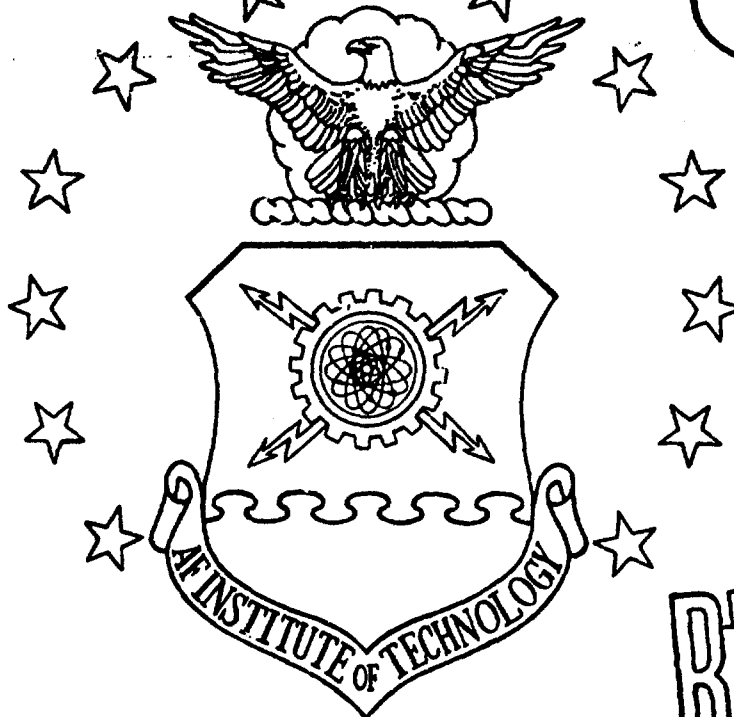


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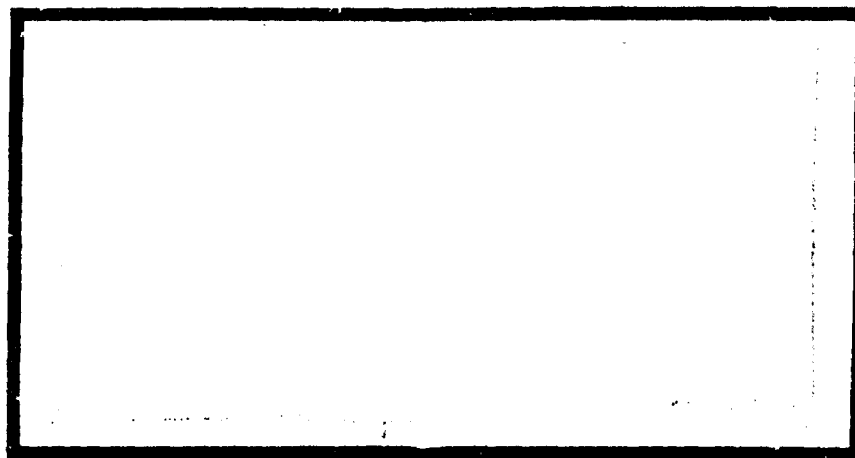
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A DYNAMIC MODEL OF THE INITIAL
SPARES SUPPORT LIST
DEVELOPMENT PROCEEDS

William A. Allen, Captain, USAF
Jack A. Riess, Jr., Captain, USAF

ISSR 2-79A

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The Initial Spares Support List (ISSL) is an integral part of the Air Force initial provisioning process. Its purpose is to provide an adequate range and depth of spare/replacement parts to keep a newly activated end item in operation until normal supply channels are developed. Historically, the ISSL has provided either too few or too many parts. These inaccuracies have resulted in either excessive system down time or an excessive amount of money spent on spare/replacement parts. As a result of these problems, Air Force Logistics Command requested that a dynamic model of the ISSL development process be developed. The authors used the system dynamics approach to analyze the decision and policy making structure of the process. They constructed a dynamic model of the system and implemented the model on the computer with the DYNAMO simulation language. The model has been internally validated but needs to be verified with real world data. Once this has been accomplished, the model could be used as a tool to analyze the present ISSL policies and to experiment with revised policies in an attempt to provide more efficient support to Air Force end items.

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A DYNAMIC MODEL OF THE INITIAL
SPARES SUPPORT LIST
DEVELOPMENT PROCESS

A 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

By

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June 1979

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has been accepted by the undersigned on behalf of the faculty of
the School of Systems and Logistics in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

DATE: 13 June 1978

Thomas D. Clark Jr.
COMMITTEE CHAIRMAN

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Chapter I

INTRODUCTION

Overview

The systems that are used by the Air Force are expensive, highly complex pieces of equipment that are continually being replaced with new systems in order to keep pace with both the changing enemy threat and the evolving state of American technology. These systems are procured through the weapon system acquisition process. This process is a sequence of specified activities that extend from the system conceptual phase through the full scale production and deployment of the weapon system (5:iii).

To ensure the initial operational capability of these newly acquired systems, support material in the form of spare and replacement parts must be available immediately upon system activation and through the initial phases of operation. These initial support requirements are provided by the initial provisioning process (5:iii).

The initial spares support list (ISSL) is a part of the initial provisioning process. Its purpose is to provide the initial range and depth of items required to support weapon system activations. The items that are included on the ISSL are

determined at a provisioning conference by the technical equipment specialist, the system manager, the item manager, and representatives from the using command (6,8,11,13:12-30). The ISSL establishes a special inventory level at the base that is receiving the new system. Special levels

. . . when used wisely . . . are valuable tools in effectively supporting operational activities; when the intent of special levels policy/procedures is abused, the overall ability of logistics managers to provide effective support is degraded [16:11-7].

Historically, the inventory levels established by the ISSL have been either too large or too small. In 1971 the ISSL stock levels were relatively large and the base level units complained that too much stock sat at base level without being used (7:1,8). A General Accounting Office study showed that in 1971 the Air Force spent several million dollars on spare/replacement parts which were never used (21:1). The next year, 1972, Headquarters Air Force Logistics Command (AFLC) implemented Department of Defense Directives that significantly reduced the ISSL stock levels. After the implementation of the new directives, the base level units complained that not enough stock was being provided by the ISSL to support weapon system activations (7:1,8).

The problem of inaccurate ISSL quantities still exists. As recently as March 1979, the overall Air Force parts use rate for ISSL items was 17% and, in particular, the parts use rate from ISSL

stocks for the F-15 through March 1979 was 10% (2). On the other hand, AFLC continually receives requests to increase ISSL authorizations for other items (6). These facts indicate that there are still a significant number of cases in which the incorrect items in the incorrect quantities are being placed on the ISSL.

