUTOPROC is an initiative of the Supply Systems Redevelopment Project (SSRP).

38 Group Captain G.N. Chandler, *The Logistic Branch Way Ahead. A System Fully Orientated to the build Hierarchy of Weapon Systems*, 13 July 1989, para 1.

39 LOAS - List of Authorised Spares. LOAS is a computerised application which links all technical items in the RAAF inventory to their higher assemblies/PE or to a common heading.

40 Ibid, para 13.

41 RAAFSUP is the current RAAF Supply information system.

excluding maintenance planning and control. These functions will be contained in CAMM2. Hence, the APL should be electronically linked to the system selected for CAMM2.[42]

MRPII. At a conceptual level, proposals to link BDS and MMI management align with the Manufacturing Resource Planning (MRPII) philosophy. 'MRPII is based on the philosophy that efficient manufacturing results from clear and precise communication throughout the organisation.'[43] It is a closed loop system which seeks to link planning and execution of all manufacturing activities and associated resources, as illustrated at Figure B-3.

In the MRPII philosophy, the availability of material, including BDS, is seen as 'the most important factor in on-time and efficient production.'[44] Material requirements are derived from master schedules (ie, maintenance plans) and accurate Bills of Material (ie, a physical structure breakdown similar to LOAS and the APL). The MRPII philosophy has been successfully applied in a number of Australian repair and overhaul environments, and is being implemented in the United States defence environment.[45]

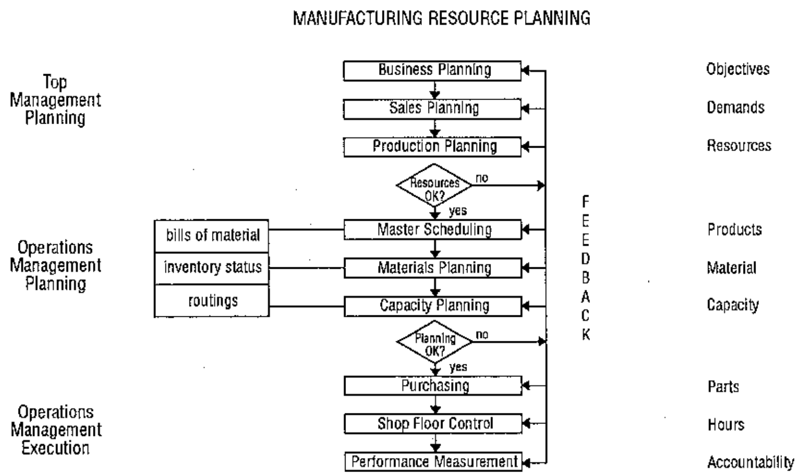

Figure B-3. MRPII model[46]

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42 At the time of writing, a software package had not been selected for CAMM2.

43 Carleton F. Kilmer and Richard J. Golden, *Manufacturing resource planning is coming of age in defense*, in *Defense Management Journal*, First Quarter 1986, p 20.

44 Woodrow W. Chamberlain and Carleton F. Kilmer, *MRP in the defense and aerospace environment*, in *National Defense*, October 1987, pp 37-40.

45 Australian organisations utilising MRPII in a repair and overhaul environment include Cummins Diesel, Westrail, NSW State Rail Authority. Numerous articles discuss MRPII application in the US Defense environment, including: W. Steven Demmy, *MRPII in AFLC Maintenance Planning and Control*, in *Air Force Journal of Logistics*, Fall 1990, pp 7-11.

46 *Class A MRPII Performance Measurement*, Booklet, David W. Buker, Inc. and Associates, p 3.

3AD/501 Wing MRPII Implementation. Prior to the formation of 501 Wing at Amberley, No. 3 Aircraft Depot (3AD)[47] had been implementing MRPII since the early 1980s. The DECOR (Depot Control and Reporting) System was developed to support its implementation. 'Implementation struggled to proceed' during the late 1980s due to the development of 'a customised system and inadequate widespread education.'[48] With a change of management in 1990 came the recognition that a major cultural change was required to support MRPII. This recognition evolved into the 501 Wing 'World Class Programme', which complements MRPII with RAAFQ, Just-In-Time, quality accreditation and a range of supporting strategies.[49] Although implementation has been protracted, 501 Wing remains committed to MRPII. The MRPII implementation experience contains valuable lessons in the attempt to link BDS and RI management.

System Change and Review

TMS. Concern was expressed at the 1987 meeting about increasing Time to Make Serviceable (TMS).[50] The use of work study and microcomputers was suggested as a key to productivity improvement. One significant work study was conducted at 3AD in 1989. Through the application of computerised planning and scheduling tools, which improved workshop scheduling and visibility of task completion, the time required to complete a major R5 servicing on an F111-C aircraft was reduced from 40 weeks to 20.

RAAFQ ANALYSIS

RAAFQ Reviews

Adoption of the RAAFQ Approach. The implementation of RAAFQ[51] in HQLC began in 1989. It was pursued through focusing on a small number of specific activities. 'RI Process improvement' was 'seen as *the* important priority'[52] for RAAFQ implementation by senior HQLC managers. This approach was also recommended in a 1990 review conducted under the auspices of the HQLC Provisioning Review by Group

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47 3AD amalgamated with No 482 Maintenance Squadron at RAAF Base Amberley in 1992 to form 501 Wing.

48 Squadron Leader M.W. Scott and Flight Lieutenant T.H. Brougham, *The change management processes necessary for the Royal Australian Air Force to introduce MRPII to a Repair and Overhaul Centre. A Case Study*, in *The Fourth Conference Proceedings, Australian Production and Inventory Control Society, Melbourne, 6-8 Noveember 1991*, p 68.

49 Enclosure 1 to 501WG/4360/27/2 Pt2 (14), *501WG World-Class Programme Strategic Plan*, 18 March 1993.

50 TMS is the actual amount of time expended by technicians in conducting maintenance activity.

51 RAAFQ is the RAAF's adaptation of Total Quality Management (TQM).

52 *Summary of TQM Meeting 27 Nov 89*, TQM 4360/10/4, 1 December 1989, para 3.

Captain (Ret) J.E. Townsend. In particular, he believed that the most effective method to improve TAT was probably 'to examine in detail the TAT elements on an item type, facility, or contractor basis' using Process Action Teams (PATs).[53]

In March 1990, Air Commodore C.E. Bradford, the Senior Logistics Support Officer (SLSPTO), directed that SORO lead PATs to examine specified aspects of the RI circuit. Group Captain K.J. Cairns, then SORO, believed that the task of reviewing the entire RI circuit was 'mammoth'[54] and could not be undertaken within resource and time limitations. Hence, the strategy adopted was 'to select important and manageable segments of the overall task and to lead the PATs progressively through them until completion.'[55]

DLM Circuit Review. Two PATs were established in parallel; one to review the DLM circuit for a non-aircraft RI, the other to examine the DLM circuits for F111-C aircraft RIs. The F111-C review adopted a macro-level perspective, with the aim of identifying delinquent sub-processes for further review.

The F111-C PAT experienced difficulty in accurately flow charting the DLM process due to process complexity and differences between authorised and practised procedures. Rather than chart and measure progress of RIs through the circuit, they chose to measure the quantity of assets in various locations and states of serviceability. Taking a sample of 282 RIs with MUEs,[56] they determined that 62 (22%) had an availability below customer requirements.[57] Based on the distribution of assets in this category, further review of the production process at Service DLM venues and RI provisioning were recommended.

'Judgemental analysis'[58] was used to recommend additional areas of review. These included training and 'awareness' of personnel, production performance monitoring, and the use of production incentives and penalties. Improvements were implemented in contractor performance monitoring and AMP production, and work continues on some other recommendations, notably development of RI management training and consolidation of publications.

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53 Group Captain (Ret) J.E. Townsend, *Interim Report on a Study into Aspects of Repairable Item Determination and Control*, 13 August 1990, para 32.

54 *RAAF Quality - Process Action Teams in SLSPTO Branch*, SORO 4014/2/1/ (19), 29 March 1990, para 2.

55 loc cit.

56 The role of the MUE as a system control parameter is discussed at Annex A, p A-5.

57 The definition of available assets and the band of RI availability constituting customer requirements is explained in detail in *Process Action Team Interim Report - Review of the Depot Level Maintenance Process for Aircraft Repairable Items*, SRO4/4600/3/PROCEDURE Pt 5 (10), October 1990.

58 Ibid, paras 41-46.

Further RAAFQ reviews did not proceed, possibly due to the recent HQLC restructure and the consequential competing priorities. The PAT noted that application of RAAFQ tools had been 'cumbersome and time consuming,' and that 'insufficient time was allocated to do the task justice.'[59]

Hewlett Packard Review. An alternative approach using RAAFQ methods is illustrated by a project undertaken jointly by No 1 Aircraft Depot and Hewlett Packard in 1989. A PAT was established to investigate the circuit for a specific non-aircraft RI for which lengthy maintenance pipeline TAT was an ongoing problem. Using RAAFQ techniques the PAT found that for an item requiring nine days to repair, on average a further 33 days was required for approval of orders where the repair cost exceeded $500. Additionally, an average of 34 days was wasted awaiting Quality Assurance acceptance. Both of these delays could be overcome through amended policy or procedures.

RAAFQ Implications

Macro Level Application. The RI system is of a size and complexity which makes analysis and improvement at the macro level difficult, as suggested by both Group Captain Cairns and the experience of the AFO Working Party. From a RAAFQ perspective this difficulty is increased by the fragmentation of process control and the historical lack of a system 'owner' who is in a position to control, influence, or coordinate both daily activity and system improvement. Tackling system improvement in manageable segments, as was planned by SORO, demands a reasonable understanding of the total system. This is necessary to select wisely appropriate system segments for review, and to assess the possible impact of recommended changes throughout the system, thus avoiding sub-optimisation.

The F111-C PAT attempted to tackle these issues by commencing analysis at the macro-level of the DLM circuit and forming a cross-functional PAT. However the team did not include members from maintenance venues or base Supply organisations,[60] and they were unable to flow chart the complete circuit due to perceived complexity. This indicates that the analytical tools, training, and time available to the PAT may have been inadequate for the task.

Micro Level Application The results of the Hewlett Packard PAT suggest that RAAFQ techniques are a viable vehicle for review and improvement of appropriately defined segments of the system. Given an appropriate system owner and improved system understanding at the

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59 Ibid, para 53.

60 The planned follow-on PATs may have rectified this anomaly.

macro level, RAAFQ techniques have potential ongoing application to RI management.[61]

RELIABILITY MANAGEMENT

Much of the debate presented above focused on management of RI circuits or pipelines. In terms of Operational Availability (A_O)[62] these improvements focused largely on the control and reduction of the system downtime components of Logistics and Administrative Delay. A complementary approach to improving A_O is to reduce the number of maintenance arisings; that is to increase the Mean Time Between Maintenance (MTBM).

In-Service Reliability Management

MTBM is affected by both unscheduled and scheduled maintenance arisings. Hence, MTBM becomes a function of equipment design, the conditions under which equipment is used, and scheduled maintenance policy. The scheduled maintenance requirements for each in-service weapon system are reviewed on a cyclic basis by AIRREG3 at HQLC using Maintenance Engineering Analysis (MEA) techniques. Their role includes recommendation of RIs as modification candidates to Weapon System Logistics Engineers (LOGENGs),[63] but performance of this role is limited by inadequate data availability.[64] The design of RI modifications by LOGENGs generally occurs in response to performance degradation reported from Unit level through the Defect Reporting system. Occasionally an RI manager will identify a modification candidate, but reliability improvement is not systematically used to increase RI availability.[65]

The Need Recognised

Wing Commander D.A. Smith, then AEENG2[66] at HQLC, proposed a reliability improvement program in 1988 in response to a general challenge regarding technical item lifing and reliability issued by Air Commodore J.B. Macnaughtan, Senior Logistics Engineering Officer.[67] Wing Commander Smith felt that the first hurdle was to develop a method

61 The strengths and weaknesses of RAAFQ are discussed further in Chapter Ten. the suggestion is made that RAAFQ should be complemented by tools better suited to analysis at the macro level.

