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A CONCEPTUAL MODEL OF THE
AIR FORCE LOGISTICS PIPELINE

THESIS

Craig A. Bond
Captain, USAF

Marvin E. Ruth
Captain, USAF

AFIT/GLM/LSM/89S-2

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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AFIT/GLM/LSM/89S-2

A CONCEPTUAL MODEL
OF THE AIR FORCE LOGISTICS PIPELINE
THESIS

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Logistics Management

Craig A. Bond, B.S.
Captain, USAF

Marvin E. Ruth, B.A.
Captain, USAF

September 1989

Approved for public release; distribution unlimited

Preface

This study develops a conceptual model of the Air Force logistics pipeline. This model may help top AF managers to visualize and understand the general flow of assets through the various segments of the pipeline.

An extensive search of existing literature was conducted to determine just what has been written about the pipeline. The research revealed detailed discussions of many pieces of the pipeline, but none of the entire system. Several models were analyzed and used to conceptualize a more complete model for the flow of reparable spares. Therefore, an unlimited and much more detailed analysis of the pipeline can and should be made. A simulation model of the entire AF logistics pipeline would be an excellent way to reveal areas where pipeline time could be improved.

In both the researching and writing of this topic, we had excellent help from others. We are most indebted to our advisor, Major David K. Peterson for his knowledgeable advice, patience, and direction throughout the process. We would also like to thank our readers, Lt Col Bruce P. Christensen and Capt John Sullivan for their valuable comments and advice. Most of all, we are forever grateful to our families and friends for their unwavering love and support.

Craig A. Bond and Marvin E. Ruth

Table of Contents

	Page
Preface	ii
List of Figures	vii
List of Tables	x
Abstract	xi
I. Introduction	1
Background	1
A Generic Pipeline	3
Pipeline Definitions	5
The Classic Pipeline Model	8
The Acquisition and Logistics Pipeline	10
Mission and Objectives of Logistics	
Systems Components	10
Requirements Determination	12
Spares Acquisition	12
Transportation Management	12
Inventory Management	13
Maintenance Management	14
Information Management	14
Summary of Pipeline Subsystems and Components	15
Problem Definition	16
The Management Question	16
The Research Question	17
Limitations of Study	17
Investigative Questions	18
Chapter Summary	18
Overview of Chapter II	19
II. Literature Review	21
A Pipeline Model in a Non-Military Environment	21
A Wholesale Warehouse Inventory Model	21
Distribution Centers	22
The Base Pipeline Subsystem	25
Recoverable Item Management	25
Supply Warehousing and Related Functions	30
Flow Patterns	30
Receipt Processing	34

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	Page
Turn-in Processing	38
Issues/Shipments	42
Supply Points	44
MICAP and Lateral Support	45
Pickup and Delivery	46
Inspection	46
Base-Level Maintenance	49
The Maintenance Process	49
Base Maintenance Organizations	54
The Customer Order Cycle	57
Base Repair Cycle Maintenance	
Actions	59
The Repair Cycle Demand Level	61
Base Stockage Model (BSM)	62
Base-Level Replenishment Lead Time	64
Transportation Management	66
Transportation Costs	68
Military Standard Transportation And	
Movement Procedures	69
Transshippers	70
Traffic Management	75
Surface Carriers	77
Motor Trucks	77
Railroads	78
Other Surface Carriers	78
Air Carriers	79
LOGAIR	79
Commercial Air	80
Aerial Port Operations	80
Surface Freight Operations	81
Priority Systems	85
Force/Activity Designator	87
Urgency of Need Designator	88
Priority Grouping	88
Order and Shipping Time	88
Delivery Date Criteria	90
Urgency Justification Code	91
Supply Processing Standards	91
Intermediate Summary	92
The Depot Pipeline Subsystem	92
Air Logistics Centers	93
Depot Supply	93
Depot Transportation	95
Depot Maintenance	96
METRIC Model	101
Mod-METRIC Model	104
LMI Aircraft Availability Model	109
Dyna-METRIC Model	112
Procurement/Repair Model	118

	Page
Distribution and Repair in Variable Environments	120
LSAO Depot Reparable Simulation	123
Requirements Determination	125
Measurement of Repair Cycles	126
Procurement Lead Time Model	132
The Acquisition Pipeline Subsystem	136
The Acquisition Plan	137
The Contracting Process	138
Industrial Capacity	140
The Disposal Pipeline Subsystem	142
Collective Pipeline Models	145
AFIT Three Level Model	146
LMI Exchangeable Flows Model	148
Chapter Summary	151
Overview of Chapter III	156
III. Methodology	157
General Issue	157
Specific Problem	157
Investigative Questions	158
Particular Method	158
Interview Experts for Information	159
Model Development	159
Chapter Summary	160
Overview of Chapter IV	161
IV. Findings, Model Presentation, and Conclusions	162
Findings	162
Investigative Question 1	162
Investigative Question 2	163
Investigative Question 3	166
Model Presentation and Explanation	168
The Overall Logistics Pipeline	168
Pipeline Model Analysis	169
Model Presentation	171
Base Pipeline Subsystem	172
Base Maintenance	175
Base Reparable Maintenance	176
Base Exchangeable Pool	178
Transportation Linkages	186
Depot Pipeline Subsystem	188
Central Exchangeable Pool	188
Depot Reparable Maintenance	194
Depot Maintenance	199
Acquisition Pipeline Subsystem	201
Disposal Pipeline Subsystem	204
Conceptual Model Summary	205

	Page
Conclusions	210
Recommendations for Future Research	213
Appendix A: HQ USAF/LE Letter	216
Appendix B: Base Repair Cycle Information Flow	218
Appendix C: Base-Level Demand Process	226
Bibliography	240
Vitas	246

List of Figures

Figure	Page
1. "Generic" Pipeline Segment	4
2. WWI Supply Pipeline Model	9
3. The Acquisition and Logistics Pipeline	11
4. A Two-echelon Inventory System	23
5. A Multi-echelon Inventory System	24
6. General Recoverable Item Flows	27
7. Recoverable Item Pipelines	28
8. Typical Cyclic Flow Pattern	32
9. Typical Straight-line Flow Pattern	33
10. Standard Base Supply Material Flow	35
11. Material Flow through Receiving	36
12. Flow of Receipt Due-out Releases	39
13. Flow of Receipt Notices to Stock	40
14. Flow of Turn-ins through Base Supply	41
15. Flow of Issues from Stock	43
16. Ingredients of Availability	51
17. Corrective Maintenance Cycle	52
18. Customer Order Cycle	58
19. Maintenance Pipeline Model	60
20. Base Stockage Model	63
21. Elements of the Order Cycle	64
22. Aerial Port Terminal Cargo Flow	82
23. Surface Freight Terminal Cargo Flow	83

Figure	Page
24. Typical Daily Over-The-Road Transit Times	86
25. DS Organizational Structure	94
26. Basic Depot Repair Pipeline	99
27. Depot Repair Cycle	100
28. METRIC Model Theory	102
29. METRIC Model	103
30. Mod-METRIC Model	106
31. Mod-METRIC Repair Concept	108
32. Aircraft Availability Model	111
33. Aircraft Logistics Support Network	115
34. Dyna-METRIC Aircraft Logistics Support Network .	116
35. Depot Procurement Model	119
36. DRIVE Model	121
37. LSAO Depot Repair Simulation Model	124
38. LSAO Segmented Repair Cycle Time	128
39. LMI Segmented Repair Cycle Time	129
40. LSAO Proposed Procurement Lead Time Model	135
41. Federal Contracting Process	139
42. Three-level Pipeline Model	147
43. Exchangeable Flows Model	149
44. Exchangeable Impact Graph	152
45. The Overall Logistics Pipeline	169
46. Exchangeable Flows Model	173
47. First Level Explosion of "Base Maintenance," Flight Line Maintenance Process	174

Figure	Page
48. First Level Explosion of "Base Repairable Maintenance," Maintenance Shop Repair Process	177
49. First Level Explosion of the "Base Exchangeable Pool," Customer Demand and Issue Process	179
50. First Level Explosion of the "Base Exchangeable Pool," Receiving and Storage Process	182
51. First Level Explosion of the "Base Exchangeable Pool," Repairable Asset Turn-in/Shipment Process	184
52. Transportation Process	187
53. First Level Explosion of the "Central Exchangeable Pool," Serviceable Spares Receipt and Storage Process	189
54. First Level Explosion of the "Central Exchangeable Pool," Repairable Spares Receiving, Storage, and Distribution Process	192
55. First Level Explosion of the "Central Exchangeable Pool," Serviceable Spares Issue Process	193
56. First Level Explosion of "Depot Repairable Maintenance," Maintenance Inventory Center Process	196
57. First Level Explosion of "Depot Repairable Maintenance," End-item Repair Process	197
58. First Level Explosion of "Depot Maintenance," Program Depot Maintenance Process	200
59. First Level Explosion of "Industry," Acquisition and Production Process	202
60. First Level Explosion of "Attrition," the Disposal Process	206
61. Document Flow for DIFM Processing	219
62. Base-level Demand Process	227

List of Tables

Table	Page
1. Delivery/Maintenance Repair Priority Designators	47
2. CONUS Transit Time Standards	70
3. UMMIPS Segmented Processing Actions per TP Codes	71
4. Transportation Priorities and Recommended Shipment Modes	76
5. MII ^c TRIP Priorities	89

Abstract

The study develops a conceptual model of the Air Force logistics pipeline. The pipeline may be defined simply as the flow of material from procurement to usage, with consideration of all factors that affect that flow. This study provides a "generic" view of the pipeline for wider applicability and ease of understanding. It is limited to the movement of reparable spares which represent a significant fraction of Air Force's stock replenishment funds. "Reparable" refers to the class of assets which are considered more economical to repair than replace.

A literature review consolidated previous works concerning reparable item pipelines and portions thereof. The review found many models that explain specific segments of the pipeline, but no complete model examining the intricacies of the entire Air Force logistics pipeline.

The conceptual pipeline was divided into four major subsystems. The base and depot pipeline subsystems represent the repair cycle process through supply and maintenance. The transportation system composes the linkages between and within subsystems. The acquisition subsystem the procurement process for acquiring new and

replacement reparable spares. The disposal subsystem eliminates excess and condemned assets from the pipeline.

After evaluating various existing models, the Exchangeable Flows Model, developed by the Logistics Management Institute (LMI), seemed to most accurately depict the general Air Force logistics pipeline. The proposed conceptual model is an extension of this LMI model. It adds detail to broad subsystems identified in the LMI Exchangeable Flows model.

The conceptual model of the Air Force logistics pipeline is an initial step in pipeline studies. Additional information of the pipeline must be analyzed and included in a model. However, this model will be useful as a basis for understanding the Air Force logistics pipeline and as a guide to further research.

A CONCEPTUAL MODEL OF THE AIR FORCE LOGISTICS PIPELINE

I. Introduction

Background

The Air Force logistics system which creates and sustains defensive fighting capability is often referred to as the "Pipeline." This pipeline consists of an extensive network of interrelated systems whose collective efforts finance, procure, distribute, and maintain the weapons systems, facilities, spares, and consumable items used to achieve a high state of readiness and to support wartime objectives.

Studies of the Air Force logistics pipeline have revealed some real concerns about pipeline efficiency. The complexity of the pipeline often results in a lack of understanding of the overall logistics system by the people charged with making the system work. The pipeline is so large that it is nearly impossible to accurately track all the assets it contains, or to describe where the pipeline begins and ends. While interactions within activities of the system may be well-managed, the interactions between activities may cause inefficiency and lost control of pipeline assets. The Air Force allocates a significant proportion of monetary resources to the millions of assets tied up in procurement, distribution, maintenance, and disposal channels. Estimates of the cost to hold and

maintain current quantities of assets in the logistics pipeline range upward from \$50 million per day (50).

The logistics pipeline is a system. Each of the activities within the pipeline is a subsystem operating within the whole. Max Weber described the organizational structure of a system in his model of bureaucracy in the early 1900s (56:3-2). His model emphasized strong organizational structure for efficiency, subdivisions within the organization, and specialization of labor in terms of the tasks completed by each individual. Weber's work was followed-up by other management theorists who advanced management science in the 1920s, and those who advanced scientific management in the 1950s (56:3-3). Today, these management theories can be summed up into systems approaches (56:3-4).

In its text, Military Logistics, the Air Force Institute of Technology defines a system as follows: "(1) a set of (2) objects (3) together with relationships (4) between objects and attributes (5) related to each other and to their environment (6) so as to form a whole" (56:3-2). Their definition has six distinct characteristics. The set refers to the fact that there are numerous elements to the system. Objects in the system include inputs, processes, and outputs. Taken together, the inputs, processes, and outputs have characteristics unique to themselves and the group. These characteristics affect each object in the system and objects

in the system environment. The combined effects of inputs and outputs form a complete system.

The logistics pipeline may be viewed as a collection of objects. Each object is either an input, an output, or a process. These objects relate to each other, to themselves, and have an effect on their environment. Taken together, they form a whole system. Inputs include information gathered to establish requirements, supplies needed to satisfy the requirements, and other resources. The final outputs for the system are mission ready aircraft. Each subsystem takes inputs from its environment and other subsystems, processes them, and outputs them to other subsystems.

The main subsystems that compose the Air Force logistics pipeline include:

- (1) The base pipeline subsystem
- (2) The depot pipeline subsystem
- (3) The acquisition pipeline subsystem
- (4) The disposal subsystem

Each of these subsystems are composed of smaller elements which will be referred to as "components" of the subsystems. The primary subsystem components are supply, maintenance, and distribution. When considered as a group, these subsystems and their components make up a pipeline.

A Generic Pipeline. Figure 1 represents a conceptual view of a generic pipeline. A pipeline has attributes of

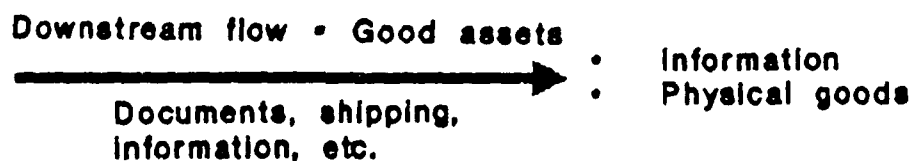
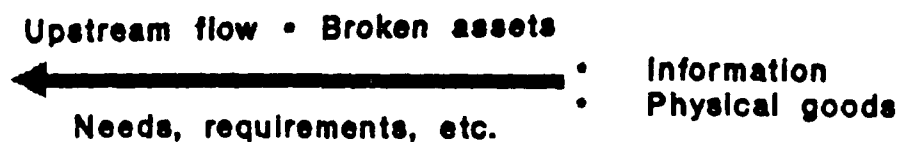
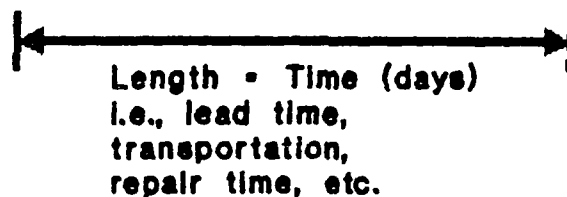
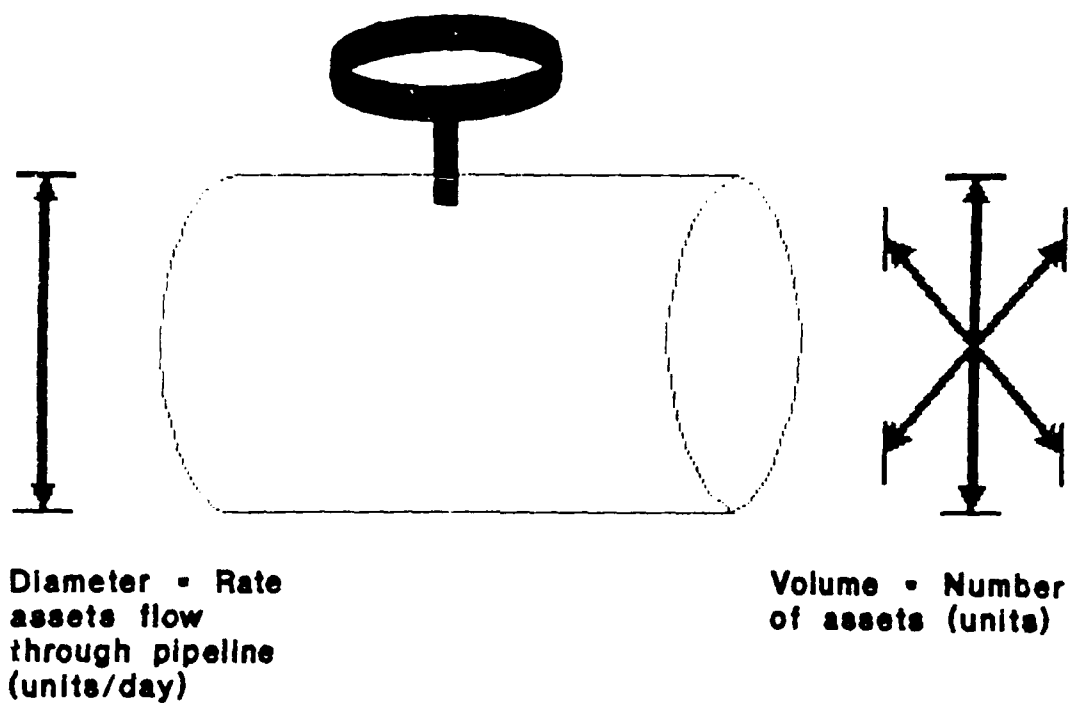


Figure 1. "Generic" Pipeline Segment

length, diameter, and volume. The external structure of the pipeline describes the movement of assets. Information flows are controlling factors in the processes that direct the movement of assets. The pipeline diameter controls the speed with which pipeline assets flow through the system. Some processes may also restrict the movement as shown by the control valve that regulates pipeline flow. The length of the pipeline segments can represent the total time that it takes to move assets from point to point along the pipeline. This length may be affected by many factors, such as the order cycle time, production rates, and shipping modes. The total volume of the pipeline represents the quantity of assets in the pipeline system. While this section has described the authors' view of a logistics pipeline, the next section discusses pipeline definitions found in the literature.

Pipeline Definitions. Providing a collective definition of the Air Force logistics pipeline requires an accurate understanding of the term "pipeline" as it is used in the logistics discipline. Several similar but distinct definitions of pipelines have been identified in the literature.

The first definition comes from The Official Dictionary of Production and Inventory Management Terminology and Phrases, a publication of The American Production and Inventory Control Society (APICS). This dictionary defines

"pipeline stock" as the "inventory to fill the transportation and distribution system including the flow through intermediate stocking points" (55:23). It further describes the effect that pipeline stock has on total inventory investment. A larger pipeline requires more resources; therefore, pipeline stock ideally should be the minimum quantity of assets that fills the system. The factors that affect this quantity are "order transmission, order processing, shipping, transportation, receiving, stocking, and review time" (55:23). This definition of the pipeline stock refers to the quantity of assets necessary to fill the logistics system. The Air Force must define the pipeline, including both assets and physical processes.

The Rand Corporation defines "pipeline" as "a network of repair and transportation channels through which repairable and serviceable parts flow as they are removed from their higher assemblies, repaired, and requisitioned from other points of supply" (35:xv).

Identification of pipelines for repairable spares was a key element of the Rand model depicting the movement of repairable assets through various levels of supply and maintenance activities. It is important to note the distinction between "reparable" and "repairable". Reparable refers to the class of assets which are generally more economical to repair than replace. The term repairable describes the physical condition of the spare when it is broken. The

Dyna-METRIC model defines pipelines for reparable by total "assets contained in the network. The model computes the expected quantity of assets in each "segment of the pipeline network" (45:11). The network includes base- and depot-level repair, transportation channels between repair and supply facilities, and resupply transportation channels.

Similarly, the USAF Supply Manual, AFM 67-1, Volume I, Part One defines a pipeline as "the channels of support or specific portion thereof by means of which material flows from sources of procurement to their point of use" (10:1-34). The length of time an asset is in the pipeline is given by the actual number of days from the submittal of a requisition until the person submitting the order receives the material (10:1-34).

Finally, the Air Force Institute of Technology provides another definition of pipeline quantity in its compendium of logistics terms and acronyms. The definition, taken from DoD Manual 4160.21-M-1, defines pipeline quantity as "a sufficient quantity of assets, on hand or on order, to meet forecast demands through a period equal to the procurement lead time plus the safety level" and other material reserved for wartime usage (11:322).

These definitions are very similar but vary in emphasis. The APICS definition applies to assets moving through channels of distribution to their points of use. The Rand Definition applies to the term as it identifies

quantities within the repair process. The Air Force Supply definition describes the system where material is transferred from procurement to usage. The DoD definition simply describes the number of assets necessary to cover spares procurement.

Thus, each of these definitions describes a portion of the logistics pipeline, but not its entirety. Understanding the concept of pipeline times, actual quantities, and requirements will be key to the overall definition of the Air Force logistics pipeline.

The Classic Pipeline Model. The US Army used a logistics pipeline to distribute military supplies to the American Expeditionary Forces in France during World War I (46:67). Figure 2 shows resource inputs to central base depots with connecting spouts to lower levels of supply. The diagram emphasizes the "flow" of supplies. In this analogy, supplies were represented by water flowing through a system of pipes, pools, and control valves. Supplies entered through large parallel pipes regulated by valves of domestic contract requisitions and local procurement. These supplies were collected into a large pool of base depots which in turn released them to intermediate and advanced depots. From the advanced depots, supplies were broken down into quantities used by each field unit. These last lengths of pipeline were the longest and narrowest, with the greatest opportunity for loss.

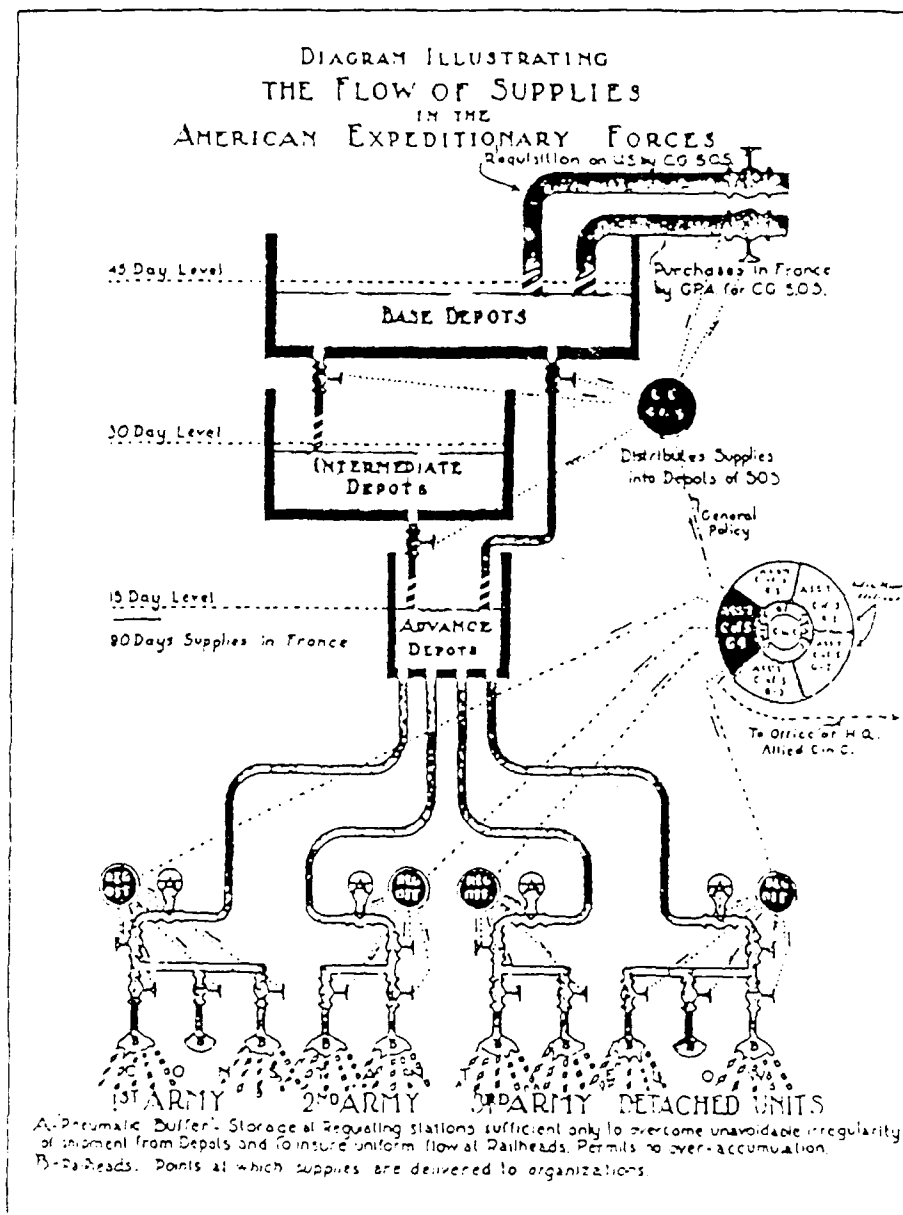


Figure 2. WWI Supply Pipeline Model
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The Acquisition and Logistics Pipeline. Figure 3 shows one conceptual view of the acquisition and logistics pipeline (37:2). The main driver of what will be procured is military strategy. Strategy begins the "flow" of the acquisition process.

Logistics processes such as requirements determination, acquisition, maintenance, and distribution feed depot or "wholesale" logistics activities. Depot activities and base-level, or "retail" activities, are linked by lines of communication and transportation. A priority system determines the order for satisfying demands for spares. The diagram finally shows the bases as the users of spares procured at higher levels. The outputs of this acquisition/logistics pipeline are readiness, sustainability, modernization, and force structure which in turn translate into military capability (37:2). The interesting aspect of this model is its portrayal of the many factors that may impact the Air Force logistics pipeline.

Mission and Objectives of Logistics Systems Components

As the previous example showed, a pipeline includes an entire network of logistics components which collectively support an entire organization or mission. Key logistics systems components include requirements determination, acquisition, transportation management, inventory management, maintenance, and information management (56:1-3). These activities take place within various subsystems in the

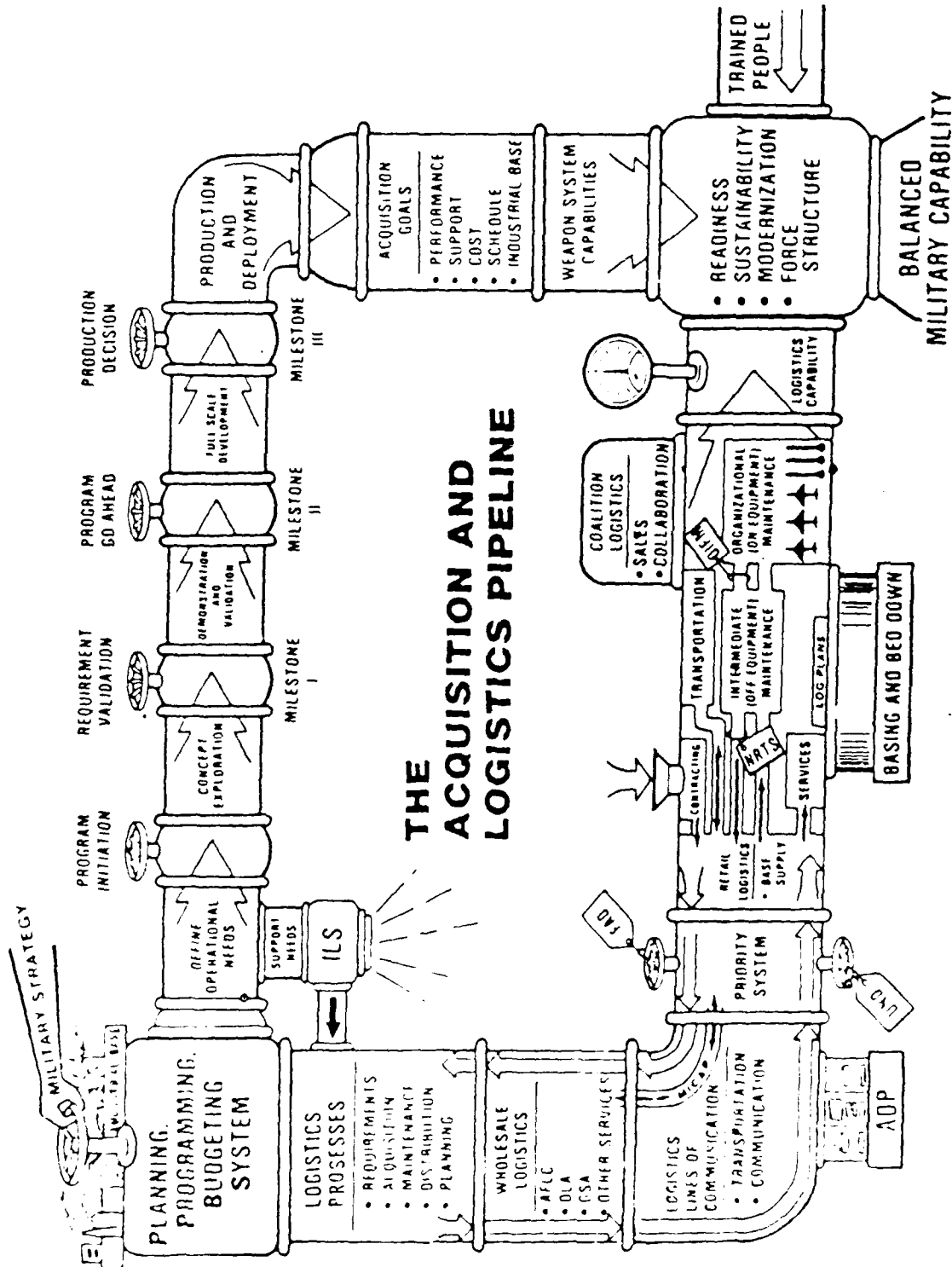


Figure 3. The Acquisition and Logistics Pipeline
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pipeline. Recall, the major subsystems in the pipeline were defined as acquisition, depot-level, base-level, and disposal. The following sections will identify and describe some of the more important subsystem components.

Requirements Determination. Requirements determination is the component that initiates the processes in the logistics pipeline. Requirements determination consists of formally identifying needs for new and replacement parts to support weapon systems. Requirements determination takes place at all levels of the system. Needs are identified at both the base- and depot-levels to ensure that adequate stock is on hand when needed. At each level, inventory models are used to establish stockage requirements for items with recurring demands. Once these requirements are identified, they are sent to the acquisition subsystem of the pipeline for procurement action.

Spares Acquisition. The spares acquisition process is the method to satisfy the needs identified in the requirements determination component of the pipeline. Spares acquisition may take place at either the depot- or base-level pipeline subsystems. A one time need may be best satisfied through base-level contracting while a recurring need for a common usage reparable spare should be purchased through central procurement channels.

Transportation Management. The military transportation system is a crucial component of the overall pipeline

because it enables the movement of pipeline stock to support mission requirements (56:6-1). A large percentage of the total assets in the pipeline are within the transportation system enroute to multiple Air Force users in the field. The transportation process serves to move material between operational bases, depot repair and storage facilities, and forward operating locations in multiple types of environments. Supplies and equipment are moved to locations around the United States and the world. The transportation system, and all assets tied up in it, is the most visible element of the pipeline.

Inventory Management. Inventory managers at the base-level, in conjunction with depot-level inventory managers, exist to provide assets to using repair organizations and operational units when and where needed (56:7-1). Depot Supply is the central source of supply for numerous detached units and operational bases. Depot Supply activities coordinate with the acquisition system to ensure adequate resupply of consumable and reparable items. Supply inventory levels are replenished through a network of government contractors, depot repair facilities, and redistribution of base assets. Base Supply is an intermediary in this distribution system. The base supply system computes requirements at the local level, maintains quantities to provide desired service levels, and issues assets to base organizations as required (56:7-1,2).

Maintenance Management. Maintenance managers have the primary responsibilities of ensuring continued serviceability of weapon systems, and for restoring damaged or broken spares to a serviceable condition as long as it is economically feasible to do so (56:8-2). Maintenance activities exist at both the depot and base-levels in the logistics pipeline. Depot repair includes more specialized activities such as nonroutine maintenance and complete overhaul of weapons systems. Depot repair facilities fix major components/end-items that exceed base repair capabilities or authorizations. Base-level maintenance organizations perform more routine repairs and preventative maintenance. Base-level technicians perform maintenance directly on the weapon system or in the more specialized "back shops" that are removed from the immediate area of the weapon system (56:8-10,11). Once a component is no longer economically repairable, it is sent on into the disposal subsystem. At both the depot and base-level, maintenance units perform vital functions for keeping weapon systems mission ready (56:8-1).

Information Management. Smooth flows of information are important to maintaining consistent operations, keeping all pipeline activities working together, providing accurate and timely data to technicians in the field, and enabling logistics managers to make good decisions that benefit the overall support effort. For that reason, information management plays an important part in maintaining the Air Force logistics system. Information managers maintain the

computer systems that store the massive data resources and program codes which all levels of logistics support rely on for material requirements computation, system maintenance activities, supply inventory records, transportation of materials, and financial records. The increased use of and dependence on automated data processing equipment will cause the information management component to play an ever increasing role in the measurement and definition of the Air Force logistics pipeline (56:14-1).

Summary of Pipeline Subsystems and Components. The Air Force logistics pipeline system is composed of a number of organizations whose activities influence each other and combine to form a whole. These organizations exist on at least four different levels: acquisition, depot, base, and finally disposal. The depot and base-levels both involve requirements determination, inventory management, and maintenance. The acquisition subsystem feeds the system while the disposal subsystem eliminates assets no longer required. The entire system is interconnected by transportation linkages and information flows. Understanding the common procedures and connecting links within the entire system is important to gaining an overall appreciation of the logistics pipeline.

Problem Definition

The Management Question. The US Air Force Air Staff in Washington D.C. believes pipeline management is critical to the Air Force's ability to efficiently allocate and control its scarce resources. A letter sent to the Air Force Institute of Technology School of Systems and Logistics (AFIT/LS) expresses Air Staff concerns about the massive size of the logistics system and the excessive costs associated with maintaining current pipeline quantities (50). A copy of this letter is shown in Appendix A. The letter emphasizes that most estimates of pipeline costs are dated, and that an accurate description of the pipeline is unavailable. Two unnamed studies are cited; one study conducted several years ago estimates the pipeline cost at \$55 million per day, while a more recent study estimates the cost at \$50.8 million per day. The letter recommends performing research to: 1) provide a collective definition of the pipeline, and 2) to identify possible system inefficiencies that waste critical resources and detract from mission capability (50).

A greater understanding of the logistics pipeline is essential to effectively manage and improve the efficiency of operations taking place between logistics agencies. Managers within the logistics pipeline must be aware of how their decisions and activities affect others throughout the supply network. The collective definition of the Air Force logistics pipeline requested by Air Staff is a logical first

step toward achieving a greater understanding of this complex logistics system.

The Research Question. The particular problem associated with defining the Air Force logistics pipeline is that no complete definition or model of the pipeline exists. Segments have been defined and studied, but usually without regard to the rest of the pipeline.

The research question is: How do all of these components and subsystems fit together? This study develops a conceptual model of the Air Force logistics pipeline.

Limitations of Study

The scope of the total Air Force logistics pipeline is broad to say the least. Many factors, seen and unseen, influence its nature from one moment to another. This study concentrates on the general characteristics of the pipeline and its most common day-to-day influences. In doing so, the reader will gain a better appreciation of the fundamental pipeline without overemphasizing unusual events that may affect the "norm" of the pipeline characteristics.

Four specific limitations are required to meet this objective:

1. The pipeline model will assume a peace time environment. Many aspects of the logistics pipeline are modified in a dynamic wartime environment.
2. The pipeline model will not investigate budgetary constraints.

3. The pipeline model will be limited to only the movement of reparable spares within the Continental US (CONUS). Since the majority of the money spent for spare parts is spent and/or saved on this category of items, it is most logical to concentrate on a model that tracks their movement.
4. The pipeline model will not analyze the flow of data and information through the logistics system. Only the physical movement of the actual assets will be discussed.

Investigative Questions

This research will specifically address the following investigative questions:

1. Can the logistics pipeline be accurately subdivided into major subsystems such as base-level, depot-level, acquisition, and disposal?
2. What processes take place in each subsystem of the pipeline?
3. What are the transportation linkages within and between major pipeline subsystems?

The investigative questions will be answered by researching the logistics literature and performing interviews with managers and technicians at different levels of the pipeline. Their responses will be used to gain an overall understanding of the logistics pipeline and to develop a conceptual pipeline model.

Chapter Summary

This chapter presented the basic motivation for the pipeline study. Lack of an adequate definition of the Air Force logistics pipeline requires research to provide a better description of the system. The logistics pipeline

may be described as a system containing inputs of assets and information, processes within the acquisition, distribution, maintenance, and disposal subsystems, and outputs of mission readiness. The acquisition subsystem of the logistics pipeline for reparable spares is driven by strategy. Processes of requirements computation, acquisition, and depot maintenance feed base-level activities through transportation and communication linkages. The US Army used a pipeline model to describe its logistics system during WWI. The classical pipeline model has continued to provide a basis for pipeline definitions.

This study reviews literature relevant to the logistics pipeline and interviews experienced logisticians to develop a conceptual model of the pipeline.

Overview of Chapter II

Chapter II will review available sources of information about pipeline activities and about current logistics pipeline models. The chapter begins by identifying and discussing two commercial applications for pipeline systems. Then, base-level processes such as supply warehousing, maintenance, and the customer order cycle are examined. To complete the discussion of the base subsystem, base repair cycle models are presented. Next is a review of how distribution channels affect the pipeline. Following the section on distribution is a review of the priority system

governing the movement of spares within the logistics system. The depot and acquisition pipeline subsystem models are discussed next. Finally, the disposal subsystem is reviewed.

II. Literature Review

The system providing supplies and support to military members in intermediate and field units has long been described as a pipeline. Supplies flow along predetermined paths on their trips from depot distribution points to their destinations in the field. Logistics involves more than just the flow of supplies. For each item that flows through the pipeline, multiple bits of information direct and control the movement. In the logistics system, assets and information constantly flow both up and down the pipeline (37:1). The following discussion will examine the academic and practitioner literature pertaining to the models for describing asset movement through the pipeline and identifying the four subsystems of the Air Force logistics pipeline by examining pipeline models, both past and present.

A Pipeline Model in a Non-Military Environment

The first section of the literature review will identify two pipeline models adapted for use in commercial settings.

A Wholesale Warehouse Inventory Model. Carl Schultz diagramed a two-echelon inventory model in 1980 to show the movement of items between a central warehouse and various retail stores (47:2). The model was used as a framework for forecasting demands at the warehouse level from multiple

retail stores. Figure 4 represents Schultz's model. The model described the stock levels and demand rates throughout the two echelon system. Asset flows in this model were strictly one directional; property flowed from the warehouse to the stores to satisfy customer demands. The aggregate demands of individual stores made up total demand for the central warehouse. Each of the stores placed a demand on the warehouse once their inventory balance reached a predetermined level established to minimize inventory costs and risks of stock shortages. The two echelon structure of Schultz's model applies to the military environment in that the interactions between stores and warehouse are similar to the interactions between bases and depots.

Distribution Centers. In another commercial application of the multi-echelon inventory model shown in Figure 5, John A. Muckstadt and L.J. Thomas describe a three level system consisting of a production facility, central distribution centers, and local warehouses (39:139). The multi-echelon system allows the organization to reduce total holdings of inventory by offsetting high demands at one location with low demands at another. By centralizing inventory at the second level distribution centers, the organization can lower total inventory investment while minimizing the impact on customer service. Although not all demands may be satisfied from the local warehouse,

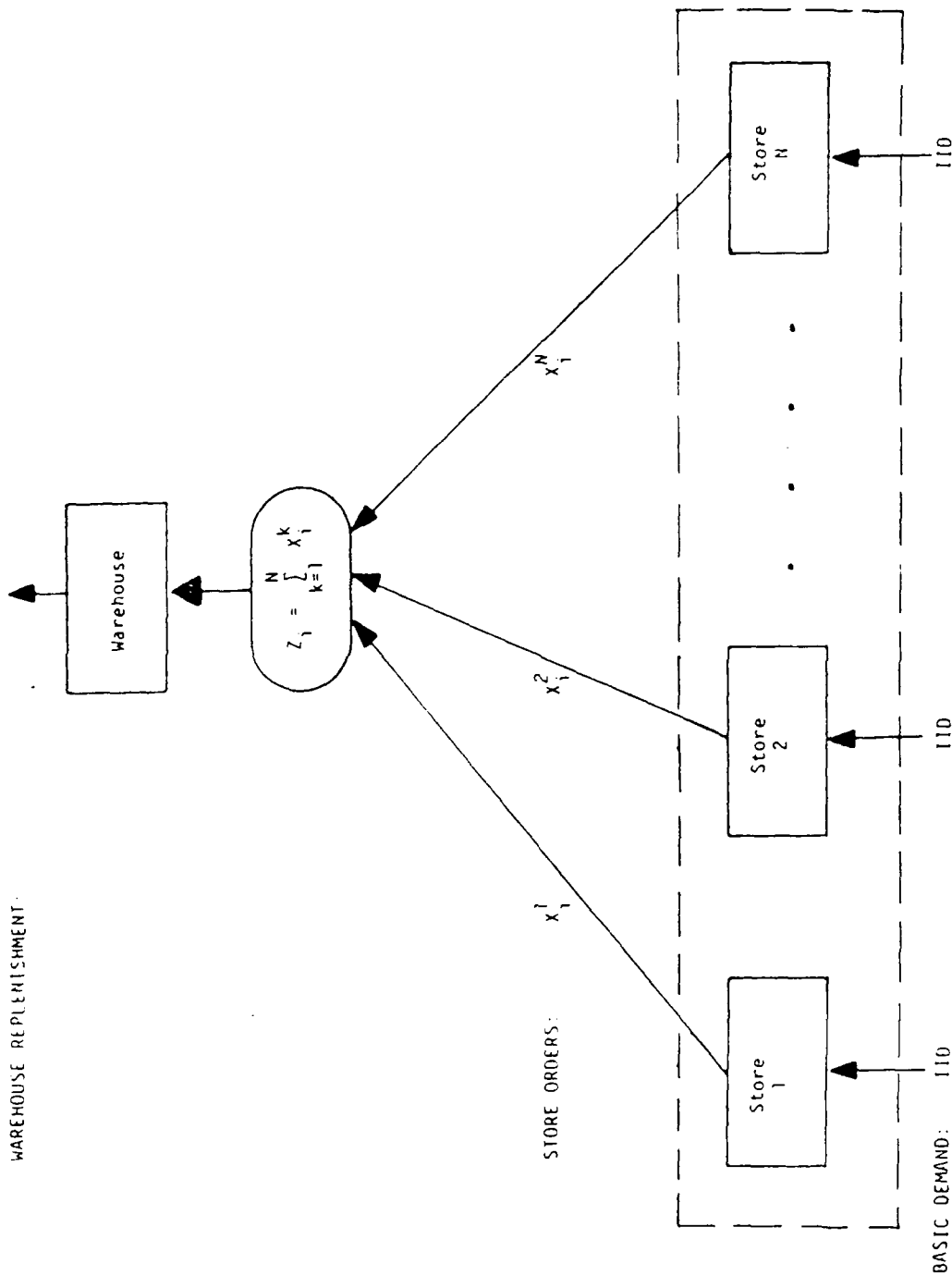


Figure 4. A Two-echelon Inventory System
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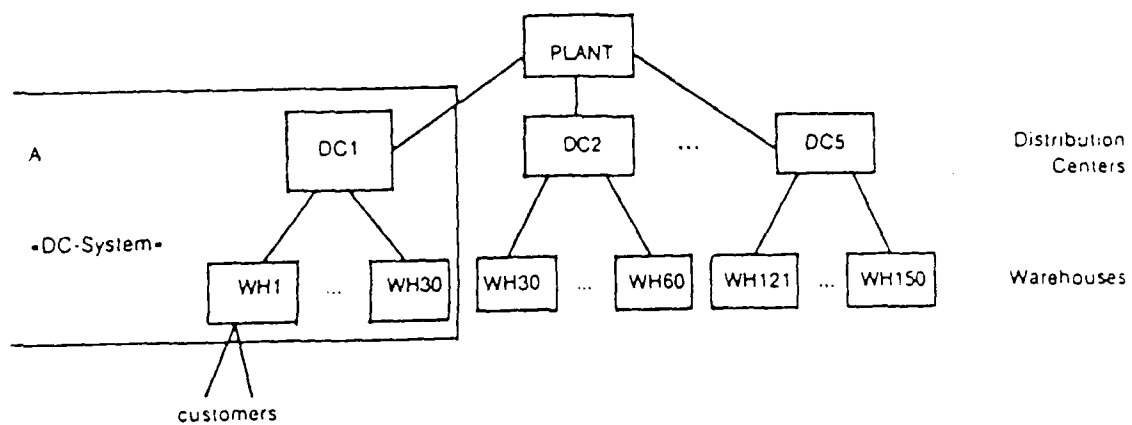


Figure 5. A Multi-echelon Inventory System
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central distribution centers will provide faster resupply than from the manufacturer (39:139).

The relationships between the plant, the distribution centers, and the warehouses in Muckstadt and Thomas' model are analogous to Air Force depots and bases. The rationale behind the military multi-level structure is to improve efficiency in providing services and to reduce total inventory investment from the level necessary to supply all bases individually.

The Base Pipeline Subsystem

Base-level organizations are the final destination for most assets tied up in the logistics pipeline. The actions taking place within base-level components of the system influence what is currently in the logistics pipeline and what will be in it in the future. The base-level subsystem will be discussed first because it is most directly affected by the ultimate consumers of supplies in the logistics pipeline. This section first discusses the general aspects of the base-level pipeline, then discusses the components of the base-level pipeline subsystem, and finally discusses the inventory and repair cycle models that have been used extensively to describe the base-level pipeline subsystem.

Recoverable Item Management. "Recoverable items represent an important subset of the total population of Air Force Logistics Command (AFLC) managed items" (9:281). This

is because reparable (or recoverable) assets may be repaired after failure and represent a significant inventory investment. "Recoverable items are typically expensive and their individual demand rates are usually relatively low" (38:472). There are approximately 180,000 Air Force reparable items whose inventories are valued in excess of \$30 billion (24:4-22), and they make up a large percentage of the Air Force's investment in spares. It is important, therefore, to understand how these assets flow through the base repair cycle system and where this system fits into the logistics pipeline.

The base repair cycle is the first echelon of a multi-echelon system like the ones illustrated in Figures 6 and 7. Whenever a reparable item fails, a maintenance specialist identifies the broken part and orders a replacement from Base Supply (8:7-2). If a spare is in stock in Base Supply, it is issued to the maintenance activity to expedite end-item repair. The failed part is removed from the end-item and sent to a maintenance shop to determine if base repair is authorized and feasible. If the item is repaired at base-level, it is turned-in to supply as "serviceable" and replaces the part previously issued (8:7-2).

Sometimes, however, the broken item exceeds base repair capabilities. If the item may be condemned at the base-level by either flight line maintenance or back shops, it is turned-in to Base Supply as "condemned." Base Supply then

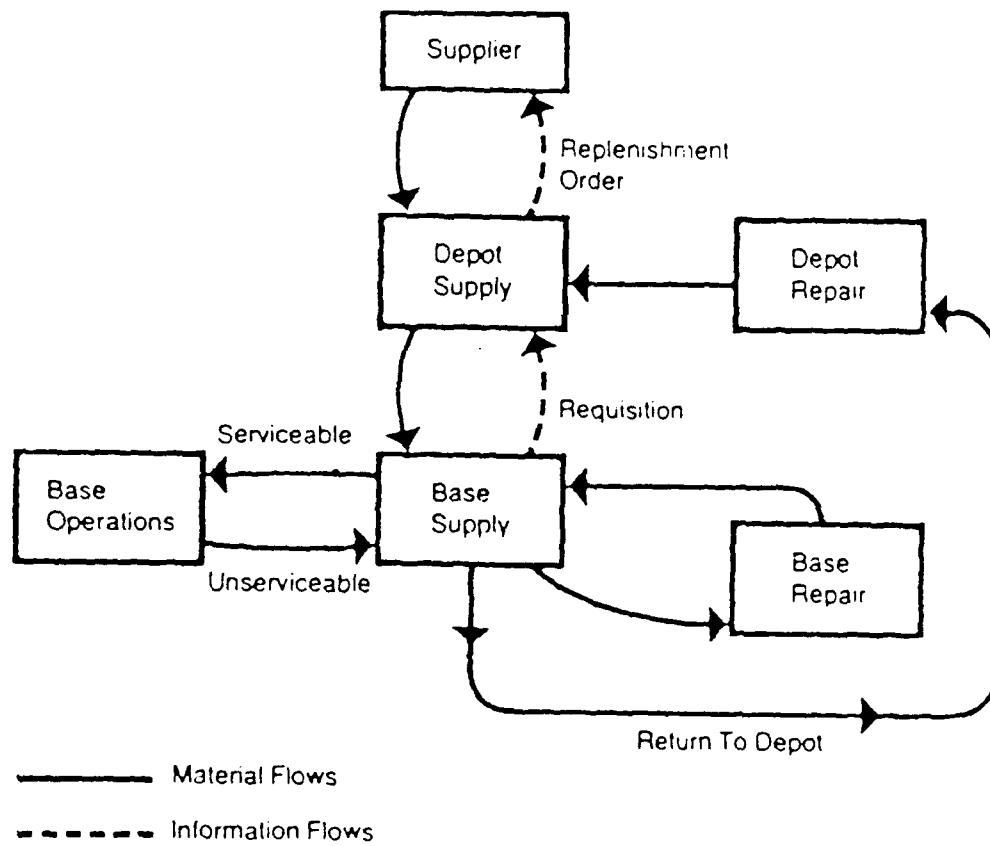


Figure 6. General Recoverable Item Flows
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PIPELINES

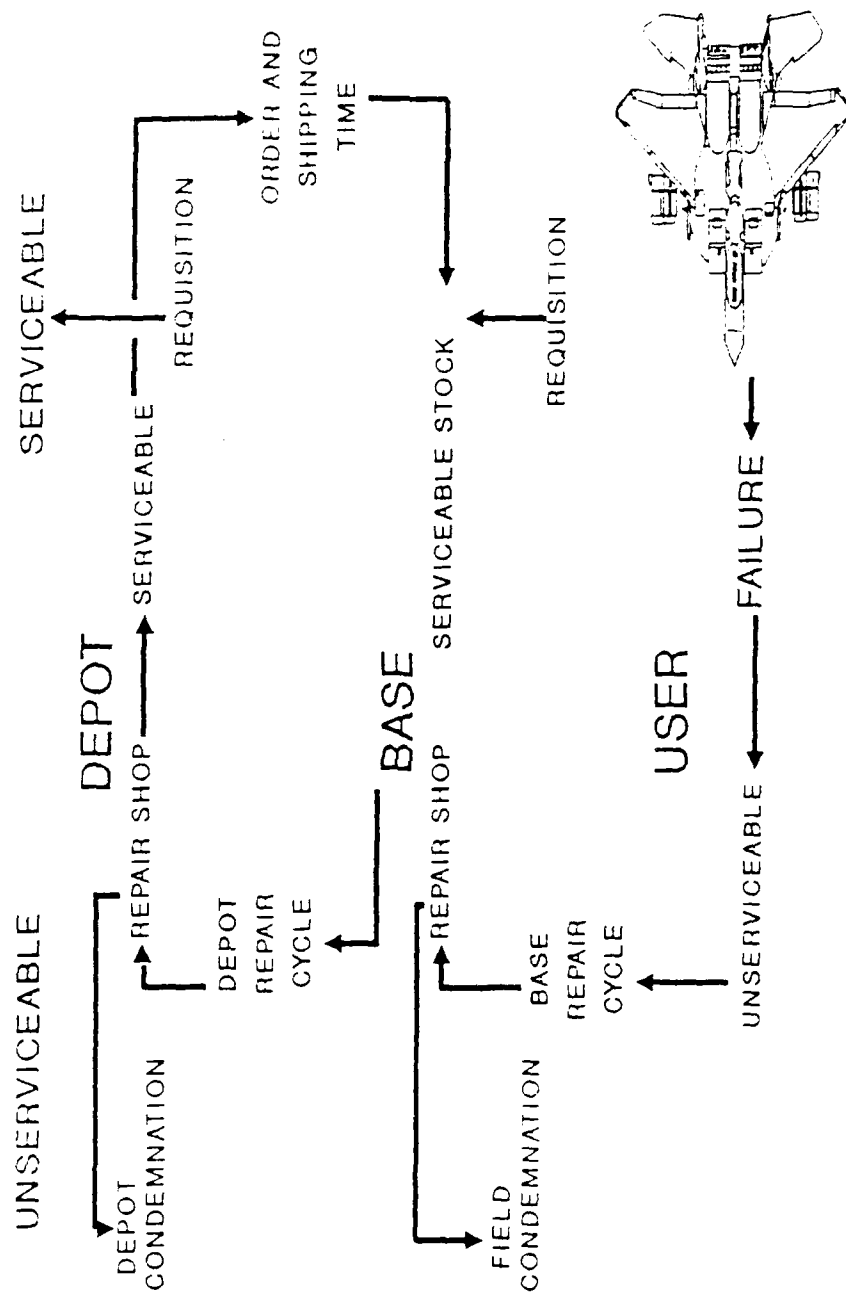


Figure 7. Recoverable Item Pipelines (8)

sends the condemned item to the Defense Reutilization and Marketing Service (DRMS) for salvage. Otherwise, the maintenance activity turns-in the item to Base Supply as "Not Repairable This Station" (NRTS). The item is held in supply until appropriate shipping instructions are received to send the item on to the responsible Air Logistics Center (ALC) for depot maintenance repair (8:7-2). The depot performs higher level repairs with the use of more sophisticated equipment and specialized skills (9:281). At the time of turn-in for a NRTS item, a requisition to the depot is made to bring the base stock level back to equilibrium for the original item issued (8:7-2). How Depot Maintenance repairs NRTS items is discussed later under "Depot Repair Cycle."