Because of this problem, AFLC requested that a study be initiated to develop a model of the ISSL development process (9:1). Two factors prompted this request: first, the procurement of too many or too few items during the provisioning process and, second, the apparent lack of understanding of the ISSL development process on the part of the Air Force logisticians who operate the Air Force supply system (2,6,8,11). Thus, the objective of this research effort was to develop a dynamic model of the ISSL development process. Specifically, a system dynamics approach was employed to develop a model of the system. This method was chosen because it provides a systematic approach to model construction through its treatment of ". . . the central framework underlying . . . activity [3:vii]." It provides a logical cause and effect means of analyzing the underlying management decisions that make up the ISSL development process.

While this research effort was directed towards the ISSL development process in general it specifically addressed Air Force managed economic order quantity (EOQ) items. In addition, the reader

must keep in mind that the initial spares support list (ISSL) becomes a follow-on spares support list (FOSSL) ". . . once the weapon/end article has transitioned from the "initial" to "follow-on" support. . . [15:12-33]." The transition from ISSL to FOSSL is determined by ". . . the system manager (SM)/end article item manager (IM) ISSL/FOSSL monitor. . . [15:12-33]." Thus, this study applies not only to the ISSL, but to the FOSSL as well.

Background

Through the weapon system acquisition process, the Department of Defense procures the weapon systems required to counter the threat posed by the forces of a potential enemy. The acquisition process is a sequence of specified activities designed to achieve program objectives. It extends from the system conceptual phase through the full scale production and deployment of the weapon system (5:iii). To ensure the initial operational capability of the newly acquired weapon system, support materials in the form of spare and replacement parts must be available on or before the system activation date. These initial support material requirements are satisfied through the provisioning process (5:iii).

During the initial provisioning process, decisions are made which can affect the future capability of DOD agencies to support their operational weapon systems. In addition, the initial provisioning decisions cause the expenditure of millions of dollars

for spare and replacement parts (21:1). These provisioning decisions must be made in light of the initial provisioning objective of assuring

. . . the timely availability of minimum initial stocks of support items at using organizations and at maintenance and supply activities to sustain the programmed operation of end items until normal replenishment can be effected, and to provide this support at the least investment cost [18:2].

The principle objective of initial provisioning, of which the ISSL is a part, is to assure the timely availability of initial stocks, at a minimum required level, at the using organization and maintenance activities to maintain the programmed operations of a weapon system until normal supply channels can be established. Moreover, this system support must be provided at the least possible cost (6,8,14:2-3).

The initial provisioning process is employed to procure needed support items that are not currently in the DOI inventory. These support items have been developed specifically for the weapon system and in many instances the support items themselves are made up of several separate subunits which must also be supported (13:1-1). The number and type of spare and support items required to initially support a weapon system are predicated upon the system's anticipated geographic deployment, mission profile, and the maintenance concept to be employed (13:1-8).

Two important factors used in determining the appropriate maintenance concept for a given spare or support item are the reliability and maintainability of the item. For the new items coming into the inventory the reliability and maintainability data are based on engineering estimates until actual failure rate data can be obtained from the operational use of the item (6,8,11, 15:12-3).

During the initial provisioning conference the reliability and maintainability data are considered along with any actual failure rate data in developing the ISSL. The ISSL is thus composed of those items that have been determined by the item manager/system manager, and representatives from the using command to be essential to weapon system operation for an initial period of time, and as such the ISSL is the central element of the initial provisioning process (15:12-5). Despite the coordinated efforts of the item manager, system manager, and the using command there have been numerous occasions where too few or too many items were included as part of the ISSL (2,6,8,11).

The procurement of too many or too few items can have a detrimental effect on the operational capability of the weapon system the ISSL is designed to support. The procurement of too few items results in an increase in the Not Mission Capable - Supply (NMCS) rate due to a lack of spare/replacement parts.

Conversely, the procurement of too many items results in the unnecessary expenditure of funds when the monies could have been better spent elsewhere (2,6,8,11). Because of these problems, AFLC requested that this research project be accomplished. The study used the system dynamics approach to analyze the ISSL development process.

Justification

"Aircraft, missiles, engines, equipment, and other end articles coming into the inventory, . . . must be supported as soon as the end article(s) is received by the location/base from which it will operate [15:12-3]." These items constitute the end items procured by the DOD through its acquisition process. An integral part of the acquisition process is the initial provisioning process whereby spare and replacement parts are procured to support the end item until normal supply channels can be established (15:12-29).

The provisioning process is a series of critically timed actions designed to ensure that the new end items will have adequate support. The process extends ". . . over a wide range of functions, including design, maintenance planning, supply, requirements determination, item inventory control, procurement, cataloging, and contract administration [20:Encl 1-2]." This initial provisioning process ends with ". . . the delivery of a

minimum range and quantity of support items. . . for support during an initial period of service [20:Encl 1-2]." These activities of initial provisioning bring the process into line with the stated DOD objective of providing the right part in the right place at the right time and in the right quantities. The DOD stated objectives of initial provisioning must be carried out under the concept of minimum supply response (18:2). The Air Force logistician is charged with the responsibility of achieving ". . . maximum initial support within available resources. . . under a concept that requires minimum supply response time [19:2]."

Minimum supply response is achieved through the attainment of a balance between ". . . pipeline inventory and costs related to holding inventory [19:2]." The implementation of this concept of minimum supply response is predicated upon the inventory policies providing for a coordinated approach to the elements of

. . . program development; the depth of stocks provided in the initial requirements computation; the range of items selected for initial stockage; and the requirements computation policy. . . [19:2].

Therefore, the minimum supply response concept can be likened to the initial provisioning process in that both have the objective of ensuring that the base has ". . . available a given range and depth of stock to ensure acceptable support from the first day the end article(s) is assigned [15:12-3]." The range and depth of items to be provided are ". . . agreed to during the provisioning process

[15:12-3]." The concept of acceptable support is geared towards providing an adequate range and depth of spare and replacement parts to meet the programmed operations of the end item at the base level.

There are three important questions which must be answered during the provisioning process to determine the range and depth of items to be provided as part of the initial provisioning or ISSL package. These questions are: (1) how critical is the item considered for inclusion on the ISSL to weapon system operation; (2) what will the demand rate be for the item; and, (3) how much money is available for the purchase of these spare/replacement items (1:1)? The answers to these questions are difficult to ascertain particularly when an ISSL pertains to a new weapon system and the component reliability data are based on engineering estimates rather than actual operating performance (6). However, through application of the system dynamics approach and the resultant information-feedback model, potential decisions regarding levels of spare/replacement parts can be analyzed to ascertain the level of system support that will be provided by that level of support. By testing the different stock levels the Air Force logistician will be in a better position to meet the initial provisioning objective by providing to base level units an adequate and accurate ISSL.