62 A_O is discussed at Chapter Three, p 3-7.

63 LOGENGs were previously known as System Engineers, or SYSENGs.

64 Squadron Leader P. McLennan, AIRREG3, Interview, 21 July 1993.

65 Flight Lieutenant G. Hoffman, SRLMSQN 501WG, Interview, 23 July 1993.

66 AEENG2 - Airframe Equipment Engineer 2.

67 *Technical Equipment Lifing*, AIR/4320/1/12 (19), 28 March 1988.

of determining, preferably by electronic means, which MMIs would yield best returns in terms of reduced maintenance effort for minimum engineering effort. The second hurdle was that of staffing pressures. System Engineering resources were 'not readily available for the task of MMI reliability improvement (unless this is in a deteriorating condition).'[68]

To overcome staffing pressures, Hawker de Havilland (HdH) were contracted to investigate a means of identifying improvement candidates. Their proposal for construction of a new database by data transfer from existing RAAF databases was rejected due to the high cost involved, and to avoid creating another information system. Instead, data gathering and manipulation using CAMM2 became the preferred alternative.[69] CAMM2 has the ability to capture data on RI failure and maintenance, including resource consumption. Thus, given an appropriate analysis strategy, CAMM2 has the potential to support reliability improvement.[70]

Directorate of Integrated Logistics Processes (DILP) Project

Project Objective. The HQLC 1991/92 strategic plan required DILP to make progress in both RI management and the implementation of Logistics Support Analysis (LSA).[71] Ongoing development of LSA software and associated databases had commenced, with the expectation that implementation across all weapon systems will be protracted.

In the interim, DILP undertook a parallel 'fast track' project. This project involved stratification of the RI inventory for each weapon system based on maintenance costs and availability An analysis of the poorest performers to identify improvement opportunities then followed. The project aimed to 'produce a technique that enables RI managers to identify the most important RIs, given a less than perfect information database, and to enable them to decide, approximately, the best option to produce major RI availability improvements.'[72] Reliability improvement through modification or MEA was to be pursued prior to pipeline TAT improvement,

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68 Wing Commander D.A. Smith, *Reduced Expenditure on MMI Maintenance - An Initiating Strategy*, 1988, para 9.

69 Decision recorded at *Minutes of a Meeting to Discuss Repairable Item Improvement Projects held at HQSC on 10 August 1989*, DEV2/4300/5/9/2 (41).

70 Such data will include failure frequency, failure modes, PE role and operating conditions at time of failure, repair times, and (uncosted) resources consumed in maintenance (such as labour and spares). CAMM2 is also expected to be capable of sorting MMIs on the basis of defined reliability parameters, a function which will aid in identification of potential improvement candidates. Interview, Squadron Leader G. Wadham, CAMM2 Project Manager, 21 July 1993.

71 LSA was introduced at Chapter Two, p 2-5.

72 *RI management /LSA Investigation Action Plan*, DLPD/4000/91/EO1.4.2/1 (19), 28 January 1992, para 14.

on the rationale that 'changes to the maintenance process could radically modify the repair cycle.'[73]

Project Results. Once DILP had developed a stratification strategy an attempt was made to establish a PAT led by SRLMSQN, 501 Wing.[74] The project proposal was well received at 501 Wing but the competing priorities of WSLM Squadron establishment overwhelmed key individuals assigned to the PAT and little progress was made. Ironically, one of these competing priorities was the implementation of LSA techniques which the fast track project was meant to supplement in the short to medium term. As with the 1988/89 AEENG2 project, this project faltered through poor data availability and competing daily priorities.

Establishment of R&M Centre of Expertise

A 1991 study of RAAF Aircraft Availability and Cost Factors found that 'further R&M research and education is warranted with the goal of implementing R&M programs for each weapon system.'[75] This finding reflects increasing recognition of the need to improve RAAF knowledge and active management of reliability and maintainability (R&M).

An R&M centre of expertise was established in 1993 in Materiel Division, Air Force Office. Its role is to advise staff in capital acquisition projects on R&M issues and provide specialist input to policy development. It is also conducting reliability management courses, pending the adoption of this function at HQLC. Development of such expertise within Materiel Division reflects both the level of specialist knowledge required to competently manage reliability, and the fact that the decisions with the greatest impact on reliability are made during the initial design and acquisition phase of the weapon system life cycle.

RI SYSTEM PERFORMANCE STUDIES AND MEASUREMENT

Given the fragmentation and poor control of the RI system in the mid to late 1980s, it could be expected that overall performance was (and is) ineffective and/or inefficient. However, it is difficult to quantify performance as measurement has been inconsistently applied at different points in the system.

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73 *Report on a Visit to RAAF Base Amberley 22-24 July 1992*, DILP 4000/4/91/EO1.4.2/1 (37), 3 August 1992, para 5.

74 SRLMSQN (Strike Reconnaissance Logistics Management Squadron) was the most mature WSLM Squadron in mid-1992.

75 *A Study of RAAF Aircraft Availability and Cost Factors*, DLDP AF91/7557 Pt1 (13), 17 September 1991, para 72.

The overall effectiveness of the RI system should be judged in terms the impact of RI availability upon the operations of end users, utilising measures such as operational availability and mission capability. A number of WSLM Squadrons are currently grappling with this issue under the guidance of the Directorate of Logistics Quality, Planning, and Evaluation (DLQPE) at HQLC.

TYPE	LINES ON SORODB (A)	LINES WITH MUE OR OTHER SER ASSET TARGET (B)	% LINES WITH MUE OR OTHER SER ASSET TARGET [(B/A)*100]	% LINES WHERE SER ASSETS ARE BELOW MUE	% LINES WHERE SER ASSETS EXCEED 2 x MUE
CT4	31	14	45.1%	50.0%	21.4%
MACCHI	151	102	67.5%	35.3%	40.0%
C130 (E & H)	389	264	67.9%	17.4%	54.9%
F111-C	854	289	33.8%	Unknown[76]	Unknown

Table B-1. Serviceability of Repairable Items[77]

DLM

From October 1989 to October 1992 SORO monitored the availability of DLM maintained RIs against Asset Availability Targets (AATs). Results of their initial study of four aircraft types, summarised at Table B-1, showed that:

a. many RIs did not have a specified serviceable asset target (from 33.8% for F111-C to 67.9% for C130);

76 The original note to this table read: 'When data was gathered, RAAFSUP did not reflect total serviceable assets for the F-111C. Serviceable assets at 482SQN were held on MTS account, which is not visible to RAAFSUP.' However, this statement is misleading. The information in the table represents RAAFSUP information processed by the CUPID information system (then located in DMMS at HQLC). The information transferred from RAAFSUP to CUPID was limited, but it is unclear why the tabulated information is unknown. My thanks to Squadron Leader Secker for clarifying this point.

77 *Serviceability Levels of Repairable Items*, SORO 4300/21/1/3 (31), 9 November 1989, Annex A.

b. of the RIs which did have a target (based on MUE), serviceability levels were below that required for a large range of items (from 7.4% of those RIs with MUE for C130 to 50% for CT4); and

c. many RIs had serviceable asset levels greater than 100% above MUE (from 21.4% of RIs with MUE for CT4 to 54.9% for C130).[78]

The temptation exists to draw conclusions regarding the application of resources between RIs based on the above figures. However, it is difficult to draw any valid conclusions from this data, except perhaps with regard to the difficulty of establishing appropriate availability targets. The AAT is a point target derived from the spares assessment computation. In this computation, process variation and buffer stocks are explicitly modelled. Hence, the reality is that RI availability could lie above or below the AAT yet remain within acceptable process control limits.

RIAAMS

In late 1991, SG representatives agreed upon a method of setting AATs with process control limits for all RIs. Specification of control limits to enable monitoring of RI availability against a target range, rather than a point estimate was agreed. Following this, a statement of requirements was written in 1992 for an RI Available Asset Monitoring System (RIAAMS). However, RIAAMS has not been developed.[79]

F/A-18 MSI Work Study

A Work Study of MSI management within Tactical Fighter Group was performed in 1989. Data gathered on a sample of 140 F/A-18 MSIs showed that available assets were less than the Base Entitlement[80] for 44% of these MSIs. This shortage impacted on operational readiness, as Fly-Away Kits (FAKs) could only be filled to 40% capacity from available serviceable assets.[81]

The Work Study team highlighted poor asset visibility and procedural inconsistencies, between and within units at Williamtown, as the main management problems. Their prime recommendation was to centralise MSI management at the ILM level at Williamtown through the establishment of a Base MSI store. An MSI store had already been successfully implemented at Amberley.

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78 Ibid.

79 It is unclear whether RIAAMS would provide an improved leading indicator of impending availability shortfalls versus the current priority demand (UNDA/AOG) system.

80 The Base Entitlement Quantity(BEQ) is the sum of all Unit Entitlements (UEs) for units located at a single base.

81 RAAF Work Study Team, *F/A-18 MSI Management, Work Study No: 4/2/89*, November 1989, Executive Summary.

While this case may not be representative of the extent to which RI availability had degraded at all ILM units, it is indicative of the problems existing at this level and their potential impact on operational readiness.

CONCLUSION

During the 1980s, the RAAF struggled to define an RI management philosophy and RI system. Several policy studies conducted during this period described RI management as fragmented. The system was an amalgam of supply, maintenance and engineering policies and practices which had been designed and implemented in isolation. Further, the emphasis during the mid-1980s was on defining a coordinated system which would overcome organisational boundaries to meet RI availability targets.

The RI circuit, or pipeline, was the focus of much analysis and debate. It was thought that circuit performance held the key to improved RI management, and that improved coordination and control of the activities which constituted the circuit would improve RI availability. However, system redesign proved difficult for a number of reasons, including the incomplete understanding of system behaviour, and the inadequacy of information systems to support proposed methods of coordination and control.

RI management policy, first published in December 1989, incorporated some of the principles derived by earlier RI working parties. It was also used as a vehicle to set longer term development objectives, many of which responded to concerns raised in forums such as the 1987 RI management workshop. One of the key principles underlying the policy is the assignment of responsibilities throughout the system as a means of overcoming fragmentation of activities. Interestingly, it was argued by some that this approach merely institutionalised that fragmentation.

The current policy is clearly focused on pipeline management, and assigns a subordinate role to R&M. This reflects the perspective and analytical emphasis of most system studies conducted prior to policy development. There is evidence of a recent growth of interest in R&M. However, these factors are currently managed in a very reactive manner.