What if a serviceable replacement is not available in Base Supply stock? If the failed part is base repairable, it is repaired and replaced back on the end-item with no physical demand on Base Supply (although a requirement for the item is noted in the supply computer). The end-item repair, however, is delayed by the time required to repair the part. If the broken part is not base repairable, then a demand is made on Base Supply, creating a backorder (requisition) to the depot for a serviceable asset (8:7-3). Simultaneously, the unserviceable asset is sent from the base to the depot for repair (8:7-3).

When a spare is issued from Base Supply to maintenance, a clock starts to track the repair cycle time. When the

item is turned-in to Base Supply, whether in a serviceable, NRTS, or condemned condition, the repair cycle time ends as supply processes the turn-in. The repair cycle time is strictly monitored and recorded by the maintenance activity.

Supply Warehousing and Related Functions. The speed and accuracy with which property is processed through the supply warehousing system can greatly affect how much time an asset spends moving through the logistics pipeline. The key to an efficient warehousing process is to keep manual handling, cross hauling, and double handling of material to a minimum, and to eliminate backlogs and bottlenecks at material transfer points (21:3-2).

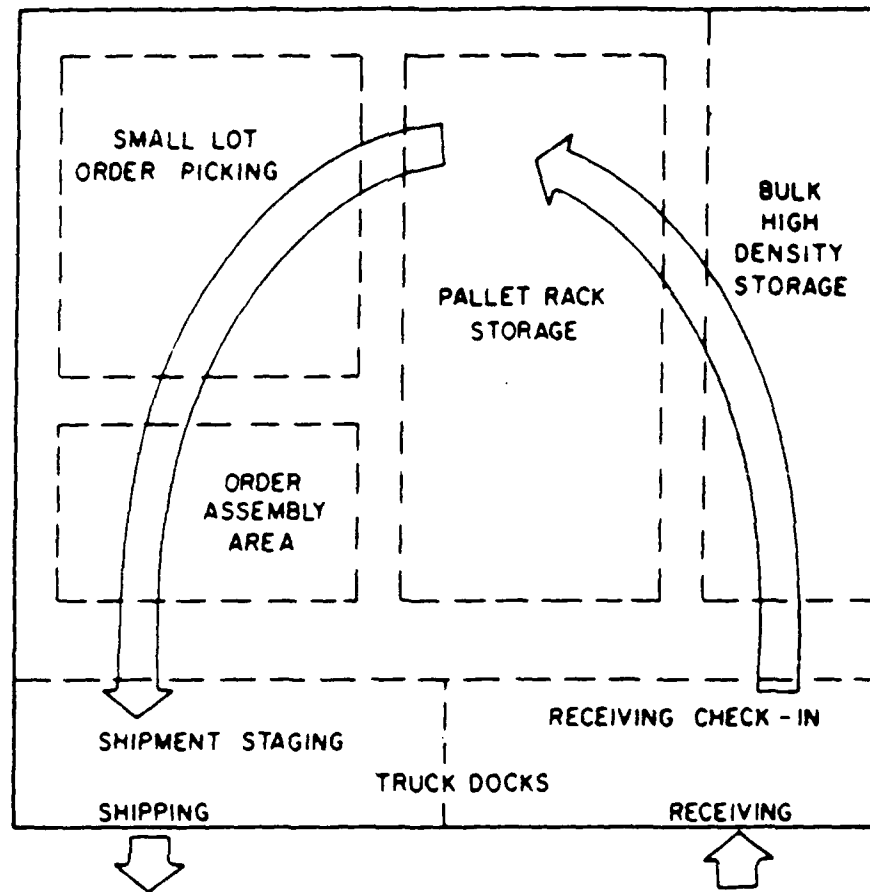
This section will look at how the general flow of property through a supply facility might affect this segment of the pipeline. Then, this section will look at how property is handled by individual functions of the supply warehousing system.

Flow Patterns. The flow of recoverable assets through a supply warehousing system greatly affects the movement time of an item in the pipeline. According to NAVSUP Publication 529, "material flow patterns in most warehouses take the form of either a cyclic flow or a straight line flow" (22:2-7). Figures 8 and 9 show typical cyclic and straight-line flow patterns in a supply warehousing function. The flow pattern used actually depends on such things as: the functional capability and

capacity of the facility; the relationship between the receiving and issue/shipping operations; and the relative size, weight, and quantity of incoming receipts and outgoing shipments.

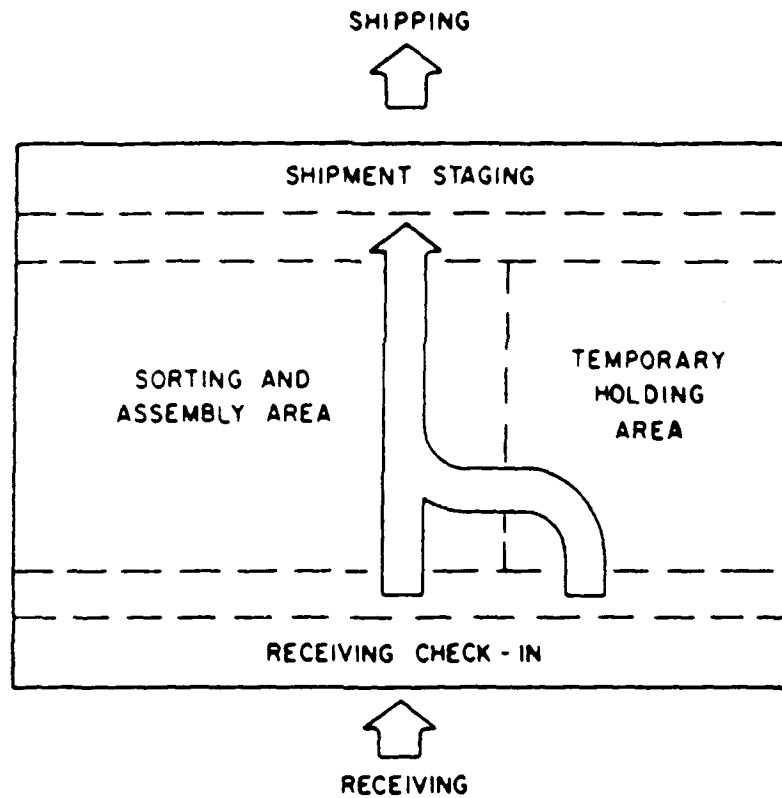
The cyclic flow pattern works best under conditions where handling of material is at a medium and low volume, and where receipts may be processed for intermediate storage and later issued or reshipped upon demand (22:2-7,9). The outgoing material may be issued/shipped in the same form as received, or it may be taken to a temporary holding bay, broken down into smaller units for order picking, and then consolidated into larger loads. Usually, the issue/shipping docks are located on the same side of the building as the receiving docks.

Straight-line material flow primarily applies to high activity distribution operations where intermediate handling operations are minimized, and emphasis is placed on "rapid and direct transfer of material from receiving to shipping" (22:2-9). An example of an activity which uses straightline flow is a high activity freight distribution center which receives truckloads of material, sorts them by destination, and immediately reloads outbound trucks, all without changing the physical characteristics of the loads. "In straight-line flow systems, the receiving and shipping docks are generally located on opposite sides of the building" (22:2-9).



TYPICAL CYCLIC FLOW PATTERN

Figure 8. Typical Cyclic Flow Pattern
Reprinted from: (22:2-8)



TYPICAL STRAIGHT-LINE FLOW PATTERN

Figure 9. Typical Straight-line Flow Pattern
Reprinted from: (22:2-10)

Storage may be included if material must be held for a short time while awaiting items arriving on another truck.

A typical Base Supply warehousing system is a combination of cyclic and straight-line flow patterns, where some of the incoming property goes directly from the receiving area to the delivery or shipping area, and some of the incoming property goes from the receiving area to storage, pending customer demand. Figure 10 shows how assets flow through the various functions of a standard base supply warehousing system (31).

Five basic supply warehousing functions specifically shown or implied in Figure 10 affect the movement of Air Force reparable assets through a supply warehousing system: receipt processing, turn-in processing, issue/shipping, pickup and delivery, and inspection. These five functions are discussed next.

Receipt Processing. "Prompt and accurate processing of receipts is a prime requisite of an effective supply system" (21:3-1). Figure 11 shows how property flows through the receiving process.

Commercial trucks delivering property going to base activities are spotted at the Supply Receiving Section truck docks for unloading (10:5-29). Supply Receiving personnel unload all property destined for the Base Supply account. When mixed cargo arrives, and most of the property is destined for the supply accounts, Supply Receiving

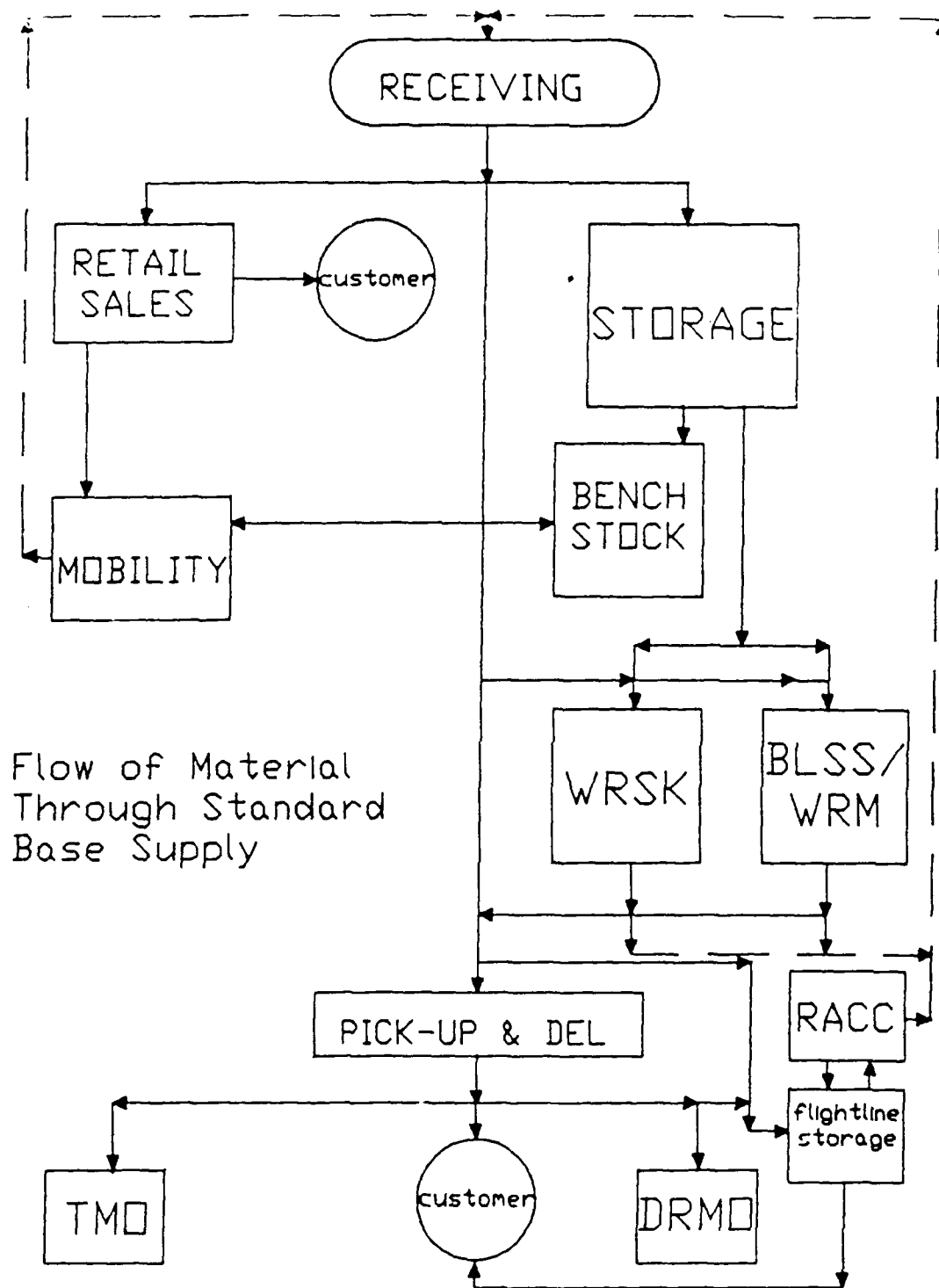


Figure 10. Standard Base Supply Material Flow (31)

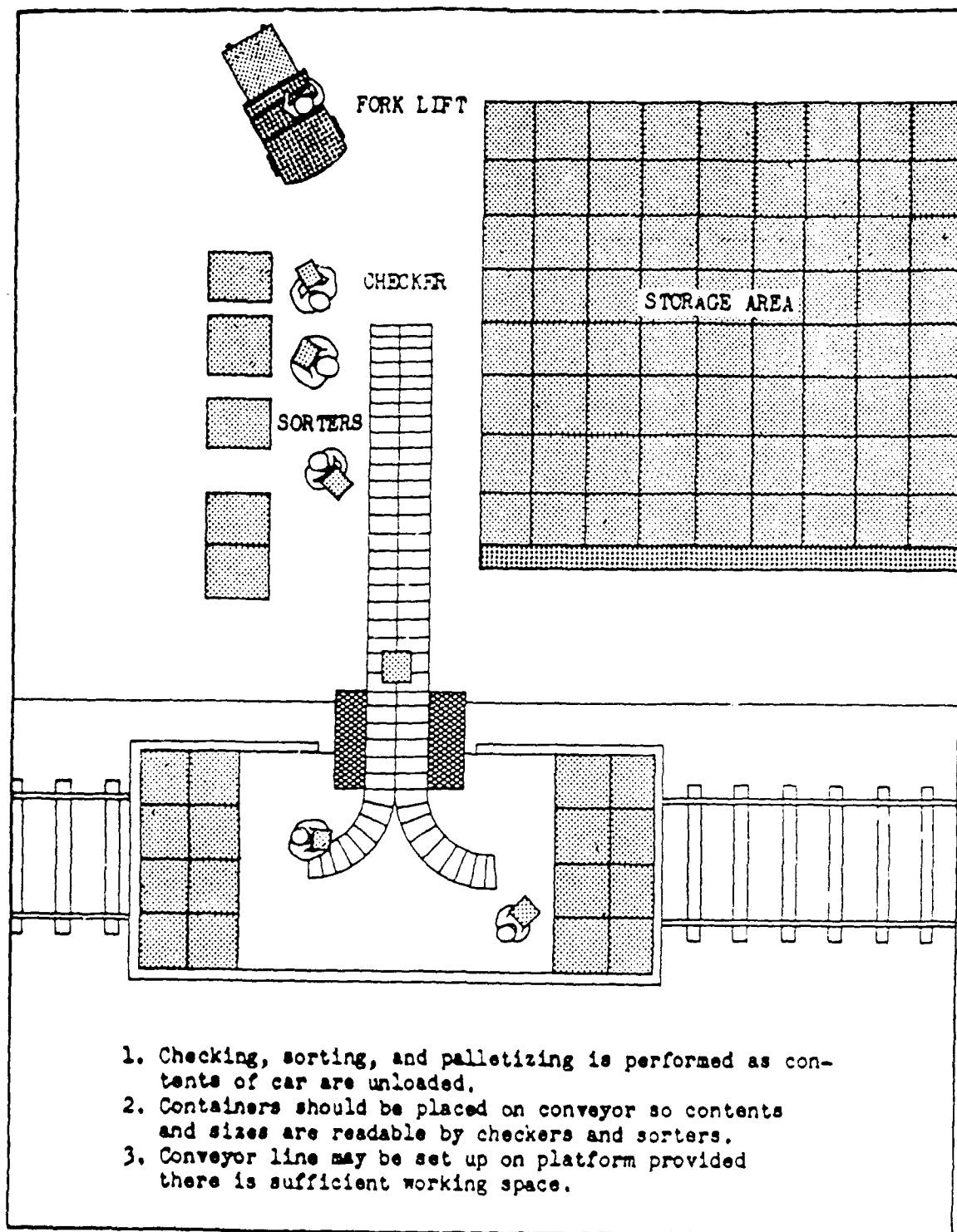


Figure 11. Material Flow through Receiving
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personnel will unload the property in the receiving area, if possible. There are specific periods of time (called free time) for which a carrier can be delayed before the Air Force must pay a penalty, so personnel must unload the property quickly to release the carrier on time. Demurrage charges may be levied for any amount of time the carrier is retained beyond the authorized free time (21:3-2).

As property is unloaded, it is forwarded to hold bays or tote boxes where it will wait for document processing which will output either a due-out release, notice to stock the property, or reject notice (14:10-12). Here, incheckers remove attached copies of receiving documents and compare the identity and quantity (14:10-10). If all entries are correct, the incheckers sign their last name and enter the correct Julian date onto the document. For efficient record keeping, the hold bay or tote box number is written on the receipt document so that when the due-out release or notice to stock is received, the material can be located quickly (14:10-13). It is imperative for Receiving Section personnel to check the hold bays and tote boxes daily and follow through with the processing of delayed material.

Once the due-out release or notice to stock has been properly matched to the receipt, the property is transferred to the next supply function for further processing (14:10-13). Receipts of recoverable items that have released to an existing backorder (due-out release) may go to the War

Readiness Section which maintains deployable assets, such as War Readiness Spares Kits (WRSK), or Base Level Sufficiency Spares (BLSS) kits/War Reserve Materiel, or they may go to the Pickup and Delivery Section for direct delivery to the user (Figure 12).

Receipts of recoverable items that have produced a notice to stock will be sent to the appropriate holding area for intermediate storage pending the demand for issue or shipment (Figure 13). The length of time an item remains in storage depends solely on the timing of demands for it.

Turn-in Processing. As seen in Figure 14, the turn-in of recoverable assets is processed much the same as incoming receipts (31). Serviceable and unserviceable reparables are turned-in by Base Supply activities (WRSK, BLSS, WRM, supply point) or from maintenance activities to Base Supply's Repair Cycle Support Section. Personnel from either the Pickup and Delivery Section or the Reparable Asset Control Center (RACC) physically pick up recoverable items due-in from maintenance (DIFM) from Maintenance Reparable Processing Centers (14:13-47). The War Readiness Section may turn-in excess serviceable assets which trigger either a notice to stock and is returned to supply stock, or due-out releases to an activity with an existing backorder for the item, or is redistributed (shipped) to another base to fill a requirement there.

FLOW OF DUE OUT RELEASE

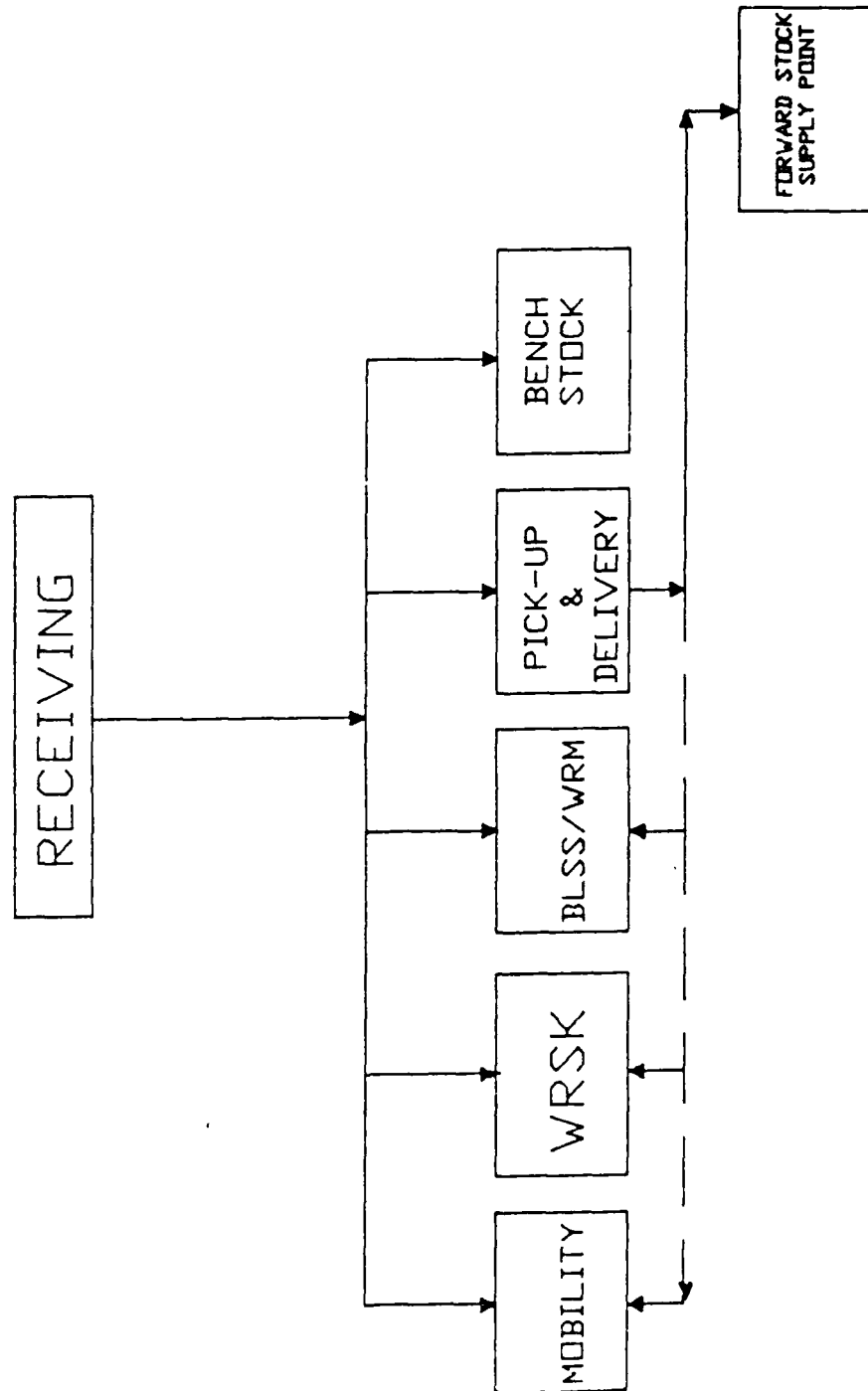


Figure 12. Flow of Receipt Due-out Releases (31)

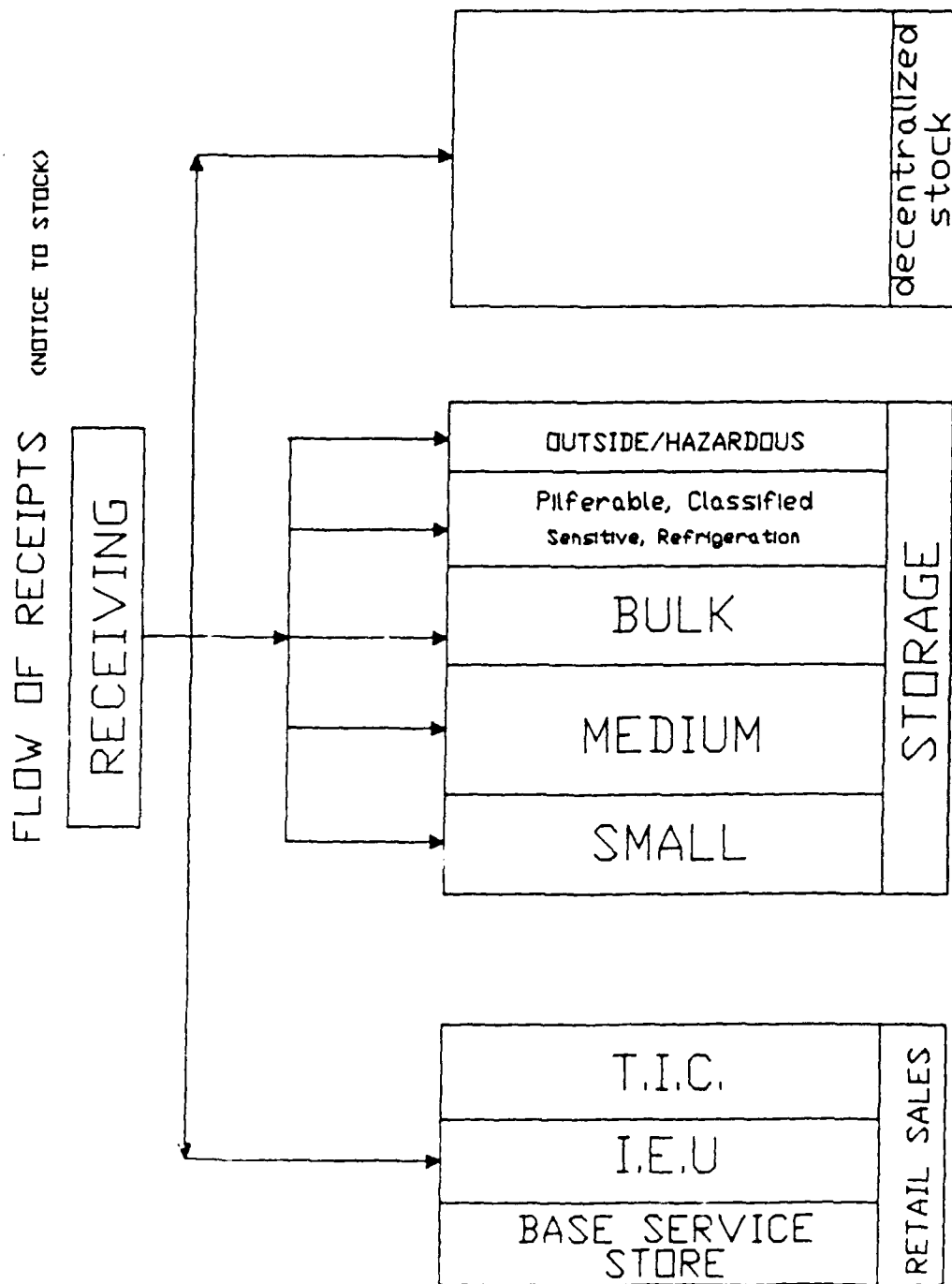


Figure 13. Flow of Receipt Notices to Stock (31)

FLOW OF "TURN-INS" THROUGH BASE SUPPLY

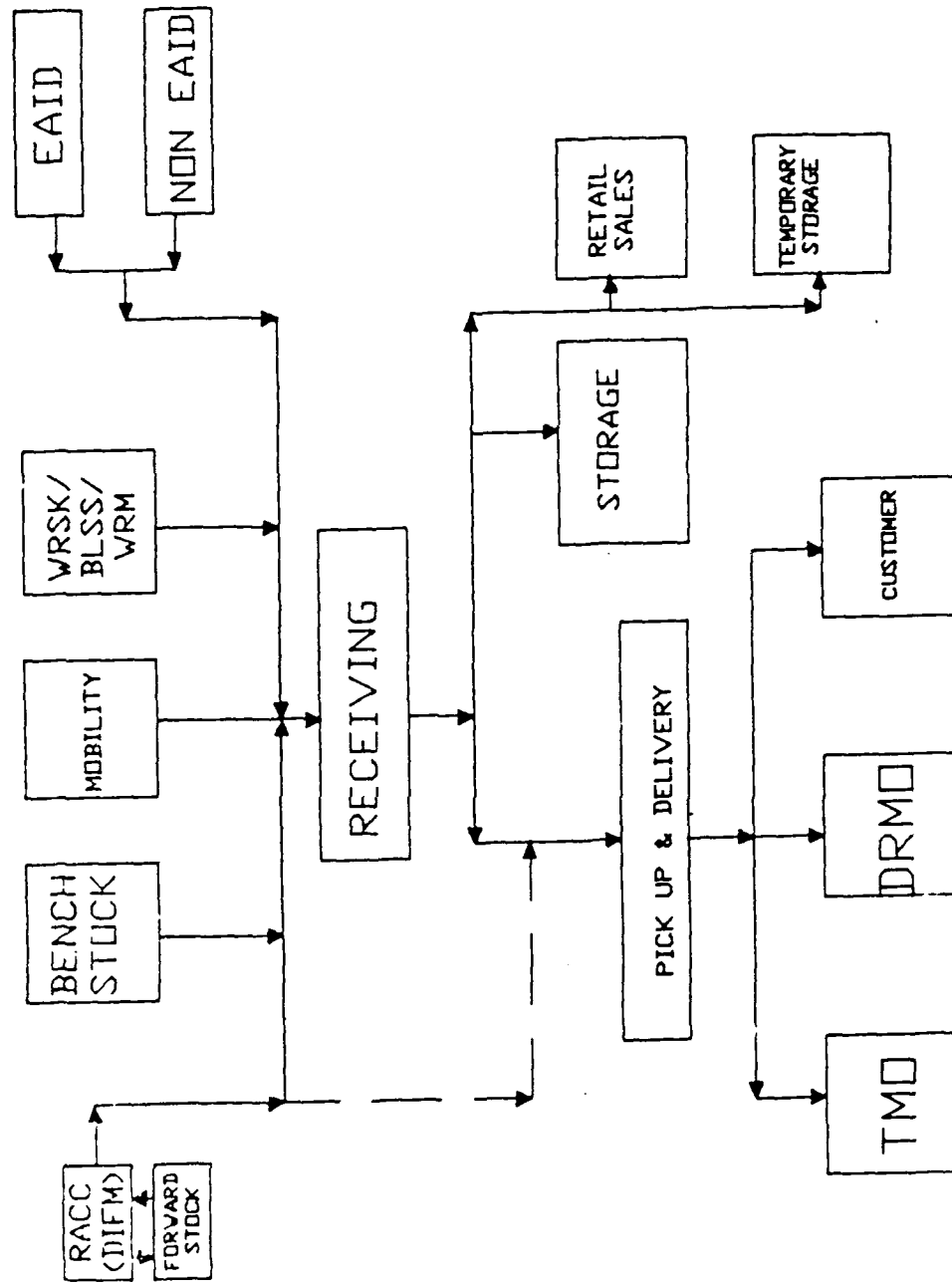


Figure 14. Flow of Turn-ins through Base Supply (31)

Unserviceable reparableables are turned-in as either Not Repairable This Station (NRTS) and prepared for shipment to depot-level repair, or as condemned and sent to the Defense Reutilization and Marketing Service (DRMS) as salvage. As with regular off-base shipments, NRTS items are physically packed and shipped by the Transportation Management Office (TMO). Condemned recoverable items are transported to DRMS by Base Supply's Pickup and Delivery Section.

Issues/Shipments. As with due-out releases, recoverable assets held in stock are issued to accounts maintained by Base Supply, such as WRSK, BLSS/WRM, and supply points, or they are issued directly to the requiring activity via the Pickup and Delivery Section. Figure 15 shows the issue process (31).

Whenever a shipment is made to an off-base activity, the supplies are picked from the storage location by Storage and Issue personnel and checked for proper quantity, identity, packing, and documentation. Once the supplies for shipment are selected and checked, they are moved to an area, such as the Packing and Crating Section of Transportation, to be consolidated with other shipments, or they are shipped direct from the Base Supply Receiving area (21:3-15). Transportation and delivery of off-base assets will be discussed in greater detail in a later section.

FLOW OF ISSUES

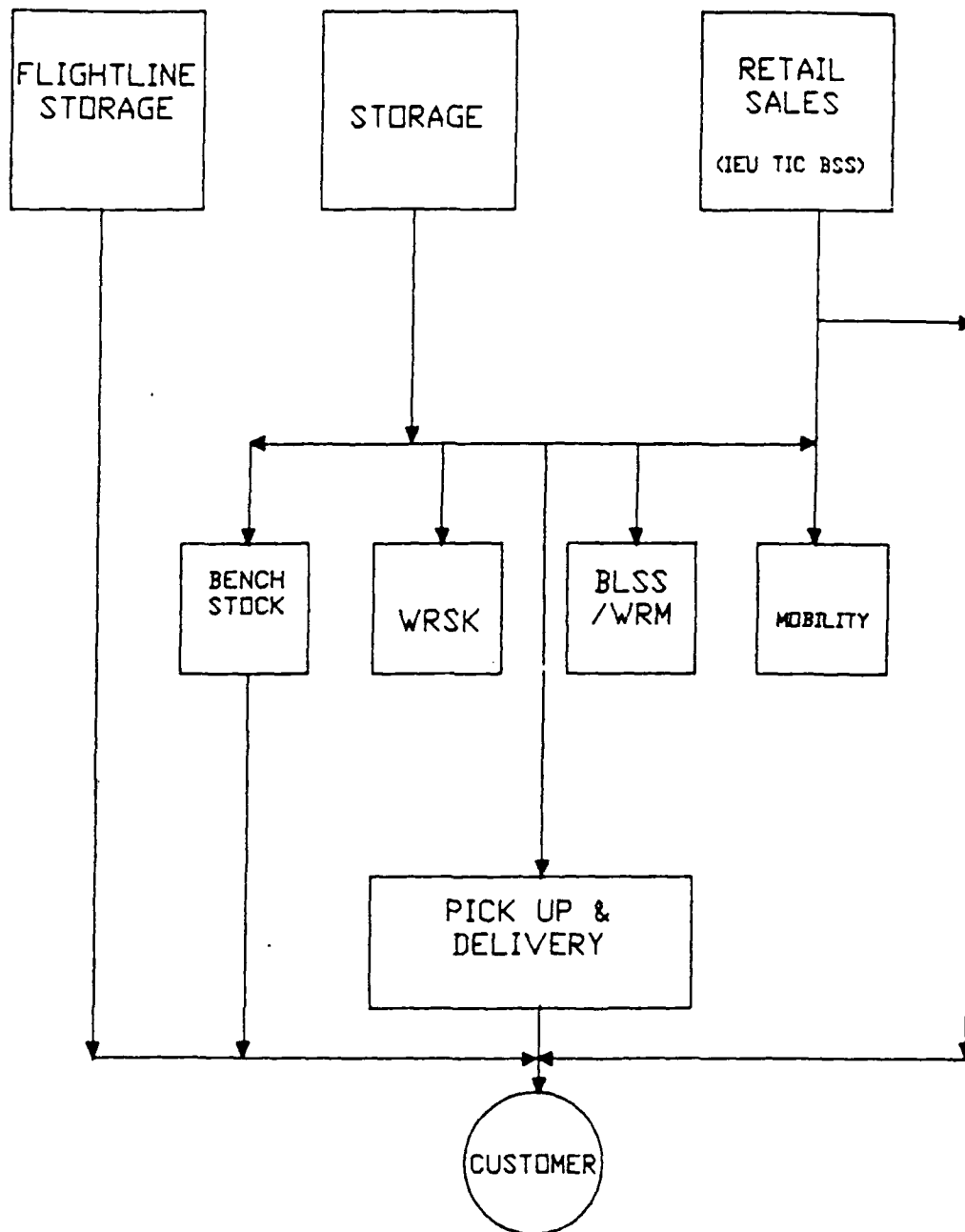


Figure 15. Flow of Issues from Stock (31)

Supply Points. "Supply points are additional warehouses located within or next to the activities they are supporting" (14:24-18,19). Items stocked in a supply point must be necessary to meet the needs of the activity it supports, although more than one maintenance function can draw common items from a single supply point (14:24-19). Base Supply is responsible for maintaining the accountability and control of assets through computerized supply point detail records (14:24-18).

To restock (issue to) a supply point, the maintenance activity requests an issue from the main supply stock using normal issue procedures (14:24-19). However, since the transaction is not used, but is merely a transfer of stock from one storage location to another, the transfer is not considered a demand, nor is the item considered consumed.

"All issues from a supply point are over-the-counter" (14:24-21). When a demand is placed on the supply point and the item is available, supply point personnel select the item from the bin and prepare an issue request. Fast moving items from supply points may be processed by supply personnel by using turnaround (TRN) procedures to record the demand data, rather than using normal issue procedures (14:24-21).

Reparable assets that have been repaired and turned-in serviceable to Base Supply may due-out release to a supply point if they are required to satisfy existing due-outs (14:24-22).

MICAP and Lateral Support. Although the goal of the Standard Base Supply System is to ensure that supplies are available when needed to keep a high level of mission capability, there are times when supply shortages occur (14:17-9). When this happens, depending on the need, urgency, and type of supplies required, Mission Capability (MICAP) requisitioning procedures are used. Maintenance personnel at base-level, for instance, must verify that the end-item is not mission capable (NMC) before MICAP procedures can be used.

The use of MICAP procedures means all efforts have been made by Supply and Maintenance personnel to locally resolve materiel shortage problems. Assets may be drawn from WRM to satisfy MICAP conditions (14:17-14). Bases may also try to obtain assets from other bases using lateral support for MICAP items (14:17-11). The ability of bases to make immediate availability checks for, and shipment of, needed assets make lateral support an effective way to obtain items quickly. Making use of other assets not readily available in Base Supply warehouses enables the Air Force to maintain its fleet in a higher state of mission readiness than would otherwise be possible and allows it to do so with a smaller number of assets in the logistics pipeline.

Pickup and Delivery. Pickup and Delivery is responsible for transporting issues and due-out releases from Supply to its customers, for picking up turn-in items from base activities and transporting them back to supply, and for transporting excess or condemned assets to DRMS (14:10-12,13). Pickup and Delivery is responsible for delivering the assets directly to the requesting base organization or to the applicable supply point.

The on-base delivery priority assigned to an item directly influences how expeditiously an issue request is processed (14:11-15). Table 1 shows the Air Force maximum allowable delivery time of supplies to customers. The time requirement depends upon the end-item affected, and directly impacts the pipeline of assets on a base.

Inspection. Incoming items or turn-ins that Inspection personnel find damaged or misidentified will cause significant delays in delivering assets to the customer. Inspection of material takes place throughout the entire supply warehousing process, and is not necessarily limited to formal Supply Inspectors. For instance, a preliminary inspection is made by Receiving personnel while unloading the carrier's vehicle (21:3-2). If there are shortages or damage, unloading will be suspended, if practical, until the carrier's representative can inspect the load. As property arrives at the Receiving Section, it is more thoroughly inspected for damage and

Table 1. Delivery/Maintenance Repair Priority Designators
Reprinted from: (14:11-62)

Supply Delivery Priority Designator	End Item Application	Supply Delivery Time
1	* Aerospace vehicles or support equipment on alert status, war plan, or national emergency missions.	ASAP, but NLT 30 minutes
2	* Primary mission air vehicles, missiles, CEM systems, and support equipment	ASAP, but NLT 30 minutes
3	* Primary mission air vehicles, missiles, CEM systems, and support equipment undergoing repair. * Spares not available in Supply. * Critical end-items and reparable spares. * Overdue scheduled maintenance. * Base emergency vehicles.	ASAP, but NLT 1 hour
4	* Routine or scheduled repair of primary mission air vehicles, related equipment, and repair cycle assets.	ASAP, but NLT 4 hours
5	* Fabrication and repair of aeronautical items. * Bench stock requirements.	ASAP, but NLT 8 hours
6	* Fabrication and repair of nonaeronautical items. * Work orders.	ASAP, but NLT 12 hours

correct identification by Receiving personnel as it is inchecked and processed.

There are a number of routine tasks performed by Inspection personnel which may affect property flow, such as changing the stock number, unit of issue, and quantity if needed (14:14-30). When items are received in unserviceable (repairable) condition, Supply inspectors also note the condition on the receiving document, which will affect how the receipt is processed. Supply inspectors send the repairable items to the repairable storage area until disposition instructions are received by higher authority (14:10-47). Repairable assets held at base storage areas may contribute significantly to the overall size of the pipeline.

Each of the activities within the supply system contribute to the handling of assets which incurs processing time thereby enlarging the base repairable pipeline. Receiving, inspection, warehousing, delivery, and turn-in processing are all necessary to make the correct items available to Base Supply customers when needed. Efficiency and accuracy should be attained in each of the supply processes to minimize the number of assets within the supply component of the base pipeline subsystem. Base-level maintenance is the primary customer of Supply for repairable assets. The base-level maintenance process will be discussed next.

Base-level Maintenance. As stated in Chapter I, maintenance activities serve to keep weapon systems and assets in working order, and restore them to serviceable condition when they break. Air Force maintenance organizations follow standard techniques to maintain end-items and reparable spares. The general maintenance process is reviewed first and is followed by a description of Base Maintenance organizations.

The Maintenance Process. Maintenance processes can be divided into the two categories: corrective and preventive maintenance (6:35):

1. Corrective Maintenance - the unscheduled actions accomplished, as a result of failure, to restore a system to a specified level of performance.
2. Preventive Maintenance - the scheduled actions accomplished to retain a system at a specified level of performance by providing systematic inspection, detection, servicing, condition monitoring, and or replacement to prevent failures.

While corrective maintenance takes place only when a failure occurs, preventive maintenance takes place on a recurring basis. If properly scheduled and performed, routine inspections and replacements of worn items may prevent major system failures. Scheduled inspections identify failures of individual system components that could lead to an entire system failure. Both preventive maintenance and corrective maintenance serve to improve overall system availability; however, by its unpredictability, corrective maintenance has a greater

impact upon base-level inventory policy. System availability drives the amount of maintenance resources needed to keep a system operational.

Juran defined availability as "the probability that a product, when used under certain conditions, will perform satisfactorily when called upon" (36:190). The life of a system may be divided into two segments: the time it is in operational readiness, and the time it is unavailable for use. The unavailable period may be divided into periods of active repair and periods waiting for parts and paperwork. Figure 16 shows the divisions between uptime and downtime according to Juran (36:190).

Blanchard describes a similar breakdown of the maintenance downtime. He divides the maintenance period into active corrective and preventive maintenance times, logistics delay time, and administrative delay time (6:36). Figure 17 shows the process of corrective maintenance from the time the failure is detected to the time the system is again available for use (6:37). The process begins with four steps from detection of the failure to just achieving access to the failed component. Then, the component may be removed and replaced with a spare, or removed, repaired and replaced on the system. Following reassembly, any final adjustments must be made before an inspection of the repaired system. Halpern portrays a like process for corrective maintenance action. h. lists the corrective

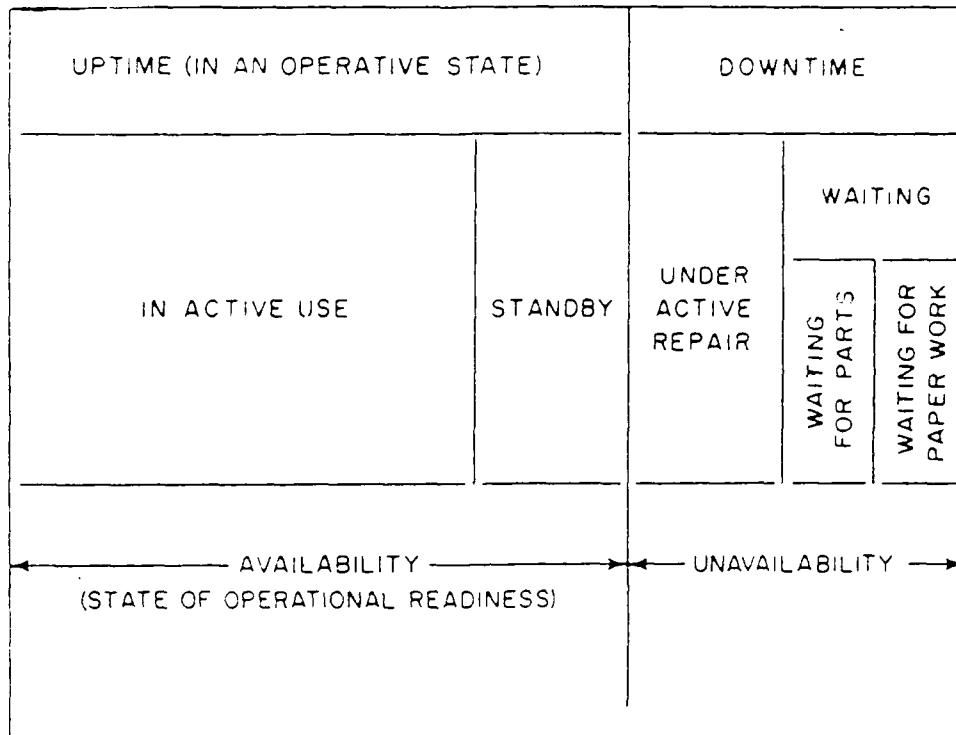


Figure 16. Ingredients of Availability
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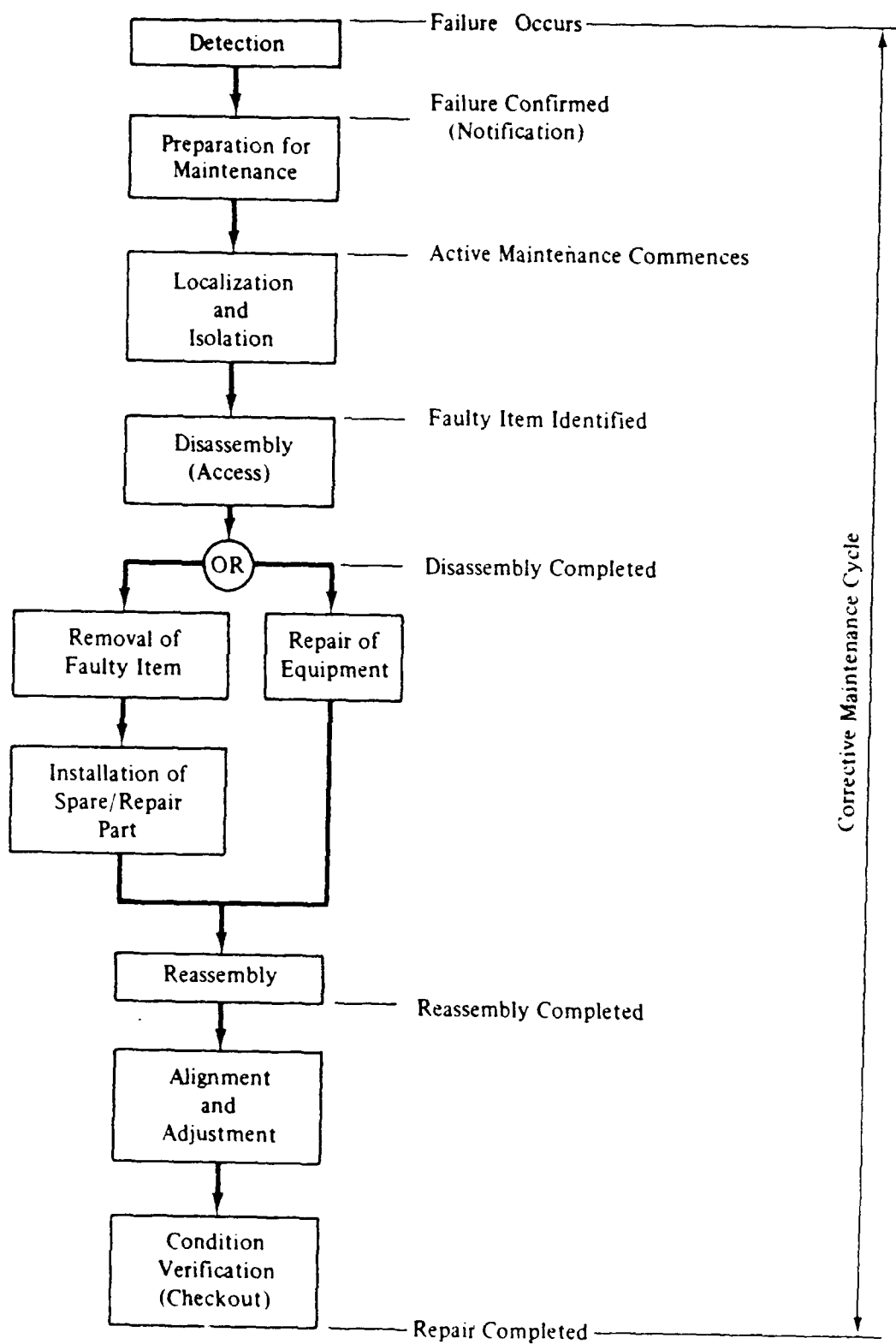


Figure 17. Corrective Maintenance Cycle
Reprinted from: (6:36)

maintenance activities as follows: (1) Localization, (2) Isolation, (3) Disassembly, (4) Interchange, (5) Reassembly, (6) Alignment, and (7) Checkout (30:352).