During the initial provisioning process an inventory management specialist assigned to Headquarters, Air Force Logistics Command (AFLC) uses the engineering reliability data in conjunction with ". . . base order and ship time, base repair cycle and initial operating level. . . [9:1]," to determine the quantities required for each item chosen to become part of the ISSL (9:1-2). The mathematical models used by the inventory management specialist were developed by the Department of Defense and are contained in DOD Instruction (DODI) 4140.42. DODI 4140.42 gives the control of the variables used in the model to the headquarters level activity responsible for the logistical support of the weapon system (19:3). The Directorate of Materiel Requirements (LOR) in Air Force Logistics Command Headquarters is responsible for the calculations affecting the depth of items to be provided as part of the ISSL.

When calculating the number of a given item to stock as part of the ISSL, the specialist assigned to AFLC/LOR must work within the parameters established by the engineering specialist. While working within these parameters the LOR specialist must assume that the data supplied by the equipment specialist is accurate; thus making the initial requirements computations accurate. However, according to an inventory management specialist assigned to AFLC/LOR, the quantities of items carried on the ISSL are not always accurate as evidenced by the numerous requests for changes to the ISSL stockage level which are being received by AFLC/LOR (2,6,8,9:1,11).

Two examples of problems associated with an inaccurate quantity on a ISSL were given by a supply system analyst assigned to the Directorate of Logistics (AFLC/LOL). First of all he had a personal experience with an over stockage due to an inaccurate ISSL supporting an F-4E fighter squadron in Germany in 1972 (2).

The squadron was being supported by an ISSL which contained items valued at over \$400,000. During the two year time span of the ISSL, only 14 per cent of the items were used. The result was that approximately \$344,000 was invested in inventory that was not used. Some of this excess inventory was returned to the supply system with the remainder being disposed of as salvage material (2).

The second example concerned a problem that he was currently trying to solve. This second example also concerned an F-4E fighter squadron, but in this instance the fighters were assigned to the Alaskan Air Command. The problem revolved around the fighter squadron experiencing a 60 per cent Not Mission Capable-Supply (NMCS) rate because the ISSL did not specify an adequate range and depth of spare/replacement parts (2).

The first example serves to point out that when the engineering estimates on the reliability of components are used, the ISSL quantities can be high when predicting the depth of spare/replacement parts needed to support a weapon system during its initial period of service (2,6,8,11). The second example points

out that as a system progresses through time, and the ISSL is adjusted for the "no demand generated" items, the range and depth of items specified for system support may be low. The low system support results because the "no demand generated" items are deleted from all future ISSLs so that new system/equipment activations will not have the items included when in fact the items may be needed; thus degrading the logistical support intended for the system. Logistical support was further degraded when the different type of operating environment for the F-4E was not taken into consideration when the required support items were specified for the Alaskan Air Command (2).

In the recent past, the ISSL estimates were predominantly high, which caused the expenditure of several million dollars for the procurement of spare/replacement parts which were not used (21:1). The high expenditure of funds caused the House Appropriations Committee to direct the General Accounting Office (GAO) to conduct an investigation into the initial provisioning practices of the Air Force (21:1). A 1971 GAO report stated

The Air Force spends hundreds of millions of dollars annually to obtain spare parts needed to support new aircraft during an initial period of operation. . . . Initial provisioning is one of the most important activities of military supply. If not enough parts are purchased, operational capabilities of new aircraft can be reduced. If too many parts are purchased too soon, or if wrong parts are purchased, money is wasted or prematurely spent [21:1].

The report continued and said

The appropriations Committees of the Congress and other committees may wish to consider the matters discussed in this report in connection with future Air Force requests for spare parts to initially support new weapon systems [21:4].

As a result of this unfavorable GAO report, DOD directives were implemented by the inventory specialists at AFLC which significantly reduced the ISSL stock levels (7:1). The Inventory management specialists who were interviewed pointed out that the ISSL stock levels have become insurance items until normal supply channels can be established and each item on the ISSL has had an opportunity to go through its demand development period (2,6,8,11).

The demand development period extends from the item's preliminary operational capability date to that point in time when the item requirements "... can be forecast based upon actual demand or other empirical data indicative of the need for spare and repair parts [19:Encl 4-1]." The demand development period cannot exceed two years; however, in some cases the period may end in a relatively shorter period of time (19:Encl 4-1).

Other factors which the inventory specialists pointed out indicate that there is an inadequate feedback system due to an apparent lack of understanding of the ISSL development and adjustment process. Perhaps the most graphic portrayal of this lack of understanding occurs when the spare/replacement parts are requisitioned from the base supply system. For example, the requisitioning code oftentimes does not reflect the proper priority code; i.e.,

an expedite code is used instead of a routine code when applicable (2). The impact of these expedited requisitions is felt at the provisioning conference. The provisioning conference serves as a forum at which the system manager, item manager, and representatives from the using command meet to review and discuss the range and depth of items designated to become part of the ISSL (15:12-29). The major command representatives oftentimes comes to these conferences with requests for changes to the levels of certain items which are based on personal experiences, actual or historical, on similar items.

Once the ISSL has been established changes to the computed stock levels may be submitted to Directorate of Materiel Requirements (AFLC/LOR) for review and possible inclusion in the ISSL (2,6,8,9:1). Currently, AFLC policy authorizes units to submit requests for changes to the computed ISSL quantity levels, provided the changes are based on sound managerial judgement and submitted in writing to AFLC/LOR (6,8,9:1). The intent of this policy was to allow for unusual circumstances to be rectified. These written requests for changes to the computed levels were expected to be the exception rather than the rule. However, change request letters are continually being received and processed by AFLC/LOR, which indicates a lack of understanding of the ISSL process and its purpose by the using agencies (6,9:1).

To put the foregoing into perspective, the initial spares support list (ISSL) is designed to provide an adequate range and depth of spare/replacement parts at base level to support weapon system/equipment activations until normal supply channels can be established. The depth of items provided is fixed for 730 days unless actual demand exceeds the anticipated usage (15:12-29).

Based on the preceeding information the problem for our research effort is to develop a dynamic model of the ISSL development process. Since the steps applicable to a system dynamics approach will be employed in the model construction several research objectives were established and research questions were formulated to guide the research effort. These research questions and objectives were designed to uncover the structure of the ISSL development process because uncovering the structure of a system ". . . tells how the parts are related to one another [3:15]."

Applying System Dynamics

System dynamics was selected as the approach to study the ISSL development process because it provides ". . . a way of studying the behavior of industrial systems to show how policies, decisions, [and] structure . . . are interrelated . . . [3:vii]."