During the late 1980s and early 1990s, several new influences began to predominate thinking about logistics and RI management. The implementation of RAAFQ at HQLC and subordinate units spurred review of RI processes at lower organisational levels. While this resulted in new process insights it also promoted review of isolated elements of the total system, with the potential for sub-optimal process redesign. Additionally, the implementation of functional integration gained momentum, accompanied by changes such as Weapon System Logistics Management, ANNEX C

SYSTEMS ARCHETYPES[1]

ARCHETYPE ONE: LIMITS TO GROWTH

Generic Structure

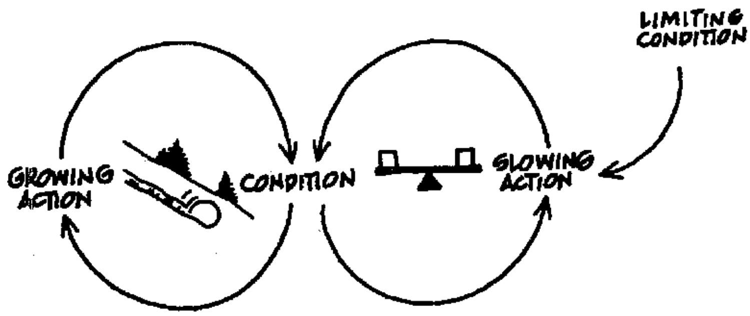

Figure C-1. Generic Structure - Limits To Growth[2]

Description

A process feeds on itself to produce a period of accelerating growth or expansion. Then the growth begins to slow (often inexplicably to the participants in the system) and eventually comes to a halt. It may even reverse itself and begin an accelerating collapse. The growth phase is caused by a reinforcing feedback process. The slowing arises due to a balancing process brought into play as a 'limit' is approached. The management principle to apply in this situation is not to push on the reinforcing (growth) process, but to remove (or weaken) the source of limitation.

1 Nine systems archetypes are presented in Peter M. Senge, *The Fifth Discipline, The Art & Practice of The Learning Organization,* Random House Australia, Milsons Point, 1992, Appendix 2. The illustrations and descriptions of generic structure used in this annex are taken directly from Senge.

2 Source: Senge, op cit, p 379.

Example One: A Strategy to Speed Input of Unserviceable RIs to Maintenance Pipelines

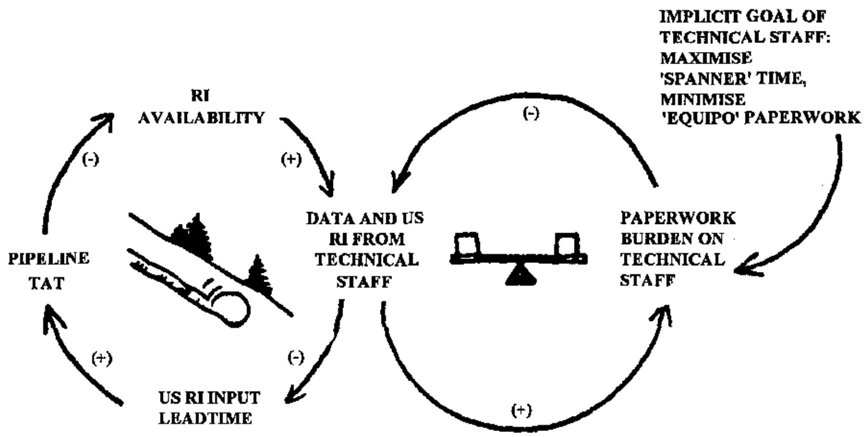

Figure C-2. Limits To Growth Example One

At a RAAF venue, technical staff pass unserviceable RIs to equipment staff. The equipment staff then complete necessary paperwork and input the item to a maintenance pipeline. Some of the information needed to complete this paperwork is of a technical nature. It is not always readily available to equipment staff, and inaccurate data is commonly used. To correct this problem a strategy is implemented which requires technical staff to provide technical information on a return proforma and pass to equipment staff with the unserviceable RI ***(CONDITION)***.

The increase in data provided by technical staff will reduce the time taken by equipment staff to input the RI to a maintenance pipeline. Reduced input time will also reduce overall pipeline turnaround time (TAT), with the effect of increasing RI availability. Seeing the improvement in RI availability, technical staff would feel encouraged to continue providing data on the return proforma in a timely manner ***(GROWING/REINFORCING ACTION)***.

These links are explained to technical staff who agree to trial the system. However, the technical staff have an implicit attitude that their role is to perform maintenance work, not complete 'equipo' paperwork ***(LIMITING CONDITION)***. As a consequence of this implicit attitude, during the trial the technical staff increasingly regard the paperwork as burdensome. This creates resistance to filling in the proformas on which the success of the strategy depends ***(SLOWING/BALANCING ACTION)***. The solution to this problem is not to alter the proforma or pressure technical staff to provide data, but to alter their attitude toward, and perception of, 'equipo' paperwork.

Example Two: Workshop Incentive Scheme

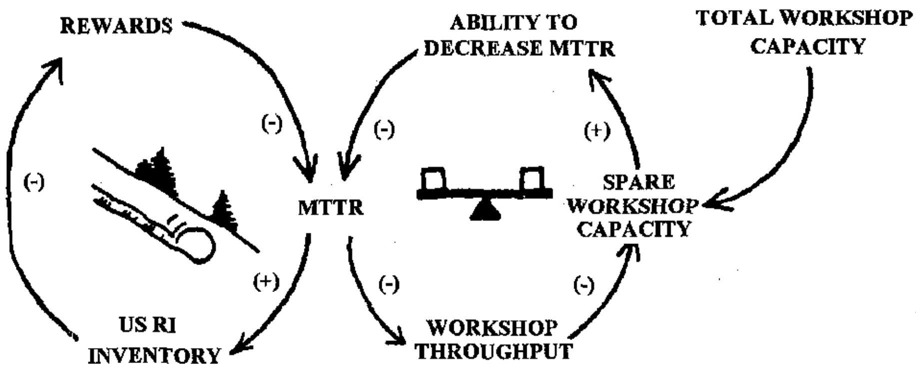

Figure C-3. Limits To Growth Example Two

An incentive scheme is introduced in an RI maintenance workshop. Rewards (eg, time off work, a free lunch) are tied to reduction in the level of unserviceable RI inventory backlogged in the workshop. Reduction in this inventory is obtained through reducing Mean Time To Repair (MTTR) ***(CONDITION)***. A reduction in MTTR will decrease the level of unserviceable (US) RI inventory. As this level falls there is an increase in the rewards received. The receipt of rewards encourages ongoing reduction in MTTR ***(GROWING/REINFORCING ACTION)***.

In this example, the reduction in MTTR is limited by total workshop capacity ***(LIMITING CONDITION)***. As MTTR lowers workshop throughput (the number of RIs repaired in a given period) also rises. As total workshop capacity is finite, the increase in workshop throughput reduces spare workshop capacity. A reduction in spare workshop capacity lowers the ability to decrease MTTR further ***(SLOWING/BALANCING ACTION)***. The solution to this problem is not to alter the incentive scheme or to encourage staff to 'work harder', but to increase workshop capacity.

ARCHETYPE TWO: SHIFTING THE BURDEN

Generic Structure

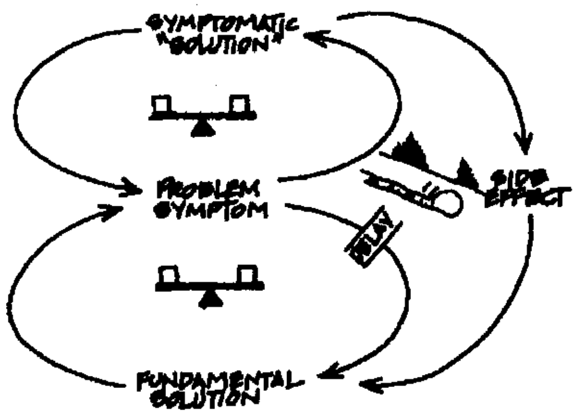

Figure C-4. Generic Structure - Shifting The Burden[3]

Description

A short-term 'solution' is used to correct a problem, with seemingly positive immediate results. As this correction is used more and more, fundamental long-term corrective measures are used less and less. Over time, the capabilities for the fundamental solution may atrophy or become disabled, leading to even greater reliance on the symptomatic solution. The management principle to be applied here is to focus on the fundamental solution. If symptomatic solution is imperative (because of delays in fundamental solution), use it to gain time while working on the fundamental solution.

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3 Source: Senge, op cit, p 380.

Example: Purchasing RIs in Response to Lowering RI Availability

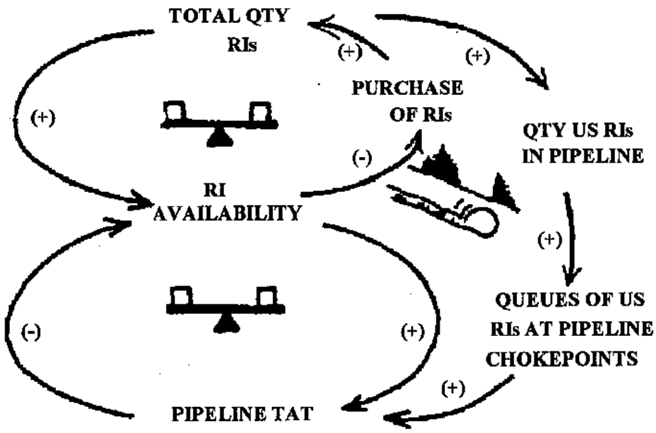

Figure C-5. Shifting The Burden Example

In response to a situation of decreasing RI availability ***(PROBLEM SYMPTOM)*** a decision is made to purchase more RIs. When the purchased RIs are introduced to the system the total quantity of RIs increases, thus initially increasing RI availability ***(SYMPTOMATIC SOLUTION)***. However, the decrease in RI availability was actually due to a rising maintenance pipeline TAT. Now, as the newly purchased RIs become unserviceable they enter these pipelines, whose poor TAT has not been addressed. The total quantity of unserviceable RIs in the pipeline increases, and queues grow at certain pipeline chokepoints. The net effect of this is to further increase pipeline TAT ***(SIDE EFFECT)***. Unless problems within the pipeline are rectified ***(FUNDAMENTAL SOLUTION)***, RI availability will again fall and dependency on the symptomatic solution will grow.

This example is relatively common in the RAAF RI management system due to the use of historical pipeline TAT figures for assessment of in-service RI spares replenishment. The higher the TAT figure input to the spares assessment model, the higher the recommended purchasing quantity.

ARCHETYPE THREE: FIXES THAT FAIL

Generic Structure

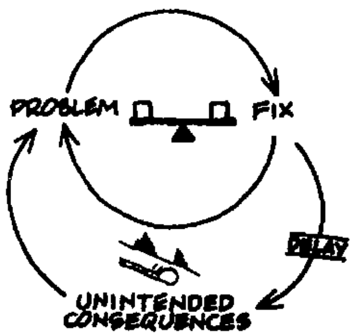

Figure C-6. Generic Structure - Fixes That Fail[4]

Description

A fix, effective in the short term, has unforeseen long-term consequences which may require even more use of the same fix. The management principle to apply here is to maintain focus on the long term. Disregard short-term 'fix' if feasible, or use it only to 'buy time' while working on the long-term remedy.

Example: Lowering MTTR to Reduce Unserviceable RI Inventory Levels

A rising level of unserviceable RIs in a workshop ***(PROBLEM)*** creates pressure to reduce MTTR ***(FIX)***. The reduction in MTTR decreases the unserviceable inventory level, alleviating this pressure. However, in the effort to reduce MTTR less attention is given to some aspects of the maintenance task, with the consequence of reducing maintenance quality.

4 Source: Senge, op cit, p 388.

Hence, 'lower quality' RIs are placed in serviceable stock, and eventually fitted to aircraft. Because these RIs fail more frequently, overall failure arising rate increases ***(UNINTENDED CONSEQUENCES)***. An increasing arising rate lowers the Mean Time Between Maintenance (MTBM), which increases the unserviceable inventory level. In this situation there is a need to maintain focus on the long-term - to implement methods of reducing MTTR which do not diminish maintenance quality.