Blanchard's and Halpern's descriptions of the maintenance process are essentially the same with the exception that Halpern's description begins after detection has already occurred. The other seven steps of Halpern's model are identical where "interchange" corresponds to "Removal of Faulty item" and "Installation of spare/repair part" in Blanchard's model. Understanding the flow of materials in a simplified example of the repair process is basic to the description of the base-level subsystem of the logistics pipeline.

The corrective maintenance process may be represented by the length of time for each repair on the system. A commonly used measure for the aggregate of all repairs to a particular system is the Mean Time To Repair (MTTR) (30:352, 6:35). Repairs to a particular system often fall within a normal distribution about the MTTR. The MTTR is an approximate measure of the "maintainability" of a particular system (36:191), while the Mean Time Between Failures (MTBF) approximates the "reliability" of the system (2:A-1,2). Highly reliable and easily maintainable systems require less maintenance action and thus less pipeline stock for continued support.

Reparable spares in the Air Force inventory are handled by a maintenance system similar to the ones discussed by Blanchard and Halpern. As failures are discovered through daily operational inspections of weapons systems and periodic functional checks of spare parts, repairable assets enter the base-level repair pipeline. The length of time that repairables stay in this repair process, and the frequency with which they require corrective maintenance, affect the total quantity of assets needed to fill the base subsystem of the logistics pipeline. The next section identifies the primary maintenance organizations responsible for keeping repairable assets moving through the base-level pipeline.

Base Maintenance Organizations. Maintenance organizations at the base level perform both on-equipment and intermediate level maintenance (56:8-11). On-equipment maintenance includes more routine removal and replacement types of tasks while intermediate maintenance requires more extensive testing plus removal, repair and replacement of smaller components to the system. The organizations that actually perform the flight line repairs and more specialized intermediate maintenance vary by major command. Three primary types of maintenance organizational structures exist; the first is the Specialist Oriented Maintenance Organization (SOMO), the second is the Combat Oriented Maintenance Organization (COMO), and the third is

the Readiness Oriented Logistics System (ROLS) (56:8-25,27).

Under the SOMO organization, Maintenance Control performs the bulk of the planning, scheduling and directing tasks. Maintenance Control determines the priority of assignments and schedules maintenance accordingly to meet sortie taskings. Maintenance Control is referred to as the "nerve center of the entire maintenance complex" (56:8-25).

Also under SOMO, Organizational Maintenance Squadrons perform routine flight line maintenance and repairs (56:8-26). The crew chiefs are not specialists, but must call in other technicians from Field Maintenance, Avionics Maintenance, or Munitions Maintenance for more complex system analysis and repairs.

The COMO organizational structure, used by the Tactical Air Command, combines many of the skills found in Organizational, Avionics, and Munitions Maintenance Squadrons into the Aircraft Generation Squadron (AGS) (56:8-28). Within AGS, Aircraft Maintenance Units (AMUs) are assigned to particular squadrons of aircraft and perform the majority of on-equipment maintenance. The last major change under COMO was to move most of the supervision out of Maintenance Control and make AGS responsible for planning, scheduling, and meeting sortie taskings.

COMO is a relatively new maintenance organizational structure, designed to bring many specialized tasks under

one organization that is closer in proximity and orientation to the mission requirements of the wing. Movement of assets may be reduced, by the co-location of specialists and crew-chiefs, thereby decreasing pipeline time for flight line repairs. Capabilities may be duplicated by the existence of multiple AMUs to perform flight line maintenance. Under the SOMO structure, centralized scheduling may lead to the maximum use of repair capacity while the AMUs under COMO may be under- or overused (56:8-28).

Prompt preventive and corrective maintenance are necessary to ensure maximum system availability and operational readiness. The base-level repair system must make optimal use of local repair capacity while minimizing administrative delays and movement of assets between units to provide rapid resupply of repaired assets. Both SOMO and COMO organizations use maintenance processes similar to the ones described earlier to perform repairs.

In both SOMO and COMO, more specialized repairs are performed away from the flight line in the repair shops. Maintenance control records the movement of these broken assets through the maintenance complex and processes the requests for supplies needed to perform repairs. Repaired assets are then returned to the aircraft, Base Supply, or supply points that store parts nearest to their points of usage. Through an efficient base repair and distribution

system, total quantities of assets needed to support the base-level pipeline are minimized.

The Customer Order Cycle. Base-level maintenance organizations are the primary customers of Base Supply. Maintenance technicians use spares to repair end-items and thereby resupply base stocks with repaired assets. Stock and Lambert pictured the customer order cycle as including the functions shown in Figure 18 (52:504). This is comparable to a portion of the base-level supply to maintenance relationship where demands are created by component failures and resupply is accomplished through the base-level repair cycle.

The processes involved with the customer order cycle begin with customer order preparation, order transmittal to the supplier, and order entry into the supplier's system. Once the order is entered, the supplying organization must check its inventory balance and fill the order from stock or schedule production. Once the item is available, it is pulled from stock or production facilities and delivered to the customer. Scheduling production when stock is unavailable is comparable to base maintenance organizations filling requirements through repairs of broken parts. While Stock and Lambert's description of the customer order cycle was designed for a manufacturing firm, the next sections document similar flows of assets through the base repair cycle system.

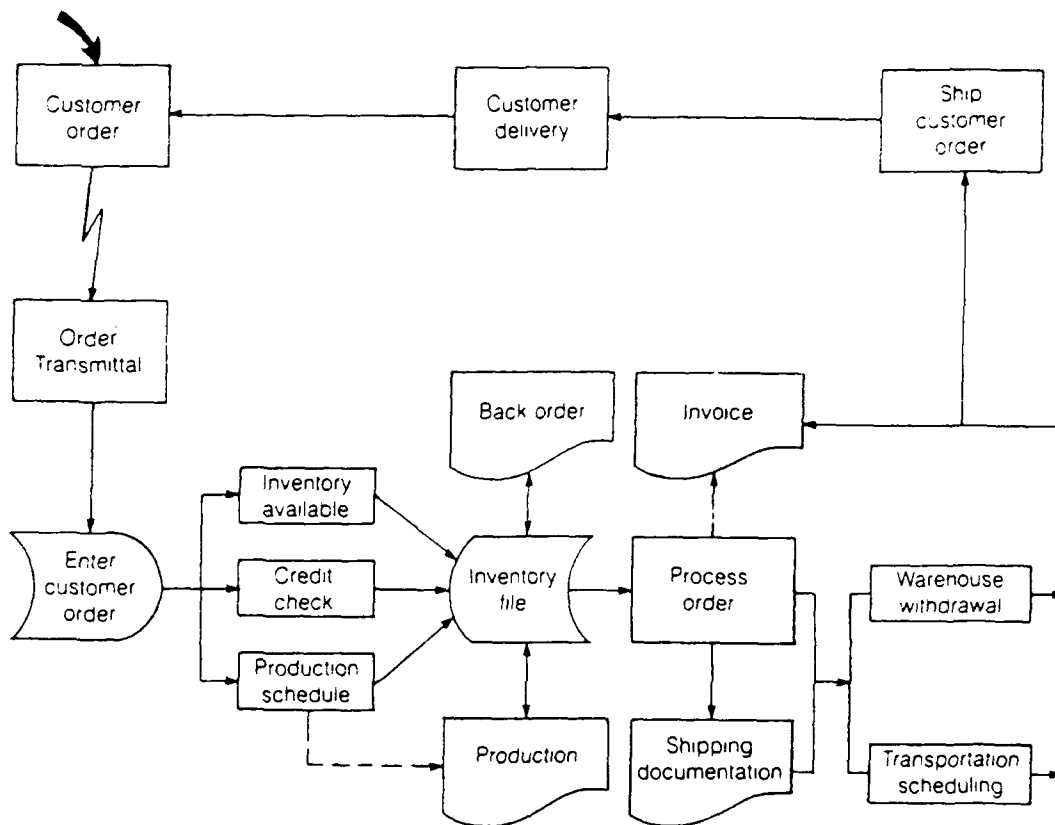


Figure 18. Customer Order Cycle
Reprinted from: (52:504)

Base Repair Cycle Maintenance Actions. Carroll

Widenhouse, a professor at the Air Force Institute of Technology, developed a pipeline model of the base repair cycle system emphasizing maintenance actions and information flows (57:2). This model is another visualization of the base repair cycle pipeline (Figure 19). Information flows follow the routing of paperwork through the system.

The work order, Air Force Technical Order (AFTO) Form 349, initiates the maintenance activity. An AFTO Form 350 is attached to the removed item and used to document the corrective maintenance action taken and the assets's identity. Repaired assets are coded with an Action Taken Code (ATC) indicating that the item was either repaired, condemned, NRTS, or bench checked and found serviceable. The item is turned-in to supply with the AFTO Form 350 specifying the appropriate action taken. NRTS assets are sent on to the depot for repairs. Repairs, NRTS, and condemned assets result in a demand being placed on Base Supply; assets bench checked and found serviceable do not. A serviceable asset is issued from Base Supply to satisfy a demand if one is available. If not, the requirement must be satisfied by either base-level repair, depot stock, or depot-level repair.

Appendices B and C give more detailed descriptions of the base-level repair cycle demand process and information

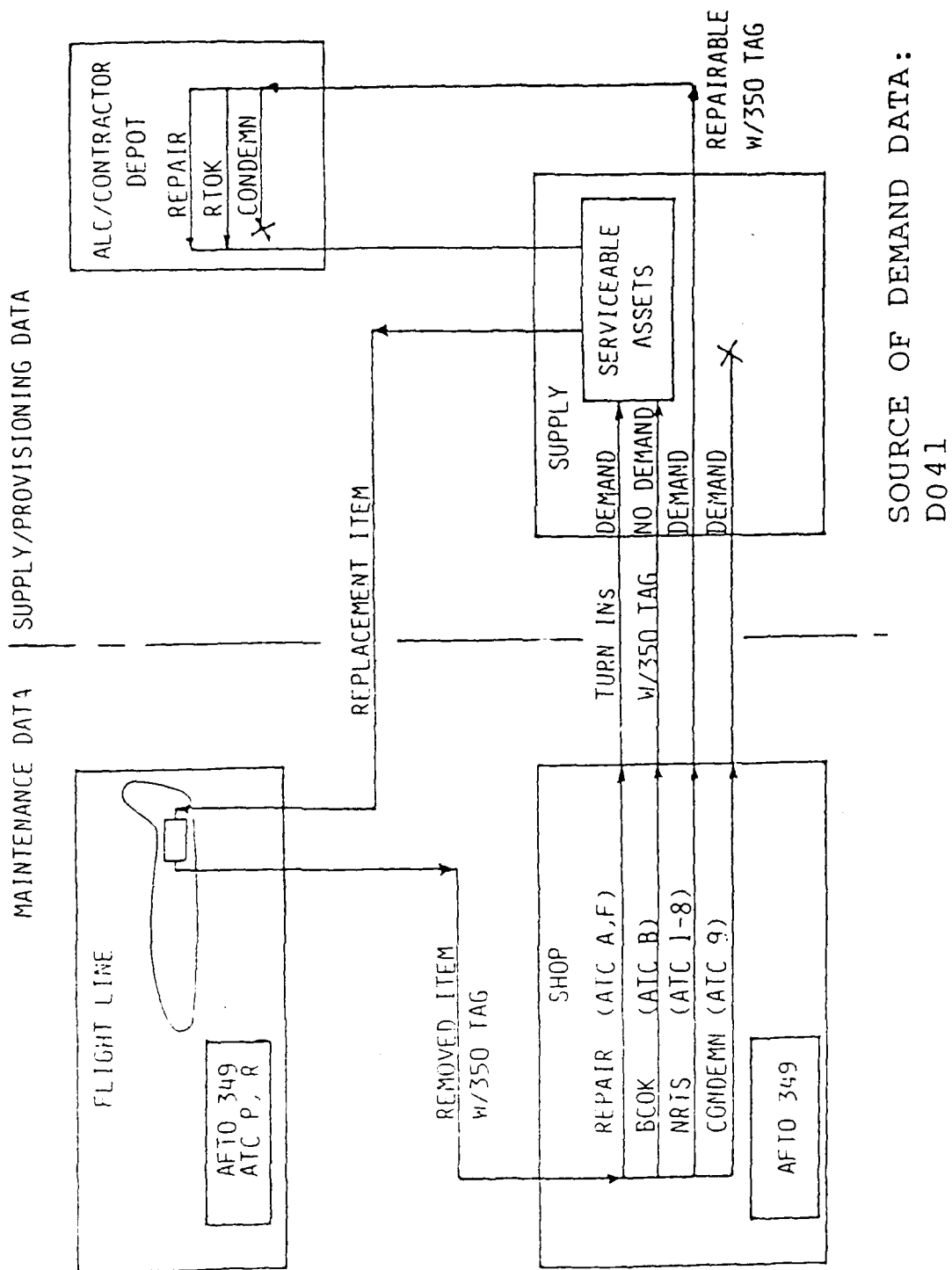


Figure 19. Maintenance Pipeline Model (57)

flow. The Repair Cycle Demand Level (RCDL) Model which determines the stockage requirement for reparable items at the base-level is discussed next.

The Repair Cycle Demand Level. The RCDL inventory model, which manages the one-for-one requisitioning of reparable items to the depot, was developed in the 1960s (7:21). The RCDL model treats each item independently and is used to establish spare stockage levels in the Standard Base Supply System (SBSS) according to the demonstrated repair capabilities of each individual base. The stock levels of spares are calculated as a function of pipeline time and are set to cover for an asset undergoing base-level repair and those in the depot-to-base replenishment cycles, with a fixed safety level added for protection against stockouts (8:7-4). The RCDL model is actually an (S-1,S) inventory policy.

The S-1,S inventory policy is a continuous review inventory system where the total stock on-hand plus stock on-order minus the backorders always equals the spare stock level, S. The S-1 is the reorder point and the S is the spare stock or demand level authorized for base stockage covering pipeline time and protection against stockouts (8:7-4).

Under the RCDL model, when the inventory balance falls below S, an order is placed to replenish the stock level. Ordering replacements when the on-hand inventory balance falls below S, is necessary to maintain the appropriate number of spares in the depot to base replenishment pipeline.

Base Stockage Model (BSM). To Feeney and Sherbrooke, conventional pipeline models like the SBSS RCDL model fell short of the mark in establishing accurate stock levels because they ignored unit cost (33:43). In 1963, Feeney and Sherbrooke developed the Rand Base Stockage Model, "a base-level stockage policy for recoverables which considered the level of system support provided by varying levels of inventory investment" (Figure 20) (42:22). Under the RCDL model, items having the same demand characteristics would receive the same stock level even though their unit prices may differ. Feeney and Sherbrooke argue, however, that a better stockage policy would be to stock a larger quantity of low cost assets and rely on premium transportation to expedite high cost items from the depot to base level when needed (33:43). The logic behind this argument was based on previous studies which revealed evidence that most reparable spares experienced low and highly variable demand (42:23). The cost trade-off, then, minimizes the number of expected backorders subject to a budget constraint.

The Base Stockage Model considered resupply time as base repair cycle time, depot resupply cycle time or some combination of both. Previous research found that routine base repair cycle times averaged one week or less. Order and shipping time between the base and depot was assumed to have a mean of 6.74 days and a standard deviation of 4.43 days (42:23,24).

Flow of Serviceables and Unserviceables

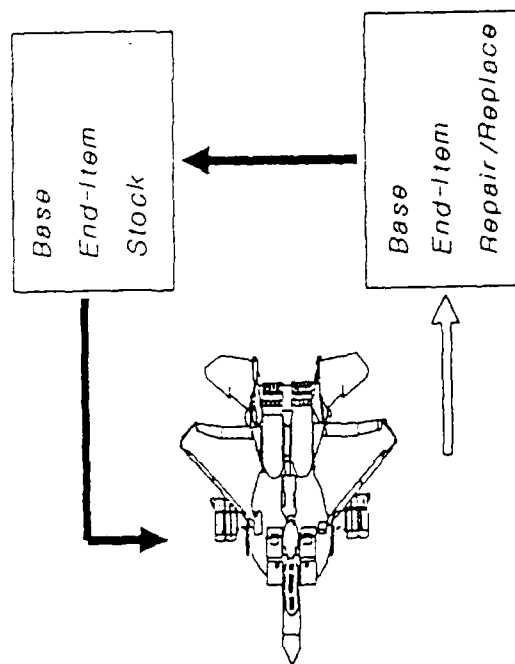


Figure 20. Base Stockage Model (8)

The base repair cycle system contains numerous assets; each revolves through the storage, distribution, usage, and maintenance components in the base pipeline subsystem. The RCDL and Base Stockage models describe this movement at the base-level and provide good examples for understanding the base-level pipeline. The model presented in the following section describes the movement not only at the base-level, but between the base and depot as well.

Base-level Replenishment Lead Time. The base-level processes for ordering and receiving goods are similar to those used by other organizations. Tersine explains one conceptualization of the order cycle for firms obtaining materials from suppliers outside their organizations (Figure 21) (54:12).

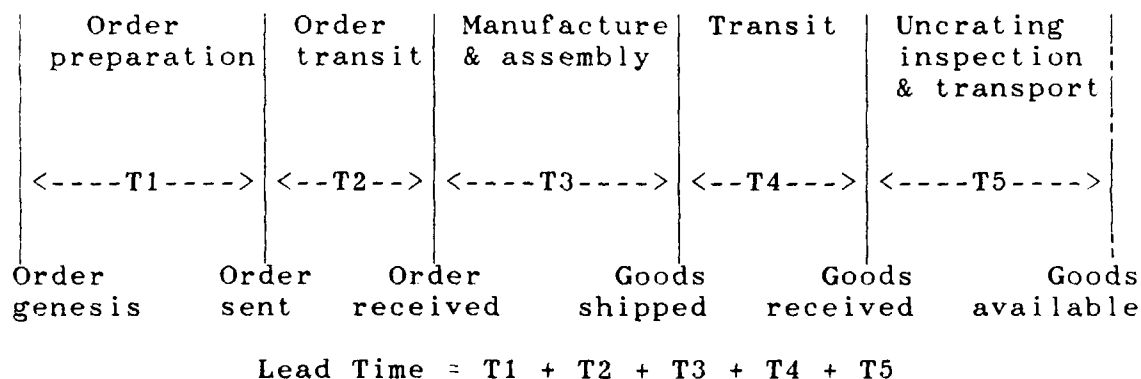


Figure 21. Elements of the Order Cycle (54:12)

Total lead time is divided into five distinct time periods: (1) order preparation; (2) order transit; (3) manufacture and assembly; (4) material transit; and (5)

uncrating inspection and transport. The duration of each order cycle component affects the total pipeline quantity needed to keep the using organization stocked with supplies. Yet only the first and last of these five processes is directly controlled by base-level organizations. In the Air Force logistics pipeline, base-level organizations can only influence the duration of the middle three processes through need prioritizing schemes.

Each process under Tersine's order cycle roughly corresponds to similar interactions taking place between the base and the depot. Base Supply establishes requisitions to fill routine stock replenishment requirements and maintenance backorders. Order transit time may vary with the urgency of the order. Factors outside the control of both the depot and base may affect the length of time needed to transmit the order. Requisitions may be delayed by equipment failures or by mishandling by personnel at either the base or depot. Manufacture and assembly time may be compared to the time it takes to pull an asset off the shelf, procure a new spare, or to fix a broken spare awaiting repair at the depot. The length of time needed to fill an order will depend on the stockage policies, funding constraints, and repair capacity. Transit/shipping times between the depot and base may differ between priorities, across longer distances, and between various modes of shipment. Transit times greatly affect the total order

cycle time. Finally, uncrating, inspection, and transport are activities undertaken by Base Supply to deliver the asset to its ultimate destination.

The processes involved between base and depot affect the total lead time between initial receipt of an order and satisfaction of the need. The length of time it takes to process and receive the order affects the amount of pipeline stock needed to keep base-level activities running during the replenishment cycle. Transit and order filling time are dependent on the distribution and priority systems.

The next section of the literature review addresses the distribution system as it relates to pipeline management. The bulk of pipeline assets are tied up in distribution channels of one form or another. Managing the transportation system within the logistics pipeline presents an exceptional challenge to logistics managers. Numerous shipping modes exist which affect the speed of asset delivery. These modes, chosen to provide timely delivery, yet minimize total costs, have a great effect on the overall logistics pipeline.

Transportation Management

Logistics naturally involves the transport of goods from the place they are produced to the place they are consumed. Not only does transportation add place value or utility to the pipeline by moving material across distances,

it also creates time utility by controlling how fast a product moves from one point to another (52:172). For a private company, the results of not having a product available at the precise time it is needed could be lost sales, customer dissatisfaction, and product downtime (52:173). For the Air Force, not having a spare available can delay or prevent units from fulfilling missions. The military transportation system may be seen as a value added process because it enables mission accomplishment by moving spares to the exact locations where and when they are needed.

In order for the Air Force to transport assets effectively and efficiently, several transportation functions such as traffic management, contract surveillance, plans and programs, vehicle operations, vehicle maintenance, and aerial port operations are included in its transportation management program (13:6). Directly linked to the physical movement of Air Force assets through the logistics pipeline are the priority given to the item, the modes of transportation selected by the traffic management function, and the flow of cargo through air freight terminals, managed by aerial port operations. These functions will be discussed after taking a brief look at the factors influencing transportation costs and the criterion used to track transit time.

Transportation Costs. There are two major categories of factors influencing transportation costs: product-related factors and market-related factors.

Stock and Lambert list four product related factors which affect transportation costs. These are: (1) density, (2) stowability, (3) ease of handling, and (4) liability (52:174,175). Those factors primarily affecting the logistics pipeline are ease of handling and liability. Some spares such as large generators and jet engines may have special handling requirements that may require the shipper to have specially designed trailers and material handling equipment for loading and unloading. Carriers must also be concerned with liability because of the extremely high replacement cost if the carrier damages or destroys the spare through negligence.

Market-related factors are those factors outside of the nature of the product which may also influence the costs of transportation. Stock and Lambert list the following as examples of market related factors: competition between carriers, market locations, government regulations, freight volume within a market area, and seasonal factors. Each of the market related factors may affect costs of transporting military spares. The product and market related cost factors affect the modes of shipment selected and in turn affect the speed which assets travel in the pipeline. The

speed of travel in the pipeline relates to the quantity of assets needed during order and ship time.

Military Standard Transportation And Movement

Procedures. Military Standard Transportation And Movement Procedures (MILSTAMP) is DoD policy which provides guidance essential for the proper movement and transport of materiel to, within, and beyond the Defense Transportation System (DTS) (17:1-A-1). The DTS includes any terminal facilities controlled by the military, Military Airlift Command (MAC) airlift or any arranged by MAC (including LOGAIR and QUICKTRANS), sealift controlled or arranged by Military Sealift Command (MSC), and any other air or land transportation controlled by the government.

Proper planning must be made to influence a timely response to transportation needs (17:2-B-1). Documents prepared and decisions made by the shipper influence a shipment and its cost/funding throughout its movement (17:2-A-1).

The DoD uses a transit time criterion in order to track just how long an item is traveling between origin and destination points. "Transit time starts when the shipment is signed for and picked up by the origin carrier and stops when the shipment is offered for delivery" (12:45). Stated differently, transit time is concluded either when the destination carrier notifies the consignee that the shipment is available, or when the shipment is actually received by

the consignee. Weekends are included in the number of transit time days, but holidays are excluded. CONUS transit time standards are provided in Table 2 below.

Table 2. CONUS Transit Time Standards (13:40)

	<u>Normally not prior to</u>	<u>NLT</u>
1.	TP-1: 15 days after shipped date	30 days after shipped date
2.	TP-2: 20 days after shipped date	40 days after shipped date
3.	TP-3: 40 days after shipped date	60 days after shipped date

As indicated in this table, the first element that the shipper determines is the Transportation Priority (TP). Table 3 shows how these time standards are segmented into handling/processing actions. Note that the Uniform Military Movement and Issue Priority System (UMMIPS) is a scheme for relative prioritization of customer supply requests and is detailed in a later section. The time standards used in MILSTAMP compose the order and ship time used in computing stock levels for the RCDL model. When an order is placed to replenish stock, the priority assigned is a TP-3. Longer delivery times associated with the lower priority make it necessary to stock more items in the logistics pipeline.

Transshippers. Most shipments in the DTS involve other activities, other than the original shipper and final

Table 3. UMMIPS Segmented Processing Actions per TP Codes
Reprinted from: (17:2-B-30)

UMMIPS TIME STANDARDS (IN CALENDAR DAYS)

TIME SEGMENT	TIME STANDARD (IN CALENDAR DAYS) FOR UMMIPS PRIORITY DESIGNATORS			
	01-03 (TP-1)	04-08 (TP-2)	09-15 (TP-3)	
Requisition Submission	1	1	2	For use only when shipments are consoli- dated at origin into SEAVAN Containers
Passing Action	1	1	2	
ICP Availability Determination	1	1	3	
Depot/Storage Site	1	2	8	23
Transportation Hold and CONUS Intransit to CONUS Requisitioner, Canada or POE	3	6	13	13

receiver, which "handle or document the transfer of shipments between conveyances" (17:3-A-1). These activities are referred to as transshippers. There are four major transshippers: the Consolidation and Containerization Point (CCP), the Air/Water Port Of Embarkation (A/WPOE), the Air/Water Port Of Debarkation (A/WPOD), and the breakbulk point. More than one of these may be involved in any given shipment.

The CCP combines shipments for multiple shippers who do not regularly generate full container or air pallet loads of cargo for shipment direct to the receivers (17:3-B-1). Several CCPs exist throughout the CONUS to consolidate cargo for continued transport to its final destination. There are two Air Force Consolidation and Containerization Points (AFCCP): Robbins AFB and McClellan AFB (17:F-87). Since the CCP is not required to identify in advance the consignee for each container requested, loading is accomplished as cargo is received and consolidated. The CCP will strive to meet delivery requirements at the lowest overall costs (17:3-B-2). Therefore, it consolidates cargo into containers in the following descending order of preference:

1. A full container load for a single consignee
2. A container load for delivery service to multiple consignees in the same geographic area
3. A container load for delivery to multiple consignees through a breakbulk point

POEs are normally authorized points where shipments leave a country, but they may also be used to ship DTS transshipments not leaving the country (e.g., LOGAIR) and which use the same MILSTAMP requirements (17:3-C-1). The Military Transportation Management Command (MTMC) operates and manages all common-user military water terminals in CONUS. AFLC manages the LOGAIR systems. MAC operates air terminals serving channels flown by scheduled MAC aircraft.

PODs are normally authorized points where shipments enter a country, yet these ports may be used to receive DTS transshipments from within the country, providing they follow the same MILSTAMP requirements (17:3-D-1).

Breakbulk points receive multiple consignee shipments which have been shipped in bulk (17:3-E-1). "The breakbulk point separates the unitized shipments into individual shipment units and forwards them to the ultimate consignee" (17:3-E-1). Shipments are directed to a breakbulk point when there is not enough volume available to justify shipment directly to the final consignee.

The breakbulk point unloads the unitized shipment, inventories the cargo, and segregates the individual shipment units for forward movement to the final consignee. The breakbulk point forwards shipments, within priorities, on a first-in/first-out basis unless there is an overriding urgency for a particular shipment (17:3-E-2).

Holding, diverting, and tracing are all actions in which a shipper or transshipper may be involved due to irregular or interrupted movement of cargo in the DTS (17:2-B-22, 3-E-3). The shipper or transshipper may hold and/or divert a shipment for a wide variety of reasons, including a consolidation delay, a wait for an export traffic release, or an embargo. For instance, after the shipment has reached the transshipper, a diversion to a different consignee or destination may result from conditions such as:

1. Strikes, national disturbances, or acts of God
2. Supply cancellations
3. Termination of projects
4. Changes in logistics buildup
5. Change in the receiving locations for mobile units (17:2-B-22, 3-E-3).

Use of transshipments reduces the number of carriers needed to provide delivery service between all locations in the DTS. While property may travel a greater total distance to arrive at its ultimate destination, a greater efficiency is achieved by using a central breakbulk point. Transportation managers must continually be aware of circumstances which may cause bottlenecks in the transshipment process, and minimize holding assets to speed the flow of assets through the pipeline.

Traffic Management. The traffic management operation is responsible for making mode of transport and carrier selections, decisions critical to meeting maximum standard delivery time criteria (51:63).

The mode of transportation and the routing to be used in shipping property is a part of traffic management that is considered frequently in daily operations. Urgency of need, pipeline time standards, carrier performance, and other factors must be considered in determining the mode of transportation to be used (13:8). Table 4 shows the mode and method of transportation selected must get assets delivered to their final destination within UMMIPS time standards at the lowest overall total cost to the government (13:8).

Applying this policy to a situation where a relatively large amount of material has an early delivery deadline or other urgent requirement, the use of more expensive modes of transportation may be necessary (13:8). In this case, the agency submitting the demand (Supply, Contracting, Program Manager, etc.) must determine the minimum amount of material needed by the using activity to meet their requirements until additional assets arrive by the more by the more economical method (13:8). Only the minimum amount of material needed in the interim is forwarded by the premium transportation. For high priority shipments, the mode of transportation which provides delivery at the

Table 4. Transportation Priorities and Recommended
Shipment Modes Reprinted from: (17:2-B-29;
10:24-31)

Priority Group/TP (Designator)	Work Schedules and Processing Time Measurements	Material Release to Consignor TO	Transportation (Recommended Shipment Mode)
1 (01 - 03)	24-hr workday; 7-day workweek.	Within 24 hours after recording commences.	High speed or most expeditious considered the normal means.
2 (04 - 08)	Priority designator 04-08 MICAP are processed the same as priority designators 01-03. All other priority designators 04-08 are processed as a minimum during the normal workweek. Recording time commences on the hour of receipt of the requisition.	Within 72 hours after recording commences.	(Air)
3 (09 - 15)	* Regular shift workday. * Normal five-day workweek. * Recording time commences at the start of business on the day following the day of receipt of the requisition.	Within 8 calendar days after recording commences.	Same as above when the RDD demands less time for transportation than is normally required for the SDD; otherwise, the SDD criteria will be the determining factor.
			(Surface)

earliest possible date must be used (10:24-4). Routine shipments, such as stock replenishment, generally use routine handling and more cost favorable transportation (10:24-4).

The Transportation Officer (TO) selects a mode of transportation from two possible categories: surface carriers and air carriers (13:8).

Surface Carriers. Surface carriers likely to move reparable items may include truck, rail, and other transportation services.

Motor Trucks. For the most part, motor carriers compete with air carriers for small shipments and rail carriers for large shipments (52:176). If the distance to transport goods from one point to the next is 1000 miles or less, motor carriers can compete with air carriers on point-to-point service for any size shipment because of the greater efficiencies motor carriers realize in terminal, pickup, and delivery operations. Motor carriers compete directly with railroads for shipments over 10,000 pounds that are transported 500 miles or more, but rails are the dominant mode when shipment sizes exceed 90,000 pounds (52:176,177).

To meet the needs of individual shippers, motor carrier services vary in range from general commodity haulers to specialized carriers (13:9). In general, motor carriers are more flexible and versatile than other modes

since they can haul various sizes and weights of products over any distance (52:177).

Railroads. Probably the major advantage of using rail over other modes of transport is that it generally costs less (52:180). On the other hand, the railways are limited compared to the national highway network, and therefore are not nearly as versatile and flexible as motor carriers. As a result, railroads use terminal-to-terminal service rather than the point-to-point service of motor carriers (52:178).

When strict arrival and departure requirements for a product exist, railroads create a disadvantage due to rigid time schedules. To alleviate some of the disadvantage, rail carriers may use "piggyback" methods (52:178). In piggyback service, truck trailers or containers are delivered to the rail terminals, loaded on flatbed railcars, and transported from terminal to terminal. A motor carrier handles the pickup and delivery of trailers or containers at the terminal facilities (52:186).

"Piggyback service thus combines the low cost of long-haul rail movement with the flexibility and convenience of truck movement" (52:186).

Other Surface Carriers. Several other over-the-road modes are used from time to time to transport reparable items between destination points.

Bus package express service transports goods from one terminal to another with pickup and delivery service available at many points at an extra cost (13:9).

Postal service is used to ship small parcels that cannot be consolidated and shipped as surface freight, the postal service may be used. This service also eliminates the use of a bill of lading (13:9).

Parcel service carriers offer a relatively quick method of transport as an alternative to parcel post. Shipments are accepted wherever a specific carrier offers such a service, and the rate charged may include pickup and delivery (13:9).

Air Carriers. In instances where an item must be delivered to a distant location quickly, air freight offers the shortest time in transit of any mode (52:181). Domestic air freight competes directly with motor carriers and, to a small degree, with rail carriers. Basically, air carriers transport expensive products with low density and weight characteristics (52:181).

LOGAIR. Military policy for air transportation require CONUS shipments to be flown to online destinations by LOGAIR, "considering the capability exists and transit time meets the user's required delivery date" (13:28). The shipping TO has the authority to forward a shipment by other available means when LOGAIR is not feasible (13:28).

Commercial Air. Using commercial air transport for CONUS shipments, TOs are authorized to route shipments weighing less than 1000 pounds. If a shipment weighs 1000 pounds or more, it must be referred to the Military Traffic Management Command (MTMC) area commands for routing (13:28).

Aerial Port Operations. For effective delivery and resupply of spares, cargo aircraft freight terminals must respond to surges in the workload in order to operate effectively (59:31). Unfortunately, most airlift resupply models assume the freight terminal meets the projected workload. The fact is that the air freight terminal can be the biggest bottleneck in cargo flow because of facility capacity and internal operations. If planners fail to recognize the part an efficiently run air freight terminal plays in the flow of cargo through the logistics pipeline, actual resupply may fall far below projections. Shortfalls in the number of forklifts, truck docks, 463L pallet pits, and people can cause long delays and severely reduce a terminal's throughput.

The Air Force Logistics Management Center (AFLMC) initiated a study of how air freight terminals operate (59:31). Two aerial ports were observed by AFLMC to understand the flow of cargo and determine where bottlenecks can occur. Basically, what the AFLMC found out is that the cargo flow has two entry points. Reference

Figure 22 for a diagram of cargo flow through an air freight terminal.

The first entry point is inbound cargo (59:31). Here materiel arrives on trucks and departs the terminal on 463L pallets. The trucks bringing inbound cargo find an open dock and are unloaded by a forklift. The cargo is taken off the truck and moved to a holding area marked for its final destination, where it will be held until enough cargo has accumulated to fill a pallet. A forklift and build-up pit are needed to build the pallet. Once the 463L pallet is built, it leaves the terminal building (via large MHE) and waits for an available aircraft.

The other cargo flow entry point is for "retrograde" materiel (59:32). At this entry point, 463L pallets arrive by aircraft and are broken down into bulk cargo. This bulk cargo is then "moved to holding areas to wait for a truck, or moved into the inbound holding area to go out to another pallet" (59:32). Once a retrograde holding area has accumulated enough cargo, a forklift is used to move the cargo to the dock and load it into a truck.

Surface Freight Operations. As with aerial port operations, surface freight terminals are potential bottlenecks not normally considered in cargo flow models. Figure 23 shows a generic relationship between over-the-road (OTR) units, documentation flow, and pickup and delivery (PU&D) to the customers. As seen in this figure,

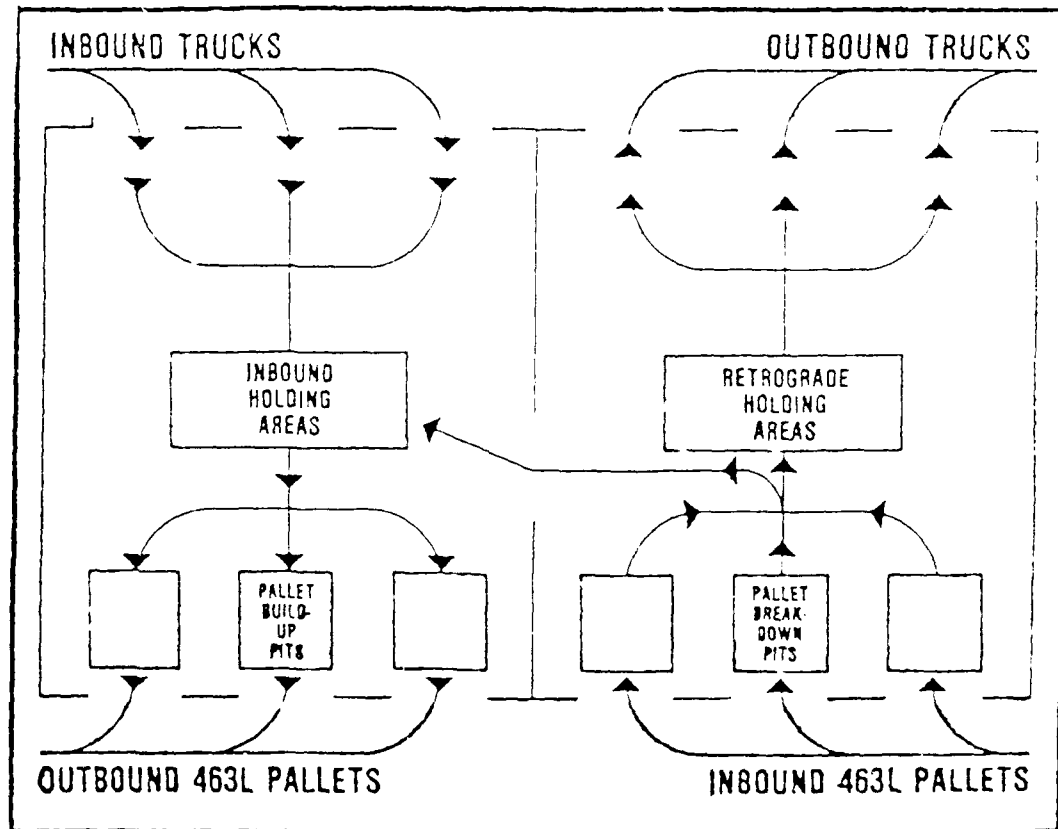


Figure 22. Aerial Port Terminal Cargo Flow
Reprinted from: (59:31)

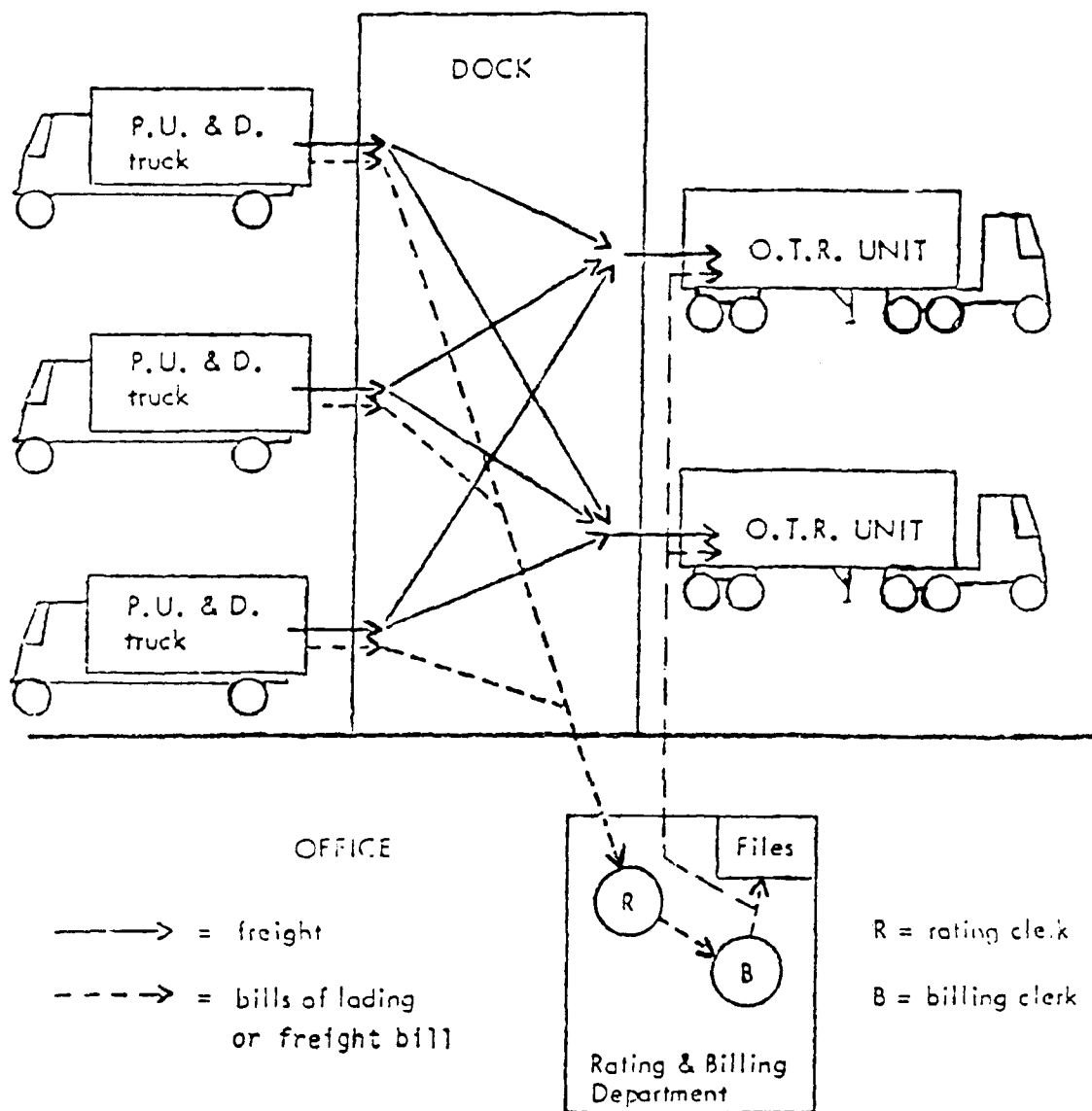


Figure 23. Surface Freight Terminal Cargo Flow (43)

the surface freight operation will, in most cases, use a straight-line flow system to expedite incoming and outgoing cargo through the terminal (43).

Property coming in to the terminal arrives on OTR vans bringing supplies from various sources of supply. The vans are spotted at a receiving dock at the terminal where the cargo is unloaded, sorted, and moved to appropriate holding areas to wait for delivery to the customer, pending processing of attached documentation. Not only is the property inspected for damage or errors in the quantity shipped, but the bills of lading (GBLs) or freight bills are checked for accuracy in shipping instructions. Once documentation processing is complete, a load of supplies destined for one particular customer will be loaded into a delivery truck at the delivery dock and transported to the user. At the base-level, serviceable spares coming in from the source of supply will almost always be delivered to Base Supply by Surface Freight personnel for receipt processing. Often, the Surface Freight and Packing and Crating Sections are located in the same facility as Supply, so incoming cargo going to Supply is transported to the Receiving Section via forklift. Materiel marked for MICAP processing is not held, but is given priority handling to meet the stringent time standards for final destination delivery.

For outgoing property, organizations deliver property in delivery trucks to receiving docks at the surface

freight terminal. Once cargo is offloaded, it is sorted and properly packaged for shipment by the Packing and Crating Section of Transportation. Most reparable spares come into the surface freight terminal from Supply, who processes them as turn-ins from the base maintenance activities and then prepares the shipping documentation. After the assets have been prepared for shipment, they are placed in holding areas to be consolidated with other shipments going to the same source of supply for repair or redistribution. The consolidated shipment will be loaded on an OTR vehicle at the shipping dock. The time materiel (both incoming and outgoing) typically spends on the road during a daily transport is shown in Figure 24 (43).

The distribution system provides the physical connection between each of the major pipeline subsystems. The length of time it takes for the movement of assets between these systems is a result of both the transportation modes selected and the priority assigned to the movement of spares between those systems. The next section will describe the UMMIPS system that governs the priority for movement of spares within the military and establishes time standards for their movement.

Priority Systems. The driving factor behind the length of time it takes spares to travel through the logistics pipeline is the urgency placed on the requirement for the asset. At base-level, each service has established

Types of Operation:

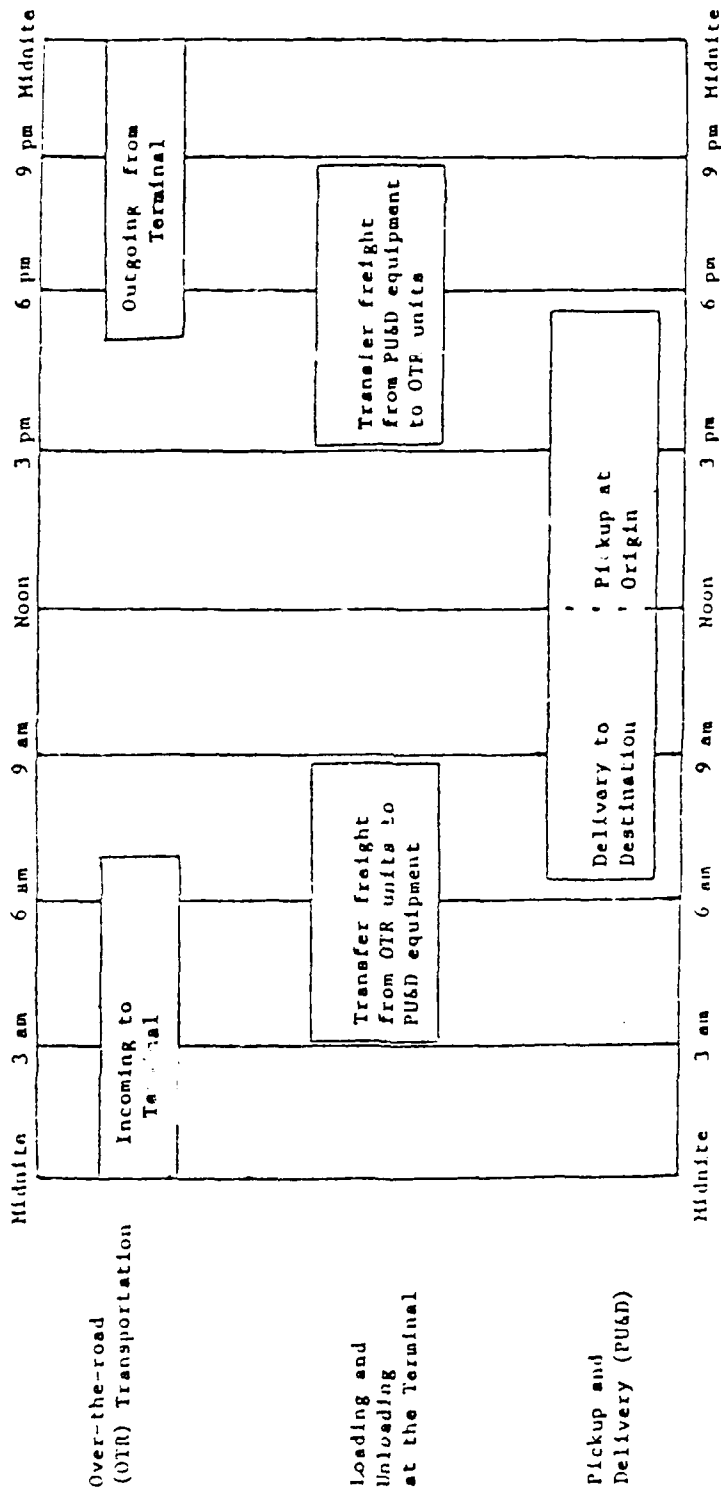


Figure 24. Typical Daily Over-The-Road Transit Times (43)

priority systems between their supply activities and the customers. In the Air Force, customer priorities (base organizations dealing with Base Supply) are determined by the priority of the end-item to be repaired and the type of supply item (8:7-26). The Uniform Materiel Movement and Issue Priority System (UMMIPS) establishes a priority system between depots and base-level supply organizations for the DoD.

UMMIPS uses a series of numeric codes, called priority designators, to emphasize the relative importance of requisitions and other transactions affecting the movement of materiel (10:24-3). For each assigned designator, a cumulative delivery time is prescribed for satisfying a customer's demand (10:24-3).

UMMIPS uses two basic codes to assign a priority: the Force/Activity Designator (FAD) and the Urgency of Need Designator (UND). In combination, these codes determine a priority designator for the asset requisition which establishes the degree of attention it will receive (8:7-26).

Force/Activity Designator. The FAD is assigned by senior defense managers and determines the relative importance of a unit or weapon system to the overall DoD mission. There are five FAD codes (10:24-4,5). The highest FAD codes are assigned to military units deemed the most vital to national defense. Lower FAD codes are

assigned to units with fewer immediate national defense commitments.

Urgency of Need Designator. An Urgency of Need Designator (UND) allows base-level customers to express varying degrees of urgency required to satisfy their requirements (8:7-27). The UND is determined by the customer, and three codes are used (14:9-111). UND A means the force/activity cannot perform its mission without the needed item. UND B is used when the mission of the force/activity is impaired, but not stopped. UND C is used for items required for scheduled repair or maintenance, and for routine stock replenishment or depot redistribution.

Priority Grouping. The 15 combinations of a FAD and UND result in the assignment of a priority designator to every DoD supply requirement. Priority designators prescribed by UMMIPS are consolidated into three priority groups to assist in allocating DoD transportation resources (10:24-3). Table 5 shows the relationship between the FAD, UND, and requisition priorities (15).

Order and Shipping Time. The UMMIPS priority designator also infers a maximum time standard for every requisition's order and shipping time (O&ST). This time is calculated from the requisition date until when the material is physically received and posted to the requisitioner's inventory record (10:24-3).