Another factor which prompted the application of system dynamics to this research effort was that the central activities of the ISSL development process are also found in the corporate activities

towards which system dynamics is directed. In his book Industrial Dynamics, Forrester said

. . . any economic or corporate activity consist of flows of money, orders, materials, personnel, and capital equipment. These five flows are integrated by an information network [3:vii].

Further, system dynamics ". . . recognizes the critical importance of this information network in giving the system its own dynamic characteristics [3:vii]."

In approaching the construction of a model of the ISSL development process system dynamics was attractive because it analyzes the real world system to ". . . determine how information and policy create the character of the organization [3:vii]," and permits the model to be used as a "management laboratory." The system dynamics approach requires a series of steps for the successful creation of the management laboratory. Two of the steps necessary for the successful application of system dynamics are

. . . first . . . to identify the problems and goals of the organization. The second is to formulate a model that shows the interrelationships of the significant factors. Such a model is a systematic way to express our wealth of descriptive knowledge. . . [3:vii].

By applying system dynamics, the model was developed that revealed the behavior of the system as determined by the interactions of the system's variables. Perhaps the greatest benefit of a properly constructed model is that ". . . proposed changes can be tried in the model and the best of them used as a guide to better management [3:vii]."

The best support for the use of system dynamics is found in Jay Forrester's book Industrial Dynamics; the reader should note that industrial dynamics is synonymous with system dynamics. In Industrial Dynamics Forrester said:

Industrial dynamics is the study of the information-feedback characteristics of industrial activity to show how organizational structure, amplification (in policies), and time delays (in decisions and actions) interact to influence the success of the enterprise. It treats the interactions between the flows of information, money, orders, materials, personnel, and capital equipment in a company, an industry, or a national economy.

Industrial dynamics provides a single framework for integrating the functional areas of management--marketing, production, accounting, research and development, and capital investment. It is a quantitative and experimental approach for relating organizational structure and corporate policy to industrial growth and stability.

Industrial dynamics should provide a basis for the design of more effective industrial and economic systems [3:13].

The ISSL development process of the Air Force supply system further lends itself to a system dynamics approach because it has all of the characteristics delineated by Forrester. These characteristics include an organizational structure, policies, decisions, information flows, money, orders, material, personnel, and capital equipment. In addition, the ISSL development process also includes areas which are equivalent to the functional areas found in private industry which include marketing, production, accounting, research and development, and capital investment. The distinct similarities that exists between the ISSL development

process and the information-feedback structure of private industrial concerns make the system dynamics approach to model construction well suited to our needs.

Research Questions

The research questions that were addressed during this AFLC requested study were:

- A. Can the pertinent dynamic interrelationships that produce the ISSL be identified?
- B. Can the cause and effect relationships of the interacting variables be traced?
- C. Can the control process be formulated to describe how decisions result from available information?
- D. Can a mathematical model of the process, information sources, and interactions of the ISSL development process be constructed?

Research Objectives

The following specific research objectives were developed to guide this research effort towards the general objective of constructing a dynamic model of the initial-spares support list (ISSL) development process:

- A. Determine the pertinent dynamic interrelationships that produce the ISSL. Identify the pertinent infor-

mation-feedback structures that exist and how they interact to produce the range and depth of items required to provide end item support.

- B. Trace the cause and effect relationship of the interacting variables. By accurately tracing the relationships that exist between the variables which have been determined to be pertinent, the central underlying structure of the ISSL development process will be revealed.
- C. Formulate the control process to describe how decisions result from available information. The formal as well as informal control processes which result in the finalized ISSL must be studied to accurately represent how the published ISSL is determined.
- D. Construct a mathematical model of the process, information sources, and interactions of the ISSL development process. The construction of a quantitative model provides a method of insuring that all pertinent variables have been included and that the constructed model accurately represents the ISSL development process.
- E. Generate the behavior of the system through time by operating the mathematical model. Through operation of the model the applicability of the model to the system

and its ability to duplicate the system will be revealed. For the ISSL development process, adequate end item support will be provided.

F. Test the internal and external validity of the model.

In order for the model to be useful it must replicate the system being studied. For this to be possible all of the internal and external functioning of model must duplicate the actual system.

In the succeeding chapters the model of the initial spares support list (ISSL) development process will be described in conformance with the research objectives. Chapter II will address the methodology of the research effort and provides an introduction to system dynamics. Chapter III presents the interrelationships and the polarity of the relationship between the variables that make up the ISSL development process.

The control processes of the system will be formulated, and a mathematical model constructed in Chapter IV. Model operation and validation are discussed in Chapter V. Chapter VI presents a summary of the study, conclusions, and recommendations for further research.

Chapter II

METHODOLOGY

Introduction

As indicated in Chapter I, system dynamics was employed to analyze the ISSL development process. Presented in this chapter are the system dynamics techniques of causal loop diagramming, flow diagramming, and equation formulation. This is followed by comments concerning model operation, validation, experimentation, and data sources. The discussion in this chapter is designed to prepare the reader for the technical discussion of the model in succeeding chapters. Causal loop diagramming is presented first.

Causal-Loop Diagramming

Goodman both defined and stated the purpose of causal-loop diagramming. He said:

System dynamics focusses on the structure and behavior of systems composed of interacting feedback loops. . . . Causal-loop diagrams identify the principal feedback loops without distinguishing between the nature of the interconnecting variables. . . . and play two important roles in system dynamics studies. First, during model development, they serve as preliminary sketches of causal hypotheses. Second, causal-loop diagrams can simplify illustration of a model. In both capacities, causal-loop diagrams allow the analyst to quickly communicate the structural assumptions underlying his model [4:5].

A relatively simple example from the ISSL development process model is presented in Figure 2-1 to illustrate the major structural features of a causal loop diagram. This diagram will be developed into a system dynamics flow diagram and a series of DYNAMO equations in later sections of this chapter.

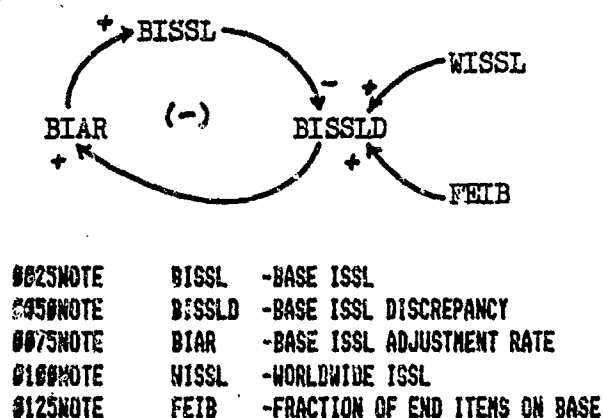


Figure 2-1. Example Causal-Loop

The three major components of the causal loop are its variables, the relationships between the variables, and the polarity of the loop. The variables are Forrester's "... factors that appear to interact to create the observed symptoms [3:13]." In the example, they are the Base ISSL, the Base ISSL Adjustment Rate, the Base ISSL Discrepancy, the Worldwide ISSL, and the Fraction of End Items on Base.