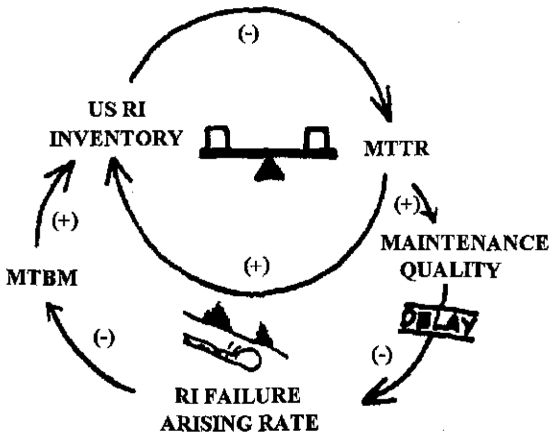

Figure C-7. Fixes That Fail Example

ANNEX D

INTRODUCTION TO *ITHINK*™ SOFTWARE[1]

INTRODUCTION

Ithink™ is a system dynamics modelling tool. It is one of the modern system dynamics software packages available commercially. While it has been used here to demonstrate the utility and ease of such software, it will not be the most appropriate package to all system dynamic modelling projects. Vensim™ is another commercially available package. Each package has particular strengths and weaknesses which should be evaluated prior to selecting a package to suit the modelling task.

The *ithink*™ modelling tool allows the model builder to construct a graphical representation of underlying relationships within a system. A diagram view of the model is constructed by placing and linking icons. The software detects where dependencies occur in the diagram and prompts the model builder to specify the relationships mathematically. When complete, the model contains a series of differential equations which define the relationships which generate system behaviour. The software is then able to simulate system behaviour by solving the series of differential equations.

MODEL BUILDING BLOCKS

A set of four generic building blocks are used to construct an *ithink*™ model. These are outlined below, and symbolised as illustrated.

Stock

A stock is analogous to a bath tub. Whilst a bath tub holds water, a stock accumulates quantities of either

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1 This Annex is based on material from three significant sources. (1) *Ithink User's Guide*, High Performance Systems Inc., Hanover, 1991. (2) Jason Y. Markham, *A System Dynamics Model of the Australian Regular Army General Service Officer Stream*, Department of Civil and Maritime Engineering, University College, The University of New South Wales, Australian Defence Force Academy, Canberra, October 1992, Appendix 2. (3) Keith Linard, *System Dynamics Modelling with Ithink* Course Notes, Australian Defence Force Academy, August 30-31 1993.

'hard' items such as cash, orders, or resources or 'soft' items such as self-confidence, commitment, or knowledge. An important characteristic of stocks is that the accumulation in the stock remains when the system simulation stops. If the *ithink*™ modelling environment is thought of as a modelling 'language', then the stocks can be thought of as the nouns of a model.

<u>Flow</u>

If a stock is considered as a bath tub or noun, then a flow is a pipe or a verb. Flows drain or fill stocks but when simulation stops they do not retain any quantities. Flows thus represent the decisions, activities, or ongoing processes within a system which cause the level or state of a stock to change.

The flow symbol is a pipe with a valve in the middle. The valve represents variation in the flow over time. In some cases the pipe will originate from or end in a cloud. The cloud represents a system boundary. Its use indicates that it is not relevant to consider whatever stock it is that should really be at the head (or tail) of the pipe.

<u>Converter</u>

The converter is a 'catch-all'. It takes the place of adjectives and adverbs in the modelling 'language', and is generally used to flesh out the detail in a set of relationships. Converters can be used to simulate:

a. constants;

b. input/output for algebraic relationships;

c. graphical functions; and

d. simplified stocks or flows.

<u>Connector</u>

The connector represents information flows (as opposed to the physical flows represented by the flow icon) or algebraic relationships. Connectors are relational indicators showing the dependency of stocks, flows, or converters on each other.

MODEL BUILDING PROCESS

A basic dynamic system model can be constructed to demonstrate the ease of the model building process. The example used is the flow of money into and from a bank account.

The first step in the modelling process is the construction of the visual model using icons. The diagrammatic representation shown in Figure D-1 is the result of this step. This diagram shows the flow of 'Income' into a stock called 'CASH IN BANK', and the flow of 'Expenses' out of the stock. Income is derived from three sources - 'Salary', 'Investment', and 'Interest'. The amount of interest is dependent upon both CASH IN BANK and the 'Interest Rate'.

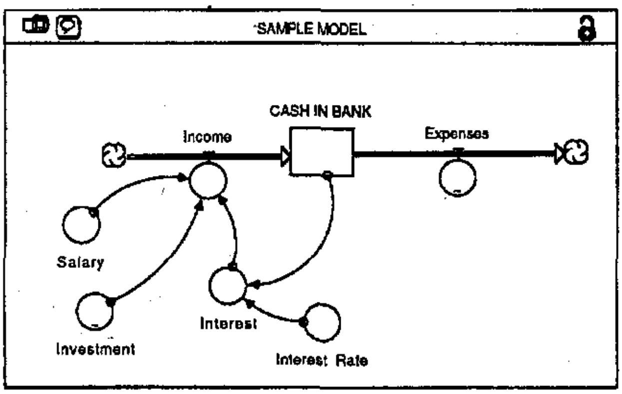

Figure D-1. *Ithink*™ Sample Diagram

The *ithink*™ software automatically sets up differential equations, as specified by the arrangement and linkage of icons in the diagram. The model builder must then enter the exact relationships. Double-clicking on the 'Income' icon with the mouse produces the view in Figure D-2 that prompts the model builder to enter an equation using the required inputs listed. Depressing the 'Document*' button enables the model builder to annotate the entry.

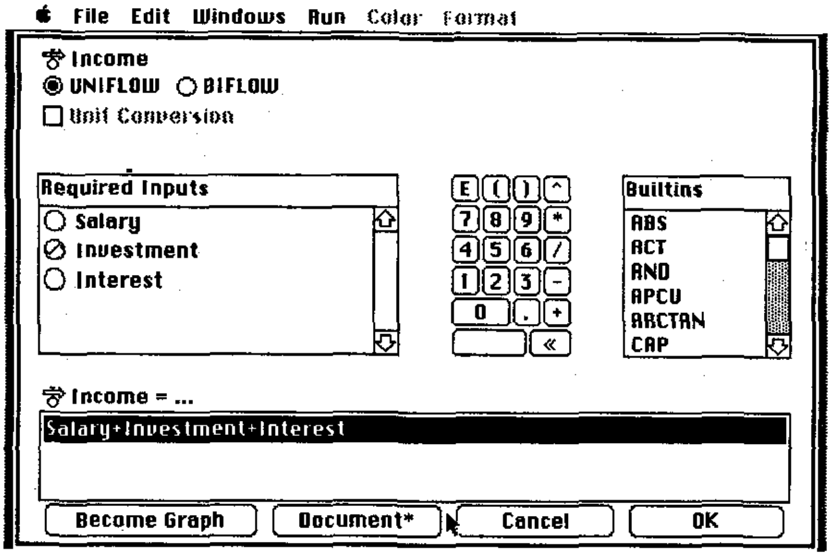

Figure D-2. Equation Input Window

The model builder continues to specify the equation or value of each item represented by an icon on the model in a similar manner. Converter values can be input using a graphical function, such as the function for 'Investment' shown at Figure D-3. Investment earnings consist of a rental income from a residential property. Normal weekly investment income is $250. The property is vacant for a short period (weeks 6 and 7) in which no rental income is received. When a converter is defined graphically a small marker is placed on the diagram, as shown on the 'Investment' and "Expenses' icons in Figure D-1.

The relationships defined by the modeller are incorporated into the system of differential equations previously established by the software. The full list of equations underlying the sample model are shown at Figure D-4.

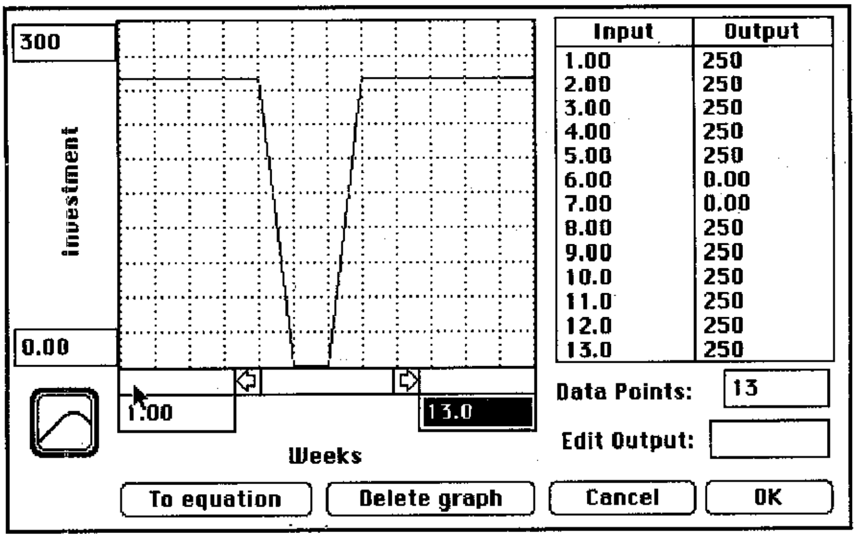

Figure D-3. Graphical Input Window

SAMPLE MODEL

☐ CASH_IN_BANK(t) = CASH_IN_BANK(t - dt) + (Income - Expenses) * dt

INIT CASH_IN_BANK = 10000

INFLOWS:

Income = Salary+Investment+Interest

OUTFLOWS:

Expenses = GRAPH(TIME)

(1, 600) (2, 625) (3, 670) (4, 600) (5, 750) (6, 550) (7, 1200) (8, 550) (9, 680) (10, 2000) (11, 1500) (12, 800)

○ Interest = CASH_IN_BANK*Interest_Rate

○ Interest_Rate = .0015

○ Salary = 500

⊘ Investment = GRAPH(TIME)

(1.00, 250), (2.00, 250), (3.00, 250), (4.00, 250), (5.00, 250), (6.00, 0.00), (7.00, 0.00), (8.00, 250), (9.00, 250), (10.0, 250), (11.0, 250), (12.0, 250), (13.0, 250)

Figure D-4. Sample Model Equations

The terms 't' and 'dt' which appear in the equations relate to the time interval between performance of successive calculations to 'solve' the equations in the model. 'Dt' is simply the interval of time between calculations. Once each dt, a round of calculations is performed. For instance, if the time unit used in the model is months and a dt of 0.25 specified, then four rounds of calculations will be performed per month.

To demonstrate how time intervals within equations are interpreted, consider the equation for 'CASH IN BANK' at figure D-4. This equation reads:

> (the amount of CASH IN BANK at time 't') is equal to (the amount of CASH IN BANK at the time 't minus dt') plus (income less expenses) accumulated over the period dt.

When the model is run, successive rounds of calculations are performed. The results of these calculations can be displayed in tabular or graphical format, with the modeller able to specify entities on which output is required, frequency of reporting, and various other output design features.

The time interval used in the Sample Model is one week, and the dt is 1.0. An output table for a model run of twelve weeks is shown at Figure D-5, and a graph for the same period at Figure D-6.