Table 5. MILSTRIP Priorities
 Reprinted from: (15:79)
 Times from: (10:24-21)

MILSTRIP PRIORITY

		URGENCY OF NEED DESIGNATOR		
		A	B	C
FORCE / ACTIVITY DESIGNATOR	I	1 7 12-17	4 11 16-21	11 24 52-92
	II	2 7 12-17	5 11 16-21	12 24 52-92
	III	3 7 12-17	6 11 16-21	13 24 52-92
	IV	7 11 16-21	9 24 52-92	14 24 52-92
	V	8 11 16-21	10 24 52-92	15 24 52-92



PRIORITY
DESIGNATOR



*TIME IN DAYS - CONUS



*TIME IN DAYS - OVERSEAS

*INCLUDES REQUISITION SUBMISSION
TIME AND RECEIPT TAKE-UP TIME

One major assumption made by UMMIPS time standards is that the required items are in stock and available for issue. UMMIPS does not consider procurement lead time (10:24-4).

Delivery Date Criteria. Two delivery date criteria are important in determining the priority handling of an item through the logistics pipeline: the standard delivery date (SDD) and the required delivery date (RDD). The SDD is established by UMMIPS time standards, and the RDD is established by the needs of the customer.

The SDD is the latest date an item is allowed to be received and documented by the consignee under normal processing and shipping time in the logistics system (10:24-11). The established CONUS SDDs are shown in diamonds in Table 6 (15) and are considered overall logistics system limits for the supply of materiel requirements. The priority group of the item and the requester's geographical location are factors used in the SDD to compute the appropriate time standard allowances with the requisition document number date.

The RDD is the actual date when an item is required to be delivered to the customer (10:24-12). The RDD is always a date which is earlier than the computed SDD. Because the RDD is a deviation from the established SDD, requisitions may be assigned an RDD only if the user can justify that an earlier date is essential to satisfy a mission requirement.

Urgency Justification Code. The Urgency

Justification Code (UJC) is used on Standard Base Supply System (SBSS) issue requests to determine the urgency of need and type of requirement (14:11-67). For instance, the USAF standard UJC for an aerospace vehicle not mission capable supply (NMCS) would be an AA. The first letter of the UJC is actually the determined UND for the item. AFM 67-1, Volume II, Part Two, Chapter 11, Attachment A-10 lists the various UJCs and their situational applications. UJCs at base-level establish the delivery priority, thereby affecting the length of time allowed to deliver the spare to the customer (Relate to Table 1 - Delivery Priorities). Faster deliveries result in less base-level pipeline stock.

Supply Processing Standards. Refer to Table 4 again. Not only does the UMMIPS specifically outline of the maximum work schedules and processing time standards for each priority group, the system defines the maximum allowable time that can expire between the customer's requisition and a material release to the consignee

For high priority requests (priority group 1), requisitions are processed through the Air Force supply system to consignor transportation officials within a maximum of 48 hours after initial receipt of the requisition. The clock starts for this requirement the next full hour after the requisition is received.

Priority group 2 requisitions are processed through the Air Force supply system to consignor transportation officials within 72 hours, maximum, after the requisitions are initially received.

For routine priority group 3 requests, requisitions are processed through the Air Force supply system to consignor transportation officials within a maximum of 8 calendar days after the requisitions are received. This 8-day time factor starts at the beginning of the business day after the requisition is initially received.

Intermediate Summary. In the logistics pipeline, goods must be physically moved from point to point in order to meet demands generated by mission requirements. Transportation ensures expeditious movement of assets at the least overall cost to the government. Numerous modes of transporting Air Force property through the pipeline are available to the TO, given UMMIPS criteria, pipeline time standards, and carrier selection guidance is followed. Setting correct shipment priorities and choosing appropriate modes of shipment help contain the overall cost of managing the logistics system, yet get needed material to its destination in a timely manner.

The Depot Pipeline Subsystem

Some of the best descriptions of the depot portion of the logistics pipeline comes from the multi-echelon branch

of inventory theory. Prior to the discussion of the inventory models, this section describes the organization of Air Force depots and the movement of spares within this industrial complex. Finally, a description of the requirements computation system is given for an overall appreciation of the depot pipeline subsystem.

Air Logistics Centers. The Air Force depot subsystem of the logistics pipeline is managed by five individual depots called Air Logistics Centers (ALCs). The ALCs are divided into directorates which are responsible for distribution, maintenance, procurement, and material management. Each of the ALCs provide similar overall functions within the directorates, but unique mission requirements at each location may require localized procedures at lower level responsibility centers.

Depot Supply. Depot Supply responsibilities are delegated to the Directorate of Distribution (DS) at ALCs. In general, DS is made up of five smaller divisions, of which two provide storage and issue functions, two provide management services, and one provides transportation. Reference Figure 25 (28).

The Supply Division stocks supplies used directly by the ALC, while the Material Processing Division maintains stocks for future usage and distribution throughout all Air Force base-level organizations (28). The Supply Division stockage of recoverable spares is based on demands

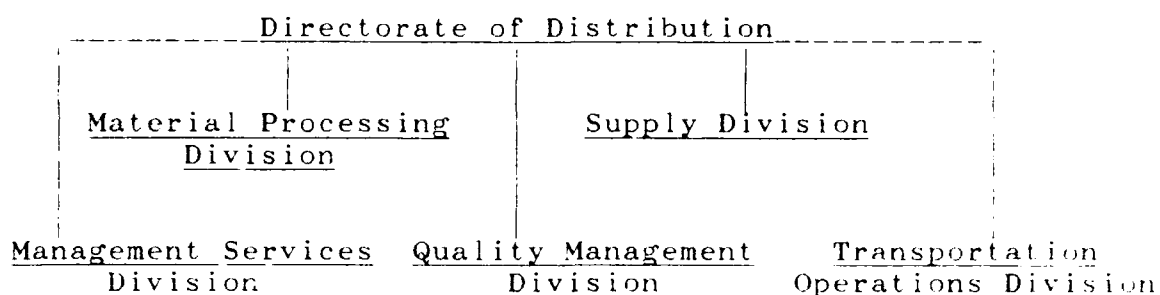


Figure 25. DS Organizational Structure (28)

generated at the depot. The primary depot for each weapon system maintains greater stocks of items that are peculiar to the components repaired at that depot. The Supply Division performs basic material management functions similar to those used by base-level organizations to keep adequate stock on hand, dispose of excess, and maintain inventory records.

The Material Processing Division contains a central warehouse of stocks that may be used by bases, depot maintenance shops, overhaul facilities, or other depots and bases (28). The central warehouse contains both serviceable and repairable spares. The Material Processing Division holds repairables until they are scheduled into the maintenance shops. Its primary responsibilities include receiving, material handling, and storage of assets. Personnel assigned ensure adequate protection of assets in storage and react to item manager requests to direct shipments.

The Management Services Division and the Quality Management Division, each within DS, provide management and engineering expertise to the distribution portion of the depot pipeline (28). While neither division physically controls assets at the depot-level, both play a significant role in managing the depot-level pipeline. The Quality Management Division is responsible for inventory control, training, and quality management. They perform all adjustments to inventory records and manage the programs for reducing discrepancies. The Management Services Division writes procedures, and performs engineering to design the processes and systems that affect the flow of reparables within the DS. The DS Supply operations serve as the central storage and processing areas for reparable spares in the depot-level pipeline. Two major warehousing operations are responsible to provide materials to the maintenance activities when needed and distribute spares to other bases worldwide.

Depot Transportation. The Transportation Operations Division, also within DS, is the focal point for transportation services between the ALC, bases, and civilian contractors (28). It contains the Air Freight Terminal, Surface Freight, and packaging activities. Transportation Operations receives assets from vendors, and processes shipments to base locations assigned by item managers. Included in their responsibilities is selecting

the mode of shipment that minimizes total costs to the government while meeting delivery time standards. The rules discussed under Transportation Management apply to depot-level transportation as well as base-level transportation. Transportation Operations is directly responsible for managing the movement of spares through the pipeline. They determine how fast items will arrive at their destinations and indirectly control the volume of the pipeline between bases, depots, and industry.

Depot Maintenance. Depot Maintenance accounts for a large share of total assets held in the pipeline and for a significant portion of the pipeline time used while assets are repaired and returned to field usage. The maintenance processes used in the depot are similar to those used by the base-level maintenance organizations. Maintenance technicians perform preventive maintenance on systems brought in for overhaul and perform corrective maintenance on spares sent out NRTS from the bases (48).

The ALC responsibility center for these activities is the Directorate of Maintenance (MA). Each ALC MA is broken down into an Aircraft Division, Product Division, Resources Division, Quality Division, and a Plant Management Division (48). The Aircraft Division generates requirements for reparableables in its overhaul facilities while the Product Divisions put reparableables back into service in their production facilities. The Quality Division ensures that

materials received and products sent out of the maintenance system conform to quality standards. The Quality Division is additionally involved in overall quality improvement programs that strive to improve processes, reducing waste and producing defect free outputs. These efforts are an attempt to lower pipeline quantities by reducing the time needed to perform repairs and correct defects. The Resources Division coordinates capacity planning, scheduling, and resource requirements activities for the Depot Maintenance complex with Depot Supply, and item managers.

The depot reparable item maintenance cycle is driven by a program called Management of Items Subject to Repair (MISTR). MISTR is the management program that determines when spares will be put into the repair process. Key aspects of MISTR are the quarterly workload negotiation and biweekly renegotiation that set production schedules based on requirements, requirement priorities, available capacity, and material availability (48). Quarterly negotiations establish production goals based on requirements identified by the D041 Recoverable Consumption Item Requirements Computation System. For more specific planning and scheduling, personnel from the MA Product and Resource Divisions, meet with Item Managers from the Directorate of Material Management, and DS Supply personnel for biweekly workload negotiations that refine production

goals based on priorities and available resources. In order to meet the production schedule set in the negotiation process, Maintenance processes reparables through its system that includes a holding area before the spares reach the maintenance shops.

As discussed earlier, repairable spares arrive from bases and other depots after base repair capabilities have been exhausted. The DS Material Processing Division holds these spares until requested by MA to be repaired. Figure 26 shows the movement of these spares once they enter the depot repair system (4). Parts enter from Depot Supply and are held in the Maintenance Inventory Centers (MICs) until actually needed by the shops (48). The MICs hold about two weeks supply of unserviceable spares waiting to go into the maintenance shops. They also hold supplies of reparable components that are used to repair broken higher level assemblies. The MIC routes materials used in maintenance to each of the shops throughout the depot. Once the spare is repaired, it is routed through the MIC to Depot Supply. Corrective maintenance actions are now complete and the part is available to fill a requirement at either the depot or any other base.

Figure 27 shows another pool of reparable items at the depot (4). "Black boxes," or repairables, are removed from aircraft at the depot for programmed depot maintenance (PDM) and sent into the repair pipeline for overhaul.

SHOP ISSUES AND RETURN

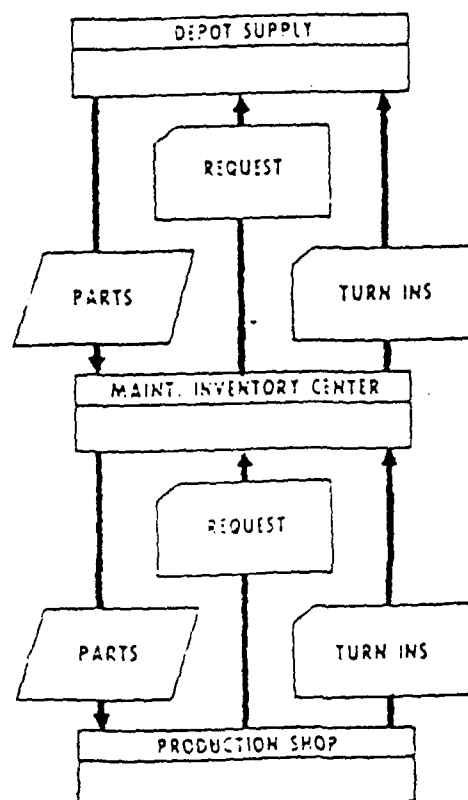


Figure 26. Basic Depot Repair Pipeline (4)

SHOP ISSUES AND RETURNS - FLOATING STOCK

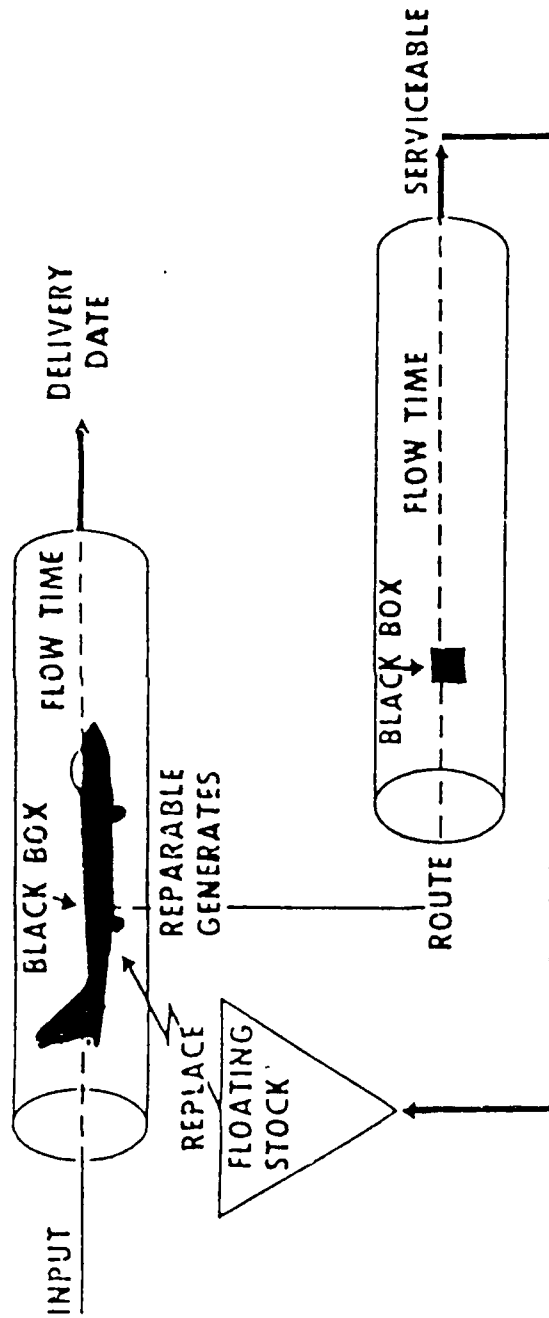


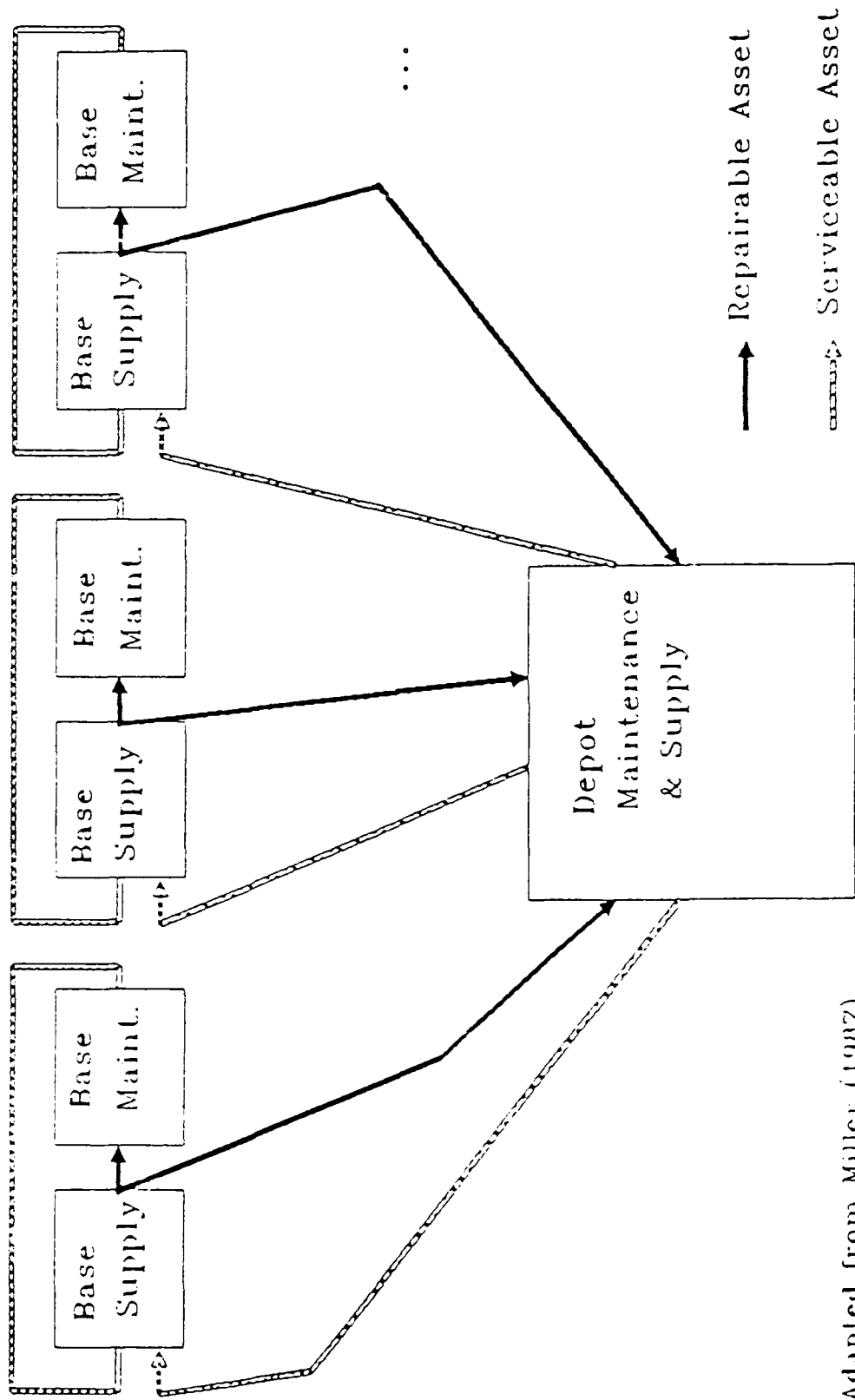
Figure 27. Depot Repair Cycle (4)

Meanwhile, a spare is taken from "floating stock" of earlier removals and replaced on the aircraft. Thus, there is a rotating pool of floating reparable stock supporting the PDM line. This simplified description provides a basic level of understanding of the overhaul activities in the depot repair pipeline.

Now that a general description of the movement of assets through the depot supply, transportation, and maintenance systems has been given, the next sections document the flow of assets through the pipeline as described by the multi-echelon inventory models. The inventory models are conceptual descriptions of the pipeline, whereas the foregoing discussion was an actual description of the depot pipeline subsystem.

METRIC Model. "In 1968, Sherbrooke developed the Multi-Echelon Technique for Recoverable Item Control (METRIC) incorporating base-level organizations and depots all in one model" (7:21). Figure 28 shows the fundamental relationship in the two-echelon nature of METRIC; one depot supports multiple bases. The METRIC model extends Base Stockage Model logic into a more detailed two-echelon pipeline system (Figure 29). The objective of the METRIC model is to determine the base and depot stock levels which minimize total expected base-level backorders for a specific set of items subject to an investment constraint (38:473).

METRIC Model Diagram



Adapted from Miller (1987)

Figure 28. METRIC Model Theory (8)

```

graph TD
    Aircraft[Aircraft] --> BaseRepair[Base End-Item Repair/Replace]
    BaseRepair --> BaseStock[Base End-Item Stock]
    BaseRepair --> DepotRepair[Depot End-Item Repair]
    DepotRepair --> DepotStock[Depot End-Item Stock]
    DepotStock --> BaseStock
    BaseStock --> Aircraft
  
```

Figure 29. METRIC Model (8)

The purpose behind the METRIC model is threefold:

1. To determine optimal base and depot stock levels for each item subject to a constraint on system investment or system performance.
2. To take fixed stock levels on each item and optimally allocate the stock between the bases and depot.
3. To provide an assessment of the performance and investment cost for the system of any allocation of stock between the bases and depot (49:123).

"Depot backorders are considered only insofar as they influence base backorders" (38:473). Input parameters to the METRIC model include the average base and depot repair times for each item, unit costs, certain probability parameters, NRTS rates, and average order and ship times (38:474).

METRIC considers only one class of assets -- those that are removed from the aircraft, repaired in either the base or depot shops, and returned either to stock or to use. Reparable items which themselves contain reparable components are considered as only one unit. This was a major weakness in the METRIC model that was accounted for in later stockage models.

Mod-METRIC Model. Muckstadt expanded the METRIC model in 1973 to permit consideration for indentured relationships which had previously caused METRIC to buy too many low cost items (7:21). METRIC did not consider the relationships between reparable end-items and their

reparable subassemblies in the maintenance process, nor did it consider the severity of backorders for end-items compared to subassemblies (9:287). The Mod-METRIC model explicitly considers these indentured relationships (38:474). Repairable spares which are removed and replaced on the flight line are termed "Line Replaceable Units (LRUs)" (9:287). Components or subassemblies of an LRU that are removed and repaired or replaced in the base or depot repair shops are called Shop Replaceable Units (SRUs) (9:288).

Figure 30 shows the flow of assets in the Mod-METRIC system. Serviceable assets are issued from base end-item stock. Repairable assets are taken from the aircraft and sent into the maintenance process. The broken SRUs are removed from the failed end-item and replaced with serviceable SRUs issued from base SRU stocks. Unserviceable SRUs may be repaired at the base or sent to depot if their repair exceeds base capabilities. If the end-item cannot be repaired at the base-level, it is sent on to depot repair as well. Once the failed LRUs and SRUs are repaired, they are put back into stock at either the base or depot-levels.

It is important to note that LRU backorders may affect mission capability more than SRU backorders.

Flow of Serviceables and Unserviceables

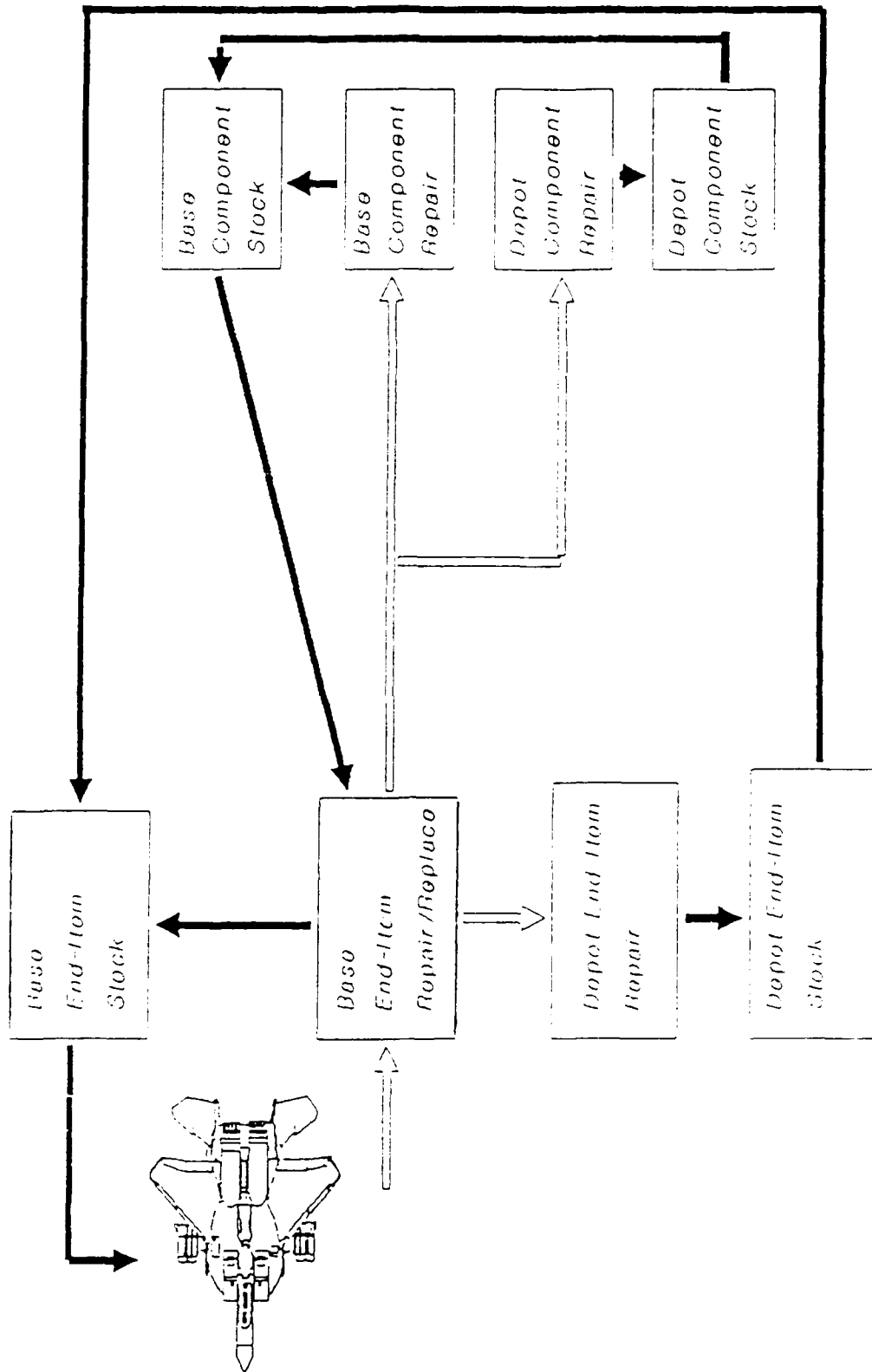


Figure 30. Mod-METRIC Model (8)

At best, a backorder for a LRU will result in an aircraft that is not fully equipped to perform its assigned missions; the worst -- a grounded aircraft.... On the other hand, backorders for SRUs result in delays in repairing the associated LRU. Delays due to SRU backorders could result in grounding of aircraft, but this effect is usually not immediate. Clearly, aircraft availability is more immediately affected by LRU backorders than by SRU backorders (9:288).

Figure 31 illustrates this point using aircraft engines as an example (38:474). The engine is the LRU or end-item, and modules are SRUs used to repair the engines (38:475).

An engine backorder indicates that an aircraft is missing an engine and is unavailable to perform its flying mission. A backorder for a module only delays the repair of an engine. The impact of module backorders and engine backorders is clearly not the same" (38:475).

The Mod-METRIC objective function minimizes total expected base-level LRU backorders subject to constraints on investment in LRUs and SRUs at both base- and depot-level (38:481). By including both end-items and subassemblies into the inventory model, Muckstadt created a better analytical representation of the pipeline than had existed previously. Muckstadt also notes that additional levels of indentured parts relationships may be added (the bits and pieces used to repair SRUs, for example). The Mod-METRIC model did not, however, predict the number of aircraft that could be expected to be mission ready given existing levels of stock on hand and on order. Later models added this capability to predict the number of aircraft that would be available.

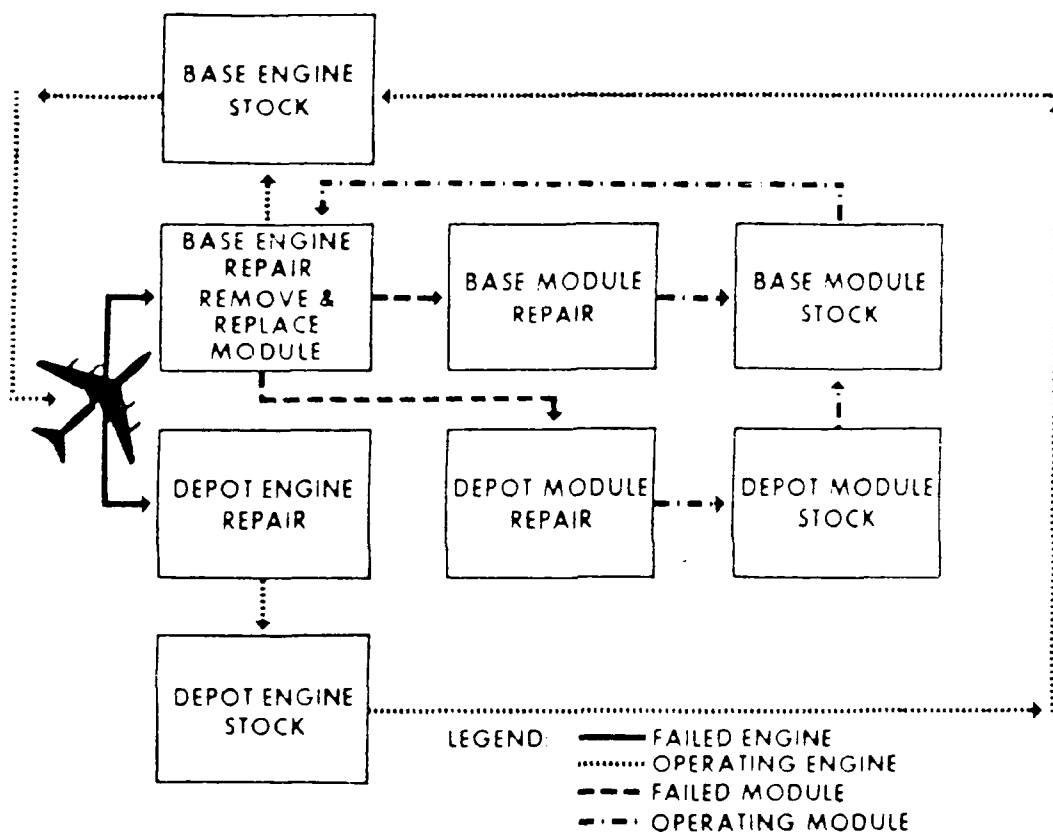


Figure 31. Mod-METRIC Repair Concept
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LMI Aircraft Availability Model. One model that computes aircraft measures is the Aircraft Availability Model (AAM). The AAM prioritizes items under consideration for procurement, ranking them in decreasing order of benefit per cost using a marginal analysis technique (41:v). The AAM, therefore, provides a "shopping list" of components which will optimize aircraft availability for any funding constraint that exists.

Under the AAM, an aircraft is available if it is not missing a reparable component. This definition of availability does not consider the shortage of consumables or on-aircraft maintenance activities; it only considers the supply of reparable spares (41:1-1).

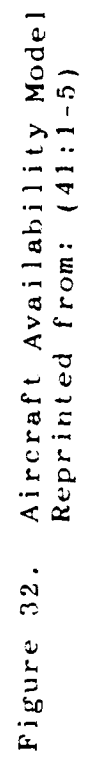
The AAM works under an environment where there are several aircraft of different types stationed at several different base locations. The aircraft are supported by reparable spares stocked at each of the bases or at the depot. The bases are assumed to have limited repair capability, and the depot virtually no repair constraints. The method of identifying a failed component, removing it from the aircraft and replacing it with a good one, and determining base-level capability to repair the broken part, is the same as discussed in the Mod-METRIC Model (Figure 30). Typically a failed LRU is the result of a failed SRU. If this is the case, the SRU may be removed

from the LRU and repaired either at base-level or sent to depot-level repair, just as the LRU would be (41:1-4).

Figure 32 shows the flow of serviceable and unserviceable units for the first two levels of indenture under the AAM. The physical flow of assets in this model is identical to the flow in the Mod-METRIC model. Failed LRUs are removed from the aircraft and sent to be repaired. Broken SRUs are removed and replaced, or the asset is sent to Depot Maintenance as NRTS. The base may repair the failed SRUs or send them to depot for repair. Repaired assets are then returned to stock.

The AAM pipeline model shows how the effect of LRU shortages and SRU shortages are quite different. If there is no spare available to replace a failed LRU, the backorder causes a "hole" in the aircraft, making it unavailable according to the AAM definition. Lack of spare SRUs delays the repair of LRUs, but spare LRUs will prevent a backorder which would affect aircraft availability (41:1-5). As mentioned earlier, an available aircraft is one with no LRU backorders outstanding.

The AAM also allows serviceable items to be removed from non-mission capable aircraft to prevent backorders. The removal and replacement of assets onto other aircraft is referred to as cannibalization. The ability to cannibalize assets to provide optimal use of recoverable spares enhances the description of the base- and depot-level



repair cycle. While the early aircraft availability models only considered all or none cannibalization capability, more recent models allow the user to enter a percentage of successful cannibalization rates for each item in the system.

Dyna-METRIC Model. Though the logistics pipeline model in this study assumes a peacetime environment, it is important to show briefly how a wartime environment affects the overall nature of the pipeline. The Dynamic METRIC model (Dyna-METRIC) is an offshoot of early Rand research into aircraft availability models. The Rand Corporation developed the Dyna-METRIC model to provide logisticians with information they needed to improve wartime logistics support within a single theater (35:1). Like other aircraft availability models, this model builds on the theory behind the METRIC and Mod-METRIC models mentioned earlier. Recall that the METRIC model considered two levels of repair capability, but did not allow for indentured relationships among reparable items. The modified version of METRIC, Mod-METRIC, allowed for multiple indentures (LRUs or SRUs), but only considered stationary or peacetime demand processes.

The Dyna-METRIC model added the capability to show the effects of wartime parts demand surges on the repair cycle and on combat capability (35:1). Other aircraft availability models assumed a stationary demand process

that followed a form of the Poisson distribution. Dyna-METRIC also assumes a form of Poisson demand, but calculates demand based on the dynamic flying hours tasked for varying days of the scenario given (45:16).

The Dyna-METRIC model calculates expected pipeline quantities for up to five levels in the logistics system (45:vii). The five echelon logistics system begins at the flight line where failed components are removed from the aircraft. Second echelon repairs take place in the base repair shops where SRUs are replaced to fix LRUs. The third echelon is the Central Intermediate Repair Facility (CIRF) which may be used when repairs cannot be made locally but when extensive depot maintenance is not required. The next level of repair takes place at the depot when bases and intermediate facilities lack sufficient repair capability. The last echelon includes civilian contractors who may perform contract maintenance, or supply new parts when needed. Each echelon may also be viewed as a source of supply. Non-mission capable aircraft may be used to supply parts to other aircraft with requirements for different items. The base, CIRF, and depot hold serviceable stocks as well. Last, serviceable spares may be purchased from industry (35:5).

The number of echelons included in a specific model calculation may differ based on the input scenario. For example, Figure 33 taken from a 1984 release of Dyna-METRIC

shows repair channels and resupply flowing from the base, through a CIRF, and to a depot. No resupply is shown from industry in the 1984 diagram. A more recent release of Dyna-METRIC showed the base dealing directly with the depot for repair and resupply (Figure 34). The CIRF was not included in the 1988 diagram, but still could be included in a Dyna-METRIC run depending on the input scenario. Excluding the CIRF may more accurately describe the pipeline for reparable within CONUS because repairs are usually made at either the base or depot-levels. Further, the concept of CIRFS is losing favor in the Air Force logistics community.

In the Dyna-METRIC model, each echelon of the logistics system is an element of the pipeline. The mathematical model calculates the expected number of assets in each level of the system based on probabilistically-specified time delays for each logistics activity. Arriving components must spend a specified delay time in each pipeline segment. Each component may have a different length of time for repairs at the local, intermediate and depot-levels. Items may also be delayed for any length of time in the transportation system depending on the time it takes to ship items between the various levels of the pipeline (35:6).

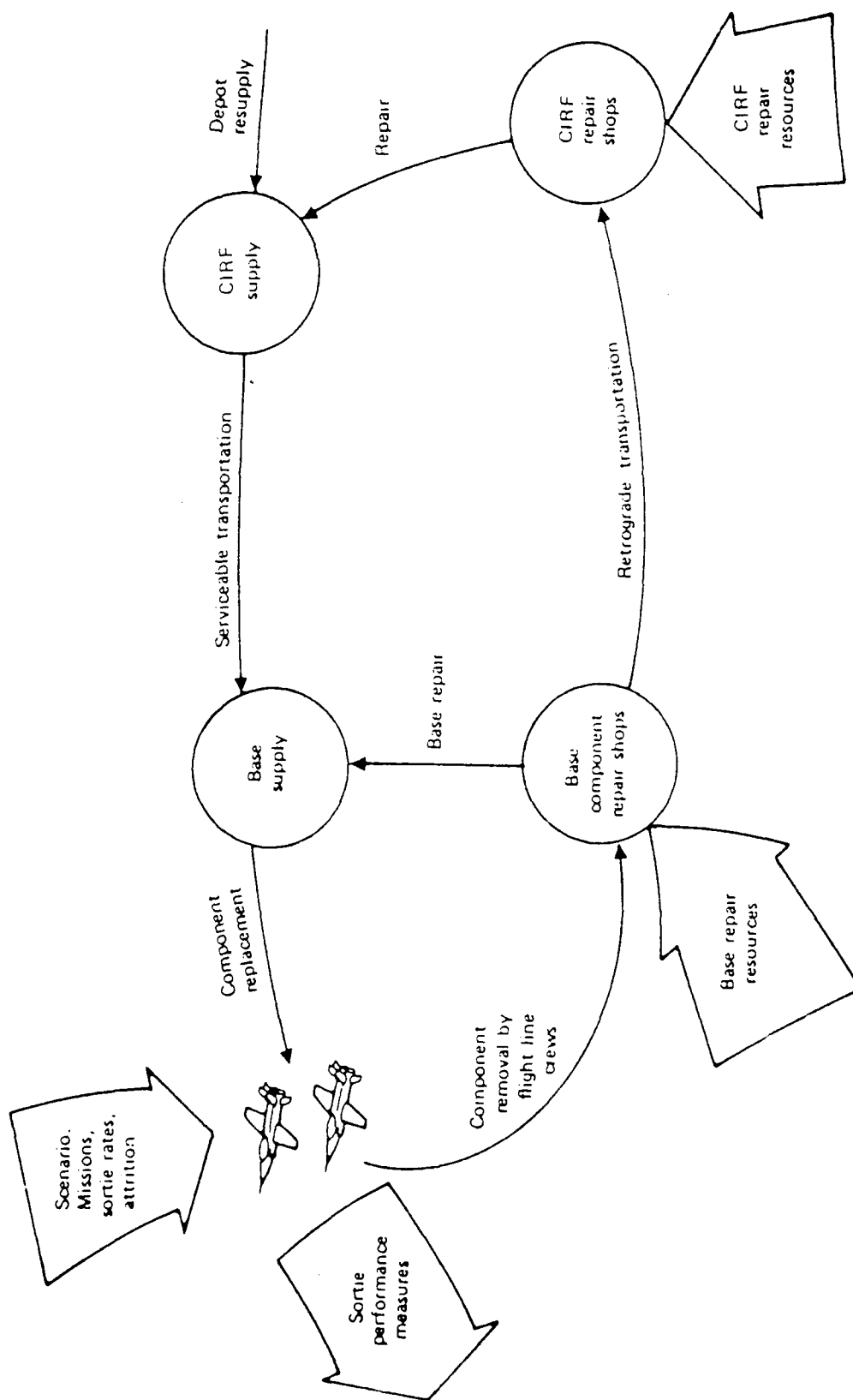
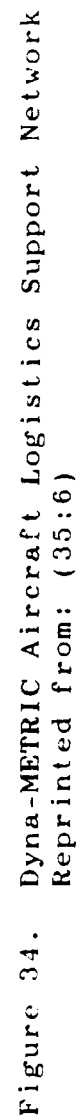


Figure 33. Aircraft Logistics Support Network
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For this study, Dyna-METRIC is important because it identifies pipeline segments from manufacturer levels down through using organizations. The total number of assets in the pipeline, or sum of all quantities in each echelon of the pipeline, determines the percentage of aircraft that are available to complete their assigned missions throughout the input scenario.

The major limitations to the Dyna-METRIC model are its assumptions that repair capability and repair times will remain constant throughout the period of heavy demands. Additionally, demand may not be predicted solely on flying hours tasked. While its limitations may detract from Dyna-METRIC's ability to accurately forecast the percentage of mission capable aircraft throughout the wartime scenario, the model remains one of the best analytical portrayals to date of the Air Force logistics pipeline.

The METRIC family of models has provided a conceptual description of the flow between depots and bases but lack sufficient detail that might explain variations in pipeline processes from one time period to the next. All transportation and distribution activities between depots and bases are categorized into order and ship time while, in fact, different processes and activities within the supply and transportation systems might have a large effect on the actual times for movements between levels in the pipeline. Likewise, all maintenance activities are summarized into

repair cycle time. More detail in these conceptual models could provide greater insight into the causes of variability between each of the subsystems in the logistics pipeline. The next model discussed will provide a priority distribution example for the depot-level repair cycle.

Procurement/Repair Model. Demmy and Presutti describe a procurement/repair model that builds on the general two echelon repair cycle model by adding the possibility of funding constraints in the repair process. A fundamental assumption underlying most repair cycle models is that sufficient funds, facilities, and manpower are available to begin repair and assets arrive at the appropriate repair facility as soon as the failure occurs (9:293). If there is insufficient funding of depot repair activities, not all of the repairable assets stored at depot can be repaired in the current fiscal year.

The Logistics Management Institute (LMI) developed the Procurement Repair model shown in Figure 35 to deal with funding constraints on current year repair processes (9:293). This model is similar to the previous repair cycle models with the addition of a "holding pool." The holding pool represents unserviceable assets which have been intentionally withdrawn from the normal repair and resupply system because of the lack of sufficient funds to continue the repair process. Individual assets placed in this pool are referred to as "dormant spares" since these

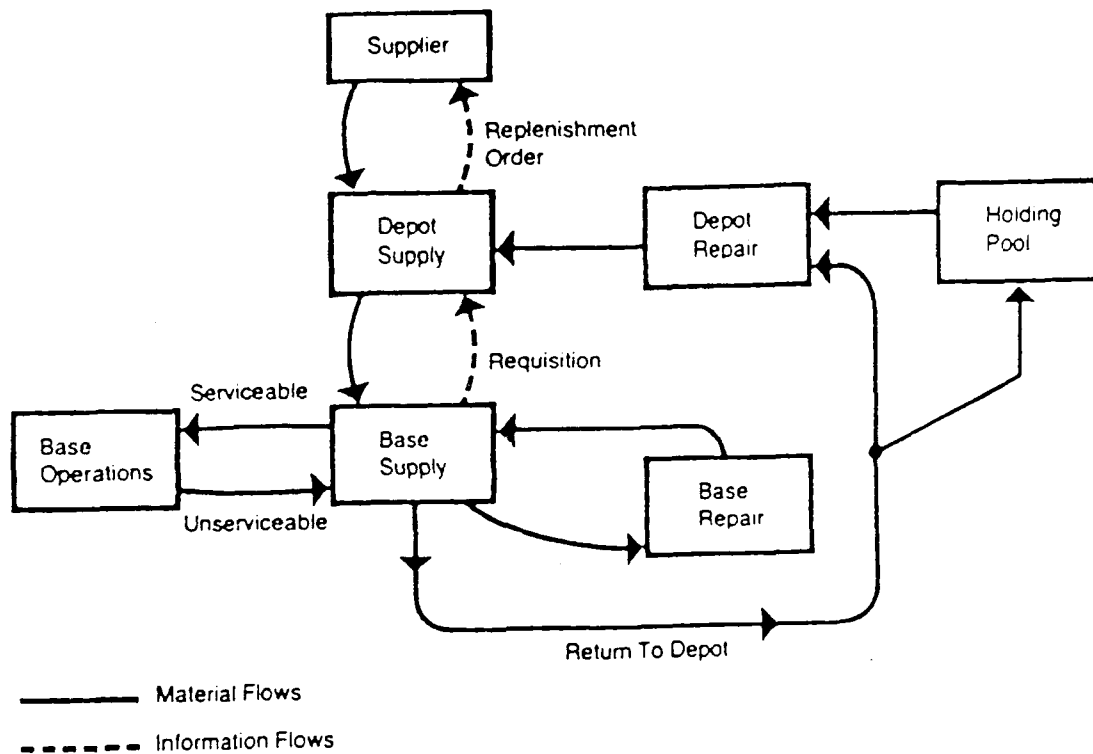


Figure 35. Depot Procurement Model
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assets may be returned to serviceable condition at some time in the future should sufficient funds become available. Dormant spares can add months to the repair cycle time of an asset (9:293). Few pipeline models explicitly acknowledge the existence of "holding pools" for repairable assets even though such pools can greatly increase the number of assets required to fill the pipeline.

Distribution and Repair in Variable Environments. The Distribution and Repair in Variable Environments (DRIVE) model prioritizes depot repair and distribution actions in order to maximize aircraft availability (3:2). DRIVE is based on the logic used in Dyna-METRIC, using demand data and asset availability to calculate expected aircraft availability (3:2). The model is constrained by existing assets and depot maintenance capacity. The DRIVE model accounts for the fact that demands can never be predicted with certainty.

The major premise of DRIVE is that the dynamics of the operational environment will make demands in both peacetime and wartime so unpredictable that the depot must be able to react on short notice. Quick response is essential to maintaining peacetime and wartime capability (3:1).

Figure 36 gives the conceptual view of how DRIVE will fit into the current reparable pipeline model (3:1). Repair priorities are determined by the requirements computation process and quarterly workload negotiations. After being repaired at the depot, reparable assets are either

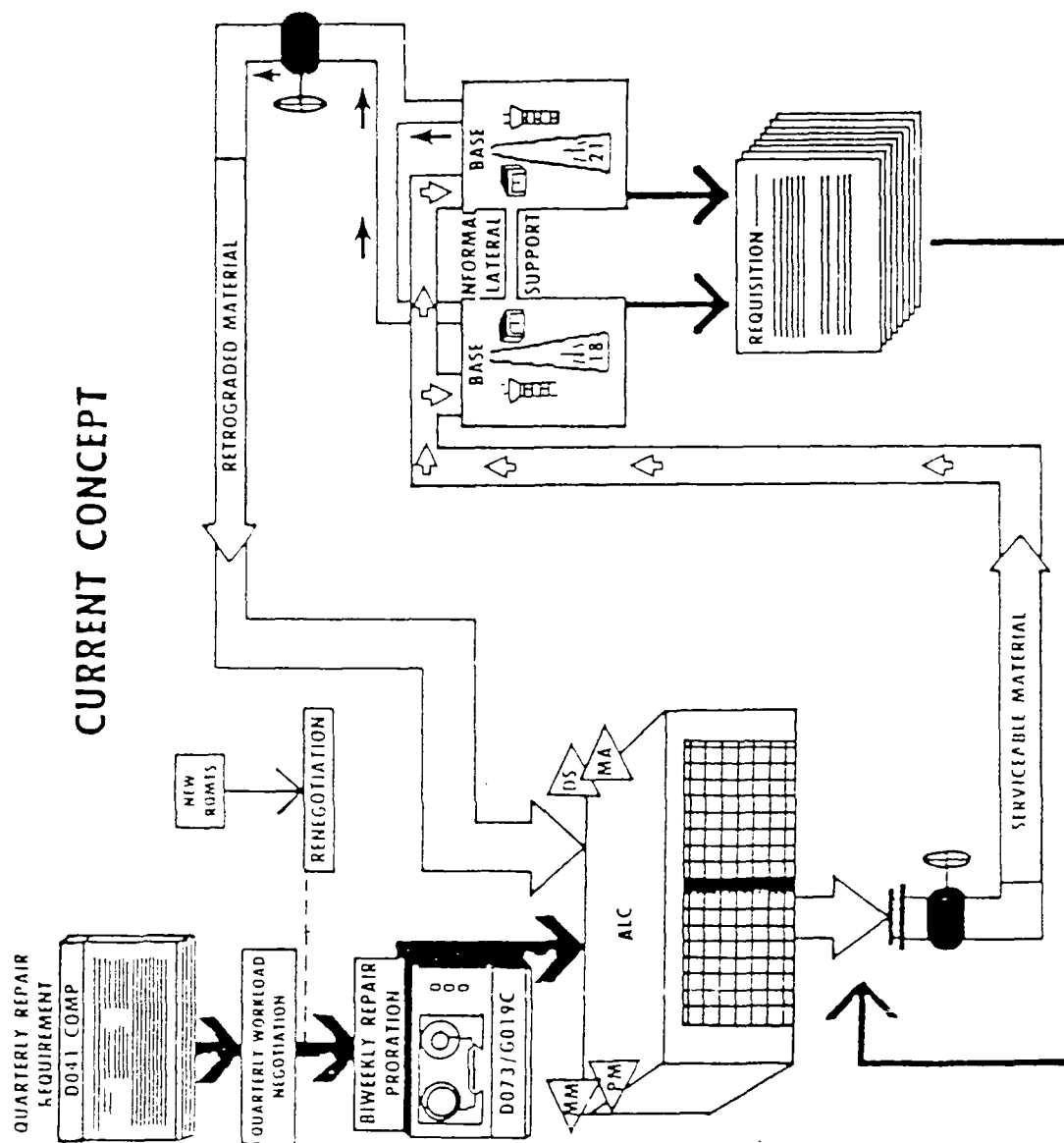


Figure 36. DRIVE Model (58)

stored in Depot Supply or sent to bases where there are unfilled requirements. "Retrograded material" refers to NRTS items. Once an item is declared NRTS, it is returned to Depot Supply where it is stored awaiting repair. New spare requirements are established when a requisition is received from a base to replace a NRTS asset. These requirements are filled either from depot stock or through the repair process. In either case, they ultimately result in additional depot repair workload. Implementation of DRIVE will replace the current repair priority system at the depot and will establish an allocation system for theater-level allocation of spares to maximize aircraft availability.

Installing the DRIVE system should improve the depot repair requirements computation and allocation processes (3:2). First, the DRIVE model uses current data from the worldwide points of use and repair instead of six to nine month old data. Next, the repair priorities and distribution are based on aircraft availability instead of first come, first served. Finally, DRIVE considers the tradeoffs between stocking LRUs versus SRUs with regards to increased aircraft availability.