The relationship between a pair of variables is indicated by an arrow. The directional influence of the relationship is indicated by the direction of the arrowhead (4:6-7). Referring to

the example, the Worldwide ISSL influences the Base ISSL Discrepancy, the Base ISSL Discrepancy influences the Base ISSL Adjustment Rate, and so on. The sign of the arrow indicates the type of influence. A critical assumption in determining the sign of a pairwise causal relationship is that all factors are held constant except for the variables in the relationship under consideration (4: 8). For example, when considering the relationship between the Worldwide ISSL and the Base ISSL Discrepancy, the Fraction of End Items on Base, the Base ISSL Adjustment Rate, and the Base ISSL are all considered to be constants. If the sign of the relationship is positive, then ". . . a change in one variable generates a change in the same direction in the second variable relative to its prior value . . . [4: 7]." In the example, an increase in the Worldwide ISSL results in an increase in the Base ISSL Discrepancy; similarly, a decrease in the Worldwide ISSL results in a decrease in the Base ISSL Discrepancy.

If the sign of the arrow is negative, ". . . a change in one variable produces a change in the opposite direction in the second variable [4: 7]." For example, as the Base ISSL increases, the Base ISSL Discrepancy decreases; conversely, as the Base ISSL decreases, the Base ISSL Discrepancy increases.

The polarity of the overall causal-loop is indicated by the + or - sign in parenthesis within the loop. If the polarity of the loop is positive, ". . . a change in one element. . . causes further

change in the same direction in an unending process [4:26]."

If the polarity of the loop is negative, the loop is goal seeking (4:9); that is, there is a feedback mechanism present which

. . . tends to keep a given system at equilibrium. In the most simple system, a single rate based on discrepancies between the desired goal and level drives the system to its goal value. Inflow or outflow rates readjust until the level reaches the desired value [4:51].

This is the case in the example. The polarity of the loop is negative; therefore, any influence that generates a Base ISSL Discrepancy will be countered by an adjusted Base ISSL Adjustment Rate until the desired Base ISSL level is reestablished.

After the entire ISSL development process was described to the point where the important variables and interrelationships were identified in a causal-loop diagram, system flow diagrams were developed.

Flow Diagramming

Flow diagramming is an intermediate step in developing a system dynamics model. Goodman stated that detailed flow diagrams must be constructed before simulation analysis can proceed from the causal-loop stage (4:12). Forrester stated that

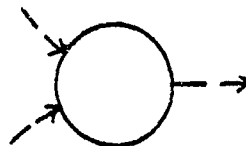
. . . a pictorial representation of an equation system is highly desirable. A diagram that displays the interrelationships between equations helps to lend clarity to the system formulation. . . . A properly constructed flow diagram is better than a set of equations for communicating the structure of a system to many practicing managers. A diagram represents an intermediate transition between verbal description and a set of equations [3: 81].

The standard symbols used in flow diagramming are illustrated in Figure 2-2 and briefly discussed below. An auxiliary variable represents a concept in the information flow channel that has an independent meaning. It can be algebraically substituted into a rate equation. A constant is a numerical value that does not change for the duration of the computation of a single model run. A decision function (rate) can be thought of as a "valve" that determines the rate of flow in a flow channel. A delay is a combination of levels and decision functions that modify the time relationships between the input flow which is given and the resulting output flow which is generated by the delay. A flow of information represents the passage of information within the system. A flow of resources is the passage of people, money, or materials into or out of the levels within the system. An information takeoff is the origin of an information flow. A level is the aggregation of resources within the system; it is analogous to inventory in a supply system. A source or a sink is an origin or destination of resources which lies outside of the boundaries of the model.

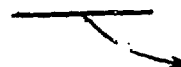
A system dynamics model is primarily concerned with levels and flow rates. Forrester said:

A basic structure of alternating levels and flow rates seems to represent the nature of industrial management systems. The levels determine the decisions that control flow rates. The flow rates cause changes in the levels. These levels and rates make up six interconnected networks

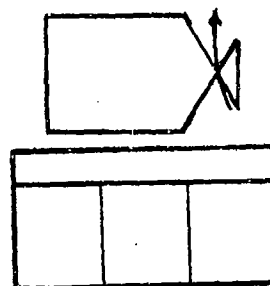
Auxiliary Variable



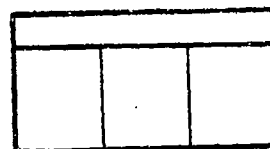
Constant



Decision Function



Delay



Flow of Information



Flow of Resources



Information Takeoff



Level



Source or Sink



Figure 2-2. Flow Diagram Symbology (3:82-84)

that constitute industrial activity. Five of these represent materials, orders, money, capital equipment, and personnel. The sixth, the information network, is the connecting tissue that interrelates the other five [3: 67].

The flow diagram corresponding to the example causal-loop diagram in Figure 2-1 is presented in Figure 2-3.

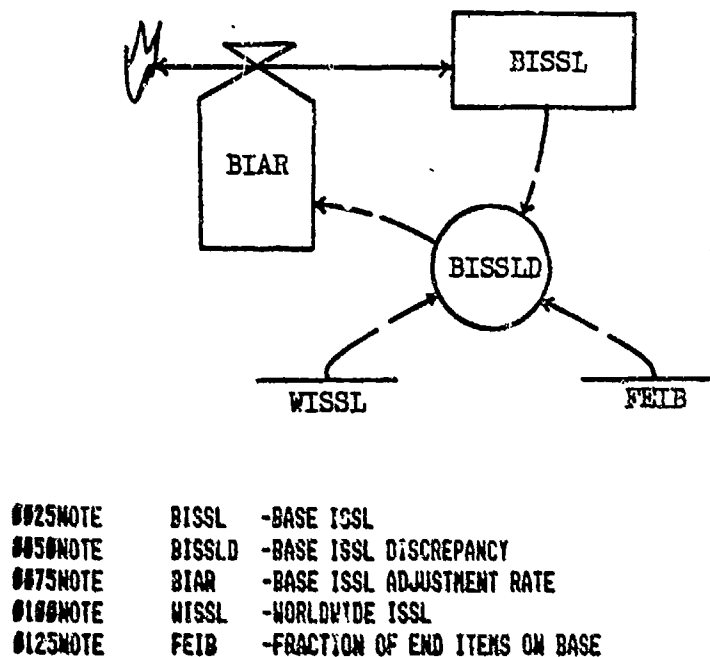


Figure 2-3. Example Flow Diagram

The primary flow in this diagram is the flow of information concerning the level of the Base ISSL. This flow is represented in the diagram as originating at a source/sink and moving through a two-way "valve" (Base ISSL Adjustment Rate) into the level "Base ISSL". The valve is controlled by the Base ISSL Discrepancy which, in turn, is a function of other factors that are determined

by management decisions. According to Figure 2-3 the Base ISSL Adjustment Rate is controlled by an information feedback loop which compares the actual Base ISSL level with the desired Base ISSL level (i.e., the Worldwide ISSL times the Fraction of End Items on Base) to determine if a discrepancy exists. If a discrepancy does exist, the Base ISSL Adjustment Rate is adjusted to correct the discrepancy. From this flow diagram it is possible to construct the mathematical equations that are required to run the model on the computer.