Page 1

Weeks	1	2	3	4	5	6	7
CASH IN BANK	10000	10165	10305	10401	10566	10582	10548
Income	765	765	765	766	766	516	516
Expenses	600	625	670	600	750	550	1200
Salary	500	500	500	500	500	500	500
Investment	250	250	250	250	250	0	0
Interest	15	15	15	16	16	16	16

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Page 1

Weeks	8	9	10	11	12	Final	
CASH IN BANK	9864	10079	10164	8929	8192	8155	
Income	765	765	765	763	762		
Expenses	550	680	2000	1500	800		
Salary	500	500	500	500	500	500	
Investment	250	250	250	250	250	250	
Interest	15	15	15	13	12	12	

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Figure D-5. Sample Model Tabular Output

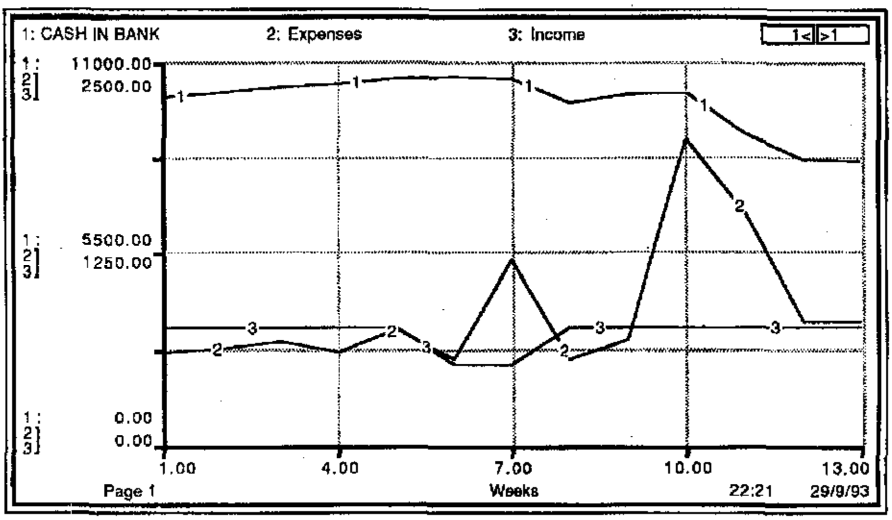

Figure D-6. Sample Model Graphical Output

The drop in income at Weeks 6 and 7 due to the lack of rental income in this period can be seen in both the table and the graph. The pattern of expenses is readily apparent on the graph. Normal weekly expenses vary around the $600 level. At week 7 a larger bill is paid. During weeks 10 to 12 the account holder indulges in a short spending spree. Fluctuation in the level of CASH IN BANK is a consequence of the pattern of both income and expenses over the period. These patterns can be observed in the graph, while exact values may be read off the table.

ITHINK™ STRENGTHS AND WEAKNESSES

As noted in the introduction to this Annex, a range of commercially available system dynamics software packages exists, each of which has particular strengths and weaknesses. A package which is suited to one modelling project may be inappropriate to another, dependent on project features such as the number of entities to be modelled and complexity of the relationships between system entities.

Strengths

The *Ithink*™ software package is very easy to use. Particular strengths of the package include the following:

a. The relatively small range of icons and functions used in model building ensure that the package can be competently used following a short period of training and/or familiarisation. Yet, the icons provided are flexible enough to represent a wide variety of entities within a system.

b. The model construction process is logical, and the model building tools intuitively appealing.

c. A model can be constructed in 'sectors' (to be introduced in Annex E), allowing the use of modular development and testing techniques.

d. The ability to document a model on screen as it is being developed encourages thoroughness on the part of the model builder, and provides a useful communication aid.

e. Choice of tabular and graphic reports output on-screen or hard copy, with the flexibility to include any of the model entities in reports.

Weaknesses

Ithink™ is compatible only with Applemac computers. This is a significant disadvantage given the predominant use of IBM-compatible hardware and software by the RAAF. It is unclear whether an IBM compatible version of the package will be released. Other notable weaknesses of the package include:

a. The lack of an 'optimisation' capability which may be desirable in some projects, and is incorporated in Vensim™.

b. As model size increases diagrams may become unwieldy and difficult to work with. This weakness is offset to some degree by the ability to divide the model into sectors and to 'ghost' icons from one sector to another, hence avoid using connectors to link icons between sectors.

c. Limited choice in the process used to build the model. Model structure can only be entered through the diagram window, whereas Vensim allows the construction of a model using equations.

ANNEX E

SAMPLE SYSTEM DYNAMICS RI SYSTEM MODEL

INTRODUCTION

A sample model of elements of the RI system, constructed using *ithink*™ software, is presented in this annex.[1] This model has been constructed to illustrate how system structure represented by feedback loops can be translated into a quantitative model, which can then be used to simulate system behaviour. Additionally, although this is a limited, unvalidated model,[2] it is indicative of the potential insights into RI system behaviour offered by the system dynamics methodology.

Underlying Concepts

Two key concepts have been embodied in the sample RI system model. These concepts may be viewed as hypotheses about system behaviour, and would normally have been developed using system performance data and the mental models of people working in the system. These concepts are:

a. Workshop capacity is a key limitation on RI repair rate, and a key driver of system behaviour (represented in feedback loop at Figure C-3, p C-3); and

b. As the level of unserviceable RI inventory in a maintenance workshop rises, pressure is created which results in lower quality of maintenance work. This lower quality has a significant impact on the RI failure rate (represented in feedback loop at Figure C-7, p C-7).

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1 The *ithink*™ software package is introduced in Annex D. As discussed in Annex D, other system dynamic modelling software packages are commercially available. While *ithink*™ has been used to construct this sample model, a range of packages should be considered prior to construction of a larger RI system model.

2 Model validation is discussed at Chapter Nine, p 9-10.

Model Limitations

To retain simplicity in this sample model it contains only the entities necessary to represent the concepts listed above. If a more complete model of the RI system were to be constructed it would incorporate a larger number of aspects of system behaviour. These aspects would include, for instance, the following:

a. management of 'holes' on aircraft, and their impact on achieved flying hours;[3]

b. existence of a number of maintenance venues and levels;[4]

c. assignment of workshop resources to support a number of different RIs;

d. RI wastage and reprovisioning activity; and

e. management of Break Down Spares.

Assumptions underlying the model are specified in the model description, presented in the following section.

MODEL DESCRIPTION

This model represents a range of processes and decisions associated with the use and maintenance of a particular avionics RI. This RI is fitted to a number of aircraft assigned to one flying squadron on a single operational base. Upon failure an RI is removed from an aircraft and sent to the base workshop. All unserviceable RIs are repaired in the base workshop and returned to serviceable stock at the flying squadron. That is, it is assumed that RIs are not subject to wastage, and all repair work is within the capability of the base workshop.

The model consists of four 'sectors'. A sector is created using an icon from the *ithink*™ menu, and is used to divide the model into discrete components representing subsets of activity within the actual system. The sector tool enables modular construction and testing of the model, and simplifies presentation, enhancing use of the model as a communication tool.

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3 A 'hole' is created when an unserviceable RI is removed from an aircraft and a serviceable replacement is not available.

4 The concept of maintenance 'levels' is introduced at Annex A, p A-2.

Model description will proceed by introducing each sector, presenting a sector diagram, and describing the flow of RIs and information in the sequence shown in the model. A full listing of model equations is provided at Appendix 1.

Flying Squadron Sector

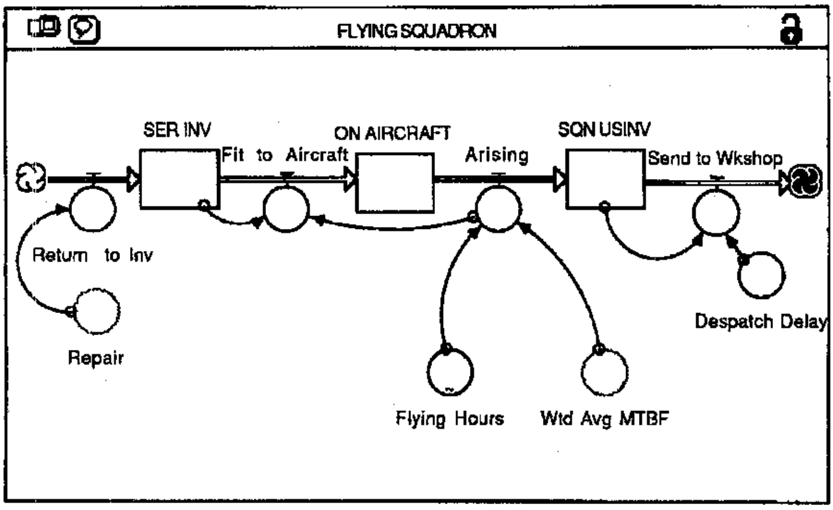

Figure E-1. Flying Squadron Sector Diagram

The Flying Squadron Sector diagram is shown at Figure E-1. This sector shows the failure of RIs fitted to aircraft at the flying squadron, their removal and replacement from the serviceable stock of RIs held at the Squadron, and the despatch of unserviceable RIs to the workshop for repair.

The **SER INV** stock contains all serviceable RIs held at the flying squadron. This is the only storage location for serviceable RIs on the base. **Return to Inv** shows the flow of RIs which have been **Repair**ed in the base workshop back into SER INV.

Serviceable RIs are withdrawn from SER INV when they are required to be **Fit to Aircraft**. This occurs whenever an RI fitted to a squadron aircraft fails and is removed. The **ON AIRCRAFT** stock represents the number of RIs actually fitted to all squadron aircraft at any point in time.

An aircraft **Arising** is the failure and removal of an RI fitted to an aircraft. The number of arisings is a function of **Flying Hours** and the weighted average MTBF (Mean Time Between Failure) of serviceable RIs (**Wtd Avg MTBF**). Flying Hours is an exogenous system input. It represents the total number of hours flown by all squadron aircraft to which an RI is fitted. The weighted average MTBF is calculated in the 'Quality Impact Sector', as described at page E-7. The number of arisings in a period is calculated by dividing flying hours by the weighted average MTBF.

The **SQN US INV** holds unserviceable RIs which have been removed from an aircraft following failure, and are awaiting despatch to the base workshop. The process of despatch is represented by the **Send to Workshop** flow. This activity is subject to a **Despatch Delay**, which is a period of time required to complete administrative processes and acquire transport to transfer the unserviceable RI to the workshop.

Base Workshop Sector

The Base Workshop Sector diagram is shown at Figure E-2 This sector shows the processes through which unserviceable RIs are repaired and returned to serviceable inventory at the Flying Squadron. It is assumed that all RIs are repaired at the base workshop, and that decisions regarding induction and maintenance of this RI are independent of those regarding other RIs maintained by the workshop.

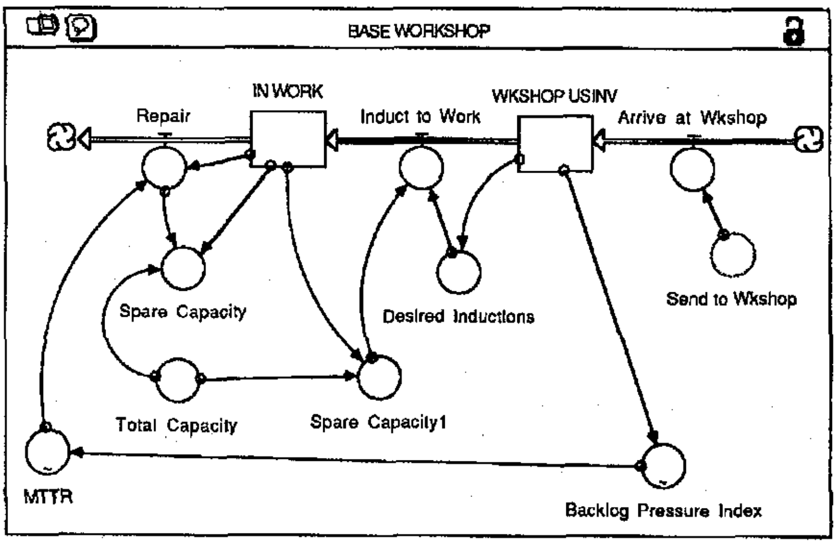

Figure E-2. Base Workshop Sector Diagram

Unserviceable RIs **Arrive at Workshop** from the flying squadron, and are held in the **WKSHOP USINV** stock to await induction.