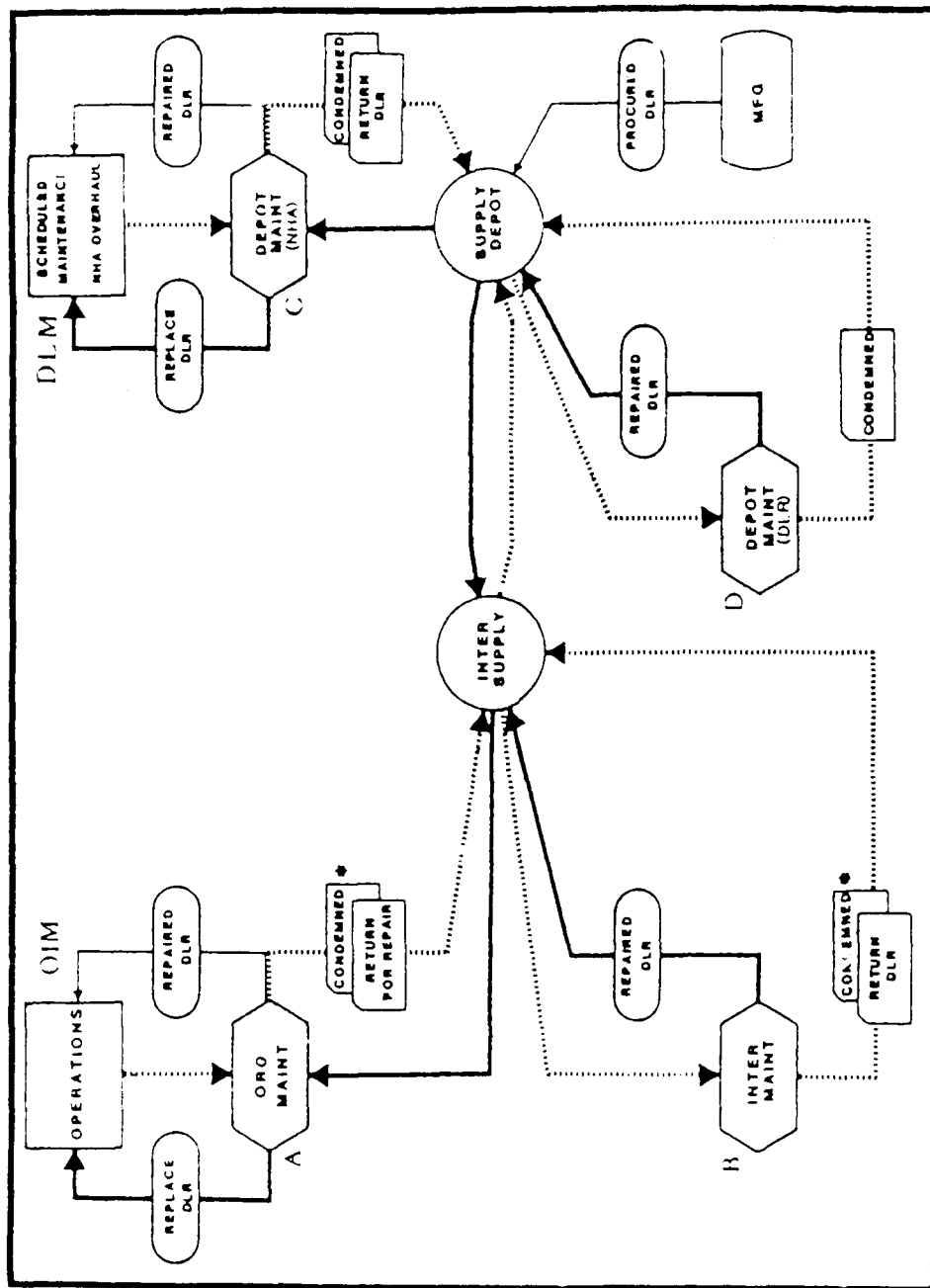
The DRIVE model is a practical application of techniques used to calculate aircraft availability to other logistics tasks. The implementation of DRIVE will improve the repair requirements computation process by using more

current data and streamlining the activities involved in setting repair priorities.

LSAO Depot Repairable Simulation. The Logistics Systems Analysis Office (LSAO) created a simulation of the Air Force repair process in its 1985 study to provide a standard description of the services' repair systems (5:1). The main emphasis of the simulation was to measure the quantities of assets in each of the channels of repair to standardize service requirements reporting processes.

Figure 37 shows the flow of "depot-level Repairables" (DLRs) within this system. The figure shows two sources of repairable assets (or requirements) and three sources of maintenance. Repairable assets are removed at Organizational/Intermediate Level (OIM) operations (base-level) and Depot-Level Maintenance (DLM) facilities during scheduled maintenance and Next Higher Assembly overhaul. Items may be repaired at either OIM or DLM activities or sent to another source of repair. OIM requirements may be sent through an intermediate maintenance facility for repair and satisfied through intermediate supply. DLM requirements that cannot be satisfied by the depot end-item overhaul facility must be sent to the Depot Maintenance shops for Depot-Level Repairs (DLR). These are Non-Job Routed (NJR) requirements and will be discussed in further detail under requirements computation.

SIMULATION



* DLRs are condemned at this level by Item Manager (IM) direction only

Figure 37. LSAO Depot Repair Simulation Model
Reprinted from: (5:21)

At each repair facility, the asset may be restored to a serviceable condition, sent on for additional repairs, or condemned (if appropriate). The condemnation of items represents losses to the system creating new system requirements that must be replaced through procurement. The simulation generates asset requirements to support condemnations, total repair cycle time at all facilities, and order and ship time between facilities. Manufacturers are shown in the diagram as the source for satisfying these requirements. The next section will discuss the process of depot reparable requirements determination including the purpose, inputs, and outputs of the requirements determination system.

Requirements Determination. The Recoverable Consumption Item Requirements System (D041) system is used in determining depot-level replenishment spares requirements for reparable items. The system uses repair data from bases and depot repair facilities, combined with estimates of usage, to calculate repair and purchase requirements. The major outputs from the D041 are notices to buy, repair, and dispose of assets (5:9).

The total estimated requirement for each asset must be projected from total expected demands at Organizational/Intermediate Maintenance (OIM) facilities and depot overhaul facilities (5:9). The number of assets that may be repaired at each of these levels during the forecast period may be

considered as a source of supply to offset these requirements. Other items may not be repaired at either the base or depot. The remaining unsatisfied demands after allowing for base and depot repair capabilities represent the requirement for the forecast period.

Many factors affect the computation of the forecasted requirement (1:1-3,4). A base period of 24 months is used for reporting demand data, condemnations, repair times and rates at the depot and base-level, and other reliability data. One of the more important factors affecting the required quantity is the length of time it takes to repair the item.

Measurement of Repair Cycles. AFLCR 57-4 defines the base repair cycle as the time between the removal of a failed item to the time it is restored to a serviceable condition and returned to supply inventory records (1:1-3). In other words, it is the time an asset spends within the base maintenance system (1:1-3). The Standard Base Supply System records actual base repair cycle times and inputs an average of these into the D041 requirements computation (1:1-3). The depot repair cycle time is considered to be from the time a failed item is removed from the aircraft at the base-level to the time it is repaired in the depot repair facility and is again available for use (25:18).

Figure 38, taken from a 1982 LSAO study, shows the relationship between the base (or field) repair cycle time

and the depot repair cycle time (19:16). The study provides a description of the repair cycle process used by each of the services for measurement of repair cycle times. Notice that both the depot and base repair cycles begin with the part failure which creates a demand. Both end when the item is ready for issue (RFI). Further, this model reveals the divisions of the depot repair cycle into field maintenance time, retrograde time, administrative time, and depot maintenance time.

The Logistics Management Institute provided another description of the components of the repair cycle time in a 1987 study of the repair cycle. The descriptions of these components were intended to be generally applicable to the repair processes in each of the services.

Figure 39 represents the LMI view of the segmentation and measurement of the repair cycle process (44:E-4). The repair cycle is divided into 11 sections defined by 12 distinct measurement points. The solid horizontal lines represent the general repair cycle flow applicable to all conditions. Dashed lines represent those segments occurring only in special circumstances. Each of the wavering lines show segments of repair cycle time excluded from the overall measurement of the Depot Repair Cycle Time (DRCT).

The DRCT begins at measurement point A of the LMI model when the item is declared NRTS and turned-in to Supply

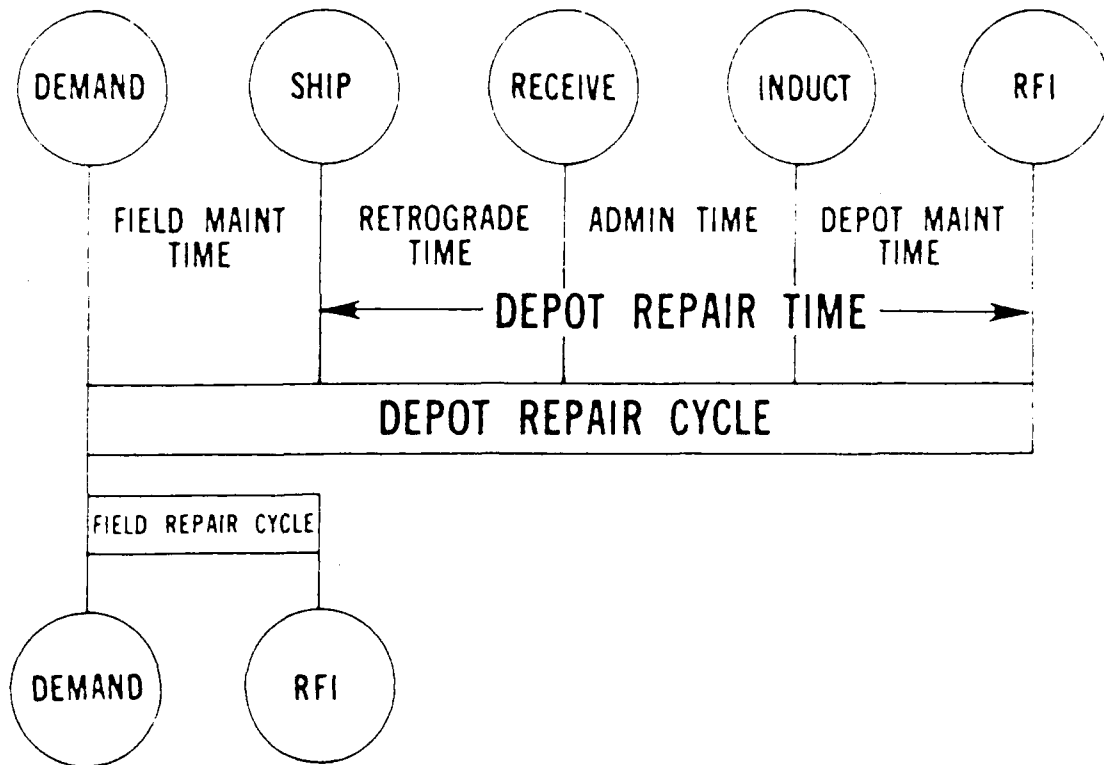
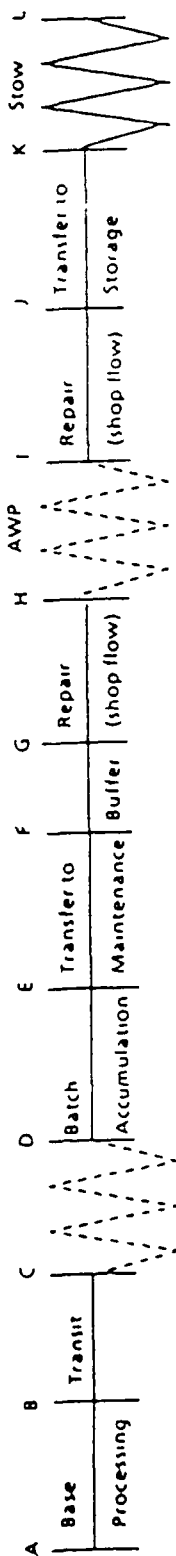


Figure 38. LSAO Segmented Repair Cycle Time
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Legend:

----- Repair cycle segments applicable to all conditions

- - - - - Repair cycle segments applicable to special conditions

/\\//\\//\\// Segments excluded from repair cycle time

A Event (ends one process and begins the next)

A - B Process that occurs between events

Figure 39. LMI Segmented Repair Cycle Time
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(44:E-4). Point B is the time when the item is shipped off-base. The time between the two is the length of time it takes to receive disposition instructions and prepare the item for shipment. The time between B and C is the transit time for shipping between the base and the Inventory Control Point (ICP). Between points C and D, unserviceable assets are backlogged if there is no immediate requirement for them. This is the same as the holding pool identified in the Procurement Repair Model. Repair cycle time is not measured during this period. The period between D and E is for batch accumulation purposes. The maintenance facility may require a minimum batch size before initiating repairs to decrease the special handling/equipment setup involved in the asset's repair. The time between E and F is the period between the maintenance request to supply to move the batch of repairables until maintenance receives them.

Another segment exists between F and G recognizing the time required for maintenance preparations. The actual repair process lasts between G and H when the asset is actually in work. If all required parts are not available to fix the item, it enters AWP status. Repair cycle time measurement is discontinued until the parts have been received. The period between I and J represents the completion of repairs. After repairs are completed, time is recorded between J and K for the transfer of the repaired assets back to supply storage. This completes the

measurement of repair cycle time. If no immediate requirements exist following repair, the item returns to storage where it awaits future demands.

Many of the elements in the depot repair cycle considered by the LSAO and the LMI studies are explicitly or implicitly considered in the D041 (1:1-4). "Base processing days" are recorded to show the time it takes to remove an asset, declare it NRTS, and initiate the shipment from Base Supply. "Reparable in transit days" are recorded to measure the shipping time between the base and depot. "Supply to maintenance days" are recorded between receipt of the item at depot and its delivery to the depot maintenance facility. The number of "shop flow days" represents the length of time it normally takes to repair the item in the depot maintenance facility. Similar times are recorded for demands generated within the depots through the overhaul depot maintenance process (1:1-5). These demands are referred to as Non-Job Routed (NJR) requirements.

Measurement of the repair cycle for both the depot and base provide necessary information to determine the quantity of assets necessary to fill the repair pipeline during the forecast period. These measures enable the requirements computation system to calculate a requirement level that will satisfy expected average forecast demands for the period. Unfortunately, many measurements must be derived through estimates and averages based on data fed to

the D041 through lower level systems (26:D-9,D-12).

Accurate data or forecasts for both demand and repair cycle times are necessary in computing valid requirements.

In addition to the quantity of assets necessary to continue operations during the repair process, a quantity must be calculated to satisfy demand during the procurement lead time (26:D-14). Procurement lead time is "the sum of Production Lead Time (PLT) and Administrative Lead Time (ALT) required to obtain spares through procurement" (1:1-5). The length of time necessary to procure spares can add considerably to overall pipeline requirements because assets must be on hand to continue operations during the replacement period.

Procurement Lead Time Model. The most significant factor affecting the spares acquisition process is procurement lead time. Procurement lead time occurs between the submission of requirements to a manufacturer and actual receipt of new assets. A 1984 study, conducted by LSAO, proposed that procurement lead time is divided into two major segments, administrative lead time (ALT) and production lead time (PLT) (27:35). The study showed that major differences exist between the services in estimating both ALT and PLT and that the estimates often understate the true lead times.

The Air Force Recoverable Consumption Item Requirements Computation System, the (D041), identifies

the beginning of ALT as the date an item manager prepares a Purchase Request or Military Interdepartmental Purchase Request. Starting the ALT at this stage does not consider the time between when the inventory balance reaches the reorder point and the initiation of the buy notice and the preparation of the Purchase Request. The end of ALT is the contract or purchase order award date (27:35).

Production lead time begins with the date of contract or purchase order award and ends with receipt of a pre-specified fraction of the total contract quantity (LSAO:7-8). Differences between industry and Air Force estimates of PLT exist. Contractors may base PLT on the interval between actually receiving the order and shipping the first units of the contract quantity (27:37). If the PLT is based on a contract estimated date of delivery (EDD), the system adds 15 days transportation time (27:36). Adding time to the contract EDD accounts for the added shipping and order transmittal time between the contractor completing production and the Air Force receiving the spares. However, it does not accurately account for the differences in the dates of significant delivery.

The LSAO study indicated that the inconsistencies between the services and other DoD agencies in estimating PLT and ALT created a need for a standard model for estimating lead times. Figure 40 shows LSAO's proposed

PLT model. Their model segments procurement lead time for all DoD activities (27:57).

As proposed, ALT begins when on-hand assets reach the reorder point (ROP). Theoretically, this is the point at which a procurement order must be initiated so that stock arrives just as the asset inventory level reaches the safety level. ALT ends on the contract award date. The PLT under this proposed model begins on the contract award date and ends with a receipt confirmation or significant delivery date. PLT includes three significant segments: (1) the time to transmit an order to the source of supply, (2) the time for assets to be produced and readied for shipment, and (3) the shipping time and time required at the depot to inspect/confirm the shipment.

Because the time necessary to acquire replacement spares has become so lengthy, the Procurement Lead Time Model is important. It acknowledges the fact of extended lead times and divides total PLT and ALT to more easily examined segments.

The requirements computation process involves computing both the repair requirement and the quantity that must be purchased to support current and planned operations. Assets that are no longer used may also be identified for disposal by the requirements computation system. The forecasted repair and purchase depend significantly on measures of the repair cycle process

PROPOSED SEGMENTATION OF PROCUREMENT LEAD TIME

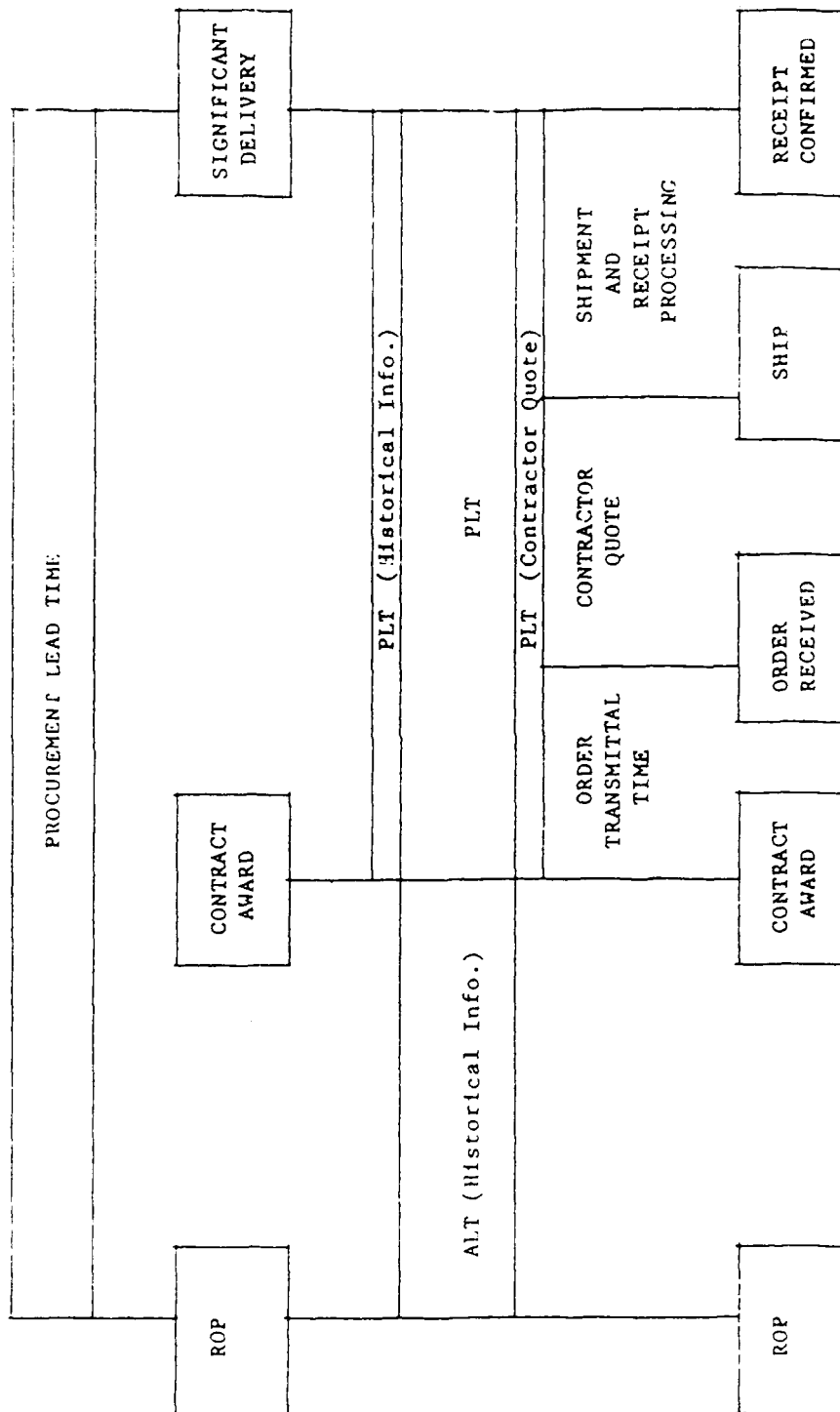


Figure 40. LSAO Proposed Procurement Lead Time Model
Reprinted from: (27:57)

and procurement lead time. Examining the segments of procurement lead time is an important step towards reducing the Air Force logistics pipeline. A discussion of factors affecting procurement lead time continues with the Acquisition Pipeline Subsystem.

The Acquisition Pipeline Subsystem

The acquisition pipeline is an important consideration when describing the Air Force logistics pipeline. The Federal Acquisition Regulation defines Acquisition as follows:

"Acquisition" means the acquiring by contract with appropriated funds of supplies..for the use by the federal government through purchase or lease. Acquisition begins at the point when agency needs are established and includes the description of requirements to satisfy agency needs, solicitation and selection of sources, award of contracts, contract financing, contract performance, contract administration, and those technical and management functions directly related to the process of fulfilling agency needs by contract (16:2.1).

Requirements to procure replacement spares must be satisfied through the acquisition pipeline. The first step in the acquisition process is to develop a strategy and an acquisition plan. Once an acquisition plan is developed, the contracting process bridges the requirement with the purchase of replacement assets. Factors in the contracting process and in the defense industrial base will affect total procurement lead times. This section addresses the acquisition pipeline as follows: (1) development of an

acquisition plan, (2) the contracting process, and (3) industrial capacity and its effects on procurement lead time.

The Acquisition Plan. Because the value of reparable spares is generally quite significant, consideration must be given to procuring the best quantity to promote overall efficiency. A formal acquisition plan must be developed for procurements whose total cost is expected to exceed \$5 million (16:Part 7.105). This plan begins with the statement of the need that has been established through the requirements determination system and reported by the Central Secondary Item Stratification. A number of decisions must be made along the way to develop the formal plan. This section briefly discusses these decisions and the plan's contents.

The first item in the plan is the Statement of Need. For recoverable spares, the statement of need comes from the requirements computation process (16:7.105). Any conditions applicable to the need must be stated such as special circumstances that might result in greater urgency or requirement change. An estimate of the cost of the procurement should be determined through historical costs for like spares, and life cycle cost of those already procured. The specifications and performance requirements for the recoverable asset must be identified and placed in

the plan so that there is no misunderstanding between the contracting agency, the user, or the civilian contractor later in the process. A date must be determined and listed in the plan for the required delivery of assets and completing the contract. Tradeoffs must be established between cost, performance and the schedule.

Additional elements to the acquisition plan may include a list of potential sources, availability of competition, and the intended source selection procedures. Arrangements must be made when government furnished property is used for the production of the replacement spares. The acquisition plan must finally address any environmental considerations, security considerations, and other logistics considerations.

Each of the elements under the acquisition planning process contribute to the administrative lead time incurred from the identification of the need up to the contract award. Ideally, the careful consideration paid to the acquisition of recoverable spares prior to solicitation and contract award will promote greater efficiency, lower the total time required for delivery of the purchased quantities, and decrease total costs to the government.

The Contracting Process. As already stated, the requirements determination process initiates the acquisition flow, and starts the process of contracting. Figure 41 describes the contracting process (53:14). As

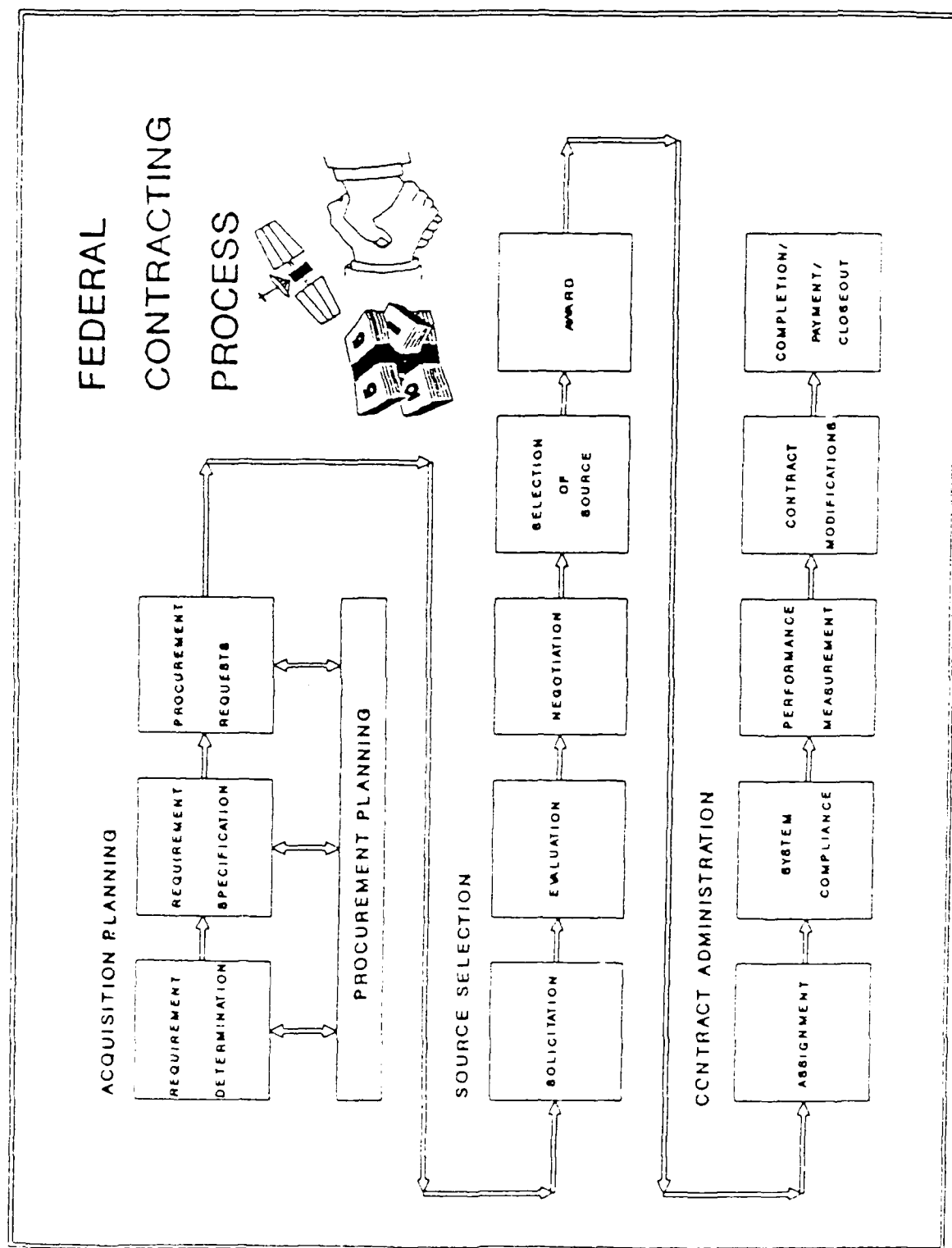


Figure 41. Federal Contracting Process (53)

shown, procurement planning is conducted concurrently with requirements determination, requirements specification, and preparation of procurement requests.

The two major phases of the contracting process are the source selection phase and the contract administration phase (53:14). The elements under source selection include solicitation, evaluation, negotiation, selection, and contract award. Activities under contract administration include assignment, measures of system compliance and performance, any contract modifications, and finally completion and close-out of the contract.

Each of the phases of source selection attempt to efficiently select and award contracts, thereby minimizing total procurement costs. The trade-off, however, is the increased ALT that occurs prior to awarding the contract. Similarly, the contract administration process follows procedures designed to ensure a contractor's compliance with the contracts to keep prices in check and deliveries on schedule. Again there is a trade-off with increased PLT as a result of reporting requirements. PLT is controllable at the contractor-level of the logistics pipeline. The next section describes the industrial capacity and its effects on PLT.

Industrial Capacity. The Air Force logistics system's capability to procure supplies in peacetime and wartime alike is dependent on the United States industrial base's

ability to manufacture and distribute military spares. During the period since World War II, concern has grown over our ability to respond to production requirements and to contain total production lead times. This section assesses the current state of the industrial production capability, and identifies programs that are being used to improve the responsiveness of the industrial base.

Low capital investment has caused numerous problems within the defense industry. Military capital investment as a percent of revenues was only half as large as for commercial enterprises (32:17). Investment has been stifled by unstable military budgets that depend on annual appropriations to fund procurement contracts. Contractors receive no long-term benefit from lowered unit costs if their contract is not renewed each year. Annual budgeting creates a lack of incentive to invest because contractors experience high risk with capital improvements.

Subcontractors have been much worse off during the decline of industry than primary contractors. Small subcontractors have moved away from military production because of low profitability, unstable budgets, and excessive regulations and reporting requirements. Fewer subcontractors creates greater difficulty identifying sources to fill requirements and may thereby increase administrative lead time.

Richard Ichord's report on the state of the ailing defense industrial base claimed that the increasing dependence on foreign sources for critical materials may increase lead times (34:1). The United States is almost entirely dependent on foreign countries for supplies of metals used in the production of jet engines. Many minerals are imported from third world countries whose economies and governments may not be reliable during a period of war.

The problems of low investment, declining productivity, and foreign dependence must all be addressed. Without solutions to these problems, the US defense industrial base is in danger of further deterioration causing lasting effects that will lengthen production lead times and lower overall industrial responsiveness (32:5).

The Disposal Pipeline Subsystem

Materials that can no longer be repaired and reused are condemned at either the base or depot levels. Repairable spares may be sent from the base to the depot after being declared NRTS. If neither the base nor the depot has repair capability for the failed asset, it is turned-in to Supply condemned and sent to salvage. The Defense Reutilization and Marketing Service (DRMS), a component of the Defense Logistics Agency, manages this disposal pipeline subsystem.

DRMS maintains about 200 field offices placed either on or nearby major military installations throughout the

CONUS (18:27). The CONUS is divided into three regions headquartered in Columbus, Ohio; Ogden, Utah; and Memphis, Tennessee (40). The field locations serve as the collection points for material that has been condemned or is no longer needed by the services. Distributing the field locations throughout the country reduces the need to move property and eliminates unnecessary handling. Once an asset has been turned-in to DRMS, it will remain at that location until another user is found, it is donated to a qualifying organization, or it is sold to the general public (40).

The first priority of DRMS is to find another user for the property (40). Reutilization enables the Air Force and other services to save procurement funds when suitable used material is available. DRMS must make information available to the services concerning the availability of spares in all of its storage facilities throughout each of the regions.

Before a potential user expends the effort necessary to view an asset that may be reentered into service, the general condition must be known (40). While the Air Force marks most spares sent to DRMS as condemned, DRMS provides another code giving its general assessment of the item. The Air Force may send reparable to DRMS if it has no current or future expected requirements for them. Some of these assets may be unused, serviceable, or reparable. DoD customers of DRMS may inquire about property contained in the disposal system through remote terminal (40). The Interrogation Requirements

Information System contains information about all the items located in DRMS storage areas worldwide. By inputting a National Stock Number (NSN) a customer can find out which locations (if any) have the part requested. The inquiry will additionally tell the customer the approximate condition of the item. Customers may also become aware of potentially usable assets contained in DRMS through the Excess Personal Property Listing (EPPL), a catalog published weekly showing the locations and condition of selected assets (20).

If an item is identified that may be reused, the DoD customer must arrange to preview it in the DRMS facility where it is held (40). When the item is found to satisfy the requirement, the agency requesting it must arrange for transportation to the location where the requirement exists. Transfer procedures to bring the item back into the Air Force supply system are relatively simple. The customer must coordinate with Supply personnel to establish a requisition and a shipment from DRMS to the requesting organization is made.

If no other use is found for an item in DRMS, it is offered to various community agencies and nonprofit groups (40). Some aircraft spares may then be sent into local museums and displays. Other assets not requested by qualifying non-profit and community groups are offered at auction for sale to private individuals.

Sealed bids may be used to sell items individually or by the lot (40). Aircraft spares may be sold in bulk as miscellaneous parts. If sold to an individual, the parts may become part of a private collection, used for other purposes, or sold for scrap.

The DRMS is the last length of a long pipeline as parts travel through the logistics system entering periods of storage, use, shipment, repair and reuse. Once recoverable spares have served out their useful life they are sent to the disposal subsystem where they are eliminated from the Air Force logistics pipeline system. Spares may spend only a few days in the disposal pipeline or they may require up to a year to find another user or buyer (40). The Literature Review has attempted to describe each of the subsystems of the logistics pipeline individually thus far. The next section addresses two models that describe, in general terms, the overall logistics system.

Collective Pipeline Models

The last part of the literature review identifies two models that address the collective pipeline. The first model is taken from the Air Force Institute of Technology Logistics Management 199 course materials. The second is from a 1978 study by the Logistics Management Institute.

AFIT Three Level Model. Charles Youther, associate professor of Logistics Management at the Air Force Institute of Technology used the network diagram shown in Figure 42 to describe the Air Force logistics pipeline (60:1). This model subdivides the overall logistics pipeline into three subsystem levels. The first level represents industry, the second depot, and the third wing or base-level. The model portrays the movement of serviceable, repairable and condemned assets through the system.

From the industry level, serviceable assets are produced by contractors and distributed to depot-level activities or sent directly to base-level. The diagram also shows the contract repair process as NRTS assets are returned to the contractor and either repaired and returned to depot, or condemned and sent to salvage.

Figure 42 shows the depot-level processes mainly revolving around Depot Supply's central receiving and shipping functions. Processes that form the depot-level system include manufacture, storage, repair, and salvage. The General Services Administration and the Defense Logistics Agency perform similar depot-level tasks for items commonly used by other federal agencies and the Department of Defense, respectively.

Base Supply is at the receiving end of industry and depot-level shipments of serviceable items. In addition to the depot and industry, bases may be supplied directly from

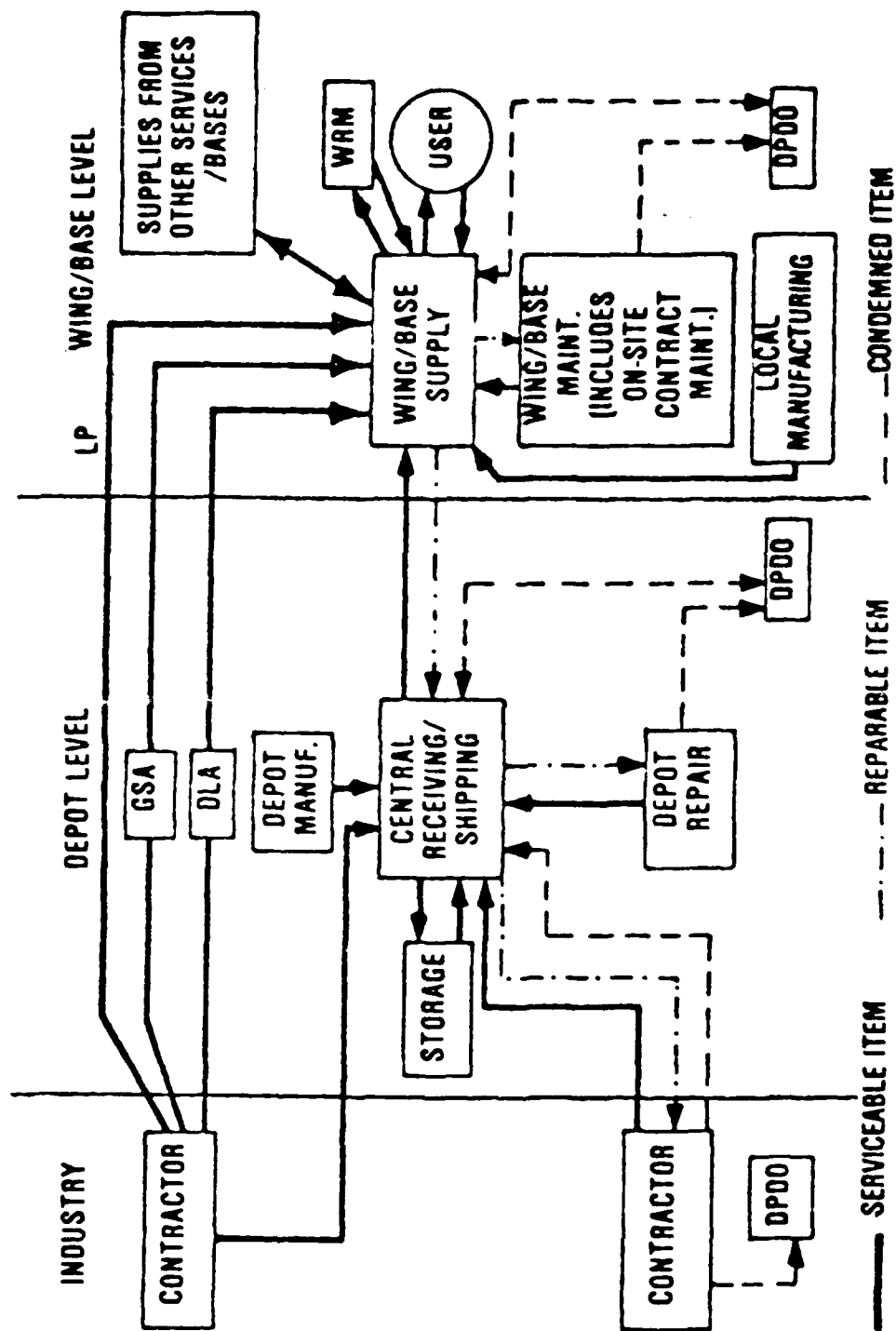


Figure 42. Three-level Pipeline Model (60)

other bases via lateral resupply. Assets may also be obtained through local manufacture. Assets are maintained within Base Supply or stocks of War Reserve Material. Serviceable assets are issued to users, and repairable assets travel through the repair cycle process. Assets are either repaired and returned to supply, condemned and sent to salvage, or returned to the depot level as repairables.

This model divides the logistics system in three levels. Each level represents a subsystem within the overall logistics pipeline. The model illustrates asset movement throughout the entire system but does not relate the information flows between activities. Further, the model lacks detailed descriptions of the processes at each of the subsystems described in the Literature Review. The Logistics Management Institute model described next provides yet another depiction of the overall Air Force logistics pipeline system.

LMI Exchangeable Flows Model. LMI conducted its 1978 study to present a "framework" for logistics management decision making (29:ii). This framework was intended to conceptualize the complex DoD logistics systems for policy analysis and decision making. The LMI model described the general activities taking place within the Air Force logistics pipeline.

The LMI diagram uses the term "exchangeables" to describe repairable assets (Figure 43) (29:3-9).

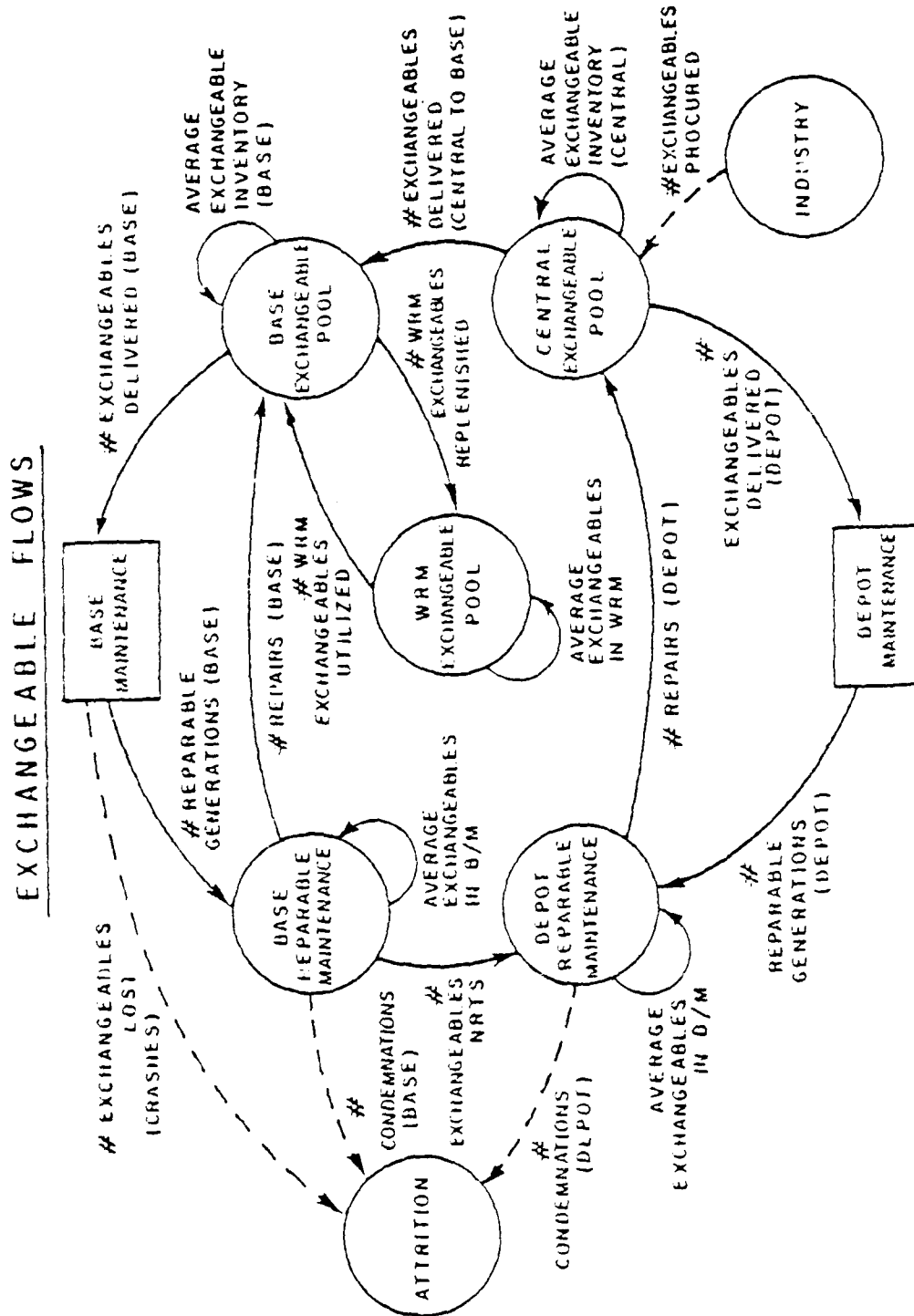


Figure 43. Exchangeable Flows Model
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Exchangeables could be repaired following a failure and then returned to stock or reused. Asset flows in the diagram are represented by the solid and dashed lines connecting each activity. The solid lines show movement of serviceable or repairable assets within the logistics system. The dashed lines show asset movement into the system as spares are procured from industry and movement out of the system as condemnations and crashes cause attrition.

Within the logistics system, assets move among pools of serviceable and repairable assets within the base and depot repair cycle systems. Circles in the diagram represent the pools of serviceable and repairable assets while the rectangles represent maintenance activities. Serviceable assets may be held in war reserve material, base operating stock, or depot stocks. Serviceable assets are issued to maintenance organizations at the base- and depot-levels. Repairables are sent to base or depot repair systems. Non-repairable assets at the base-level are sent to depot repair facilities.

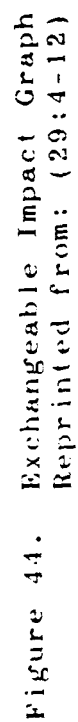
The LMI Exchangeable Flows model displays the movement of assets within the logistics system, yet does not show the factors affecting the movements between each element in the system. The Exchangeable Flows model provides a better conceptual description than other models discussed because it includes WRM at the base-level, central exchangeable pools at the depot-level, and industry providing inputs to the

the system. While activities have not yet been described in sufficient detail throughout the logistics pipeline, this LMI study documented the impacts in a separate section using an "impact graph" (29:4-12).

Figure 44 shows the LMI "Impact Graph" for exchangeable system capacities. The graph displays various interrelated conditions in separate centers. Non-connecting networks have separate, but related impacts on the overall system. The graph shows depot, base, and transportation activities are capacity constrained by funding. The number of aircraft failures, the number of spares procured, and the number of repairs completed at both the base and depot are all examples of potential impacts upon the overall system. Between the Exchangeable Flows diagram and the Exchangeable Impact Graph, LMI devised an initial framework for defining the Air Force logistics pipeline. These two frameworks must be combined and developed in greater detail to provide a more accurate conceptualization of the Air Force logistics pipeline.

Chapter Summary

Chapter II has reviewed much of the literature pertinent to the identification of pipelines. The chapter began with a discussion of two pipeline models used for commercial settings to show the commonality between military and business logistics systems. The models showed multiple



levels of production, storage and distribution to retail outlets. The base pipeline subsystem consists of supply, maintenance, and distribution activities. Within Base supply, assets flow through receiving, inspection, and delivery activities. Each of these are part of the customer order cycle. The customer order cycle includes time periods for order preparation and transmittal, retrieving the item from stock or manufacturing, plus transit, inspection, receiving, final delivery and uncrating.

Base Maintenance performs both preventive and corrective maintenance. Preventive maintenance involves periodic scheduled inspection and replacement of components to prevent unexpected breakdowns. Corrective maintenance follows a series of actions to include: identification of the failure, isolation of the cause, removal of the failed component, replacement or repair of the component, reassembly, adjustments, and testing. Base-level maintenance organizations perform both on-equipment field maintenance and off-equipment intermediate maintenance. Specialist Oriented Maintenance Organizations rely on specialists assigned to maintenance shops to perform many repairs. Combat Oriented Maintenance Organizations place most of the specialists on the flight line to be more responsive to mission requirements.

Distribution of assets to locations with current mission requirements is a value-added process. Transportation routes and modes of shipment affect the total quantities of assets

tied up in the pipeline. The priority system determines the precedence for movement of spares within the logistics system. The time standards provide general guidance for selecting the correct mode of shipment which minimizes total cost to the government and meets the urgency of mission requirements. Careful consideration must therefore be given to transportation factors and the priority system to reduce the Air Force logistics pipeline.

Most of the pipeline definitions concentrate on the movement of assets within the repair cycle. Pipeline concepts have evolved through time from the less sophisticated Base Stockage and Repair Cycle Demand Level models to the more sophisticated Dyna-METRIC and Aircraft Availability Models. While earlier models concentrated mainly on the base-level logistics pipeline level, later models incorporated both base- and depot-level with multiple indentures of spares. The early models were helpful in gaining an understanding of asset flow within a particular base; the latest models show the flows between bases and depots while calculating total aircraft availability. The DRIVE model is similar to other aircraft availability type models. It calculates depot repair requirements with current data, and bases priorities on improvements in aircraft availability.

The acquisition system for spare parts is driven by the repair and requirements computation process. Requirements computation is performed quarterly by the D041

Recoverable Consumption Item Requirements System. The system is dependent upon repair cycle information from the bases and depots. Establishing a good requirements computation system that accurately forecasts current and future needs will lead to decreased resources tied up in the logistics pipeline. Identification of lead times in the acquisition subsystem is an important factor that affects pipeline quantities. A 1984 LSAO study indicated that a need exists for standardizing estimates of total procurement lead time. The PLT model proposed by the LSAO segments administrative and production lead times into identifiable components that recognize the differences between estimates of total lead times.

The acquisition pipeline subsystem is driven by requirements and resources. Item managers and system managers coordinate with contracting officers to formally define needs, and establish plans for acquiring new spares. Procuring contracting officers solicit bids, evaluate proposals, and award contracts. Administrative contracting officers ensure that provisions of the contracts are carried out. The acquisition pipeline subsystem is dependent on the industrial base to produce the items needed quickly and in the desired quantities. Both primary and subcontractors are affected by quality issues that are important to maintain a competitive and productive industrial base. Better quality is needed to reduce lead times and pipeline quantities.

The Defense Reutilization and Marketing Service manages the disposal pipeline subsystem. Assets are condemned in base and depot repair shops. The condemned assets are sent to Depot or Base Supply. There, they are prepared for shipment and transferred to the nearest DRMS facility. DRMS disposes of assets through public auction, donation, or transfer to other military services for reuse.

Analytical models have proven useful in establishing stockage levels for both bases and depots; however, the mathematical constraints placed on these models prevent them from modeling the logistics system with the level of detail necessary to approach reality. The conceptual models developed by LSAO and AFIT provide a broad overview of the logistics system, yet fall short in describing the processes occurring in each pipeline subsystem. What is needed to more accurately describe the Air Force logistics pipeline is a conceptual flow model showing the actual movements and processes occurring throughout the logistics system.

Overview of Chapter III.

Chapter III presents the framework for completing this pipeline research. It reviews the general and specific problems of identifying the Air Force logistics pipeline, restates the specific investigative questions, and describes the specific method used to answer them.

III. Methodology

General Issue

Studies of the Air Force logistics pipeline revealed some genuine concerns about the efficiency of providing supplies to all levels of usage within the system. Literally millions of dollars are spent each day to keep these assets moving in the system and to maintain current service levels.

The US Air Force Air Staff would like to reduce the amount of its scarce resources tied up in the system, and to provide more responsive support to active units. This study attempts to collectively define the pipeline as a starting point for balancing Air Force resources, and understanding the impact of current policies on the pipeline.

Specific Problem

The particular problem associated with defining the Air Force logistics pipeline is that no comprehensive definition of it exists. Individual subsystems and components have been studied, but often without regard to the rest of the pipeline. This study describes how all of the subsystems and components fit together by modeling the complete pipeline, from raw materials to the salvage yard, including as many relevant processes as possible.

Investigative Questions

Even more important than piecing together the pipeline components, is accurately assessing the possible variables that go into each component. Many of the variables were defined in the literature review. Others were found through interviewing experts, those working within a particular component of the pipeline every day who have acquired a thorough knowledge of its characteristics. Questions posed to these experts related specifically to their jobs and how they are affected by the activities of others within the system. Interviews addressed the investigative questions asked in the introductory chapter. As a starting point, the interviews attempted to answer:

1. Can the logistics pipeline be accurately subdivided into major subsystems such as base-level, depot-level, acquisition, and disposal?
2. What processes take place in each subsystem of the pipeline?
3. What are the transportation linkages within and between major pipeline subsystems?

Particular Method

From the collection of information within the literature review, and expert interviews, a complete, single model of the Air Force logistics pipeline was developed. The model is a general, descriptive flow chart for reparable items moving through the pipeline. Variables influencing the total quantities in the pipeline, the

variability in lead times, and the allocation of assets between pipeline components were discussed in the explanation of the model. This model is particularly valuable in defining the total logistics pipeline so that questions as to its efficiency and effectiveness can be answered by qualified logistics managers.

Interview Experts for Information. As previously mentioned, those with direct involvement and experience in each logistics discipline were the best source of information about pipeline component characteristics as well as unwritten policies and practices.

Model Development. A conceptual model was synthesized from the findings of the literature review and personal interviews. In developing the model, each of the authors diagramed their versions of the pipeline independently. Once both authors had developed a conceptual representation and completed a description, the models were compared and discussed. The authors again reconstructed their models based on the mutual exchange of information following the discussion of each other's logistics pipeline diagrams. After a second revision of the models, the authors agreed upon one overall model of the logistics pipeline, and four interconnecting models for logistics pipeline subsystems.