Equation Formulation

The computer language that is used to implement a system dynamics model is called DYNAMO (10:1). This section discusses the format of the equations used by the DYNAMO program and illustrates the correlation between a flow diagram and its DYNAMO equations. The equations that correspond to the example flow diagram of Figure 2-3 are presented in the text as they are discussed.

Forrester stated that

The equations tell how to generate the system conditions for a new point in time, given the conditions known from the previous point in time. The equations of the model are evaluated repeatedly to generate a sequence of steps equally spaced in time. Level equations and rate equations generate the levels and rates of the basic model structure. In addition, auxiliary, supplementary, and initial-value equations are used [3: 73].

Before the five classes of DYNAMO equations listed by Forrester can be discussed, it is necessary to explain the time sequence that the DYNAMO program uses as a basis for its computations.

DYNAMO deals with only three times: the present time (K), the time that is one time-unit (DT) in the past (J), and the time that is one time-unit in the future (L). The time-unit, DT, is a constant that is determined by the analyst. Since the program deals with only three points in time (J,K,L), each separated by the time period DT, there are only two time periods in the model: JK and KL, each of which is DT long. When the program is run, the computer calculates all levels at time K and all rates for the time interval KL. The computer then "indexes" time one step into the future (3: 74-75).

The K levels just calculated are relabeled as J levels. The KL rates become JK rates. Time K, "the present," is thus advanced by one interval of time of DT length. The entire computation sequence can then be repeated to obtain a new state of the system at a time that is one DT later than the previous state [3: 75].

This concept is illustrated graphically in Figure 2-4 and is the basis for the formulation of the five classes of DYNAMO equations.

Level (L) equations define ". . . the varying contents of the reservoirs (stocks, inventories, balances) of the system [3: 76]". Levels would exist even if the system were brought to rest and no flows existed. Level equations are independent of each other and depend only on information before time K (3: 76).

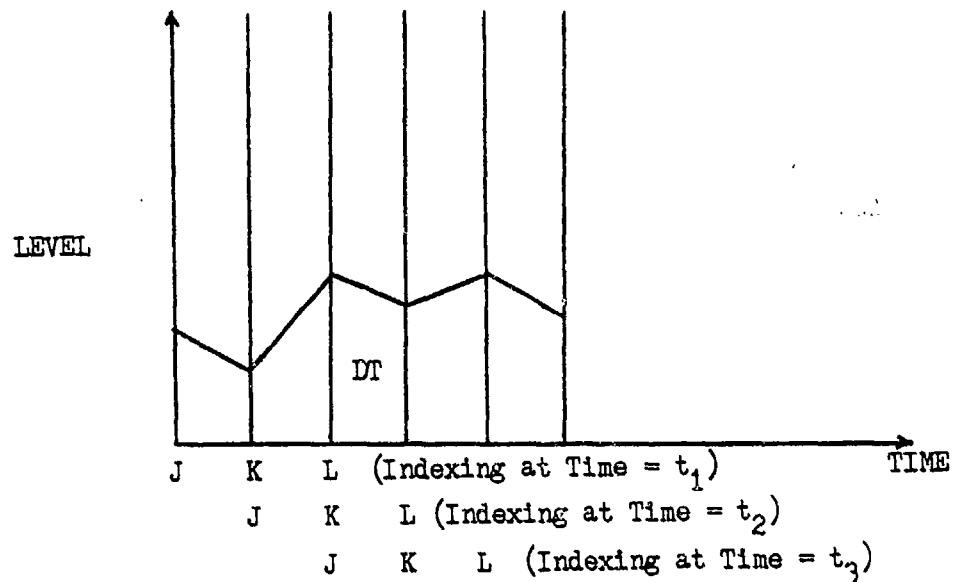


Figure 2-4. DYNAMO Time Flow

An example of a level equation from Figure 2-3 is:

$$\text{BISSL. K} = \text{BISSL. J} + (\text{DT})(\text{BIAR.JK})$$

This equation states that the present value of the Base ISSL at time K equals the previous value of the Base ISSL computed at time J plus the value of the Base ISSL Adjustment Rate during the last time interval JK times the length of the time interval JK; i.e., DT.

Rate (R) equations define the rate of flow between the levels of the system. They are decision functions of the system and are evaluated from the presently existing values in the levels in the

system (3:77). An example of a rate equation from Figure 2-3 is $BIAR.KL = BISSLD.K$. This equation states that the Base ISSL Adjustment Rate for the time period KL will equal the Base ISSL Discrepancy calculated at time K.

Auxiliary (A) equations are subdivisions of rate equations that permit keeping rate equations simple and in close correspondence with the flow diagram. Examples of auxiliary equations and their corresponding rate equation from another portion of the ISSL development model are:

$$\begin{aligned} A \text{ WIARF1.K} &= (WID1.K)(WTF1.K)(WTF3.K)/DT \\ A \text{ WIARF2.K} &= (WID2.K)(WTF2.K)(WTF3.K)/DT \\ R \text{ WIAR.KL} &= (WIARF1.K + WIARF2.K) \end{aligned}$$

Note that all three equations are composed of relatively simple mathematical terms which can be easily related to the structure of a flow diagram. If the three equations are combined into a single rate equation, the expression on the right side of the equation becomes unnecessarily complex:

$$R \text{ WIAR.KL} = \frac{(WTF3.K)(WID1.K)(WTF1.K) + (WID2.K)(WTF2.K)}{DT}$$

Supplementary (S) equations may be used to define variables which are not a part of the structure but which are of interest to the researcher (3:79). They are not used in the ISSL model.

Initial-value (N) equations are used to define the initial values of all levels, and some rates, that must be given before the first cycle of computations can begin (3:79). $BISSL = BISSLI$ is an initial value equation which states that Base ISSL equals the initial Base ISSL.