The workshop manager must decide how many RIs to induct to work. In reality RIs may be inducted at any point in time. However, due to the manner in which calculations are performed when the model is run to simulate system behaviour, inductions are only allowed once every dt.[5] For example, if the time unit used in the model is 'weeks' and a dt of 1.0 is used, inductions are allowed only once per week.[6]

This induction decision consists of two steps. Firstly, the manager must determine the quantity of **Desired Inductions**; that is, the quantity of RIs which would be inducted to work in the absence of any workshop capacity limitation. If fewer than 5 RIs are in WKSHOP USINV, the manager would like to induct 2 of these to work. This is the number of RIs which the workshop can repair in a week when working at a 'comfortable' rate. As WKSHOP USINV rises above 5, the manager's preference is to induct all but 3 of the RIs to work. These 3 RIs provide a buffer of work for the next period.

Next, the manager must consider the limitation imposed on inductions by workshop capacity. The **Total Capacity** of the workshop is the maximum number of RIs which can be **IN WORK**, that is undergoing repair in the workshop, at any one time. It is a physical limitation based on resources such as test equipment and manpower. Total capacity in this model is 8. Increasing the number of IN WORK RIs beyond this level creates unmanageable queues at work stations. Hence, to determine how many RIs to actually **Induct To Work** the manager must assess the spare capacity of the workshop. Spare capacity is the difference between the total capacity and the quantity of RIs IN WORK. The quantity inducted to work will be the lesser of Desired Inductions and Spare Capacity1.

The rate at which items are **Repair**ed and flow out of the IN WORK stock is dependent on the **MTTR** (Mean Time To Repair). MTTR is the average period of time taken to repair an RI following its induction to work. Working at a 'comfortable' rate the 'normal' MTTR is half a working week (ie, 2.5 days). However, there are times when the workshop staff experience backlog pressure. This is represented by the **Backlog Pressure Index**, which is shown graphically at Figure E-3. As the level of WKSHOP USINV increases, the backlog pressure index (BPI) rises. When WKSHOP USINV is equal to or less than 5, pressure is normal, shown as '0' on the BPI. Above this level of unserviceable inventory, the BPI rises to reach a maximum of 100, which is attained when WKSHOP USINV equals 13. At this level the quantity of unserviceable RIs is 8 above the quantity with which the workshop manager feels comfortable, reflecting the total workshop capacity of 8.

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5 The role of dt in simulation is explained at Annex D, p D-5.

6 Because of this discrepancy, the two variables 'Spare Capacity1' and 'Spare Capacity' are necessary. Spare Capacity1 is used in decision-making, while Spare Capacity is included in output reports. This is explained further in subsequent paragraphs.

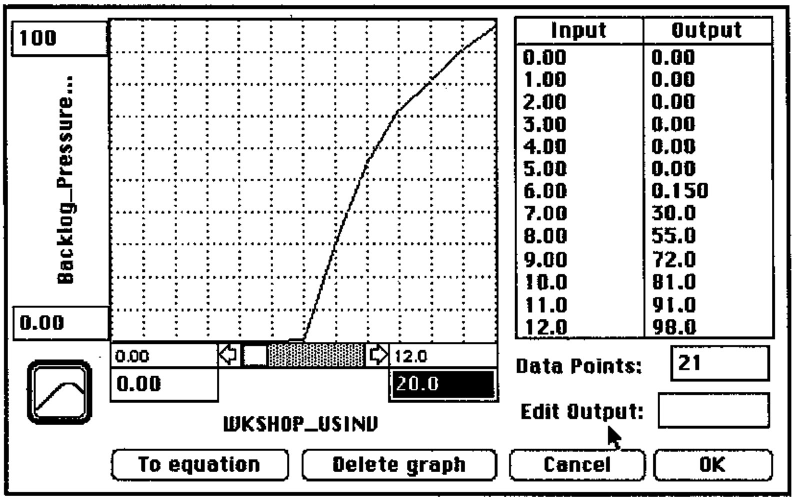

Figure E-3. Backlog Pressure Index Graph

Variation in MTTR due to backlog pressure is shown at Figure E-4. The higher the BPI, the lower the MTTR. The minimum MTTR which the workshop can achieve is 30% of a working week (ie, 1.5 working days).

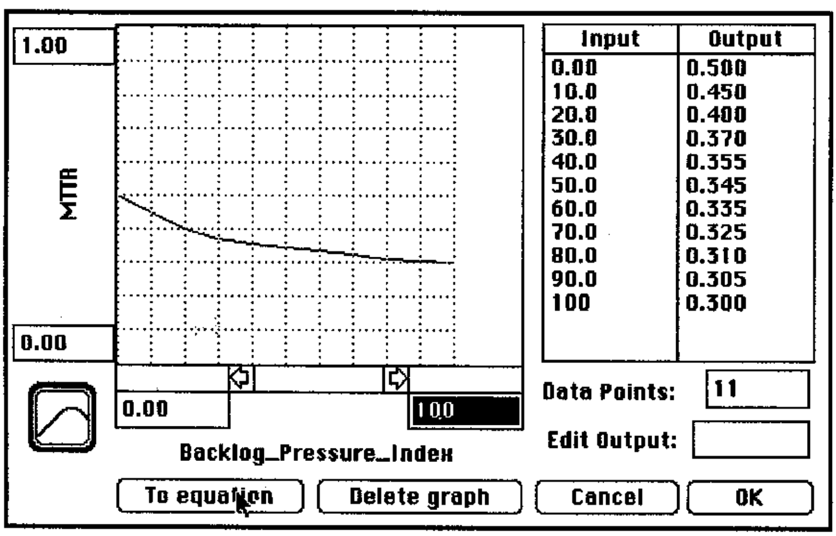

Figure E-4. MTTR Graph

When RIs have been repaired they are returned without delay to the workshop.

Quality Impact Sector

The Quality Impact Sector diagram is shown at Figure E-5. In this sector the impact of quality of work performed in the base workshop upon RI failure rate is calculated.

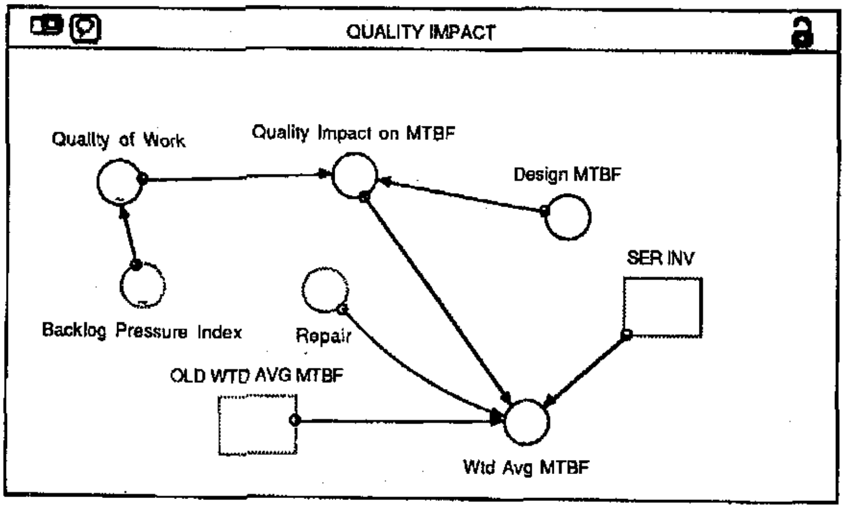

Figure E-5. Quality Impact Sector Diagram

The **Quality of Work** performed in the base workshop is affected by the backlog pressure, as shown at Figure E-6. Quality of Work falls as the BPI rises. As pressure increases, there is a tendency for less time to be spent on each maintenance task, thereby increasing the likelihood of errors. Quality of Work will fall by up to 20%; the use of automated test equipment limits the extent of diminished quality.

Quality of Work will impact the MTBF of RIs. A **Design MTBF** is specified for the RI, which will be achieved if it is operated under the conditions for which it was designed, and is well maintained. The design MTBF in this model is 50 hours. That is, on average the RI will fail once every 50 operating hours if it is used under appropriate operational and maintenance conditions. The **Quality Impact on MTBF** shows the impact of lowered Quality of Work on the MTBF which will actually be achieved in-service. It is calculated by multiplying the Quality of Work by the Design MTBF. For instance, if Quality of Work is 80%, then Quality Impact on MTBF will by 80% of 50 hours Design MTBF, or 40 hours.

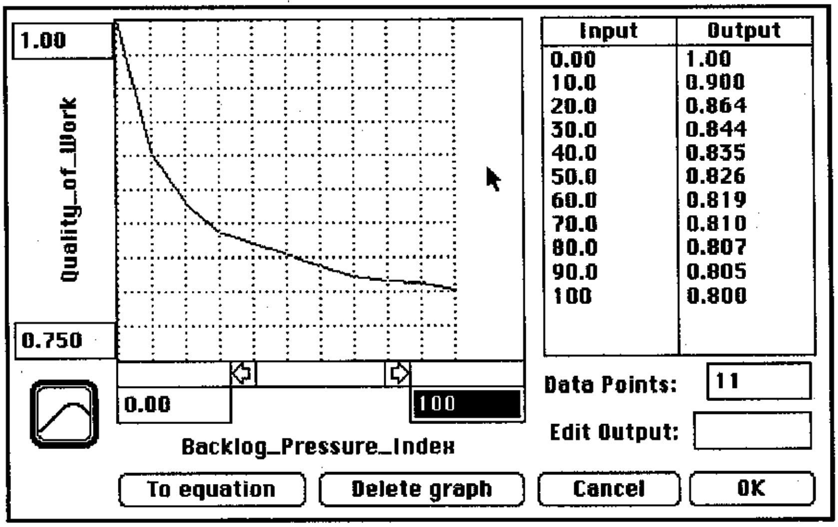

Figure E-6. Quality of Work Graph

These lower quality RIs will enter SER INV at the flying squadron, and will eventually be fitted to aircraft, operated, and fail. This impact will endure for a period of time until the lower quality RIs are used and returned to the workshop. RIs are drawn randomly from SER INV to be fitted to aircraft, rather than a 'last in first out' or 'first in first out' rule applying. Hence, it is appropriate to use a weighted average calculation to mimic the enduring impact of lower quality RIs on the number of failure arisings. The equation for the weighted average MTBF (**Wtd Avg MTBF**) is shown at Appendix One, p E-1-2.

Quality Impact Support Structure

The Quality Impact Support Structure Sector diagram is shown at Figure E-7. This sector supports calculation of the impact of quality on MTBF in the Quality Impact Sector. It records the weighted average MTBF of SER INV in one time period (**OLD WTD AVG MTBF**) for use in calculation of the Wtd Avg MTBF in the next period.