The Air Force logistics pipeline model developed does not calculate the specific time variations and typical time periods that stock spends in each component of the

logistics pipeline subsystems. Cost factors that affect both timing of procurement, total stockage levels, and modes of distribution were not addressed. This research is purely descriptive; it compiles facts into a collective pipeline model that describes the actual flows of assets within and between pipeline subsystems. The model additionally considers priority systems and information reporting that affect both the speed of asset flow and the volume of the logistics pipeline.

This methodology encountered two significant hurdles. The first was in synthesizing the information into an organized pipeline model. Secondly, it was tempting to become too involved with the details of some subsystems, thereby shortchanging other subsystems. The authors attempted to maintain focus throughout the research process to describe the pipeline subsystems and their components in comparable detail.

Chapter Summary

Chapter III presented the framework for completing this pipeline research. The methodology reviewed the general and specific problems of identifying the Air Force logistics pipeline. Investigative questions seek to identify the various linkages and processes in the pipeline. An interviewing process was used to find more information about the pipeline that was not contained in

the literature and to validate pipeline model that was derived from the literature review and initial interviews.

Overview of Chapter IV

Chapter IV contains the analysis of findings from the interviews and literature review. Responses to the investigative questions are discussed and will be combined with the information from the literature review to develop a pipeline model. The conceptual model is then presented along with an explanation.

IV. Findings, Model Presentation, and Conclusions

The literature review and interviews were used as the basis for answering the investigative questions first presented in Chapter I. Each of the pipeline subsystems was described by the literature reviewed from available published and unpublished sources. This chapter synthesizes that information to answer the investigative questions and to develop the conceptual model of the Air Force logistics pipeline. This chapter is organized as follows: (1) findings, (2) model presentation and explanation, and (3) conclusions and recommendations for further research.

Findings

The findings are discussed in order of the presentation of the investigative questions.

Investigative Question 1. Can the logistics pipeline be accurately subdivided into major subdivisions such as acquisition, depot-level, base-level and disposal?

The literature review revealed that definite distinctions exist between the various levels of the logistics pipeline although processes overlap and affect other activities throughout the pipeline system. The acquisition pipeline subsystem begins with requirements determination and ends when new recoverable spares are delivered to the depot and/or base. The depot-level pipeline subsystem begins where serviceable or repairable

assets are delivered to it from either civilian contractors, base or depot users, or redistribution from other bases or depots. The base-level pipeline subsystem begins where serviceable assets are delivered to it from depots or redistribution from other bases. Finally, the disposal pipeline subsystem exists at both bases and depots where condemned or excess assets may be sent for salvage or reuse by other DoD agencies. The disposal pipeline begins at the location where a reparable spare is condemned, and ends either with the asset reutilized by a federal agency or demilitarized and sold/given to civilian organizations. In this four level description, the transportation system is a vital element of the overall logistics pipeline. Processes within the transportation subsystem itself determine both the speed of asset flow and volume of the logistics pipeline between each of the other pipeline subsystems. Further justification for this four subsystem portrayal of the Air Force logistics pipeline is provided under the model presentation.

Investigative Question 2. What processes take place in each subsystem of the pipeline?

A brief overview of the processes occurring in each of the four logistics pipeline subsystems is presented. These processes are elaborated upon in the model presentation. The literature review documented the processes occurring in each of the subsystems. The base-level pipeline subsystem

contains both the ultimate point of use for reparable spares and limited repair facilities. Assets travel through the base repair cycle composed of Base Supply and Base Maintenance functions.

Supply pick-up and delivery, storage and issue, order processing, and base repair cycle stockage levels affect the speed of asset delivery to customers and the quantity of assets contained in the base pipeline. Base Maintenance activities affect the base-level pipeline by the speed with which they process repairables from the line to maintenance shops, the on-base repair capabilities (including quality, quantity, and speed of repair), and the accuracy with which maintenance actions are reported to supply. Inventories at the base-level are managed by the Standard Base Supply System. Stockage levels are set, issues made, and shortfalls requisitioned. Assets are held in a central warehouse located in the main Base Supply building, in WRM WRSK/BLSS kits, at forward supply locations, and in maintenance-operated supply points.

Base-level maintenance organizations accomplish both preventive and corrective maintenance. This includes organizational maintenance directly on the aircraft, and intermediate maintenance in repair shops. Intermediate repair capabilities are limited at the base-level because of the need for specialized equipment and personnel with extensive technical knowledge.

The depot-level pipeline consists of a series of interrelated systems involving supply management, distribution, and maintenance. Spares requirements computation, workload planning, material requirements, scheduling, repair processes, and storage of repairable and serviceable spares all affect the flow of assets within the depot and between depots and bases.

Depot-level inventories are managed by both the DS Material Processing Division and the DS Supply Division. The Material Processing Division stores repairable items awaiting repair and other serviceable spares waiting to fill requirements generated by either depot or base activities. The Supply Division maintains assets primarily for use by the depot repair and overhaul facilities. Depot inventories are also held in Maintenance Inventory Centers to satisfy immediate requirements placed by the depot's maintenance repair shops.

Depot-level maintenance activities accomplish the entire range of maintenance processes from simple removal and replacement of failed components to complete overhaul of both aircraft and major system components.

The acquisition pipeline subsystem coexists with the depot supply and maintenance activities at Air Force depots. Item managers interact with supply and maintenance personnel to determine requirements for new recoverable spares. Procurement personnel fill requirements through the

contracting process. Civilian contractors complete the acquisition process by manufacturing recoverable spares and delivering them to Air Force depots.

The disposal subsystem involves receiving and cataloging each item turned-in as excess or condemned. Assets are made available to other DoD agencies through a computerized reporting and retrieval system. If no DoD user is found, then Defense Reutilization and Marketing Service (DRMS) will dispose of the property by donation or public auction.

Investigative Question 3. What are the transportation linkages within and between major pipeline subsystems?

There are a number of transportation linkages available for managers to use in order to get the assets to their destinations within the prescribed time frames. Transportation Officers (TOs) have been given the authority to make mode and carrier selections for transporting supplies between major pipeline subsystems. The TO's decisions are based on the transportation priority given the item by Uniform Military Movement and Issue Procedures, and on the available transportation modes. Department of Defense materiel handling regulations and local procedures dictate how assets will be transported from one activity to another within major pipeline subsystems.

Within the major pipeline subsystems, various material handling equipment is used to transport assets from one activity to another. Forklifts and/or mechanized material

handling equipment transfers supplies from the receiving docks to storage or to the delivery docks. Manual or mechanized stock picking may be used to retrieve supplies from stock to be issued or shipped. Various sizes of trucks deliver and pickup assets on base. The priority placed on the user's need by the Department of Defense is the driving factor behind how quickly an item is moved from one activity to another. Aerial port and surface freight terminals play a major role in efficient cargo flow within pipeline subsystems because they are both the faucet and the drain to the subsystems.

Between the major pipeline subsystems, the proper mode and carrier are selected to transport supplies, again, based on the urgency of need. Many reparable spares for stock replenishment are delivered in over-the-road vehicles; however, mission needs may dictate expedited delivery by military or commercial air service. Occasionally, expedite mail services, either federal or commercial, are used to transport small, high priority assets. Aerial port and surface freight terminals are decisive factors in how smoothly supplies flow between major pipeline subsystems as well. They act as intermediate points where shipments are broken down and/or consolidated to be distributed among the many bases.

With this brief overview of the Air Force logistics pipeline's four main subsystems, the processes occurring in

each subsystem, and the transportation linkages within and between subsystems, the next section presents and explains a more detailed pipeline model.

Model Presentation and Explanation

This section contains an outline of the general characteristics of the Air Force logistics pipeline, an analysis of several pipeline models described in the literature review, and the presentation of a more detailed logistics pipeline model.

The Overall Logistics Pipeline. The Air Force logistics pipeline may be viewed as being composed of four separate, yet interdependent subsystems. Each subsystem contains smaller systems which contribute to the movement and placement of assets throughout the entire system. The four subsystems interact as shown in Figure 45. The acquisition subsystem is the initial source of reparable spares, supplying depot and base needs to the logistics pipeline. Depots typically first receive parts as they are delivered from industry. The depots may hold new parts for future requirements, or forward them to bases, satisfying existing requirements. Once in the logistics pipeline, reparable spares move between the bases and depots from which they are used, repaired, stored, and redistributed to fill needs at alternate locations.

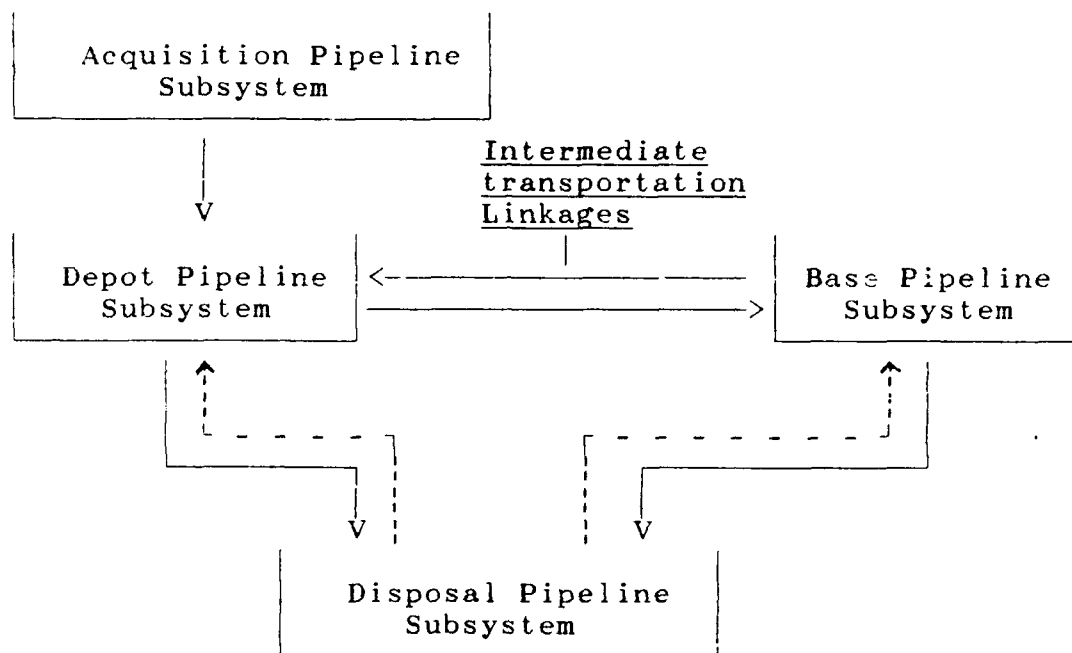


Figure 45. The Overall Logistics Pipeline

Intermediate transportation linkages are shown to document the additional handling that takes place between depots and bases. Military air shipments are sent to transshipment facilities where loads are broken down into individual shipments and reassembled into loads going to the same locations. Commercial air and trucking companies use similar methods for break-bulk operations to maximize the efficiency of transportation operations.

Pipeline Model Analysis. A meaningful conceptual pipeline model should not only describe the placement of each of the pipeline subsystems as shown above, but should also account for the interactions taking place within each subsystem. The literature review described several pipeline

models which show the flow of reparable between bases and the depots, yet no one model provided specific details about the processes taking place within these subsystems. The METRIC and aircraft availability models show only a basic flow pattern from bases to depots (Figure 34). Dyna-METRIC, one of the most comprehensive analytical models, treats the actions taken within supply, maintenance, and transportation in terms of broad measures such as average repair cycle time or order and ship time. While it allows for system losses and replacement of new spares, Dyna-METRIC does not explicitly consider the impact that maintenance, supply and transportation may have on condemnations, nor the acquisition process.

The LMI Exchangeable Flows model (Figure 43) provides a more complete conceptual description of the logistics system than the Dyna-METRIC model. Because the LMI Exchangeable Flows model did not have the analytic constraints as the math-based models, it could show some of the interactions between depot and base subsystems not readily modeled mathematically. Thus, the LMI model gives a more complete conceptual description of the flow of reparable through the Air Force logistics pipeline. In the LMI model, an entire system was presented including base, depot, acquisition, and disposal processes. The model shows that the number of assets present in each pipeline subsystem is dependent upon the number processed/generated in the preceding subsystems.

Like the other logistics pipeline models, the LMI model does not present the internal processes of each system that affect how long an asset is held, how many are present in the subsystem, and how the processes interact with other subsystems. For example, the LMI model shows a Base Exchangeable Pool with arrows connecting it to War Reserve Material, Base Repairable Maintenance, and a Central Exchangeable Pool. Yet, it does not show the supply actions such as when an asset is received from a depot, processed as a turn-in from maintenance, placed into storage, or issued from stock. Activities within each process provide the detail required by logistics managers to better understand the Air Force logistics pipeline.

Model Presentation. Future pipeline models must provide greater depth in describing each of the interconnected subsystems and subsystem components. The conceptual pipeline model presented here is an initial attempt to provide this greater detail in each of the pipeline subsystem components. This extended pipeline model is presented in flow chart format. The connections between subsystems and their components are represented by circular nodes which correspond to matching nodes of the connecting subsystem component. Rectangular boxes represent processes and diamonds represent decision points. Accompanying each flow chart is a discussion of each of its components.

The model presentation parallels the order of pipeline descriptions found in the literature review and is related back to the subsystems identified in the LMI Exchangeable Flows Model. Figure 46 shows again the LMI Exchangeable Flows Model to provide a basis of comparison with the proposed conceptual model. Superimposed upon this diagram are divisions for the four proposed Air Force logistics subsystems. Figures 47 through 61 make up the conceptual pipeline model. Base-level processes are identified in the flow chart "explosion" of the Base Exchangeable Pool and Base Repairable Maintenance. Depot-level processes appear in the flow charts of the Central Exchangeable Pool and Depot Repairable Maintenance. Next, a flow chart describes the transportation linkages between bases and depots. Last, flow charts are presented for the acquisition and disposal pipeline subsystems.

Base Pipeline Subsystem. At base-level, the pipeline seems to become more personal due to the fact that this is where the field-level repair activities are literally knocking at the door of Base Supply for needed parts. The pipeline, therefore, becomes a little more complex as it strives to meet the immediate needs of customer organizations as soon as possible. Unfortunately, no model was found which accurately explains the complexities of making spare parts readily available to the maintenance operation.

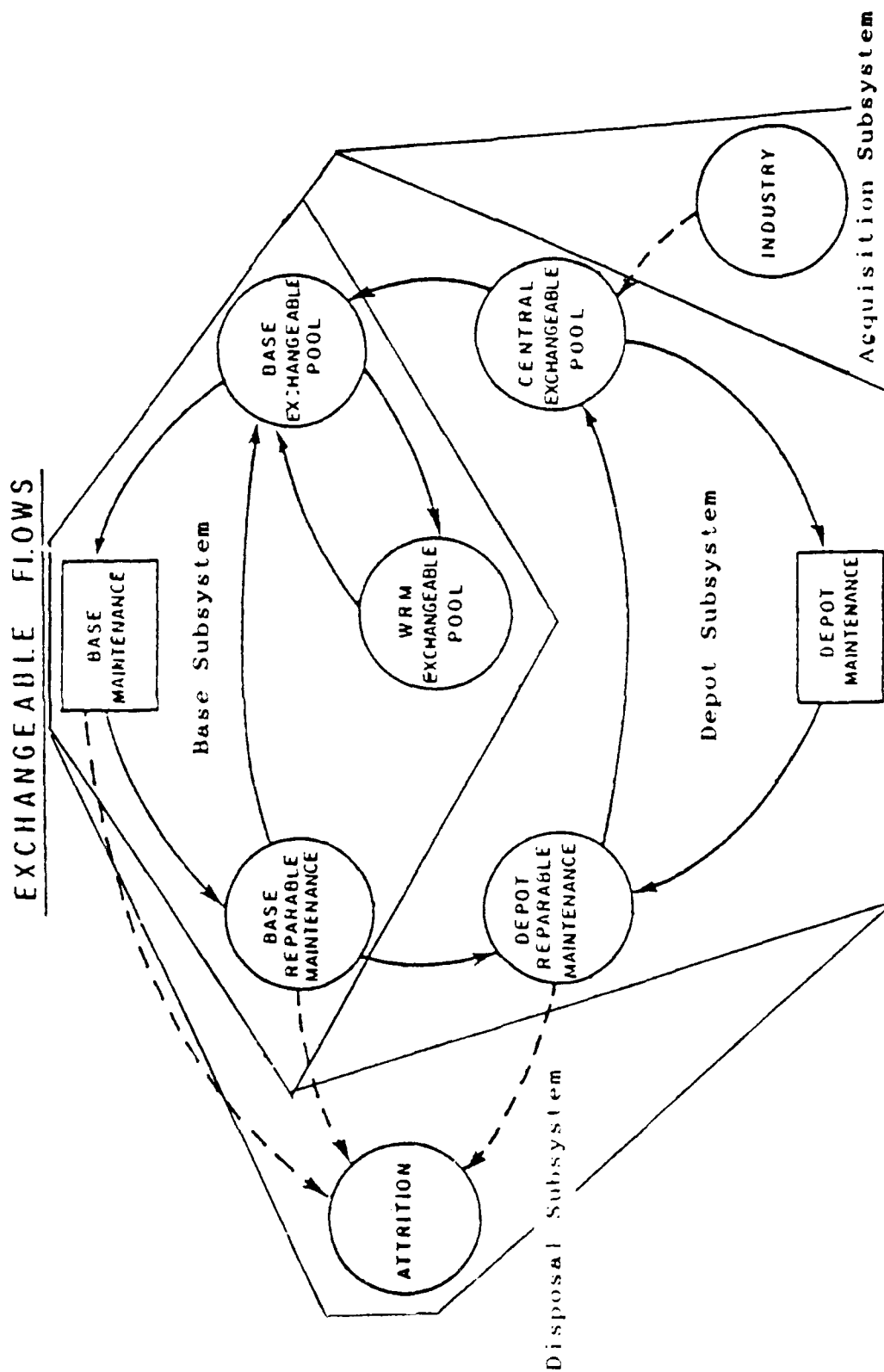


Figure 46. Exchangeable Flows Model
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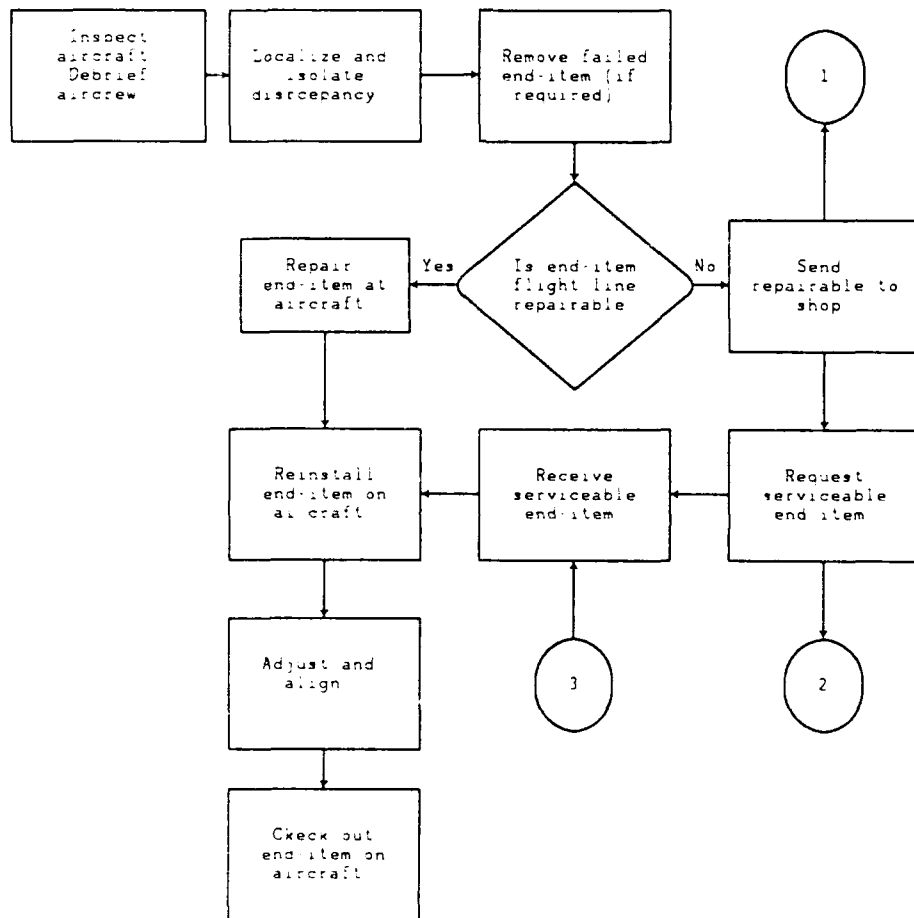


Figure 47. First Level Explosion of "Base Maintenance,"
Flight Line Maintenance Process

Base Maintenance. The demand for reparable assets by Base Maintenance to meet mission requirements is the "ignition" that starts the whole Air Force logistics pipeline "machine." The urgency behind their requirements for reparable spare parts (UND) and the designated priority of the weapon system's mission (FAD) are the driving factors behind how fast assets are acquired and handled throughout the base subsystem of the pipeline. Figure 47 explodes the "Base Maintenance" box from the Exchangeable Flows Model.

After the aircraft returns from a mission, it is inspected by the maintenance crew assigned to it. Any discrepancies are noted and isolated down to a particular part. On occasion, repairs of the end-item can be accomplished right on the flight line either with or without removing the part from the weapon system. In such circumstances, the part is repaired and replaced without placing any physical demand on Base Supply for a serviceable replacement. However, to record that an actual demand for a repaired part took place, Maintenance personnel will process a turnaround (TRN) document through Base Supply. This paperwork-only transaction will build a demand history.

If the failed end-item cannot be repaired and replaced on the flight line, the unserviceable asset is sent to the maintenance repair shops for further evaluation (Node 1).

At the same time, a demand for a serviceable replacement is levied on Base Supply (Node 2). If the end-item is available, it is issued to flight line Maintenance, who will then reinstall it on the aircraft (Node 3).

Base Reparable Maintenance. Figure 48 shows an explosion of the "Base Reparable Maintenance" activity from the Exchangeable Flows Model. This is where a majority of the maintenance decisions take place -- at the repair shops.

Remember at Node 1, flight line Maintenance personnel have sent the end-item to the repair shop for further assessment of the actual failure. At the Maintenance repair shop, technicians analyze the end-item and isolate the failed bits and pieces. Depending on the base repair capability and cost to repair the end-item, it may be repaired at the shop, sent to depot maintenance, or taken to salvage.

If base repair is authorized, technicians remove the failed parts and place a demand on Base Supply for replacement parts (Node 2). Repair actions continue as possible. When the replacement parts are received from Base Supply (Node 3), they are installed on the end-item which will then be reassembled, adjusted and aligned, bench checked (depending on the item), and tagged.

Recall that at the time the end-item is first removed from the aircraft and sent to the repair shop, a replacement unit is ordered from Base Supply. If this replacement unit

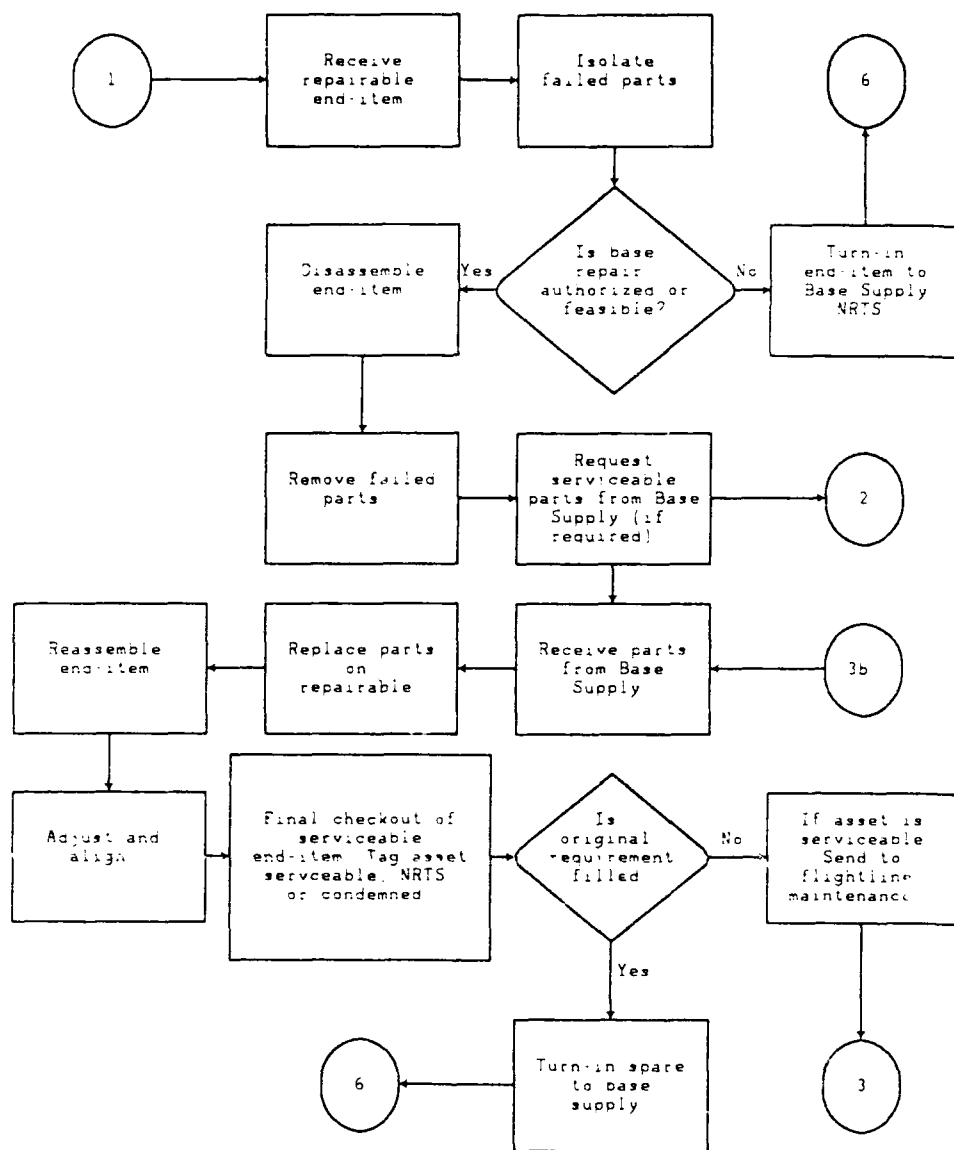


Figure 48. First Level Explosion of "Base Repairable Maintenance," Maintenance Shop Repair Process

has been received by flight line maintenance and installed before the unserviceable unit is repaired, the repaired end-item is turned-in to Base Supply for stockage (Node 6). If the original "hole" in the aircraft has not been filled, and the repaired end-item is serviceable, it will go back to the flight line from the shop and be installed. Note, if the end-item consists of an indentured LRU/SRU relationship, a subordinate level of detail for SRU repair must be added to this diagram.

What if base repair is not authorized? These assets are turned-in to Base Supply for disposition to depot maintenance activity (Node 6). These activities are discussed later in the analysis of the "Base Exchangeable Pool" portion of the Exchangeable Flows Model.

Base Exchangeable Pool. In an extension of the "Base Exchangeable Pool," it is easy to see how the Base Supply issue process affects the flow of assets (Figure 49).

When a reparable end-item is broken, or when bits and pieces are required to repair an end-item, maintenance personnel identify the need and order replacements through Base Supply's Demand Processing Unit (Node 2). At many bases (i.e., TAC and SAC), this function is located within a Supply warehouse/parts store located near the flight line. The decentralized Supply operation located near the flight line is designed to reduce the lead time involved in ordering, picking, and delivering assets to Maintenance. In

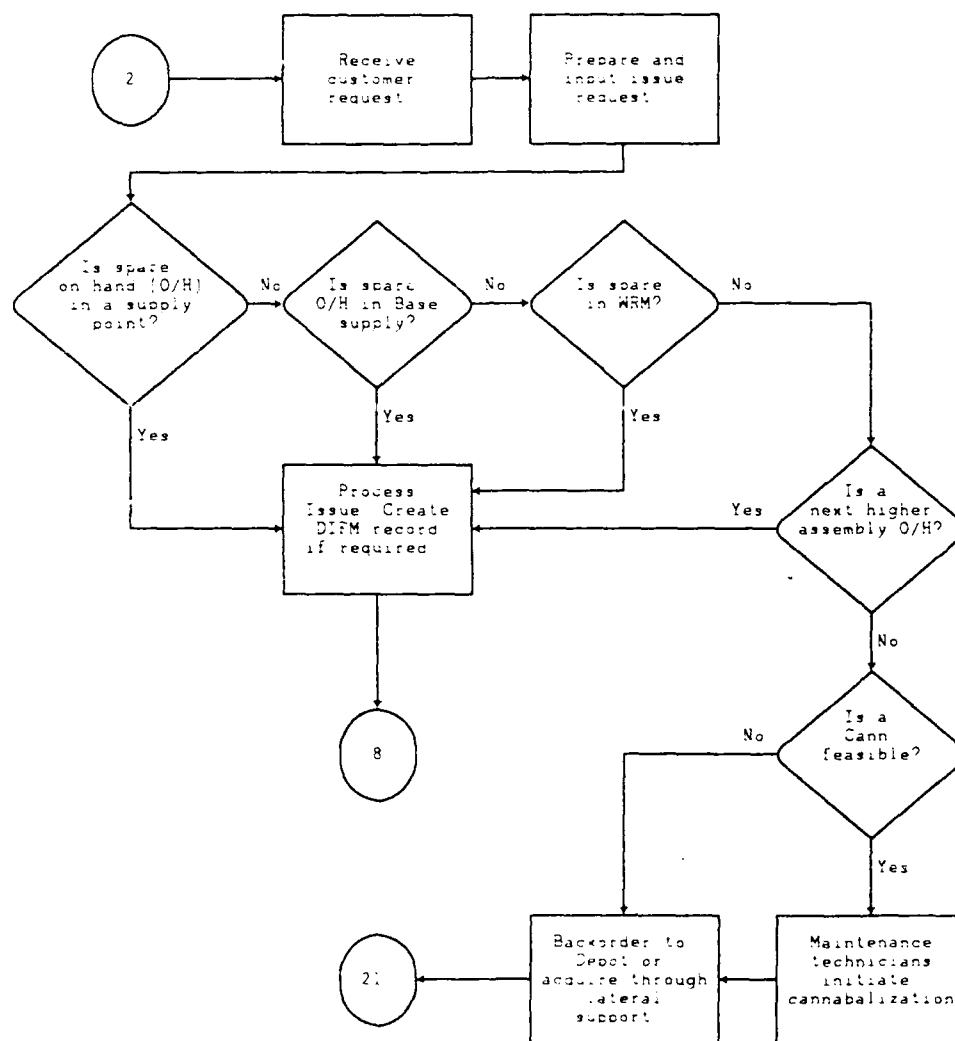


Figure 49. First Level Explosion of the "Base Exchangeable Pool," Customer Demand and Issue Process

addition to assets located in the normal supply warehouses, reparable spares used for routine shop maintenance may be located near the shop floor in a supply point. Supply points are managed by Base Supply personnel and provide readily available spares to the maintenance shops.

If the replacement asset is in Supply stock, it will be issued to maintenance personnel either over the counter at the flight line parts store or it will be issued and delivered from the main Supply warehouse (Node 8). Issues of reparable assets from a supply point are processed through Supply computer records to record the demand. Whenever issues of reparable assets are processed through the Supply system, a Due-In From Maintenance (DIFM) record is established and monitored by Base Supply to track the whereabouts of its reparable spares.

Whenever a high priority reparable asset is not available from normal Supply stock or a supply point, Supply personnel may issue from a "pool" of WRM spares located either in the flight line Supply warehouse/parts store or in the main Supply warehouse. Reference the Exchangeable Flows Model to visualize the relationship between the "Base Exchangeable Pool" and the "WRM Exchangeable Pool." These actions may be necessary to avoid a MICAP condition in which priority requisitioning from an off-base source of supply takes place.

If the request can not be filled from the previous stock locations, maintenance personnel may request that a next higher assembly be issued from either supply points, normal operating stock, or WRM. If the requirement is still unfilled, maintenance personnel may cannibalize the item from other equipment already down for parts.

If the reparable item can not be cannibalized from another broken end-item or aircraft, Supply personnel will seek lateral support from other bases with the same weapon system (generally for MICAP conditions only), or they will backorder a replacement from the depot (Node 21).

Figure 50, analyzes the flow of reparables through the Base Supply receiving process. The customer's needs affect even the way reparable spares are processed through Supply Receiving. If needed assets are not in stock at the time a replacement is needed, the required part is backordered through Supply to the appropriate source of supply. Reparable spares are requisitioned with a priority conducive to the customer's urgency of need.

As parts come in from an off-base source of supply (Node 10), they are inspected by Receiving and Inspection personnel for proper quantity, identification, condition, and possible damage. If a backorder exists, processing the receipt generates an automatic issue document, releasing the asset to the maintenance shop, supply point, or WRM pool (Node 3). If no demand for the asset currently

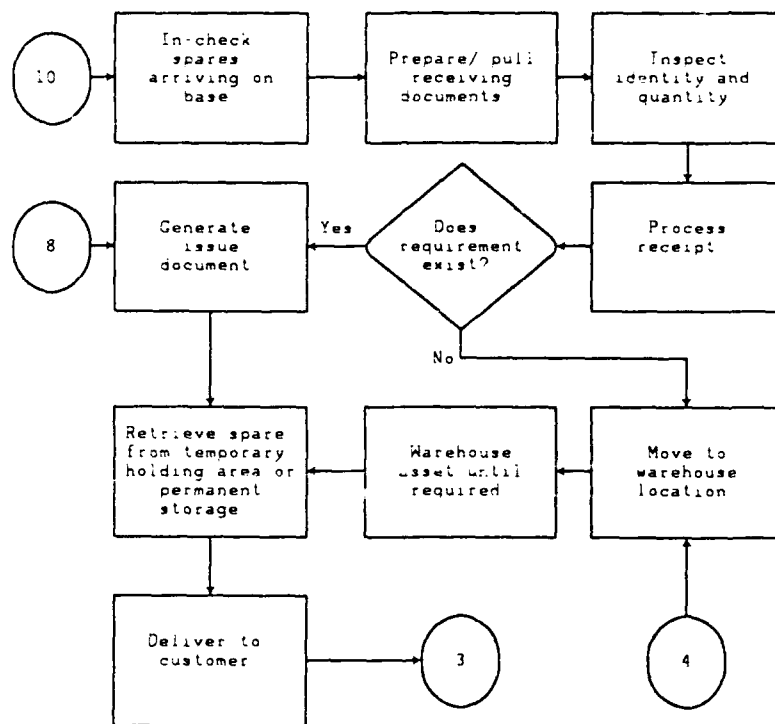


Figure 50. First Level Explosion of the "Base Exchangeable Pool," Receiving and Storage Process

exists, the receipt is for stock replenishment and processing the receipt will produce a notice to stock the item in the main Supply warehouse or the flight line warehouse/parts store. Once in stock, the asset will wait until it is issued (Node 8) and delivered to flight line maintenance for installation (Node 3).

When an item is turned-in to Base Supply from Maintenance (Figure 51), a variety of activities affecting the flow of the asset may take place depending on the condition of the item turned-in and the disposition instructions from the source of supply.

If repairs on the original failed end-item are completed after a serviceable replacement has been installed, the shop will turn-in the asset as "serviceable" to the Repairable Asset Control Center (RACC) of Supply. If repair capability does not exist at the base-level but does at the depot-level, the shop will turn-in the asset to the RACC as "Not Repairable This Station" (NRTS). If higher authority has determined that further repair of the asset is not economically feasible, the shop will turn-in the asset to the RACC as "condemned." In all three cases, when the repairable asset is turned-in to Supply (Node 6), it is inspected for proper quantity, identity, and condition. Supply personnel process the turn-in to clear the DIFM detail from their computer records in order to relieve Maintenance of accountability for the item.

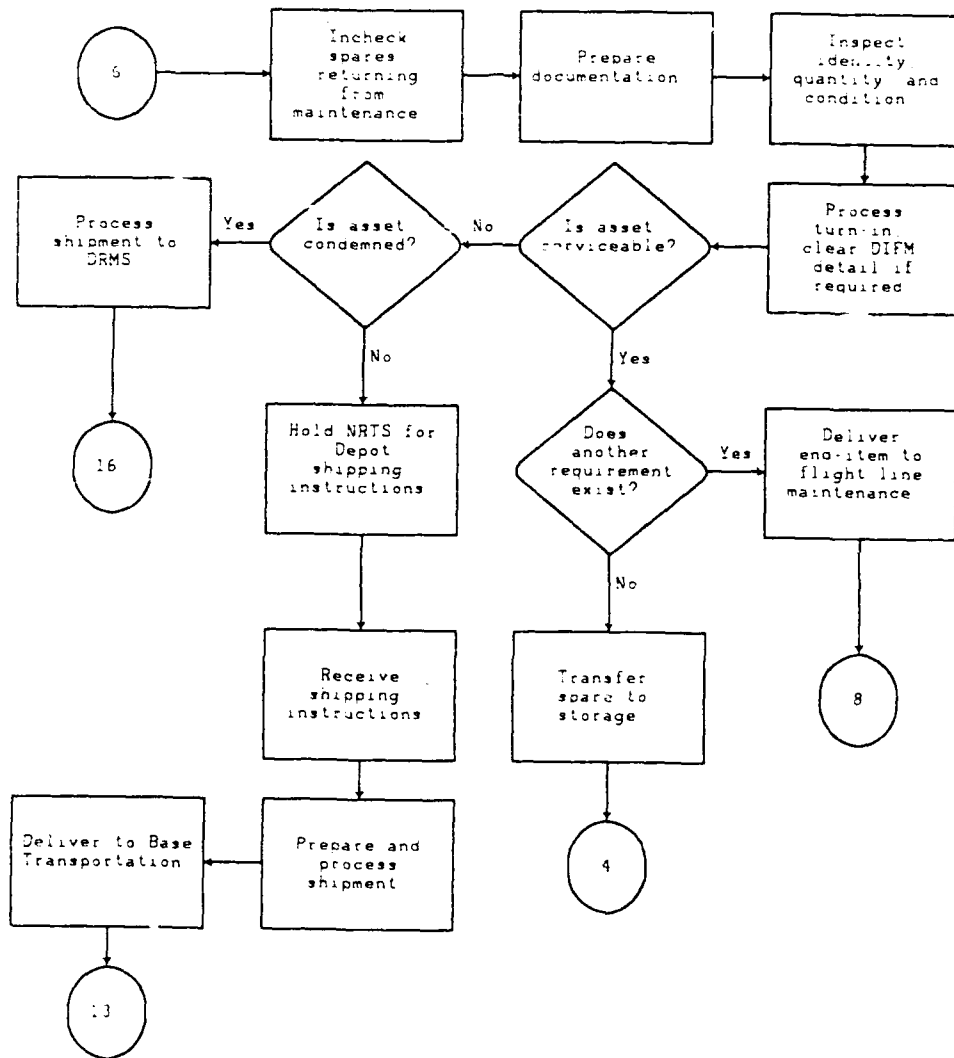


Figure 51. First Level Explosion of the "Base Exchangeable Pool," Reparable Asset Turn-in/Shipment Process

For serviceable asset turn-ins, once processed, the item will either be sent to the Supply warehouse with a notice to stock (Node 1), or it may due-out release to the maintenance supply point or WRM pool (Node 4), or due-out release back to flight line maintenance if another requirement has been generated (Node 8).

For NRTS assets turned-in, once processed, a shipping document is generated with disposition instructions to the appropriate depot repair location. In this case, the asset is delivered to the Packing and Crating Section of Transportation to be properly packaged for shipment (Node 13).

For condemned assets, once a turn-in is processed, a shipping document is generated with disposition instructions to the Defense Reutilization and Marketing Service (DRMS) for disposal (Node 16).

The Pickup and Delivery Section of Base Supply is a main player in the expedient movement of assets between both Supply and Maintenance activities. This section is essentially responsible for delivering the issues or due-out releases of reparable assets to flight line Maintenance, the WRM pool, the flight line warehouse/parts store, and to the supply point. They're also responsible for picking up turn-ins from the Maintenance shops and RACC, and for delivering shipments to the Packing and Crating Section of Transportation or DRMS. The urgency of on-base asset

delivery by Pickup and Delivery to the Maintenance activity depends on the maintenance/delivery priority specified when the issue request is made.

Transportation Linkages. The transportation process which occurs within and between the Air Force pipeline subsystems has long been overlooked by model analysts. From the manufacturer to the disposal facility, transportation management is an integral part of effective materiel flow.

The major concerns in the transportation process are traffic management (mode and carrier selection) and cargo flow through the various transition points. All property coming from and going to the bases (Nodes 10 and 13) and depots (Nodes 14 and 15) must be processed through a transshipper for consolidation or breakdown of the loads and redirected to their final destinations (Figure 52). Transportation is responsible for routing shipments through the aerial port or surface freight activity (depending on mode of shipment) at each transition point to make sure cargo is not unnecessarily delayed.

The Transportation Officer makes the carrier selection based on the urgency of the request for the asset and available transportation means. If the shipment is a high priority, it is most likely to be shipped via LOGAIR. Sometimes, however, commercial airlines are used to ship reparables when LOGAIR is not available. On occasion, the

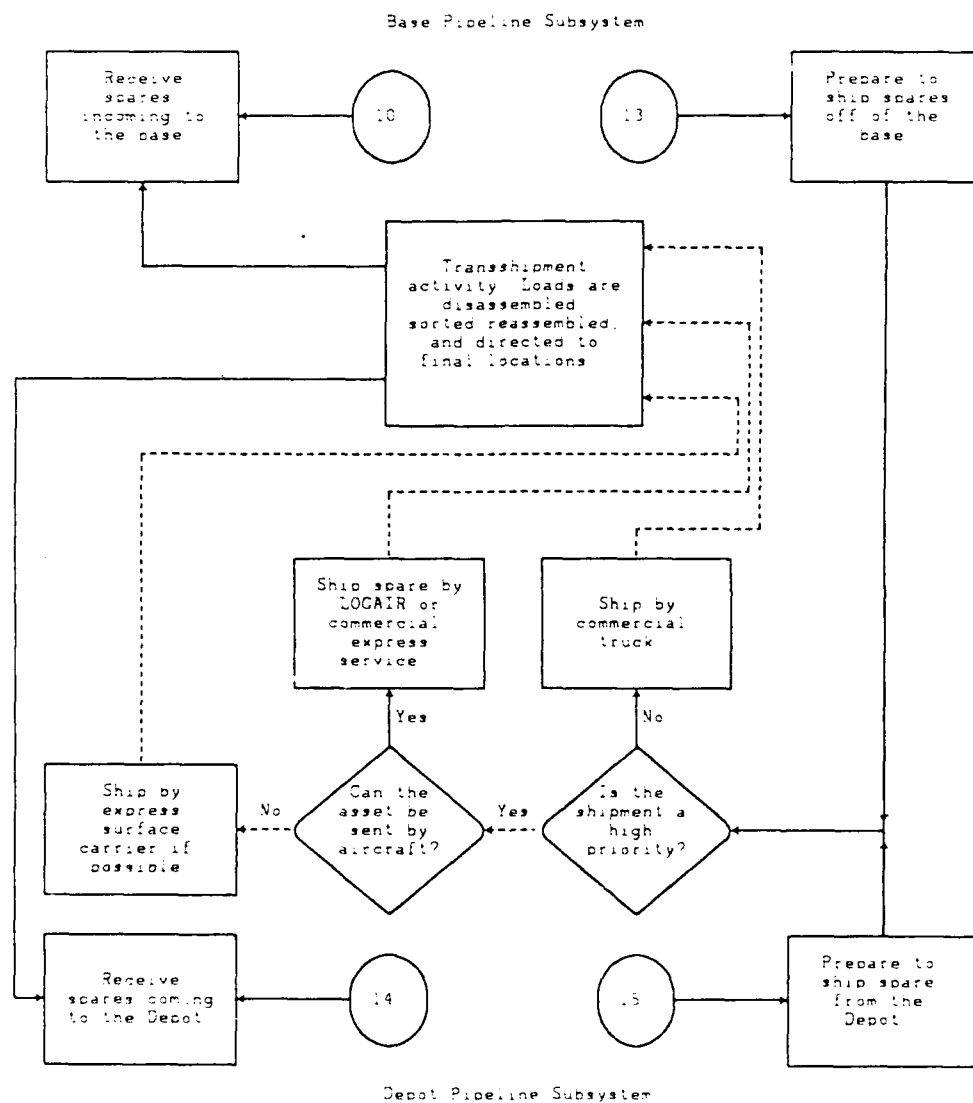


Figure 52. Transportation Process

physical characteristics of the asset will prevent shipment by air. In this case, express surface carriers are used to transport the item if possible. Repairable assets not given a high priority (usually for stock replenishment) are almost always shipped by surface carriers.

Depot Pipeline Subsystem. The Depot pipeline subsystem is an important element of the logistics pipeline. The LMI Exchangeable Flows model used three systems: Depot Maintenance, Depot Repairable Maintenance, and the Central Exchangeable Pool to describe depot pipeline flow. Each of these systems contained flows inside, yet the model did not describe them. This section explains the flow diagrams provided in the collective pipeline model as they relate to the LMI model.

Central Exchangeable Pool. Assets enter and exit the depot pipeline subsystem through the Central Exchangeable Pool. This pool contains at least three separate processes identified in the flow diagrams of the conceptual model. These processes include: the receipt and storage of new and repaired assets; the receipt, storage and distribution of repairable assets; the receipt of customer orders; and the delivery of spares.

Figure 53 shows the individual activities involved with the receipt and storage of new and repaired assets. At node 5, repairable assets arrive from commercial manufacturers. This is a direct link to the acquisition pipeline subsystem.

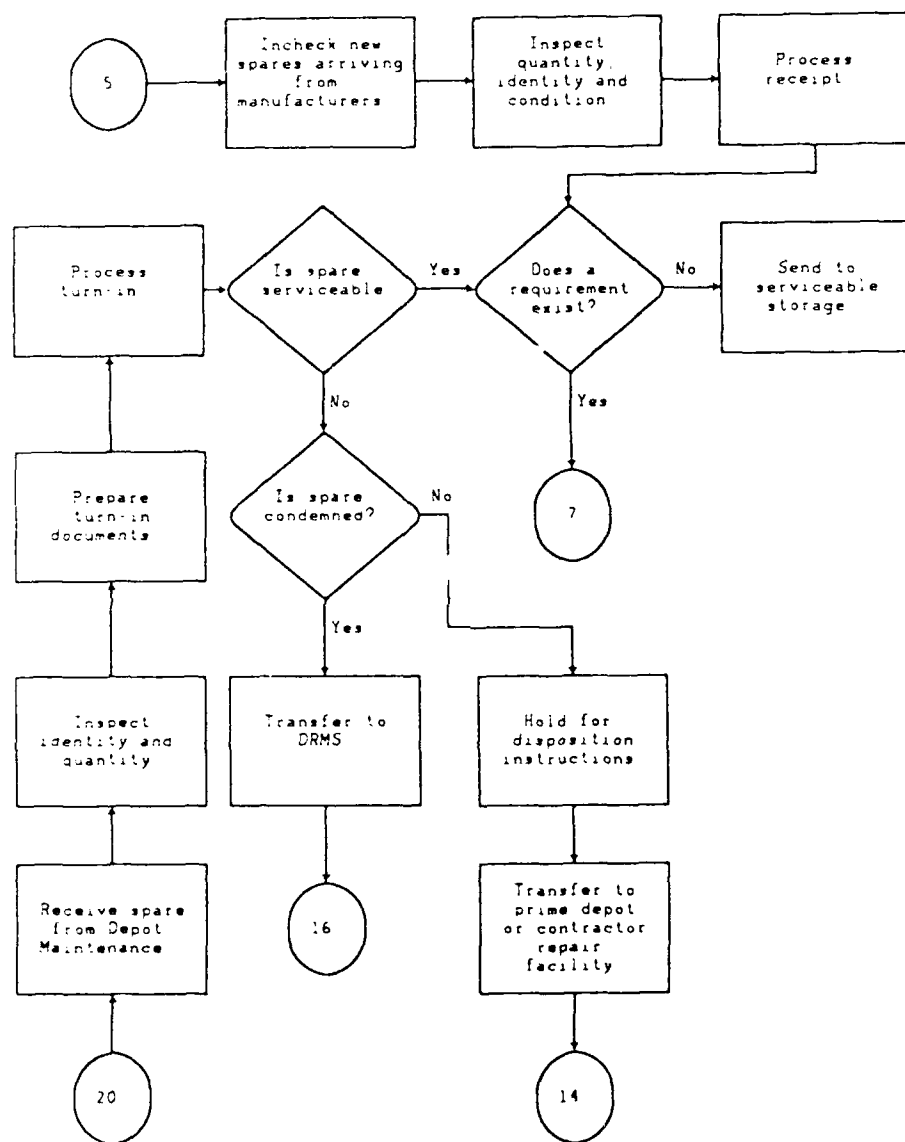


Figure 53. First Level Explosion of the "Central Exchangeable Pool," Serviceable Spares Receipt and Storage Process

Once arrived, the assets must be inchecked, and inspected for the correct quantities, identity, and signs of damage. Then the receiving documents are pulled and the receipt is processed. The new spares are initially entered into the Air Force inventory once the receipt is processed. If a current requirement exists after the receipt is processed, the spares are sent on to the customers via the customer request and delivery process (node 7). Otherwise, the spares are placed in storage.

Spares which have been through the Depot Repairable Maintenance pipeline system may enter this activity through node 20. These spares are inchecked and inspected as are new spares. Personnel must prepare turn-in documents and process the turn-in. If the spare is serviceable, the computer system determines whether or not a current requirement exists. If so, the spare is sent to the customer in the same manner as the new spares; otherwise, the spare is sent to stock. Spares turned-in unserviceable may be condemned or NRTS. Condemned assets are sent to the disposal pipeline subsystem through node 16. Repairable spares may be held for disposition instructions from the item manager before being sent to the primary depot or a contractor repair facility. These go through node 14 to depot outbound transportation.

The Central Exchangeable Pool also contains a process for handling repairable assets. Figure 54 shows how repairable assets enter the depot and are held until repairs

may be performed. The NRTS assets arrive from bases and other depots which could not perform the needed repairs via depot inbound transportation (node 15). The items are inspected for their identity, quantity, and condition before being sent to the repairable storage area. This is the "holding pool" described in the literature review section discussing the repair cycle. Assets may be held to accumulate a batch quantity, or until sufficient resources, personnel and equipment are available to perform the repairs. Once scheduled into production, the repairables are pulled from storage and delivered to Depot Repairable Maintenance by connecting node 18.