The five classes of equations discussed in this section are the basic elements of a system dynamics model which can be run on the computer with the DYNAMO simulation language. Forrester issued a word of caution concerning the DYNAMO equations. He stated that

. . . these equations are not "right" in any intrinsic or mathematical way. They merely describe what we have chosen as the most significant relationships. The equations are akin to a verbal description of the situation. They are wrong to the extent that we wrongly interpret the organization which is being described [3-141].

The "rightness" of the equations will influence the remaining steps of the system dynamics modelling process. These steps are discussed in the next section.

Model Operation, Validation, and Experimentation

Once the three processes of causal-loop diagramming, flow diagramming, and equation formulation were completed for the ISSL development process, the following three steps in the application of system dynamics were accomplished:

- *Generate the behavior through time of the system as described by the model [in this case using the DYNAMO computer program].
- . . .
- *Compare results against . . . pertinent available knowledge about the actual system.
- *Revised the model until it is acceptable as a representation of the actual system [3:13].

Model building is an experimental process. Once the basic model was developed, simulations on the computer were made. The behavior of the model was compared with expected behavior and with

the behavior of the actual system. If differences existed, changes in the flow diagrams, the equations, or both were made, and the simulation was reaccomplished. This process was repeated until the behavior of the model closely resembled the behavior of the real world ISSL development process. In this way the internal validity of the model was confirmed. The model was developed to the point where it now can be used as a management laboratory in which the analyst can experiment. It cannot predict the specific state of the system at a given point in the future, but it can show the effects of a change in policy or structure on the general behavior of the system. The ultimate goal of the analyst, and the purpose of the model, is to show the manager of the system how to improve the organization's policies and structure (3:130-133).

Data Sources

Data necessary for the construction of the causal loop diagrams, flow diagrams, and DYNAMO equations were obtained from AFLC Headquarters personnel through personal interviews and from various DOD, USAF, and AFLC publications. These sources represent the ISSL policy makers and the directives which implement their policy. Specific numerical data were obtained from actual AFLC forms where they were available; where actual data was not available, numbers were intuitively developed to enable the model to operate. Reference to specific data sources are made throughout the following

chapters. Statistical techniques were not required in the development of the model.

This completes the discussion of the research methodology. Chapter III identifies the variables in the ISSL development process and discusses the cause and effect relationships among these variables.

Chapter III

CAUSE AND EFFECT RELATIONSHIPS

Introduction

As indicated in Chapter II, the identification of the important variables and their interrelationships begins with a causal-loop diagram of the system under study. This chapter identifies the cause and effect relationships that exist between the variables that interact to form the initial spares support list (ISSL) development process. Goodman stated the purpose of the causal-loop diagram when he said, ". . . causal-loop diagrams allow the analyst to quickly communicate the structural assumptions underlying his model [4:5]."

The causal-loop diagram describes the feedback mechanisms that exist between the variables which make up the system. In order to construct a causal-loop ". . . we must first establish the pairwise relationships of relevant variables [4:5-6]." After the pairwise relationships are established the variables are then ". . . linked together to form the feedback loops of the system. . . [4:11-12]." This process is repeated until all the relevant variables and relationships have been identified and linked together to form the causal-loop diagram of the system under study.

To facilitate the construction of the causal-loop diagram of ISSL development, the process was divided into sectors so that the interacting variables could be more readily identified. Through the use of sectors functions and control processes were grouped into homogeneous areas which made the determination of variable interaction somewhat easier to follow. The sectors that were identified and pursued during the research effort were the initial spares support list (ISSL) Development, Base Inventory, Depot Inventory, and Consumption Sectors. These sectors are interdependent, and their interdependence results in the ISSL development process.

The remainder of this chapter describes each of the individual sectors as they were conceptualized. Each of the sector descriptions includes its causal-loop diagram, an explanation of the pairwise relationships that exists between the variables in that sector, and a discussion of the logic that was used in designing each sector. As the reader progresses through this chapter, the interrelationships of the variables within a given sector and the interrelationship between the sectors should become evident.

Initial Computation Parameters

Selection of items for inclusion on the initial spares support list (ISSL) is "... accomplished by the ALC [Air Logistics Center] having support responsibility for the weapon system or end article of equipment [15:12-30]." It is during the initial provision-

ing conference that the technical equipment specialist, item manager, system manager, contractor, and using command representatives meet to discuss the range and depth of items to be included on the ISSL. However, it is the technical equipment specialist who has ". . . final responsibility for determining the range of items selected for an ISSL [15:12-30]," because he ". . . holds a key role in developing and maintaining logistics support for Air Force systems and equipment [14:1]." The equipment specialist's responsibilities commence ". . . during the conceptual phase of system or equipment development and continues until the system or equipment is removed from the inventory [14:1]."

Among the important functions performed by the equipment specialist are the determination of the reparability of items, the assignment of source, maintenance, and recoverability codes, and the establishment of factors to be used for the maintenance and overhaul of Air Force spare and repair parts. With the maintenance and overhaul factors the equipment specialist is projecting the initial maintenance requirements. These factors are important because they ". . . establish the base line for initial requirements computation [14:6]." The equipment specialist must accurately assign the maintenance and overhaul factors because:

The accuracy of these factors is reflected in excess or shortages during the initial operational and maintenance support periods. In effect, the maintenance and overhaul factors predicate the total quantitative procurement, asset distribution, dollars spent for spares and repair parts support. . . [14:6].

With the computation parameters set by the equipment specialist the initial requirements computations can begin with the rates and factors furnished to AFLC/LOR on the Programming Checklist.

ISSL Development Sector

The causal-loop diagram of the initial spares support list (ISSL) development sector is presented as Figure 3-1.