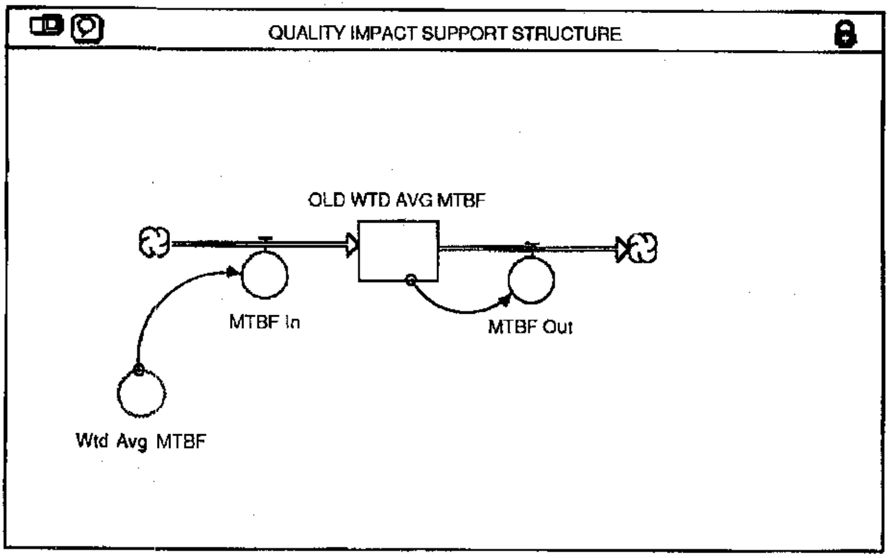

Figure E-7. Quality Impact Support Structure Sector Diagram

SIMULATION

Simulation can be used to verify that a model behaves as intended, and also to explore system behaviour and experiment with system design. Results of simulation conducted to verify model construction are not reported here. Rather, this annex presents the results of two simulations designed to test the hypotheses contained in the feedback loops at Figures C-3 and C-7.

Workshop Capacity Limitation

Simulation Objective. It was hypothesised that workshop capacity is a key limitation on RI repair rate, and a key driver of system behaviour. Accordingly, the first simulation run explores the impact of capacity limitation on base workshop activity and performance.

Simulation Inputs. To begin a simulation initial values are entered for all stocks in the model, and the pattern of exogenous inputs is determined. Key stocks in this simulation are those in the flying squadron and base workshop sectors, whose initial values are shown at Table E-1. Given these values, activity in the base workshop is initially within workshop capacity, and the level of SER INV is adequate to replace unserviceable RIs removed from squadron aircraft during the simulation period.

STOCK	INITIAL VALUE
SERINV	100
ON AIRCRAFT	30
SQN USINV	2
WKSHOP USINV	4
IN WORK	2

Table E-1. Initial Stock Values

The only exogenous input to the model is flying hours. A twelve week simulation period is used. In the first two weeks of the simulation the number of flying hours is 100. This is increased to 200 hours at weeks 3 to 5, and peaks at 400 hours in weeks 6 to 8. At week 9 the number of flying hours drops to 200, and returns to 100 in weeks 11 and 12.

Simulation Results and Discussion. Simulation results are shown in tabular format at Figure E-8. It can be seen that the pattern of arisings over time follows the flying hour pattern, beginning at two arisings in weeks 1 and 2, peaking at eight arisings in weeks 6 to 8, and returning to two per week in the final fortnight of the simulation.

Due to the impact of the despatch delay, the arrival of unserviceable RIs at the workshop lags a little behind arisings. This delay slows workshop reaction to the increase in flying hours. For instance, although the number of weekly arisings increases from two in week 1 to four in weeks 3 to 5, only two unserviceable RIs arrive at the workshop in weeks 3 and 4. Similarly, when the number of arisings increases to eight in week 6, a two week lag occurs before the arrivals at the workshop attain this level. The level of unserviceable inventory in the workshop is the basis of the workshop manager's desired inductions rate. Consequently, the level of desired inductions increases more slowly than the number of arisings.

If this simulation accurately represented the process of transferring unserviceable RI to a base workshop and assessing the desired induction rate, it would suggest the need to alter the decision-making process. More timely information is needed by the workshop manager to ensure that workshop response to an increase in arising rates is quicker. The model could be altered to experiment with linking the desired induction rate to the arising rate, or to planned flying hours, rather than workshop unserviceable RI inventory.

	Page 2						
Weeks	1.00	2.00	3.00	4.00	5.00	6.00	7.00
Flying Hours	100.00	100.00	200.00	200.00	200.00	400.00	400.00
Arising	2	3	4	4	6	8	8
Arrive at Wkshop	2	2	2	4	4	5	8
WKSHOP USINV	4	4	4	4	6	7	8
Desired Inductions	2	2	2	2	3	4	5
Spare Capacity	4	4	4	4	4	2	0
Induct to Work	2	2	2	2	3	4	4
IN WORK	2	2	2	2	2	3	4
Repair	2	2	2	2	2	3	4
MTTR	0.50	0.50	0.50	0.50	0.48	0.39	0.34
Backlog Pressure Ind	0.00	0.00	0.00	0.00	4.81	22.03	50.51
12:01 AM 21/11/93			WORKSHOP CAPACITY: (1)				

	Page 2						
Weeks	8.00	9.00	10.00	11.00	12.00	Final	
Flying Hours	400.00	200.00	200.00	100.00	100.00	100.00	
Arising	7	4	3	2	2		
Arrive at Wkshop	8	7	4	3	2		
WKSHOP USINV	12	16	19	20	19	17	
Desired Inductions	9	13	16	17	16	14	
Spare Capacity	0	0	0	0	0	0	
Induct to Work	4	4	4	4	4		
IN WORK	4	4	4	4	4	4	
Repair	4	4	4	4	4		
MTTR	0.30	0.30	0.30	0.30	0.30	0.30	
Backlog Pressure Ind	97.21	100.00	100.00	100.00	100.00	100.00	
12:01 AM 21/11/93			WORKSHOP CAPACITY: (2)				

Figure E-8. Workshop Capacity Simulation Table

As the level of workshop unserviceable RI inventory rises, so does the desired induction rate. However, when the workshop is working to full capacity (indicated by '0' Spare Capacity in weeks 7 to 12), the maximum number of RIs which can be inducted to work in any one week is four. This is equal to the number of RIs which the workshop is able to repair in a week when attaining the minimum MTTR of which it is capable, 0.3 weeks.

The impact of this limitation can be seen by comparing the induction rate up to week 6 with that in later weeks. In the initial five weeks adequate workshop capacity exists for the workshop manager to induct to work all the unserviceable RIs desired. At week 6 the number of desired inductions exceeds spare capacity, indicating that it may not be possible to achieve the desired induction rate. The workshop manager is able to induct only three RIs, one less than the desired rate. From week 7 the level of desired inductions far exceeds the rate at which the workshop can repair those in work, restricting the achieved induction rate.

The workshop unserviceable inventory peaks at twenty in week 11, three weeks after the number of flying hours began to fall. Even though the arising rate lowers significantly in these three weeks, the workshop US inventory continues to rise, albeit at a reduced rate. This lag is due to both the despatch delay previously discussed, and the workshop capacity limitation.

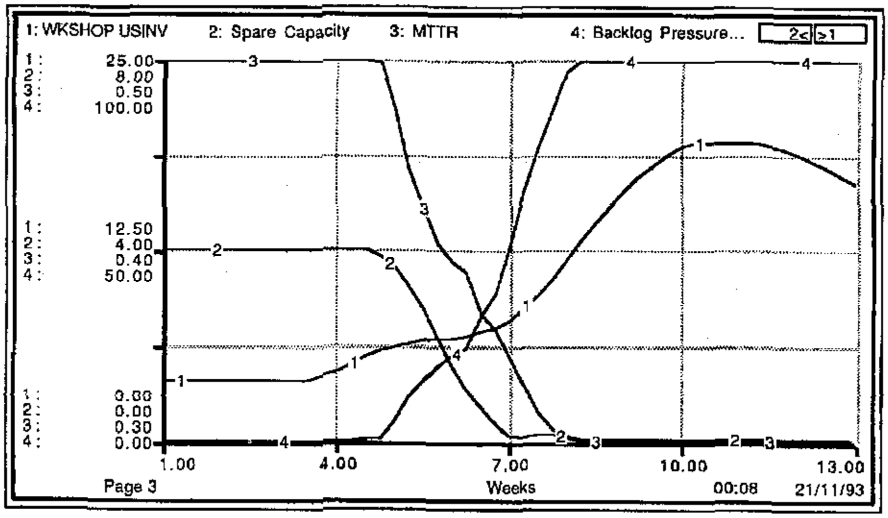

Figure E-9. Workshop Capacity Simulation Graph

A graphical report of this simulation run is shown at Figure E-9. This graph illustrates the interplay of a number of key variables. Initially the workshop unserviceable inventory is low, spare capacity exceeds unserviceable inventory, and the lack of backlog pressure is reflected in the high MTTR of 0.5 weeks. A small delay is seen in the reaction of other variables to the gradual increase in unserviceable inventory at week 3. When this increase is sustained over a longer period the backlog pressure increases, as does workshop activity, indicated by the falling MTTR. By week 9 the workshop is working to full capacity, and maintains this level of activity throughout the remainder of the simulation, despite the decrease in unserviceable inventory from week 11. The graph reinforces interpretation of the tabulated data at Figure E-8.

Quality Impact

Simulation Objective. The second simulation explores the impact of quality of work performed in the base workshop upon system behaviour. It was hypothesised that the lower quality of maintenance work, which occurs when backlog pressure rises, has a significant impact on the RI failure rate. An inverse relationship between 'Quality of Work' and 'Backlog Pressure Index' has been specifically modelled, as has a reduction in the 'Wtd Avg MTBF' due to decreasing quality of work. The link which is more difficult to mentally envisage is that between the weighted average MTBF and the arising rate. Hence, the relationship between these two variables is the focus of this simulation. To support the hypothesis a pattern of increased arisings should be clearly evident when weighted average MTBF falls.

Simulation Inputs. Initial stock values in this simulation are the same as those previously used, as presented in Table E-1. Additonally, the 'Old Wtd Avg MTBF' is set at 50 hours, equivalent to the 'Design MTBF'. The simulation period has been extended to 25 weeks. Flying hours for the first twelve weeks are identical to those input to the previous simulation, with 100 flying hours weekly for weeks 13 to 25.

Simulation Results and Discussion. Tabular simulation output is at Appendix 2. The graphical output at Figures E-10 and E-11 provides adequate information to support discussion.

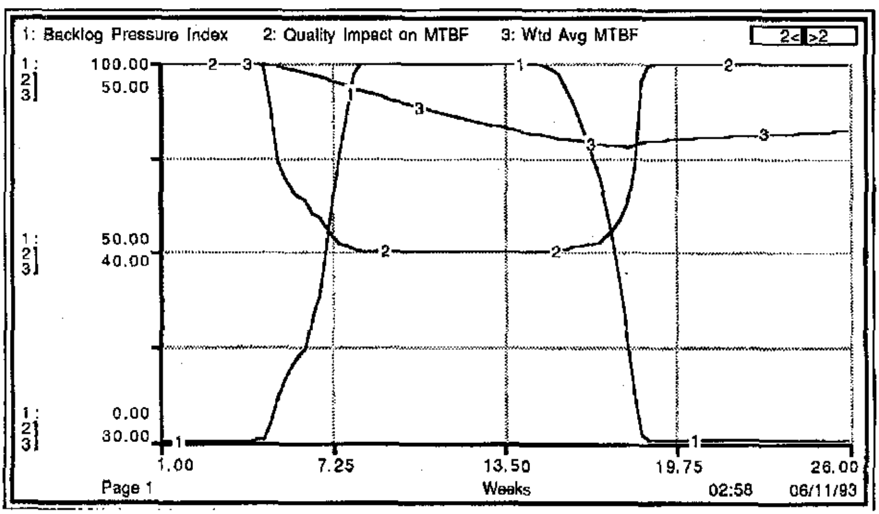

Figure E-10. Quality Impact Simulation Graph 1

Figure E-10 shows the patterns of 'Backlog Pressure Index' (line 1), 'Quality Impact on MTBF' (line 2), and 'Wtd Avg MTBF' (line 3). Initially backlog pressure is zero, hence quality of work has not diminished. Also, the weighted average MTBF equals the design MTBF of 50 hours. As the pressure increases, lower quality begins to affect the MTBF, indicating an inverse relationship. When pressure is at its maximum (100 on the BPI), the quality impact is strongest, reducing the MTBF of RIs repaired in the base workshop to 40 hours. The Wtd Avg MTBF displays a more gradual trend, reflecting the mixture of high and low quality RIs in serviceable inventory at the flying squadron. The patterns in this graph are as anticipated.