The Central Exchangeable Pool processes customer requests and delivers spares to customers using the steps show in Figure 55. Requests are sent through the Maintenance Inventory Center of Depot Repairable Maintenance and enter the Central Exchangeable pool through node 19. Requests may be received from customers at other bases and depots (node 21). Item managers may also direct the shipment of spares held at the depot to satisfy stock requirements at other locations.

Once the request is received, automated systems input the issue request. Some issue requests are also manually prepared and input into the computer. If the spare is on hand, an issue document is generated and sent to the warehouse where the spare is located. If the spare is not

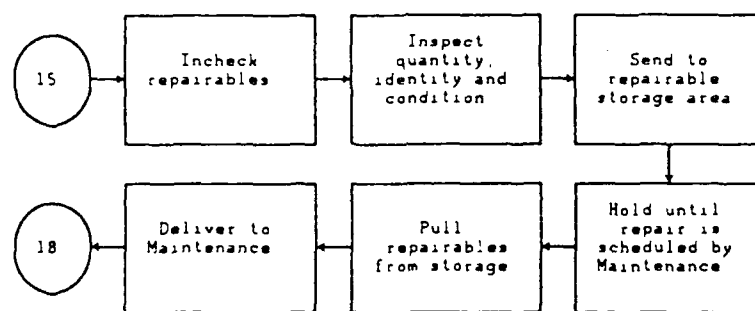


Figure 54. First Level Explosion of the "Central Exchangeable Pool," Repairable Spares Receiving, Storage, and Distribution Process

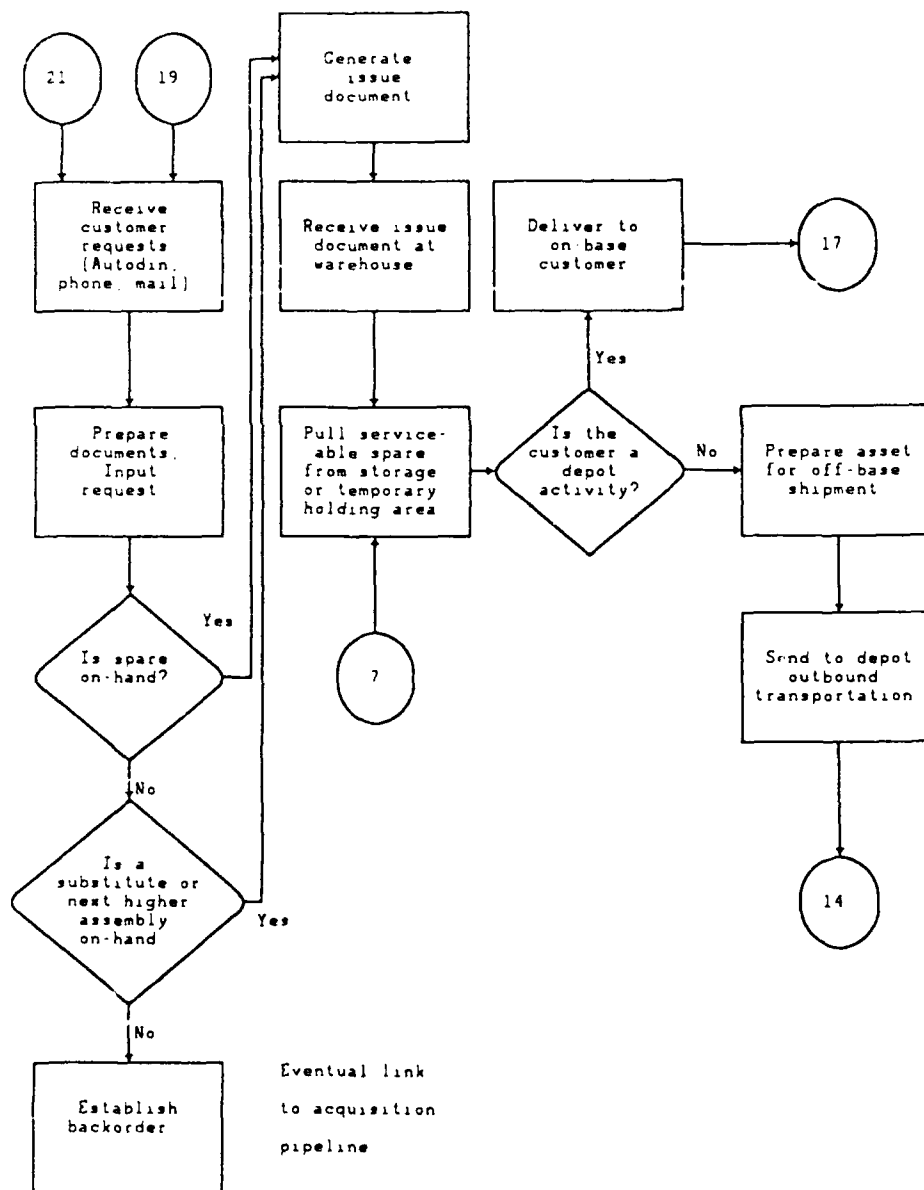


Figure 55. First Level Explosion of the "Central Exchangeable Pool," Serviceable Spares Issue Process

on hand, either automatic or manual checks must determine if a substitute, next higher assembly, or another asset is available to fill the requirement. If no spare may be found, the requirement becomes a backorder. Eventually, the requirement will be filled through acquisition of a new spare, repair of an existing asset, or redistribution of existing assets.

Once the issue document is received, the spare is pulled from temporary or permanent storage. Items recently turned-in or received by the depot are held in temporary storage areas (node 7) until personnel determine whether the item will be issued or sent to storage. Assets already in storage are removed and sent to the delivery section. From there, personnel must determine if the asset will be sent to fill an on-base (depot) requirement or an off-base requirement. On-base issues are sent to the customer via local pickup and delivery. Off-base shipments must be packaged to provide protection during shipment. The spare is then sent to depot outbound transportation by node 14.

Depot Repairable Maintenance. The Depot Repairable Maintenance component of the depot pipeline subsystem repairs assets sent to it from other subsystems in the logistics pipeline. This component may be further subdivided into processes within the depot repair shops and the Maintenance Inventory Center as shown in Figures 56 and 57 of the conceptual pipeline model.

The MIC serves as a control point for distributing assets within Maintenance and relaying supply requirements within the depot pipeline subsystem. The MIC receives serviceable spares from the Central Exchangeable Pool by node 17. Maintenance personnel inspect the spares' identity, quantity, and condition just as other systems do when receiving an asset. Personnel determine if a requirement for the item already exists. If so, the spares are sent to the shops (node 12); otherwise, they are held for future requirements. Thus, the MIC contains another holding pool of assets within the depot pipeline subsystem.

The MIC also relays parts requests from Maintenance activities to the Central Exchangeable Pool. Requests from Depot Repairable Maintenance come into the MIC through node 11. If the spare is on-hand in the MIC, it is pulled from MIC storage and delivered by node 22. If the MIC does not have the item, the request is transmitted to the Central Exchangeable Pool by node 19.

The depot repair shops perform the actual repairs of assets removed for Programmed Depot Maintenance (PDM) and received NRTS from bases and other depots. Figure 57 shows the activities occurring in the depot repair shops. The shops receive repairable spares from the Central Exchangeable Pool and from PDM ("Depot Maintenance") by node 18. Maintenance technicians follow a repair process similar to the one described in Chapter II. Once inducted, the

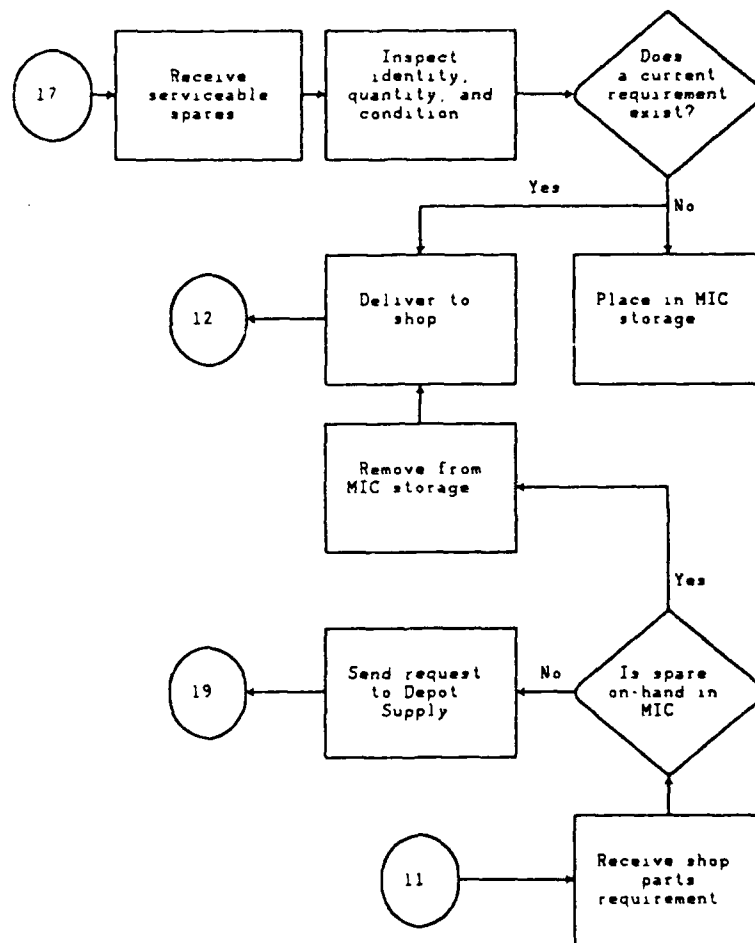


Figure 56. First Level Explosion of "Depot Repairable Maintenance," Maintenance Inventory Center Process

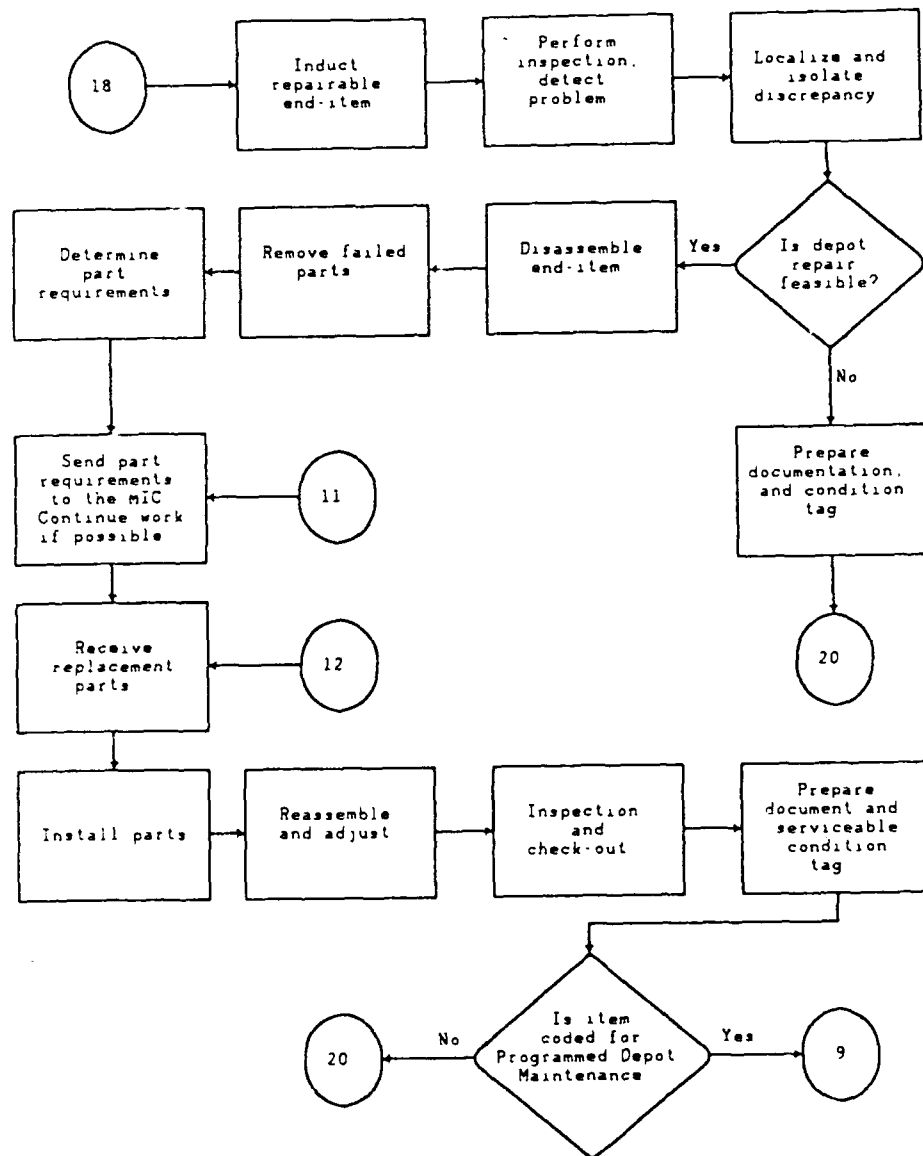


Figure 57. First Level Explosion of "Depot Repairable Maintenance," End-item Repair Process

repairable spares are inspected to identify the particular problems or malfunctions. Once the problem is identified, technicians must isolate the cause. A determination whether depot repair is feasible must be made. If the spare can not be repaired, the technician must either condemn it or return it NRTS to the primary depot or contract repair facility. The spare then returns to the central exchangeable pool by node 20.

If the asset is depot repairable, personnel disassemble it to remove the failed components and determine what parts are required to fix it. The spares request is transmitted to the MIC (node 11), and some time later, parts arrive (node 12) for the technicians to complete the repairs. Spares awaiting parts represent another possible accumulation point for inventory in the Air Force logistics pipeline.

After the parts arrive, they are installed. Technicians reassemble and adjust the spare before performing final inspection and check-out. After inspection, personnel prepare required documents and a serviceable condition tag. If the asset has been routed from Programmed Depot Maintenance, it is returned to the line by node 9. Otherwise, it is returned to the Central Exchangeable Pool by node 20.

It should be noted that in the case of indentured items, the preceding discussion is typical for LRUs, while another

subordinate depot repair pipeline exists for SRUs. This secondary pipeline was left out Figure 57 for the sake of clarity.

Depot Maintenance. The Programmed Depot Maintenance component of the depot pipeline subsystem receives aircraft from bases for periodic scheduled overhaul operations. The LMI Exchangeable Flows model represented PDM with the box labeled "Depot Maintenance". This component of the pipeline extends the aircraft's useful life by overhauling and replacing many structural and reparable end-items. Once PDM is complete, the aircraft are returned to their bases.

Figure 58 of the conceptual model shows some of the steps taken within the PDM process. Aircraft scheduled for PDM arrive at the Depot Maintenance facility where inspection and disassembly take place. End-items are removed and routed to depot repair shops. MIC personnel transfer the end-items to the repair shops (node 18) as soon as the repairs are scheduled to begin. After being repaired, end-items are returned to the PDM line for reinstallation (node 9). If one or more reparable end-items can not be replaced when needed, the aircraft will remain grounded until all spares arrive.

The PDM line presents the potential for another inventory accumulation point. If aircraft are delayed in PDM facilities for lack of one or more spares, then more

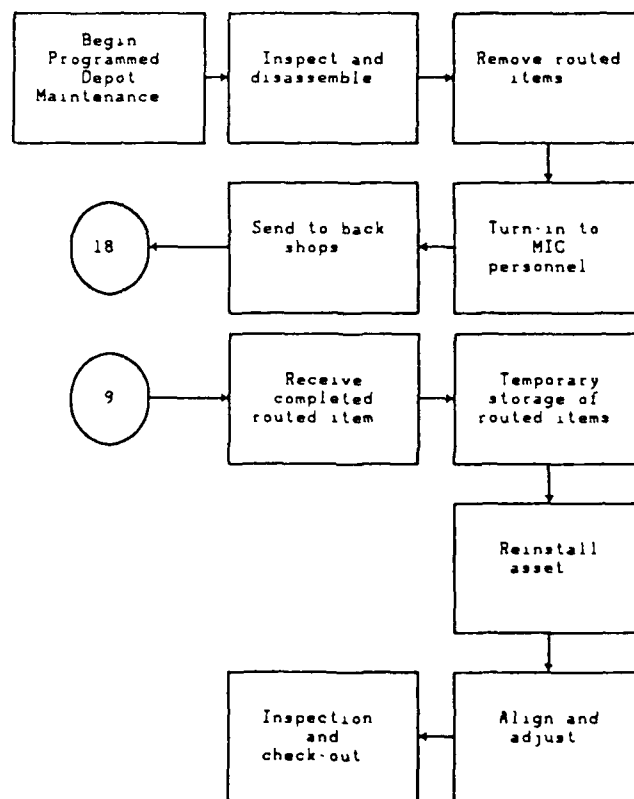


Figure 58. First Level Explosion of "Depot Maintenance,"
Programmed Depot Maintenance Process

aircraft are needed to maintain the same level of mission readiness. Once all the routed reparable spares are returned on the aircraft, final adjustments are made, and the remainder of the work package completed, the aircraft is readied for final inspection and check-out. After final flight testing, the completed aircraft returned to its base.

Acquisition Pipeline Subsystem. The acquisition pipeline supplies the depot with new assets to fill requirements for recoverable spares. The LMI Exchangeable Flows model used a circle with a dashed line from industry to represent the acquisition pipeline subsystem. The model leaves out many processes identified in Chapter II under acquisition pipeline subsystem.

The acquisition process is initiated by the accumulation of backorders (Figure 55) and stock replenishment requirements of the Central Exchangeable Pool. Requirements determination and resource availability help determine what spares and how many will be acquired new from industry. Figure 59 shows some of the general steps that are required to satisfy a need through procurement. Potential sources must first be identified before the acquisition may proceed. Some spares may have a single source of supply, while others may have numerous sources. Some may have no known sources because the spare has been out of production long enough for the manufacturing facilities and processes to have closed. The number of

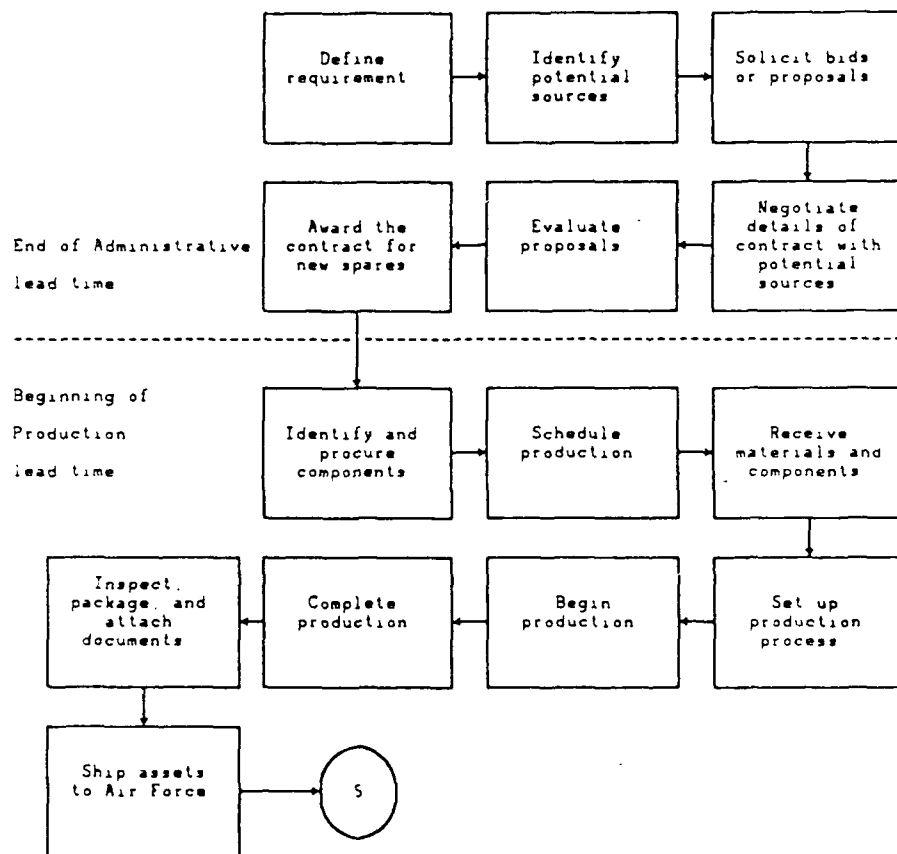


Figure 59. First Level Explosion of "Industry," Acquisition and Production Process

companies able and willing to produce a certain spare for the government has significant impact on the contracting process and on the total administrative lead time prior to the contract award. A contracting officer solicits offers from potential contractors through either a sealed bid or formal negotiations.

Competitive negotiations, used when only limited sources exist, or where the specifications are not well defined, may be used as an alternative to the sealed bidding process. Negotiation involves discussions between potential suppliers, contracting, and technicians to establish technical and performance requirements as well as the production and delivery time line.

Both negotiation and sealed bidding lead to the receipt of offers from commercial manufacturers to produce the required spare within the guidelines set out in the Request for Proposal. Evaluation of the offers received takes place. The contract is awarded to the lowest bidder who is most able to meet the terms of the contract and who has complied with all the procedures in the bidding process.

Production lead time begins once the contract is awarded. Prior to production, the contractor must estimate the amount of supplies needed to produce the spare and must schedule production. Supplies and components must be procured according their individual lead times so that they arrive in time for production to begin on schedule. Once the

materials are received, the contractor should have the production line set up to begin the manufacture of the spares. Completed spares often are inspected by the manufacturer and DoD agencies to ensure that quality requirements of the contract are met.

Inferior quality found in the inspection process can delay production by sending spares back to be reworked, or creating a need to alter the production process or find an alternate source of materials. Inefficient production processes or scarcity of needed high quality materials can greatly expand the contractor component of the acquisition pipeline subsystem.

Completed units are packaged and prepared for shipment following inspection. Spares are then shipped to the Air Force. Figure 53 of the conceptual flow model shows node B connecting the acquisition pipeline subsystem to the Central Exchangeable Pool at node 9 on Figure 59.

Disposal Pipeline Subsystem. Once a recoverable spare can no longer be repaired at either the base or depot, it is condemned and sent into the disposal pipeline subsystem. The LMI Exchangeable Flows model used the circle marked "Attrition" to account for system losses through crashes, and depot/base-level condemnations. The disposal pipeline subsystem is the end of the Air Force logistics pipeline for recoverable spares.

Spares are condemned in the base or depot repair shops once technicians have evaluated them and determined that repair is no longer economically feasible. From there, condemned items are turned-in to Depot Supply or Base Supply who in turn transfer them to DRMS.

Figure 60 describes the flow of assets from both depot and bases into the disposal pipeline subsystem. Node 16 connects to the Base Exchangeable Pool and the Central Exchangeable Pool. The DRMS maintains facilities at or near most military bases to dispose of unneeded items.

The Air Force logistics pipeline for recoverable spares usually ends at DRMS because assets usually enter it only when they can no longer be repaired or are technologically obsolete. Repairable assets turned-in as excess to DRMS have no foreseeable future usage. Once in the disposal system, DRMS personnel catalog the assets by NSN and condition. The assets are available to other military users once they are entered into the DRMS computer system. If a request arrives to remove the item from DRMS storage, the item is shipped to the DoD agency requesting the spare. If no other DoD use for the spare is found, then the item may be demilitarized (if applicable) and offered to other qualifying non-profit organizations. If still no organization requests the asset, it will be sold at public auction.

Conceptual Model Summary. This section began with an illustration of the four conceptual Air Force logistics

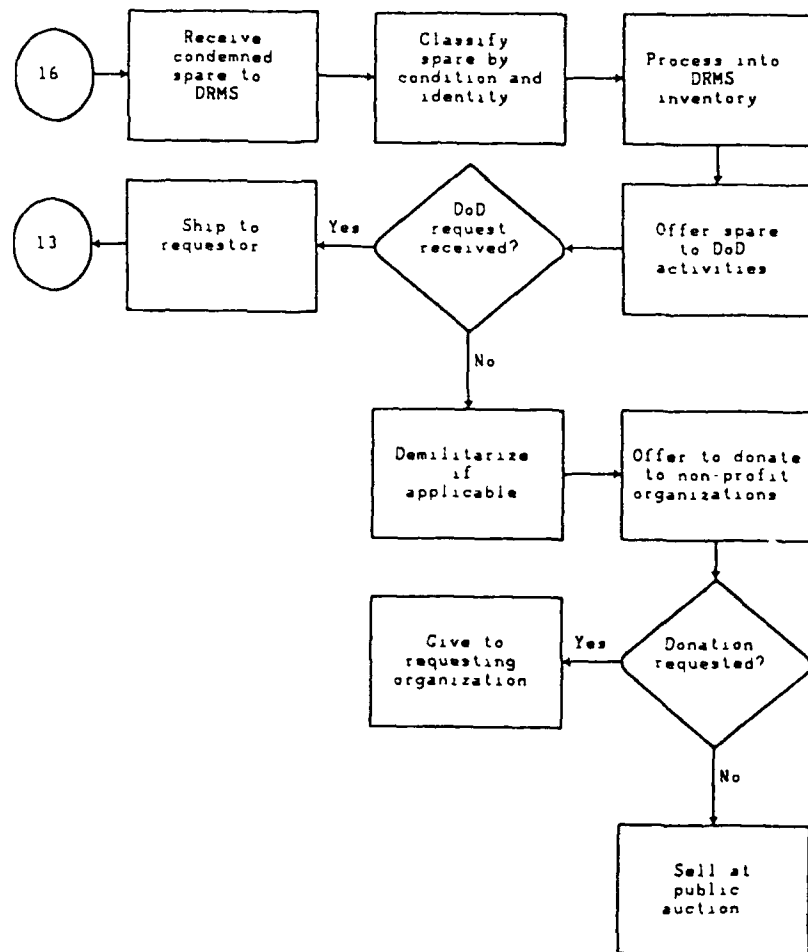


Figure 60. First Level Explosion of "Attrition," the Disposal Process

pipeline subsystems. The more complete of the pipeline models discussed in Chapter II were compared against an ideal for pipeline models. The analysis section showed that the LMI exchangeable flows model best described the logistics pipeline until now. This model was used as a standard while developing a more detailed conceptual pipeline model that added processes and specific activities controlling the movement of spares within the components of the pipeline subsystems.

The four logistics subsystems together make up one collective Air Force logistics pipeline. This section described each of the pipeline subsystems individually and related them back to the LMI exchangeable Flows pipeline model.

The base pipeline subsystem is made up of Base Maintenance, Base Repairable Maintenance, a Base Exchangeable Pool, and War Reserve Material Exchangeable Pool. These pipeline subsystem components were further broken down into separate processes and specific activities that govern the flow of assets through the base pipeline subsystem. The base maintenance process involves inspection, removal, repair and replacement of repairable spares. Base repair shops in the Base Repairable Maintenance component identify the cause of end-item failures, remove failed parts, and repair or replace those parts. The repairable maintenance system generates demands for spares from the Base Exchangeable Pool.

The Base Exchangeable Pool contains subprocesses for the receipt and storage of spares, processing of assets returned from Base Repairable Maintenance, and processing spares requests received from customers. These processes were further broken down into activities shown in the flow diagrams that depicted the movement of assets through the supply system.

The base pipeline subsystem is connected to the depot pipeline subsystem by transportation processes. The transportation process was summarized by a flow chart showing base and depot inbound and outbound activities. The transportation systems at the depot and bases use the priority and mission requirements to determine the method of shipment that best suits Air Force needs at minimal cost.

The LMI Exchangeable Flows model showed the depot pipeline subsystem as three interconnecting components called the Central Exchangeable Pool, Depot Repairable Maintenance, and Depot Maintenance. These components were broken down into processes in the conceptual flow model that linked the depot activities together. The Central Exchangeable Pool contained processes for handling receipts and storage of new spares; receiving, storing and distributing repairable spares; and filling customer spares requests. Activities within these processes connected directly to the Depot Repairable Maintenance component.

The Depot Repairable Maintenance component contains processes which control spares inventory, distribution, and requests, and which perform end-item repair in the back shops. The Depot Maintenance component generates requirements for repaired assets to fill holes on the PDM repair line. Overhauling entire aircraft involves the removal of many end-items from the aircraft, routing them through the repair process and then reinstalling them.

The acquisition pipeline subsystem fills requirements generated by depot- and base-level condemnations or new requirements. The LMI Exchangeable Flows model represented the acquisition pipeline subsystem by a circle of industry with a line leading to the Central Exchangeable Pool. The conceptual flow model added considerable detail to this component by showing many of the activities involved in the acquisition process. The activities leading up to the award of the contract were shown to contribute to administrative lead time while those activities after the contract award up to the delivery of assets to the Air Force added to production lead time.

The disposal subsystem was represented in the LMI model by a circle called "Attrition" that was connected to both bases and depots. The disposal subsystem eliminates repairable spares from the Air Force logistics pipeline if they can no longer be repaired and no other Air Force user needs them. The conceptual flow model summarized the

activities leading up to the sale of condemned assets at public auction.

The conceptual flow model contains many of the time elements and factors included in the customer order cycle as discussed in Chapter II. Each subsystem and component within the overall system is responsible for controlling some part of this cycle. For example, the explosion of the Base Repairable Maintenance process had to transmit its material request to supply before it could obtain the parts required to continue repairs. In addition, base repair shops influence the customer order cycle for flight line maintenance. Efficient repairs performed in the base repair shops provide a source of supply to the flight line maintenance activities. All other components of the logistics system influence the length of time needed to fill an identified requirement. Each logistics system component either directly handles spares or processes information that affects how long spares and spares requisitions spend in each activity.

Conclusions

Many models discussed in this study have attempted to portray some pieces of the logistics pipeline in detail. There are certainly more existing models than this report has examined. This effort has focused on those models most common to current logistics research. It is important to restate that none of the current models include all of the

processes and activities that influence the flow of property through the logistics pipeline. Often, the transportation process, for example, is only discussed as a link between different subsystems of the pipeline. That it is, but the activities associated within that linkage directly influence the efficiency and effectiveness of materiel flows throughout the logistics pipeline.

In performing the research, numerous exceptions to the generalized flow of assets were encountered. The detail necessary to document all the exceptions was avoided in the interest of keeping the model at some fundamental level of detail. One factor not considered in the model, for instance, is that locally established material handling procedures at Air Force bases can vary from base to base. The variation in these localized procedures affects the steady flow of property within and between the bases. Also, many variations in asset characteristics and mission requirements make a difference in how one part is handled throughout the pipeline verses another. Further, shortfalls in manpower and equipment requirements interrupt the flow of property through the pipeline. Budget constraints can also affect the mode and carrier selection for transporting materials. Not extensively considered in the model, either, is how the flow of information up and down the pipeline can influence the physical flow of property.

Considering all the situational variations that can take place because of the many processes and activities, asset characteristics, mission requirements, budget constraints, information flows, and shortfalls, it was difficult at best to develop an overall model that would truly represent the Air Force logistics pipeline. It is for these reasons that limitations were placed on the study, so that for the first time, additional detail could be incorporated in a model of the entire Air Force logistics pipeline. Unfortunately, by placing limitations on the study, this collective model at present is incomplete.

The conceptual model, however, has attempted to consider the processes and activities which may have an adverse affect on the flow of property through the Air Force logistics pipeline and contribute to pools of assets forming. It is at least a good starting point for developing a more complete, collective model top managers can use to analyze the Air Force logistics pipeline. There may be no definite way to come up with a model that will accurately fit all possible situations which occur at one time or another within the pipeline. However, the model presented should provide enough of a description to act as a catalyst for developing systems to simulate and analyze the flow of assets in the logistics pipeline.

Recommendations for Future Research

This model will be a useful stepping stone for continued research into the many dynamic factors influencing the flow of supplies (reparables and expendables alike) through the Air Force logistics pipeline. Three specific recommendations are made for further research.

First, validate and refine the model using experts. Those professionals working in and with the pipeline day in and day out, need to be tapped for specific information concerning the processes and activities of the pipeline. Only then will this model be truly valid.

Second, consider the limiting factors mentioned in this study-- they are crucial to developing a more detailed analysis of the pipeline. This study has described only the actual flows of assets within the logistics system and the factors affecting those flows. Future research in the area of pipeline management should concentrate on identifying the specific factors that cause variability and delays in the movement of assets. Budget constraints affect virtually every aspect of the pipeline from material handling equipment to transportation mode and carrier selection. Expendables make up a large enough portion of the pipeline budget that their movement should be modeled as well. Problems with the flow of information can cause the biggest bottlenecks in the pipeline. Proper communication and flow

of required documentation is necessary to efficiently manage the flow of property.

Third, develop a simulation model of the pipeline which can analyze the physical movement of property through the pipeline. This simulation should be detailed enough to include as many processes and activities as possible. Identifying the actual times and quantities of reparable assets in specific pipeline subsystems and components will be necessary before a complete simulation may be developed. Time and motion studies may have to be conducted in order to develop a precise simulation of a particular activity. Such a simulation model will be essential for evaluating where lead times in the pipeline can be reduced or eliminated completely. In the long run, this simulation could serve as an invaluable tool for policy makers to time and plan purchasing as well as identify new procedures to improve overall pipeline efficiency.

The ultimate question is: What can the average logistician get out of this study? Perhaps most of all, as in the case of the authors of this study, logisticians can gain a fundamental knowledge of how reparable assets flow through the overall pipeline. The conceptual model of the various processes and activities involved within each subsystem eliminates some of the "unknowns" or "black holes" into which reparable assets flow, and some of the hidden actions required to make the system work.

Finally, logisticians can gain an appreciation for the components that have a direct influence over materiel flow. They can see the coordination and teamwork that must take place between Maintenance, Supply, Transportation, and Contracting. Hopefully, this appreciation will create a new motivation to get the right parts to the right place at the right time.

Appendix A: HQ USAF/LE Letter



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D.C. 20330

REPLY TO
ATTN OF

AF/LE

17 MAY 1988

SUBJECT

AF/LE Proposed Issue for AFIT Thesis Program

TO AFIT/LS

1. In the October 1986 AF/LE - AU/XP - AFIT/LS Logistics Education Conference, the DCS/LE, AFIT/LS dean, and AU/XP agreed the interaction between LE and LS should be improved. One major step approved by all parties is for LE to annually provide major "logistics issues" to AFIT. These issues are to be areas of concern the LE community feels would benefit from rigorous examination under the thesis process. Each issue serves as an umbrella from which specific thesis topics could be chosen. Some issues could easily generate several concurrent or consecutive thesis efforts.
2. An issue of utmost concern to us is the "pipeline". For our purposes, the pipeline includes the assets which must offset the time involved in requirements computation, procurement, production, delivery, retrograde, repair, requisition processing, etc. The policies and procedures in each of these functions directly impact pipeline times. Funding levels for spares, DPEM, parts, people, and transportation also contribute to pipeline time.
3. A very large portion of our spares resources are tied up in the pipeline. A study done several years ago indicated that the value of the stock in the pipeline for one day was approximately \$55M. We recently received a note from AFLC/MM estimating one additional day of shipping time of recoverable spares is \$50.8M and one additional day at ports for overseas items is \$12.2M. The estimates would vary according to how one defines the limits of the pipeline. However, it is a fact that some large amount of our assets are tied up within the pipeline. Reducing this pipeline would free scarce assets and provide more responsive support to the users.

4. As we attempt to balance our resources and live within the constraints being imposed upon us, a clearer understanding of the pipeline and the impact of its policies and procedures would be extremely useful. It would be more productive, as a first step, to collectively define the pipeline and piece together what information is now regularly collected and used by managers. This will also give us insight into what information we don't have. We can then proceed from there.

5. We look forward to working with your faculty and students on this issue. Our point of contact is Ms Sandy Dush, AF/LEYS, auto von 697-5980.



CHARLES P. SKIPTON, MAJ GEN, USAF
Asst DCS/Logistics & Engineering

cc: AF/LEY
SAF/RLS
AF/LET
AF/LEX

Appendix B: Base Repair Cycle Information Flow

The repair cycle for a repairable spare begins with a customer request. Figure 61 shows the flow of Supply information through the base-level repair cycle (14:24-44,46). The customer requests a serviceable replacement item through the Demand Processing Section of Base Supply. Processing the customer request creates a Due In From Maintenance (DIFM) record on the supply computer records. The DIFM records are a method for keeping track of repairable assets that have been issued to users of those assets. Once a serviceable asset is issued, maintenance must return to supply a like asset that has been either repaired, coded NRTS, or condemned.

After processing through supply channels, the property and a DD Form 1348-1 issue document are delivered to the requesting activity. The customer signs for the asset to acknowledge receipt of the item. Meanwhile, the repairable asset is sent through the maintenance system to be repaired, condemned, or declared NRTS. A Supply DIFM monitor will track the status of the item in repair as repair parts are ordered and maintenance is being performed. The status will change from Awaiting Parts (AWP) to Awaiting Maintenance (AWM) alternately as the parts are received and installed. Once repaired, condemned, or declared NRTS, the asset is prepared for turn-in to supply. Appropriate documents must be attached

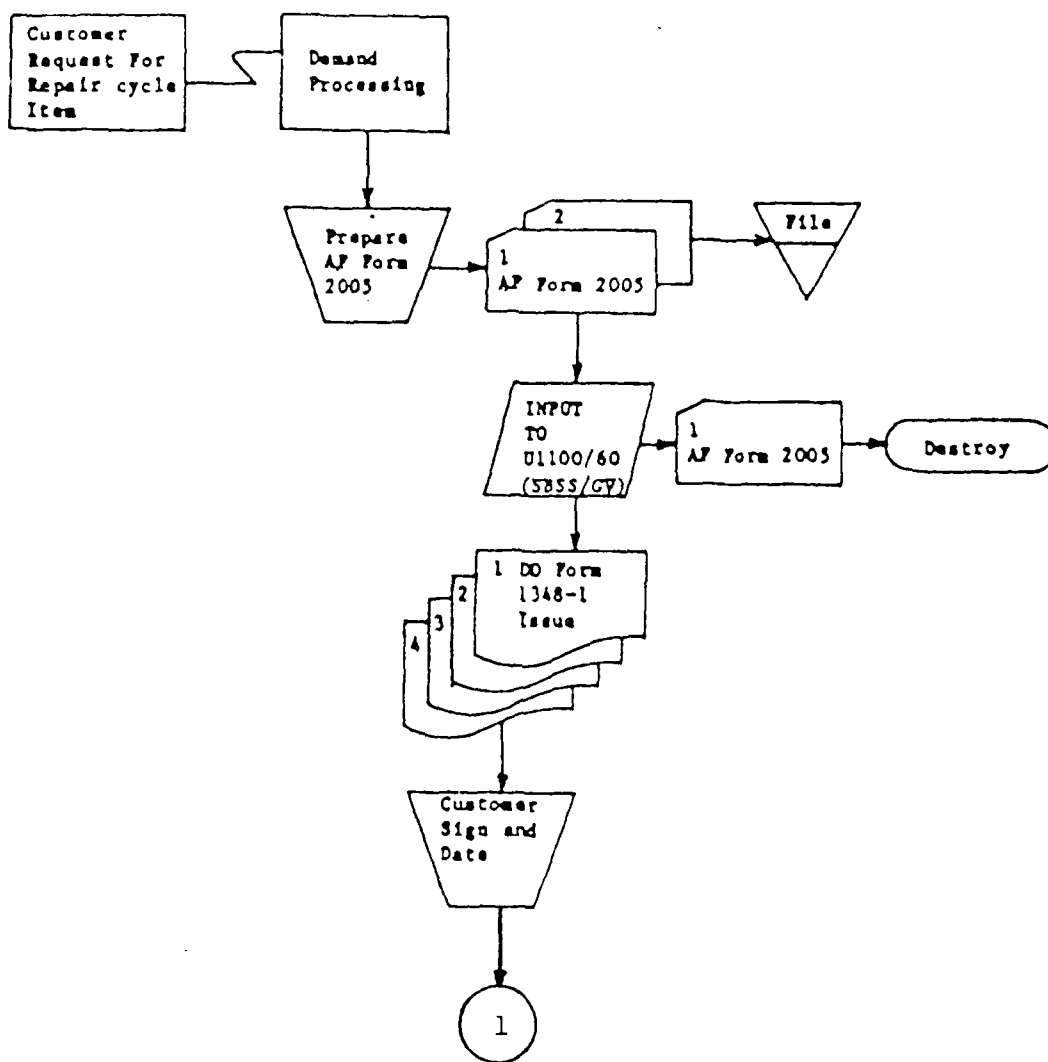


Figure 61. Document Flow for DIFM Processing
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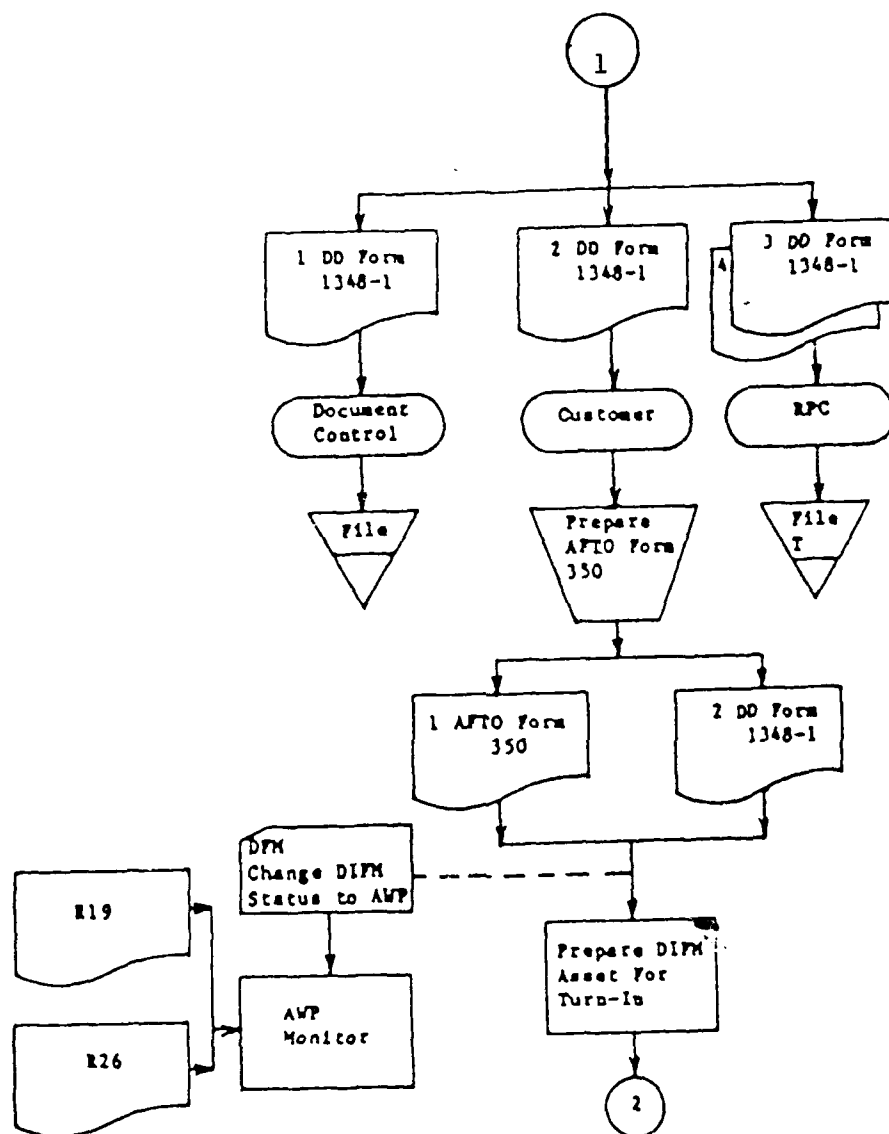


Figure 61. Document Flow for DIFM Processing
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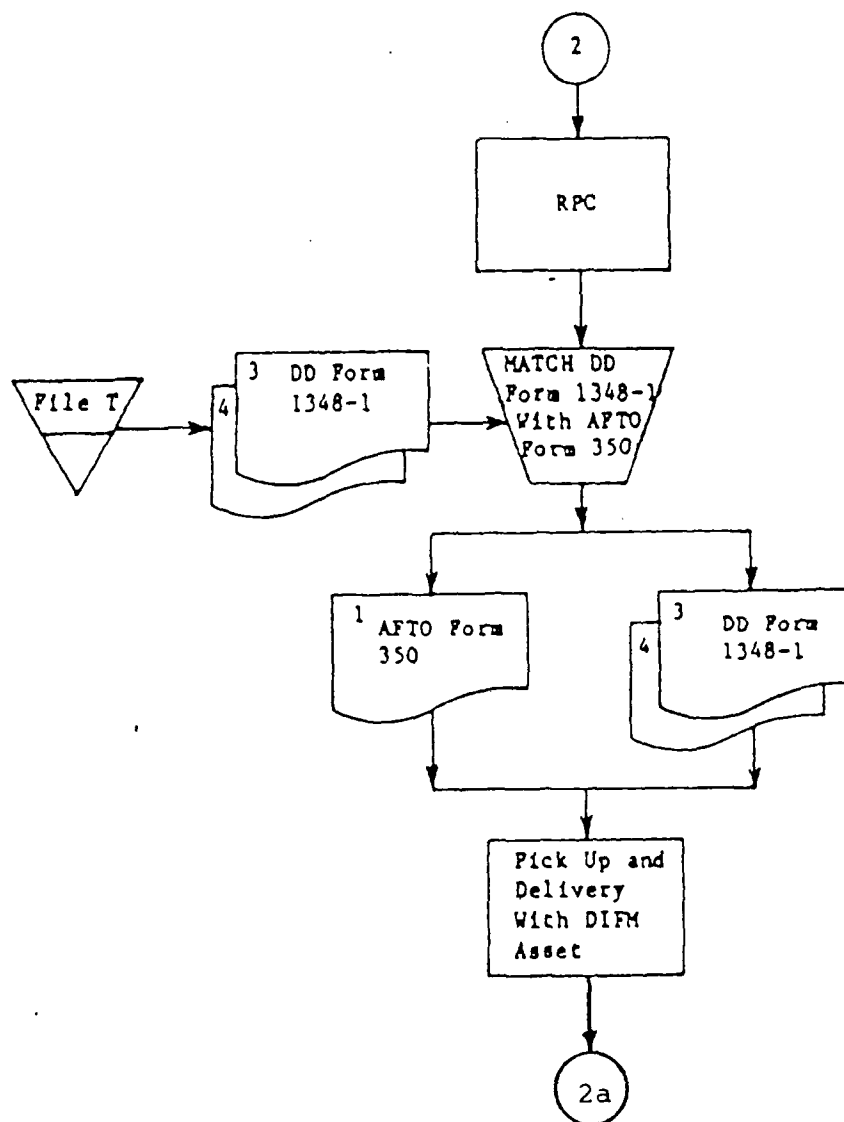


Figure 61. Document Flow for DIFM Processing
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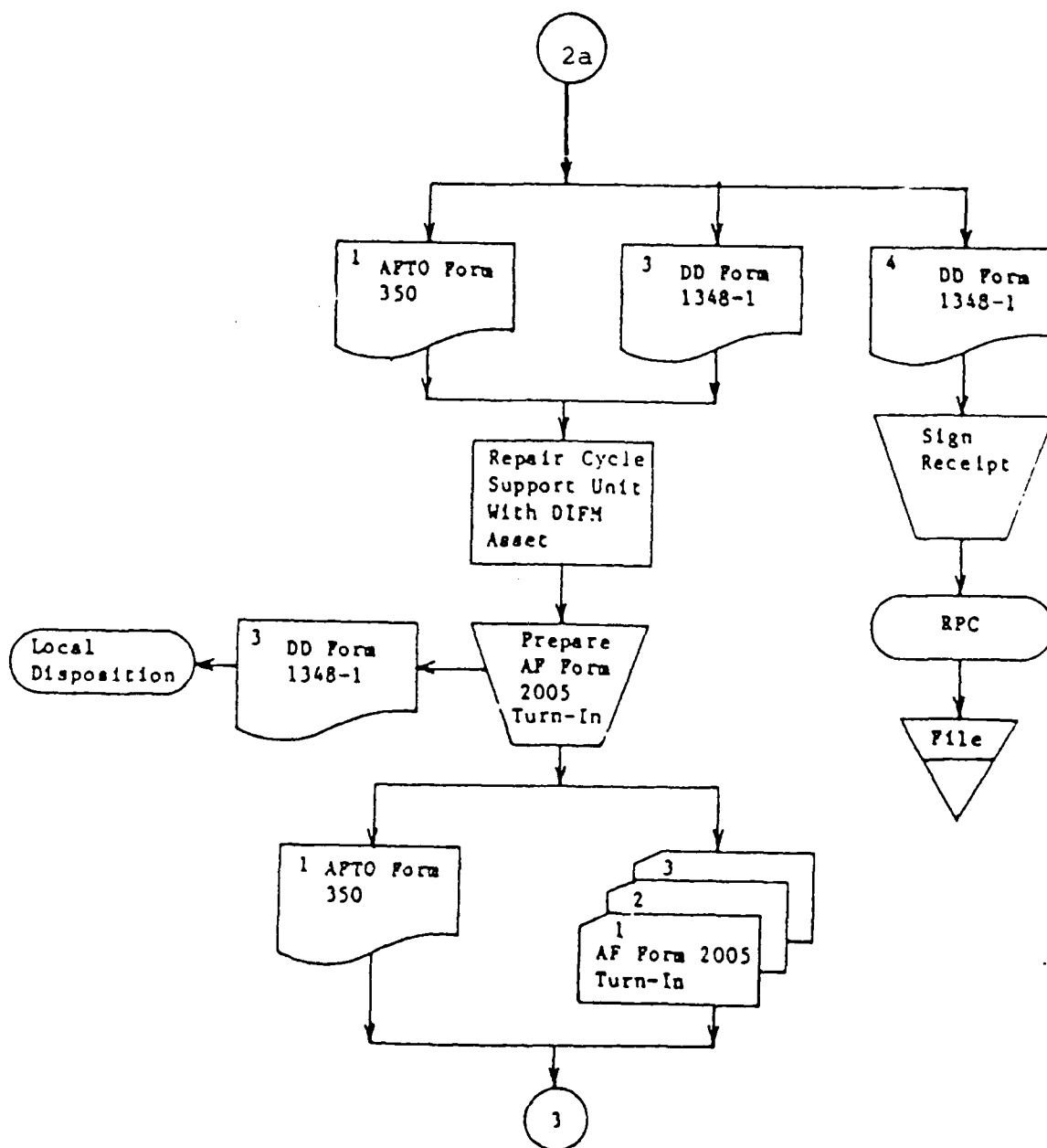


Figure 61. Document Flow for DIFM Processing
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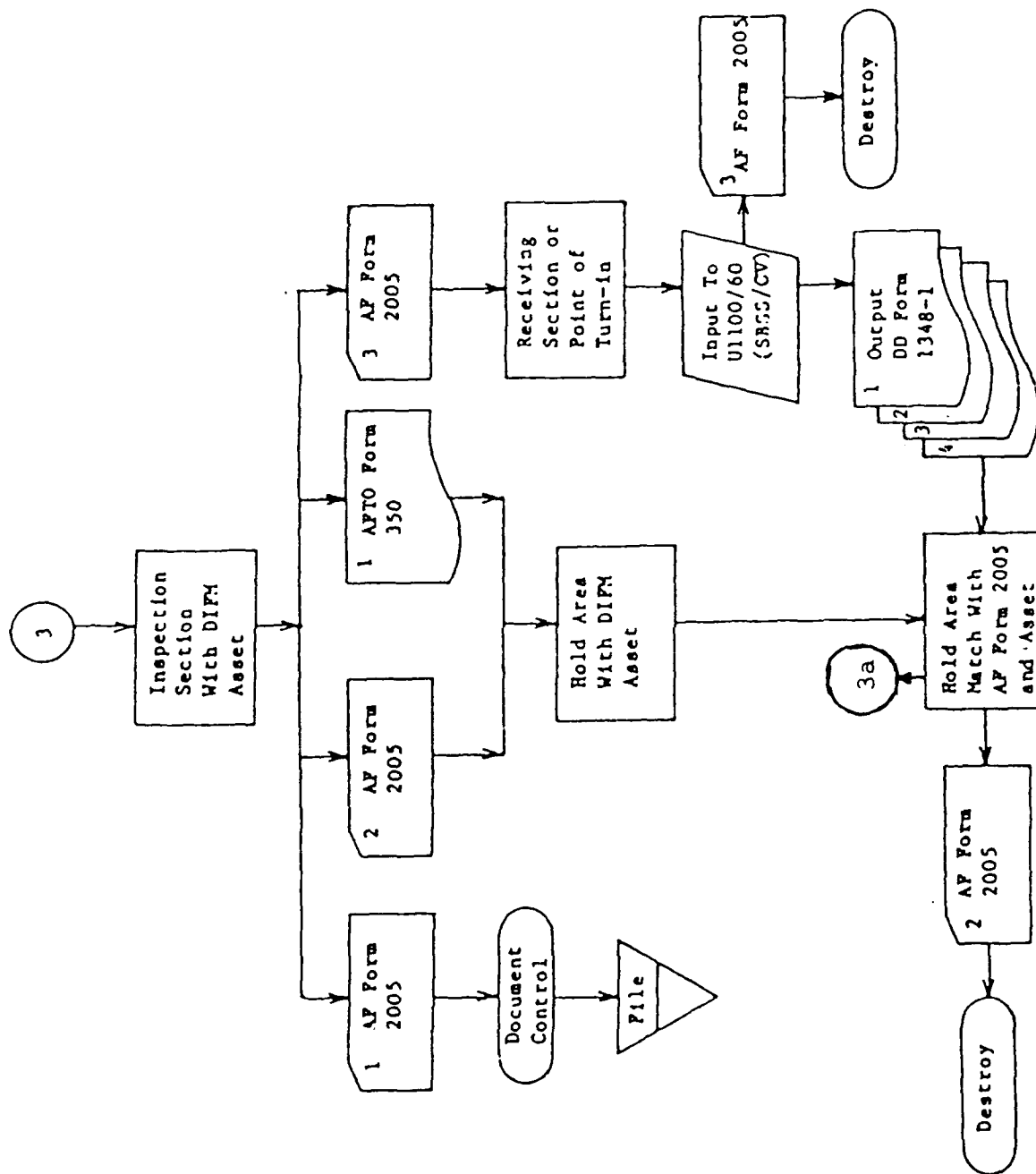


Figure 61. Document Flow for DIFM Processing
(Continued)

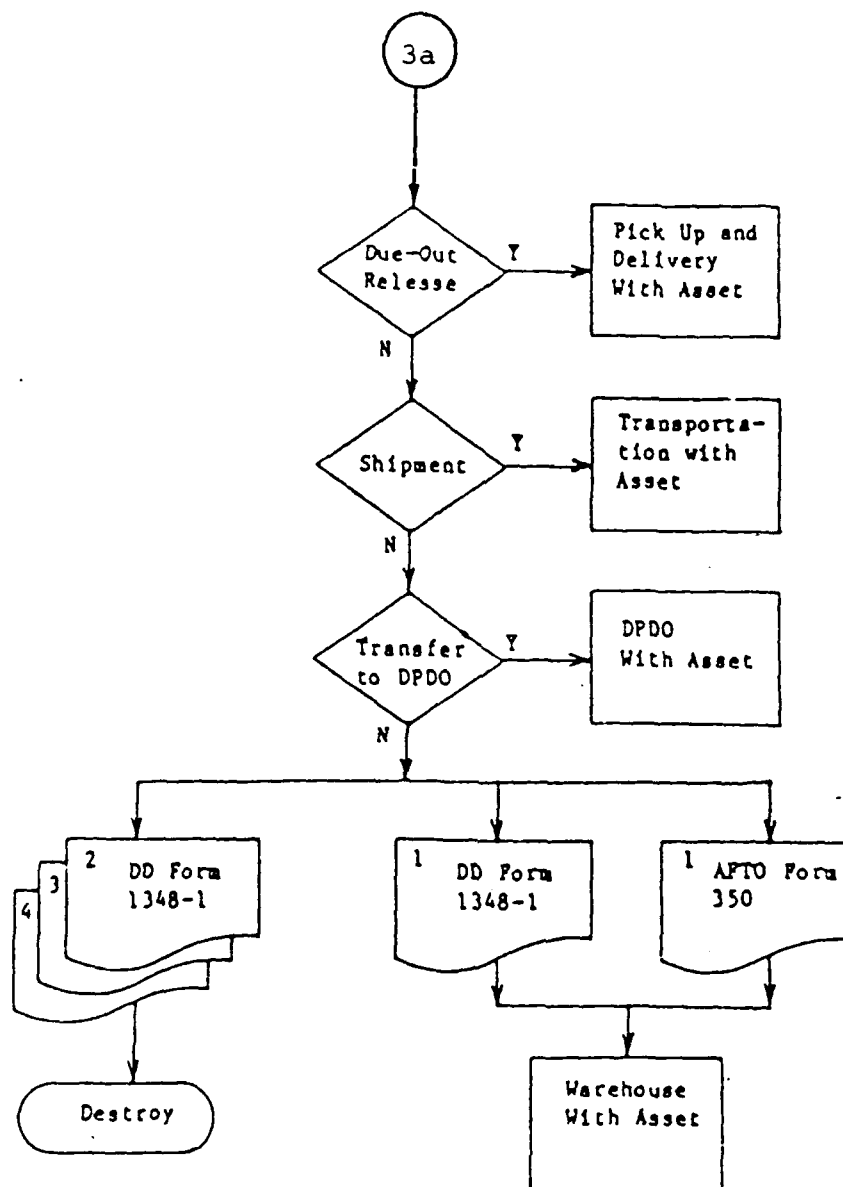


Figure 61. Document Flow for DIFM Processing
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to the property to properly identify it and specify its condition. A turn-in document is handwritten for input into the supply computer system. Processing the turn-in puts the repaired asset back into supply inventory records, and clears the DIFM suspense records. The property is then returned to serviceable stock, shipped to another location for repair, or sent to salvage. This completes the repair cycle for a single failed item in the base repair cycle system.