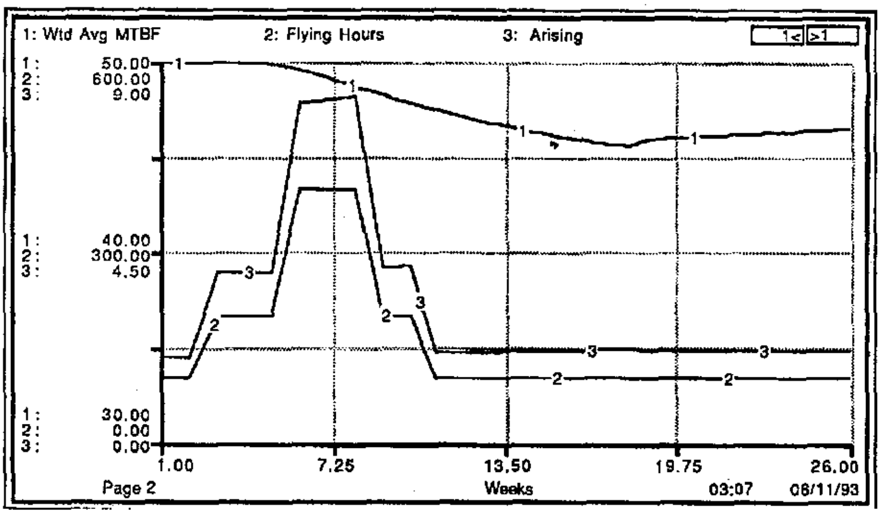

Figure E-11. Quality Impact Simulation Graph 2

The relationship between 'Wtd Avg MTBF' (line 1), 'Flying Hours' (line 2) and 'Arisings' (line 3) is shown on Figure E-11. The shape of lines 2 and 3 are strikingly similar - clearly, the Arising rate follows very similar trends to the number of flying hours. Minor variations in the distance between the two lines reflect variation in the weighted average MTBF. However, flying hours are the predominant influence upon arisings. This result runs counter to the original hypothesis, and demonstrates the surprising counter-intuitive behaviour which may be discovered using simulation.

Appendices:

1. Sample RI System Model Equations

2. Quality Impact Simulation Table

APPENDIX ONE TO ANNEX E

SAMPLE RI SYSTEM MODEL EQUATIONS

FLYING SQUADRON

□ ON_AIRCRAFT(t) = ON_AIRCRAFT(t - dt) + (Fit_to_Aircraft - Arising) * dt
INIT ON_AIRCRAFT = 30
INFLOWS:
Fit_to_Aircraft = IF(SER_INV≥Arising)THEN(Arising) ELSE(MAX(SER_INV,0))
OUTFLOWS:
Arising = Flying_Hours/Wtd_Avg_MTBF

□ SER_INV(t) = SER_INV(t - dt) + (Return__to_Inv - Fit_to_Aircraft) * dt
INIT SER_INV = 100
INFLOWS:
Return__to_Inv = Repair
OUTFLOWS:
Fit_to_Aircraft = IF(SER_INV≥Arising)THEN(Arising) ELSE(MAX(SER_INV,0))

□ SQN_USINV(t) = SQN_USINV(t - dt) + (Arising - Send_to_Wkshop) * dt
INIT SQN_USINV = 2
INFLOWS:
Arising = Flying_Hours/Wtd_Avg_MTBF
OUTFLOWS:
Send_to_Wkshop = DELAY(SQN_USINV,Despatch_Delay)

○ Despatch_Delay = .5

Ø Flying_Hours = GRAPH(TIME)
(1.00, 100), (2.00, 100), (3.00, 200), (4.00, 200), (5.00, 200), (6.00, 400), (7.00, 400), (8.00, 400), (9.00, 200), (10.0, 200), (11.0, 100), (12.0, 100), (13.0, 100), (14.0, 100), (15.0, 100), (16.0, 100), (17.0, 100), (18.0, 100), (19.0, 100), (20.0, 100), (21.0, 100), (22.0, 100), (23.0, 100), (24.0, 100), (25.0, 100)

QUALITY IMPACT SUPPORT STRUCTURE

□ OLD_WTD_AVG_MTBF(t) = OLD_WTD_AVG_MTBF(t - dt) + (MTBF_In - MTBF_Out) * dt
INIT OLD_WTD_AVG_MTBF = 50
INFLOWS:
MTBF_In = Wtd_Avg_MTBF
OUTFLOWS:
MTBF_Out = OLD_WTD_AVG_MTBF

BASE WORKSHOP

□ IN_WORK(t) = IN_WORK(t - dt) + (Induct_to_Work - Repair) * dt
INIT IN_WORK = 2
INFLOWS:
Induct_to_Work = MIN(Desired_Inductions,Spare_Capacity1)
OUTFLOWS:
Repair = DELAY(IN_WORK,MTTR)

☐ WKSHOP_USINV(t) = WKSHOP_USINV(t - dt) + (Arrive_at_Wkshop - Induct_to_Work) * dt
INIT WKSHOP_USINV = 4
INFLOWS:
Arrive_at_Wkshop = ROUND(Send_to_Wkshop)
OUTFLOWS:
Induct_to_Work = MIN(Desired_Inductions,Spare_Capacity1)
○ Desired_Inductions = IF(WKSHOP_USINV≤5)THEN(MIN(2,WKSHOP_USINV))ELSE(WKSHOP_USINV-3)
○ Spare_Capacity = ABS(Total_Capacity-(Repair+IN_WORK))
○ Spare_Capacity1 = Total_Capacity-IN_WORK
○ Total_Capacity = 8
⊘ Backlog_Pressure_Index = GRAPH(WKSHOP_USINV)
(0.00, 0.00), (1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.15), (7.00, 30.0), (8.00, 55.0), (9.00, 72.0), (10.0, 81.0), (11.0, 91.0), (12.0, 98.0), (13.0, 100), (14.0, 100), (15.0, 100), (16.0, 100), (17.0, 100), (18.0, 100), (19.0, 100), (20.0, 100)
⊘ MTTR = GRAPH(Backlog_Pressure_Index)
(0.00, 0.5), (10.0, 0.45), (20.0, 0.4), (30.0, 0.37), (40.0, 0.355), (50.0, 0.345), (60.0, 0.335), (70.0, 0.325), (80.0, 0.31), (90.0, 0.305), (100, 0.3)

QUALITY IMPACT

○ Design_MTBF = 50
○ Quality_Impact_on_MTBF = Quality_of_Work*Design_MTBF
○ Wtd_Avg_MTBF = ((SER_INV-Repair)*OLD_WTD_AVG_MTBF+Repair*Quality_Impact_on_MTBF)/SER_INV
⊘ Quality_of_Work = GRAPH(Backlog_Pressure_Index)
(0.00, 1.00), (10.0, 0.9), (20.0, 0.864), (30.0, 0.844), (40.0, 0.835), (50.0, 0.826), (60.0, 0.819), (70.0, 0.81), (80.0, 0.807), (90.0, 0.805), (100, 0.8)

APPENDIX TWO TO ANNEX E

QUALITY IMPACT SIMULATION TABLE

Page 1						
Weeks	Initial	1	2	3	4	5
Flying Hours	100.00	100.00	200.00	200.00	200.00	400.00
WKSHOP USINV	4	4	4	5	6	7
Backlog Pressure Index	0.0	0.0	0.0	0.0	7.3	26.0
Repair		2	2	2	2	2
Quality of Work	1.00	1.00	1.00	1.00	0.93	0.85
Quality Impact on MTBF	50.00	50.00	50.00	50.00	46.36	42.59
Wtd Avg MTBF	50.00	50.00	50.00	50.00	49.92	49.62
Arising		2	3	4	4	6
2:11 AM 6/11/93		QUALITY IMPACT: (1)				

Page 1						
Weeks	6	7	8	9	10	11
Flying Hours	400.00	400.00	200.00	200.00	100.00	100.00
WKSHOP USINV	8	12	17	20	20	19
Backlog Pressure Index	58.0	98.5	100.0	100.0	100.0	100.0
Repair	3	4	4	4	4	4
Quality of Work	0.82	0.80	0.80	0.80	0.80	0.80
Quality Impact on MTBF	41.01	40.04	40.00	40.00	40.00	40.00
Wtd Avg MTBF	49.17	48.70	48.27	47.87	47.48	47.13
Arising	8	8	7	4	3	2
2:11 AM 6/11/93		QUALITY IMPACT: (2)				

Page 1						
Weeks	12	13	14	15	16	17
Flying Hours	100.00	100.00	100.00	100.00	100.00	100.00
WKSHOP USINV	17	15	13	12	10	8
Backlog Pressure Index	100.0	100.0	100.0	94.6	78.1	51.5
Repair	4	4	4	4	4	4
Quality of Work	0.80	0.80	0.80	0.80	0.81	0.83
Quality Impact on MTBF	40.00	40.00	40.00	40.13	40.40	41.25
Wtd Avg MTBF	46.81	46.50	46.21	45.95	45.72	45.54
Arising	2	2	2	2	2	2
2:11 AM 6/11/93		QUALITY IMPACT: (3)				

Page 1						
Weeks	18	19	20	21	22	23
Flying Hours	100.00	100.00	100.00	100.00	100.00	100.00
WKSHOP USINV	6	6	5	5	5	5
Backlog Pressure Index	5.7	0.1	0.0	0.0	0.0	0.0
Repair	4	4	3	2	2	2
Quality of Work	0.94	1.00	1.00	1.00	1.00	1.00
Quality Impact on MTBF	47.17	49.96	49.98	49.98	49.99	49.99
Wtd Avg MTBF	45.66	45.89	45.97	46.05	46.14	46.22
Arising	2	2	2	2	2	2
2:11 AM 6/11/93		QUALITY IMPACT: (4)				

Page 1						
Weeks	24	25				
Flying Hours	100.00	100.00				
WKSHOP USINV	5	5				
Backlog Pressure Index	0.0	0.0				
Repair	2	2				
Quality of Work	1.00	1.00				
Quality Impact on MTBF	49.99	49.99				
Wtd Avg MTBF	46.31	46.39				
Arising	2	2				
2:11 AM 6/11/93		QUALITY IMPACT: (5)				

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This book was prepared at the Air Power Studies Centre as a Chief of Air Staff's Air Power Fellowship in 1993. The fellowship scheme commenced in 1990, and aims to develop awareness and foster understanding of air power in the Australian context.

The author identifies opportunities to improve RAAF preparedness through Repairable Item (RI) management. Starting with fundamental concepts of logistics, RI management, and preparedness doctrine, the book proceeds to examine analysis of RI requirements undertaken in recent preparedness studies. A central theme is the need to complement the calculation of preparedness resource requirements with ongoing system development using a systems thinking approach. Conclusions and recommended strategies to pursue identified opportunities are included.

DPUBS: 8329/93

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