Appendix C: Base-level Demand Process

Base-level Demand Process. Another more detailed description of the base-level demand process was provided by the Air Force Logistics Management Center in an unpublished 1988 study (22:1). Figure 62 traces the demand through the system from initiation to satisfaction of the requirement and replacement of the spare into the Base Supply system. This description of the base repair cycle adds the decisions and actions that must take place both when the asset is available from on hand stock, and when it must be ordered from another source.

If an asset is on hand in Base Supply, the demand is satisfied and the broken asset enters the repair process. If the asset is not on hand, the user must make a series of decisions before proceeding. Demands with low urgency may be delayed while the item is either left on the end-item, or removed and sent into repair while the item is backordered. If the requirement is urgent, the technician must determine if the item can be obtained from another source on base or repaired quickly. Unfilled urgent requirements may then be turned over to Mission Capable (MICAP) procedures to fill the requirement as quickly as possible.

Assets enter the repair process following removal from the aircraft. The assets will either be repaired and returned to stock, or repaired and issued to satisfy a

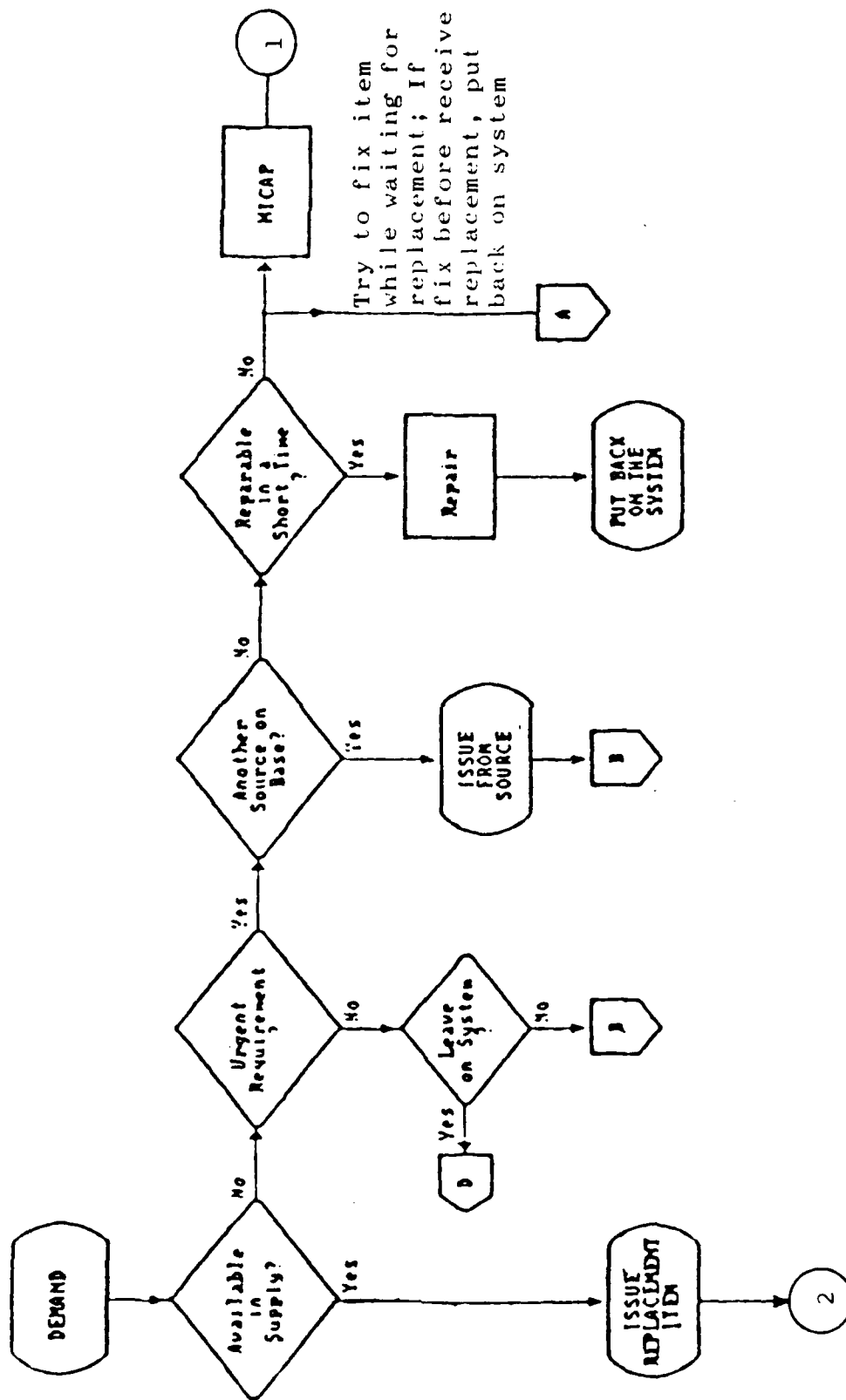


Figure 62. Base-level Demand Process (23)

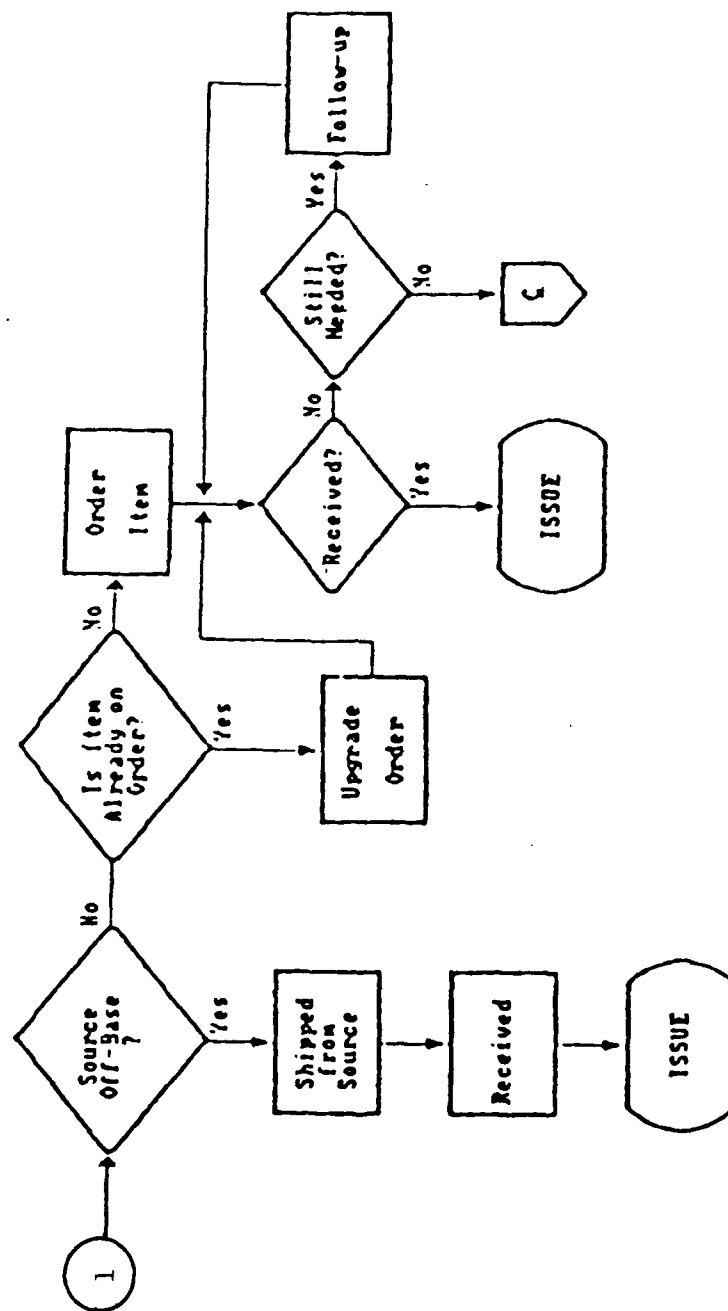


Figure 62. Base-level Demand Process (23)
(Continued)

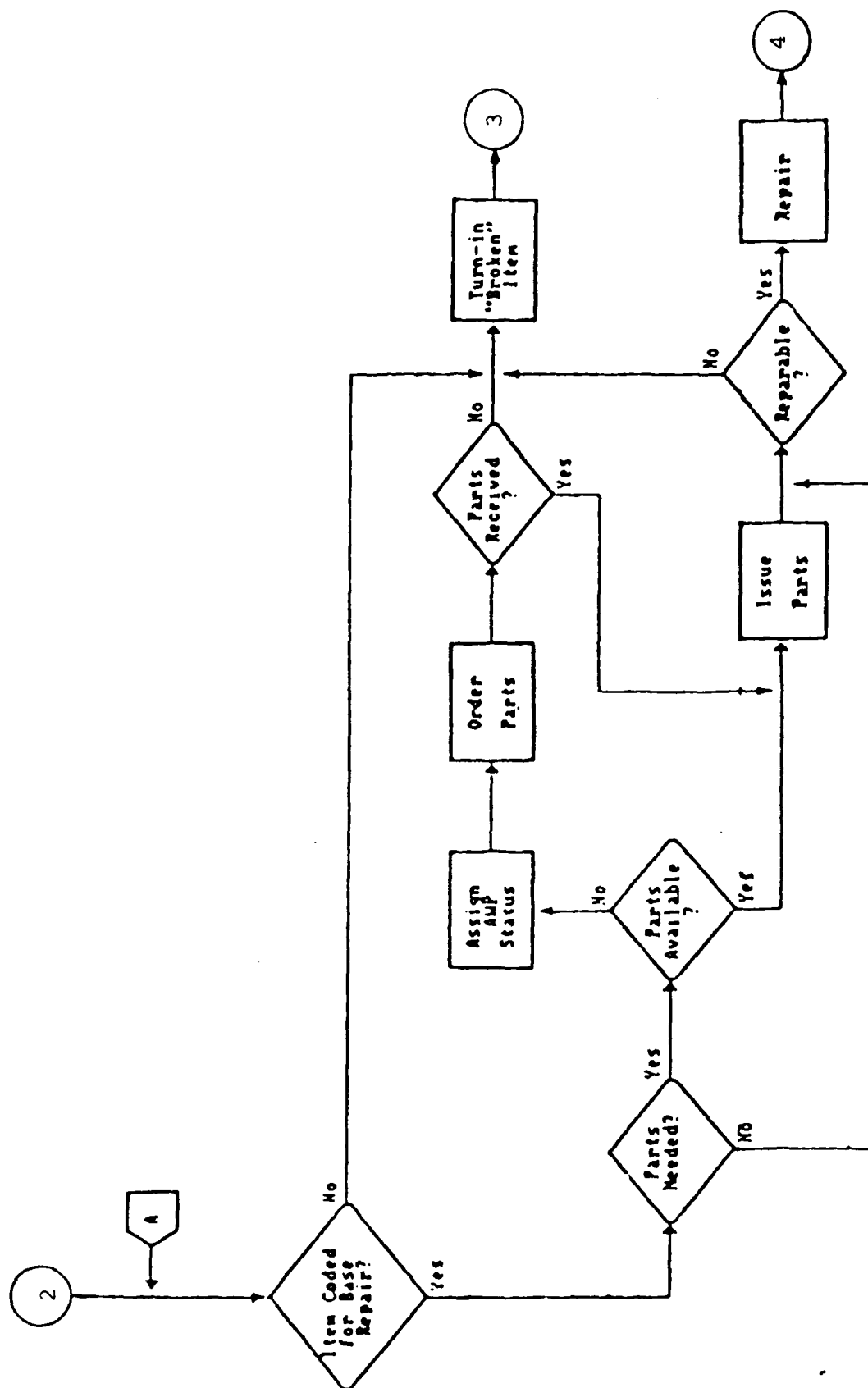


Figure 62. Base-level Demand Process (23)
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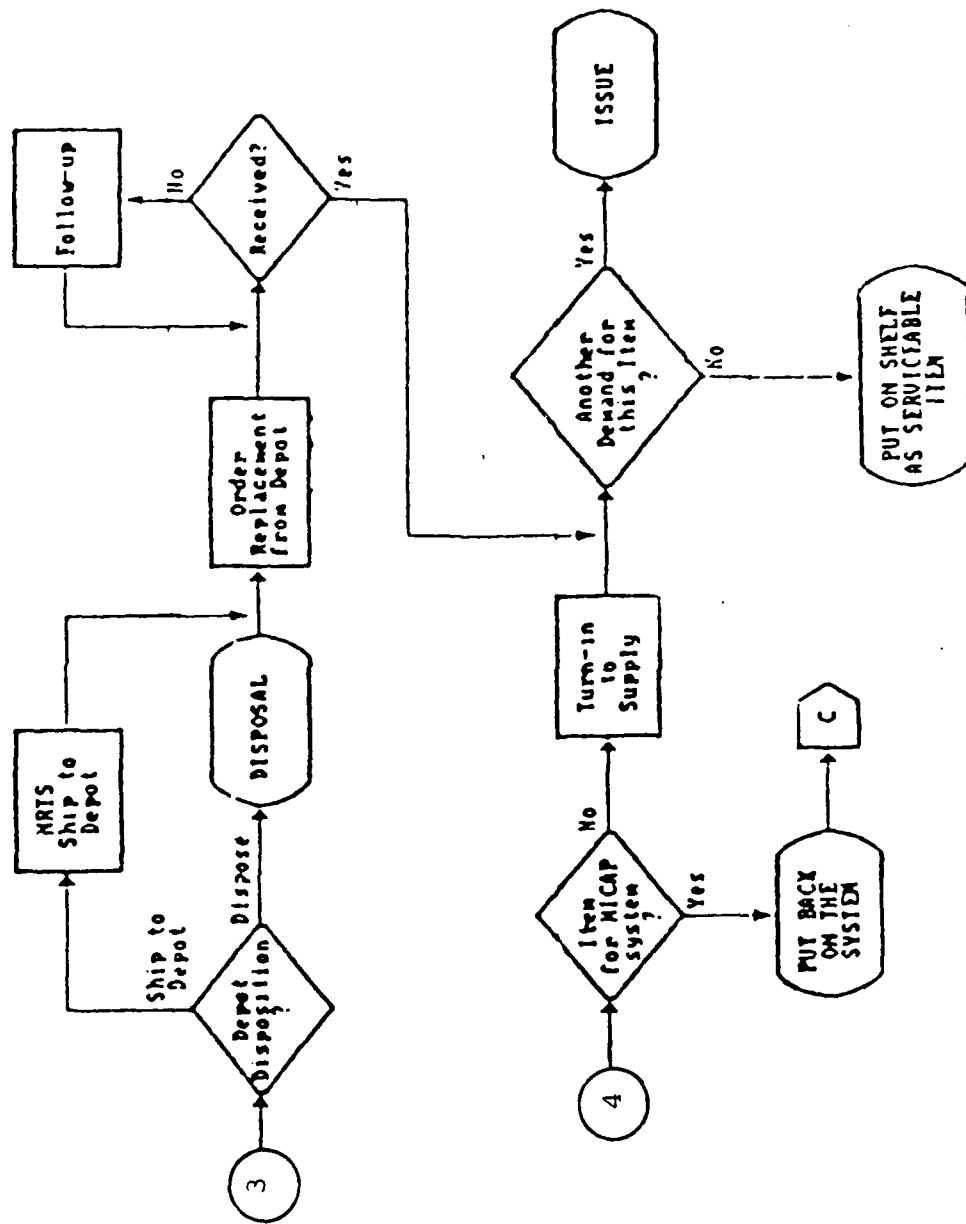


Figure 62. Base-level Demand Process (23)
(Continued)

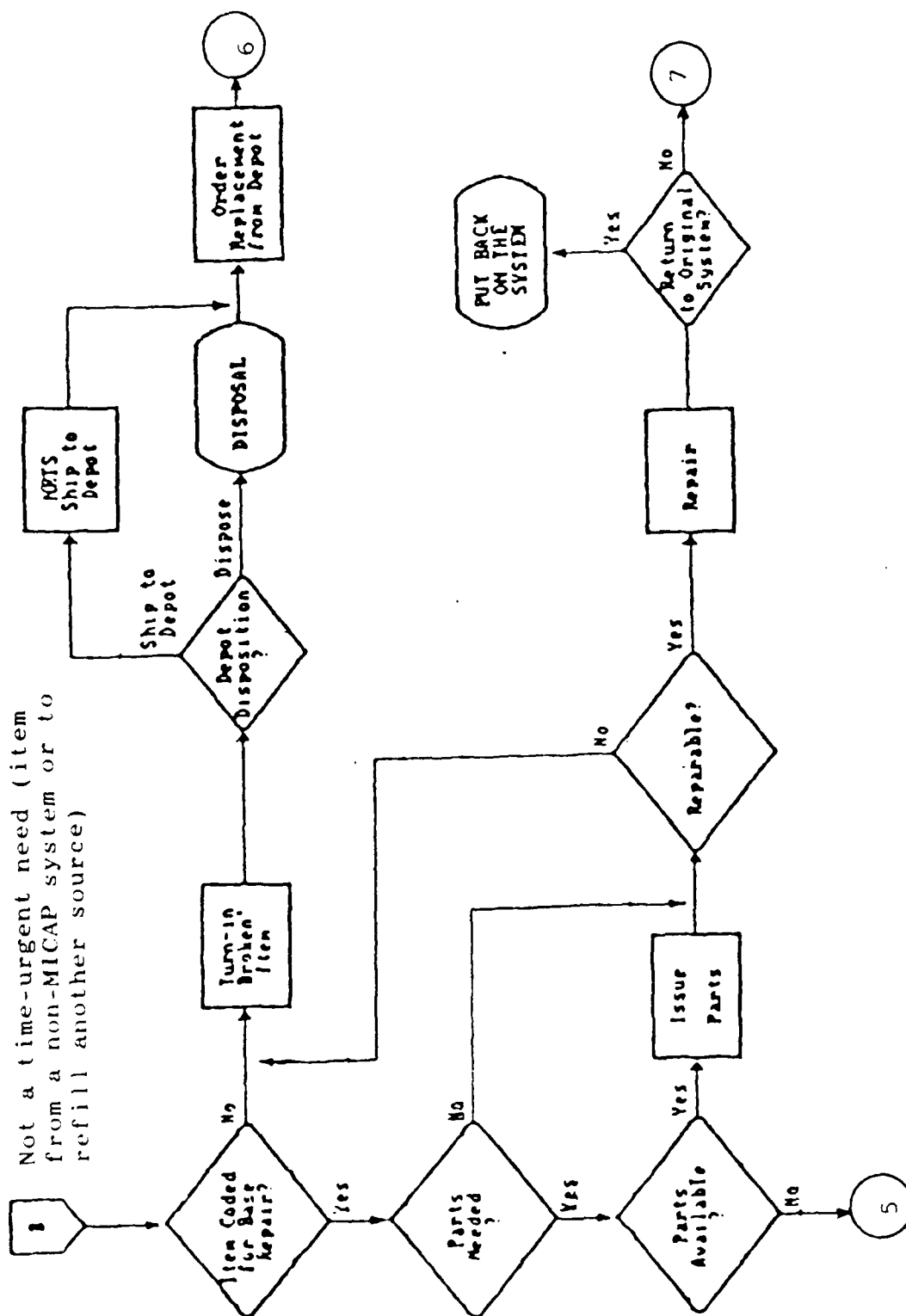


Figure 62. Base-level Demand Process (23)
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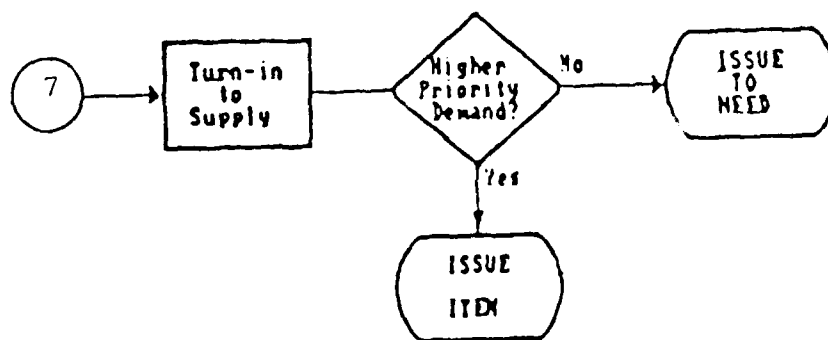
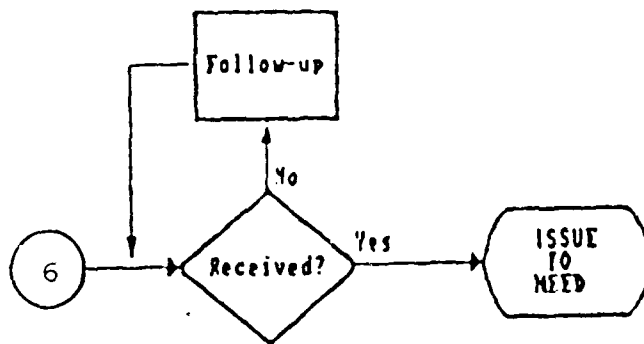


Figure 62. Base-level Demand Process (23)
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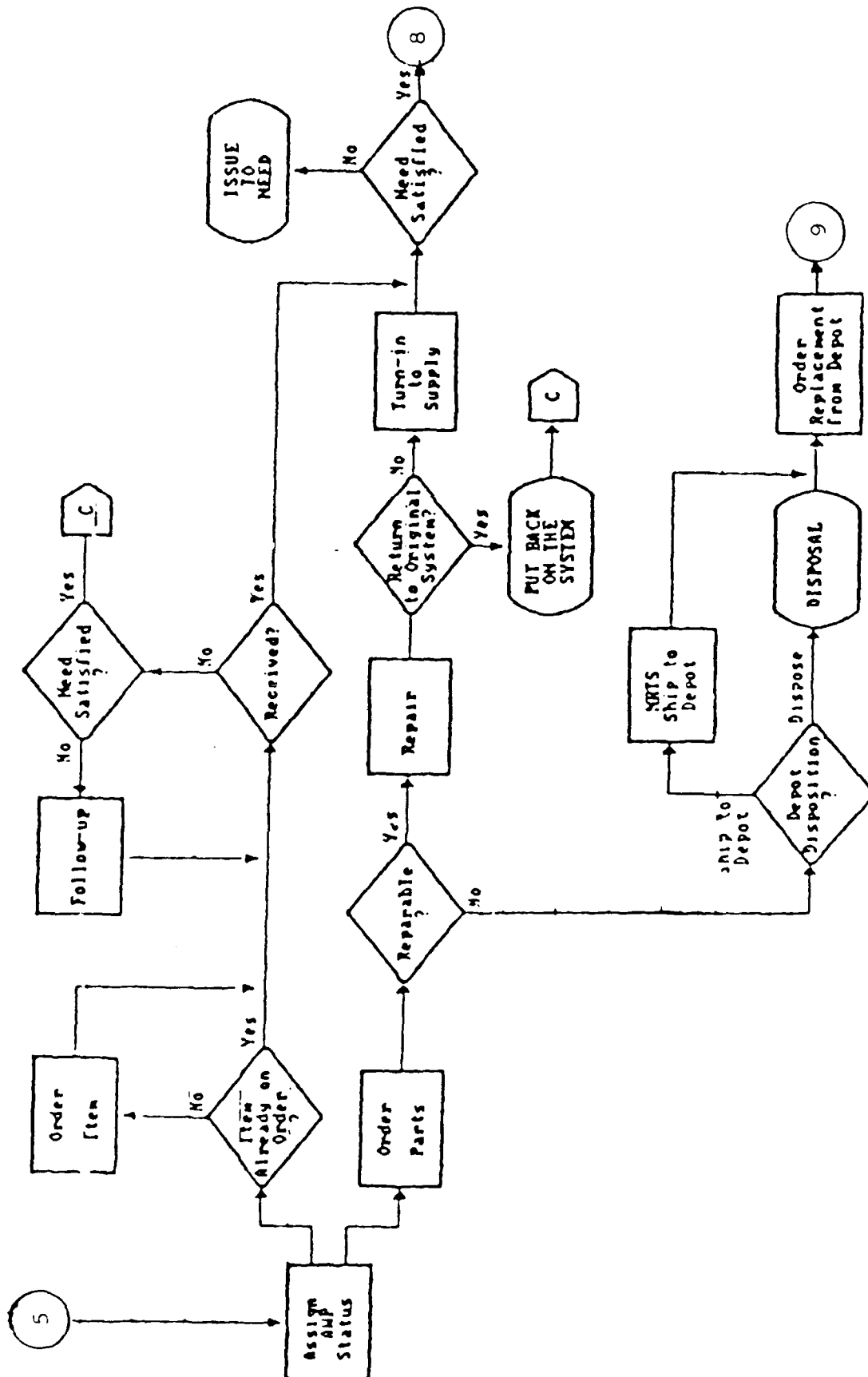


Figure 62. Base-level Demand Process (23)
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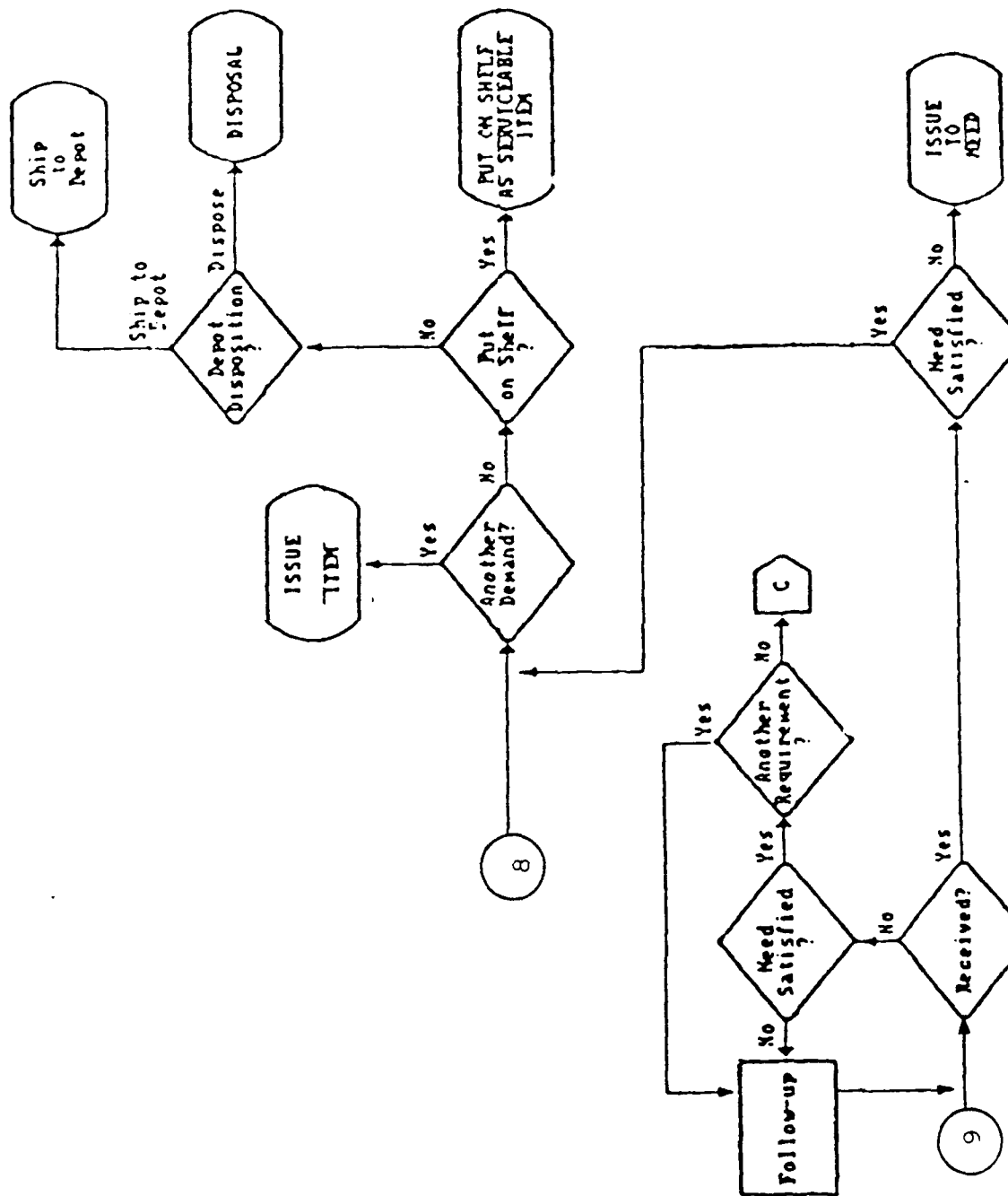


Figure 62. Base-level Demand Process (23)
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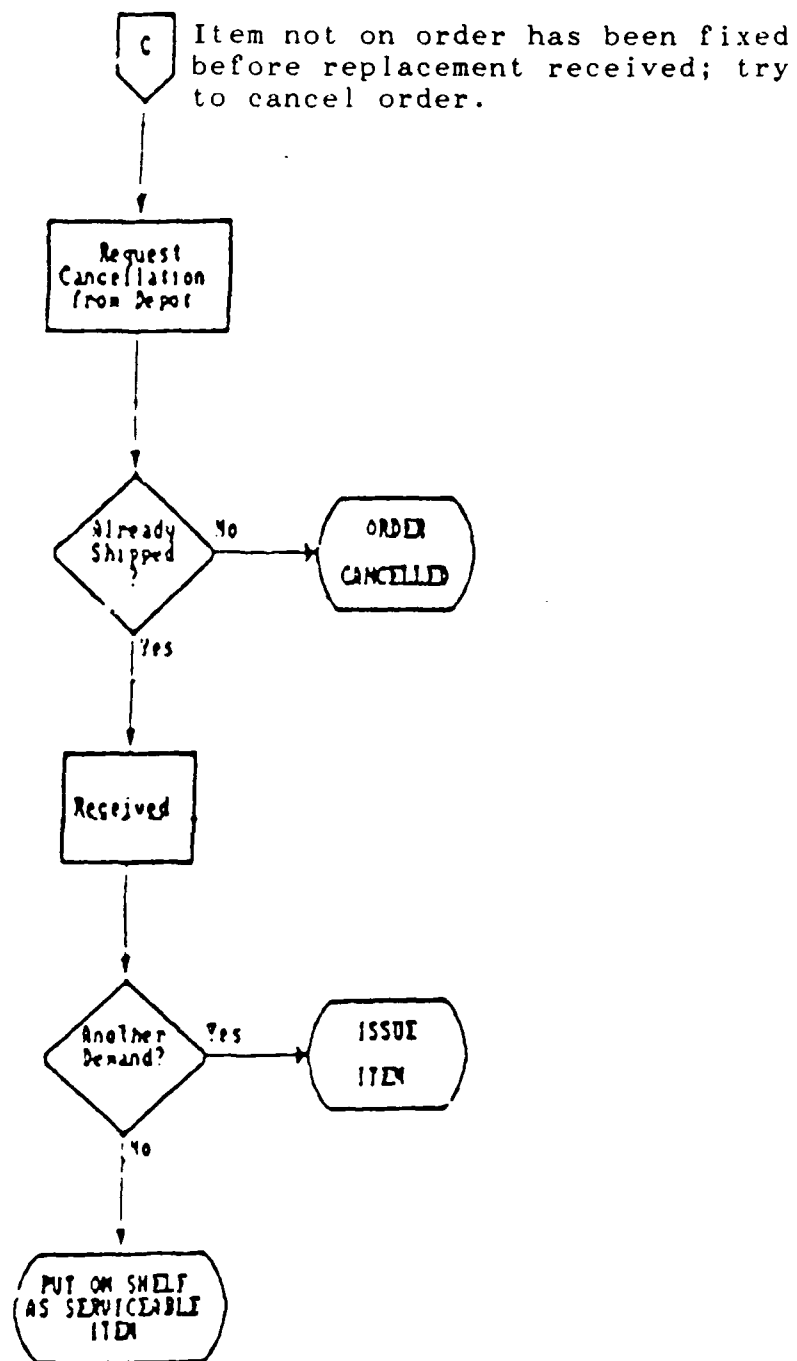


Figure 62. Base-level Demand Process (23)
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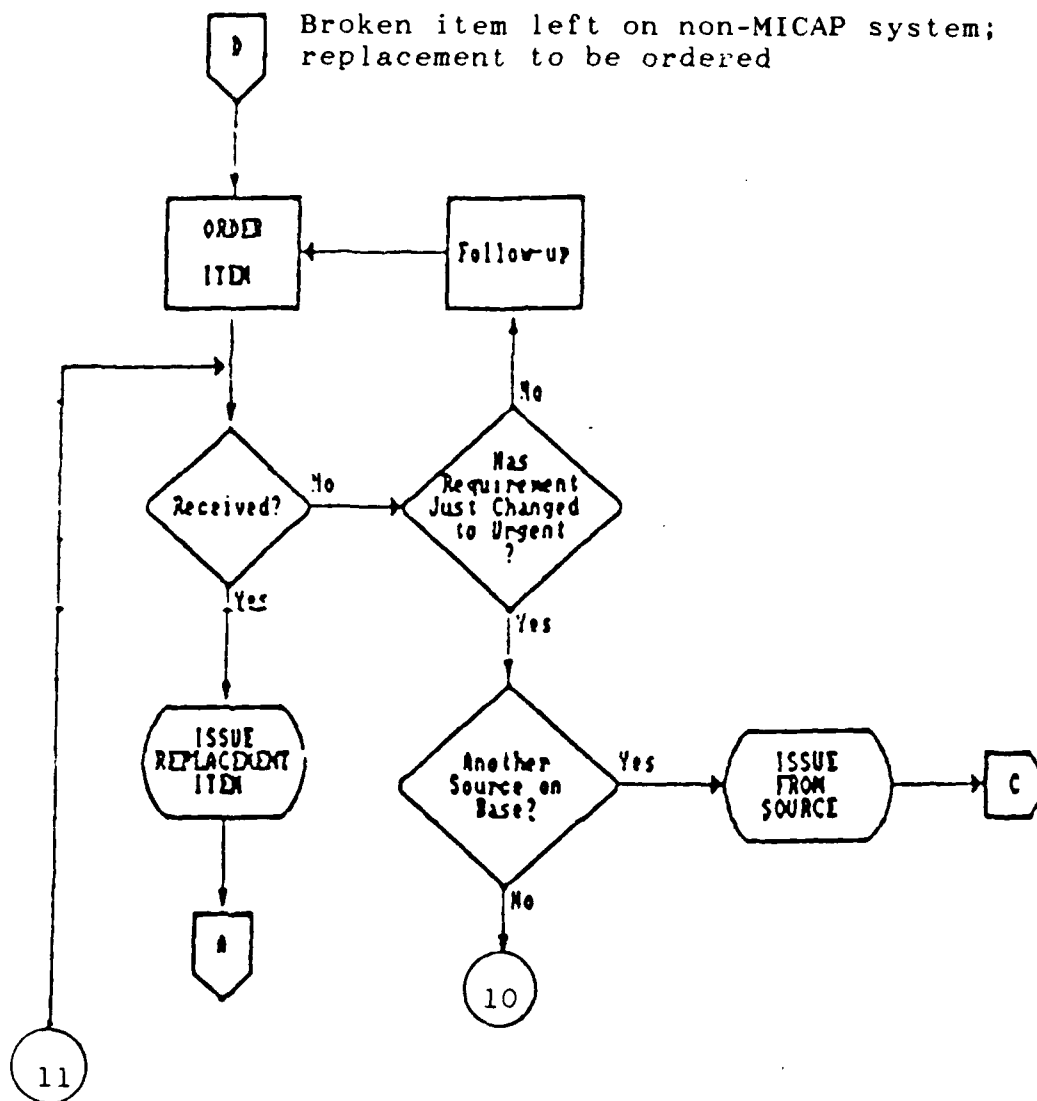


Figure 62. Base-level Demand Process (23)
(Continued)

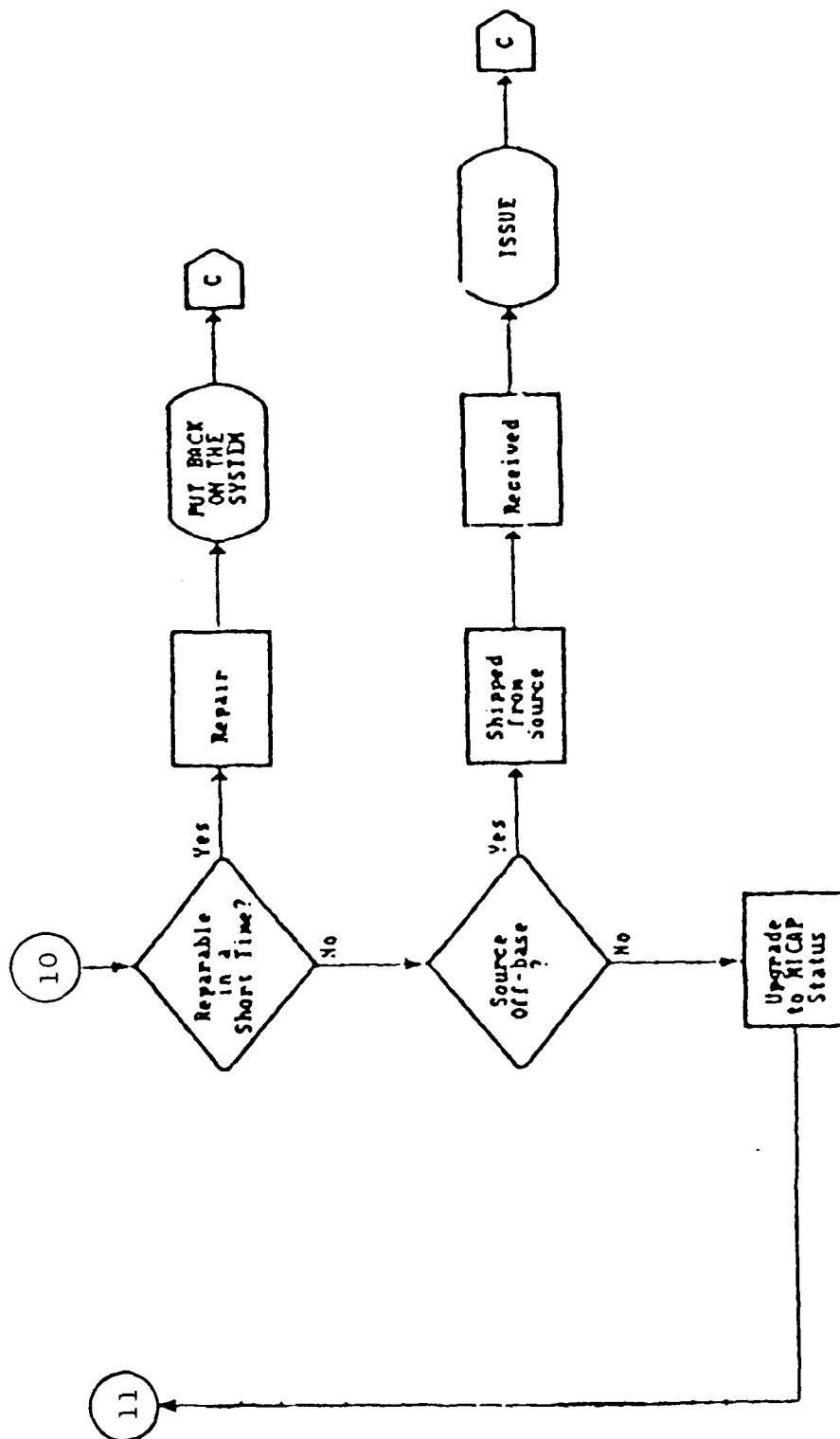


Figure 62. Base-level Demand Process (23)
(Continued)

backorder or MICAP requirement. Tab A on the first page of the repair cycle flow chart represents the normal repair cycle decisions and procedures when an asset is issued from stock, or when the asset enters repair while waiting for a receipt of a backorder. Tab B on the second page represents the repair cycle process to satisfy a less urgent requirement. In both processes, the technicians must determine whether the asset is coded base repairable. If not, the item is processed directly off base to either depot repair or disposal; in either case, a replacement item is ordered from depot. If the asset is base repairable, the maintenance personnel must determine which parts are needed to fix the asset and order these from Base Supply. While the item waits for repair parts, a status of Awaiting Parts (AWP) is assigned. If the requirement has not yet been filled, a series of follow-up actions will be completed until the bits and pieces arrive. Once the asset is repaired, it is either returned to stock or issued to satisfy the requirement.

Tab C shows the procedures for handling a backorder to the depot or another source of supply once the requirement has been satisfied through base repair of an asset. The backorder should be canceled if it has not already been shipped from the depot. If already shipped, the item will be used to satisfy any new requirements at the base for the asset. Otherwise, it will be placed in stock.

Tab D shows the procedure for handling a non-urgent requirement if the item is left on the end-item while waiting for the replacement. A series of follow-ups will be completed while waiting for the asset until it is received or the requirement is upgraded. If the requirement is upgraded, personnel will attempt to locate other base sources. If no sources are available, and the item cannot be repaired quickly, the requirement will be upgraded to MICAP. In this case, the procedures previously discussed will be followed.

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Vita

Captain Craig A. Bond was born on 3 June 1958 in Montrose, Colorado. He graduated from high school in Montrose, Colorado and attended Ozark Bible College for two years. In June 1981, he enlisted in the USAF as an Inventory Management Specialist. During his first duty assignment at Sheppard AFB, he attended Wayland Baptist University, from which he received the degree of Bachelor of Science in Occupational Education in May 1984 with a major in Logistics Management. Upon graduation, he was accepted to attend Officer Training School, through which he received a commission in the USAF in March 1985. As a Supply Operations Officer, he was then assigned to the 343rd Tactical Fighter Wing, Eielson AFB, Alaska. There, he served as Chief of the Operations Support Section, Chief of Material Management, and Chief of Material Storage and Distribution. Captain Bond entered the School of Logistics, Air Force Institute of Technology, in June 1988.

Permanent address: 240 DeMaria Road

Montrose, Colorado 81401

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Captain Craig A. Bond [REDACTED]

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The study develops a conceptual model of the Air Force logistics pipeline. The pipeline may be defined simply as the flow of material from procurement to usage, with consideration of all factors that affect that flow. This study provides a "generic" view of the pipeline for wider applicability and ease of understanding. It is limited to the movement of reparable spares which represent a significant fraction of Air Force's stock replenishment funds. "Reparable" refers to the class of assets which are considered more economical to repair than replace.

A literature review consolidated previous works concerning reparable item pipelines and portions thereof. The review found many models that explain specific segments of the pipeline, but no complete model examining the intricacies of the entire Air Force logistics pipeline.

The conceptual pipeline was divided into four major subsystems. The base and depot pipeline subsystems represent the repair cycle process through supply and maintenance. The transportation system composes the linkages between and within subsystems. The acquisition subsystem the procurement process for acquiring new and replacement reparable spares. The disposal subsystem eliminates excess and condemned assets from the pipeline.

After evaluating various existing models, the Exchangeable Flows Model, developed by the Logistics Management Institute (LMI), seemed to most accurately depict the general Air Force logistics pipeline. The proposed conceptual model is an extension of this LMI model. It adds detail to broad subsystems identified in the LMI Exchangeable Flows model.

The conceptual model of the Air Force logistics pipeline is an initial step in pipeline studies. Additional information of the pipeline must be analyzed and included in a model. However, this model will be useful as a basis for understanding the Air Force logistics pipeline and as a guide to further research.

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