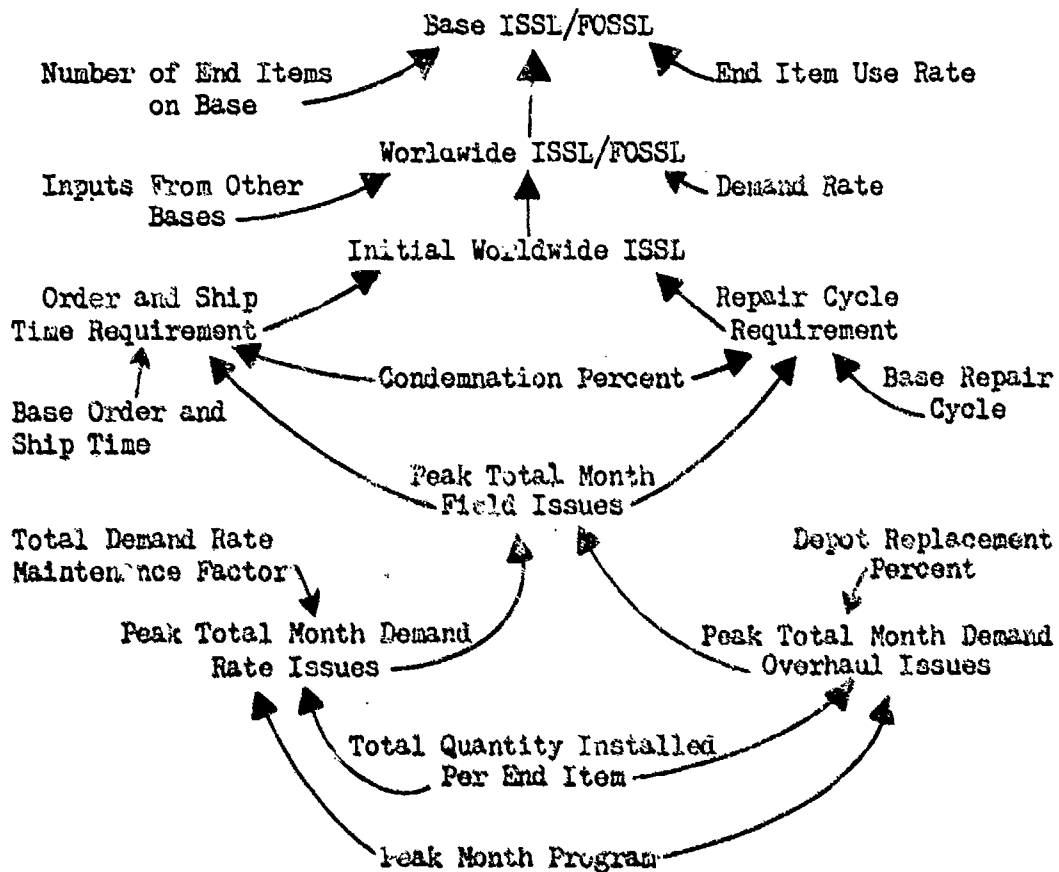


Figure 3-1. ISSL Development Sector Causal-Loop

The input variables to this sector are the initial computation parameters furnished to the Directorate of Materiel Requirements in Headquarters, Air Force Logistics command (AFLC/LOR) by the equipment specialist on the Programming Checklist (14:6-11). Using these parameters the initial requirements for the economic order quantity items ". . . which have been identified as logical spares and/or repair parts during initial provisioning. . . [12:2-1]" can be determined. AFLC Form 997, EOQ Initial Provisioning Worksheet, is normally ". . . used to manually determine initial EOQ spares/repair parts requirements for centrally procured items coded for Air Force management . . . [12:2-1]." The variables which form this sector were derived from the computation worksheet..

In Figure 3-2 are shown the relationships that exist between the Peak Month Program (projected monthly demand), Total Quantity Installed per End Item, and Total Demand Rate Maintenance Factor parameters from the Programming Check List on the Peak Total Month Demand Rate Issues (projected repair requirements) variable on the provisioning worksheet. The positive polarity of the Peak Month Program, Total Quantity Installed per End Item, and on the Total Demand Rate Maintenance Factor parameters indicate that as either one of these parameters increase there will also be an increase in the Peak Total Month Demand Rate Issues variables.

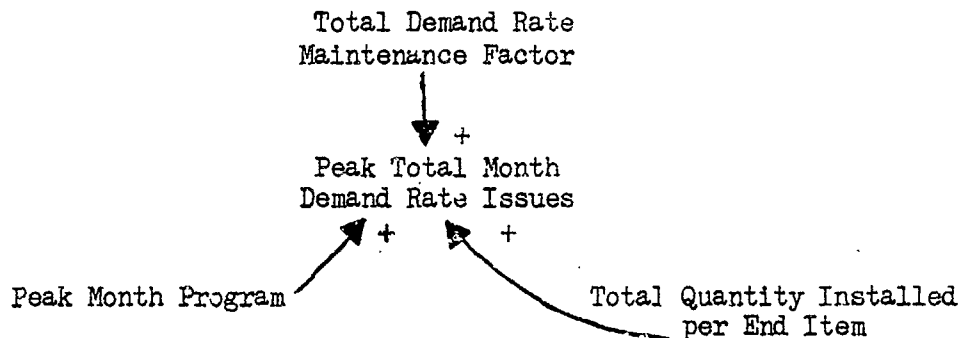


Figure 3-2. Peak Total Month Demand Rate Issues Causal-Loop

Figure 3-3 shows the relationship and polarity that exists between the same Peak Month Program and Total Quantity Installed per End Item parameters, and the Depot Replacement Percent parameter which is "... developed from the overhaul replacement factor or the provisioning document [12:2-2]," with the Peak Total Month Demand Overhaul Issues (projected depot level issues for repairs). As indicated in the causal-loop diagram for this portion of the sector all three of the parameters have a positive effect on the computation of the requirement variable which means that as the parameters increase so will the calculated variable value (12:2-2,3).

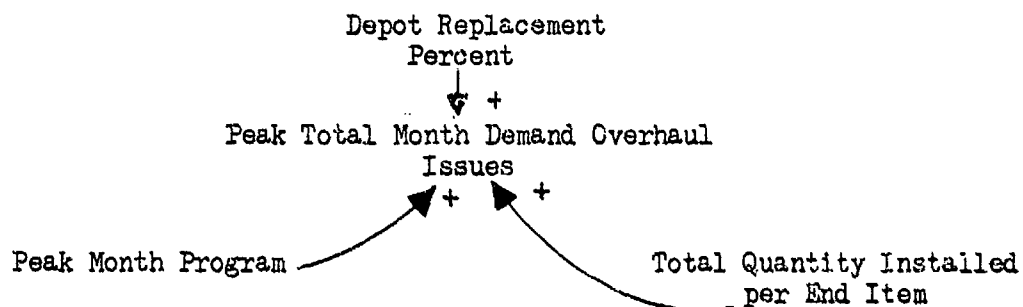


Figure 3-3. Peak Total Month Demand Overhaul Issues Causal-Loop

The calculated values for the Peak Total Month Demand Rate Issues and Peak Total Month Demand Overhaul Issues have an impact on the provisioning worksheet value for the variable Peak Total Month Field Issues (projected base level issues for repairs). The interrelationship of the calculated variables is indicated in Figure 3-4. As the Peak Total Month Demand Rate Issues increase so will the Peak Total Month Field Issues; however, as the Peak Total Month Demand Overhaul Issues increase there is a decrease in the Peak Total Month Field Issues (12:2-3).

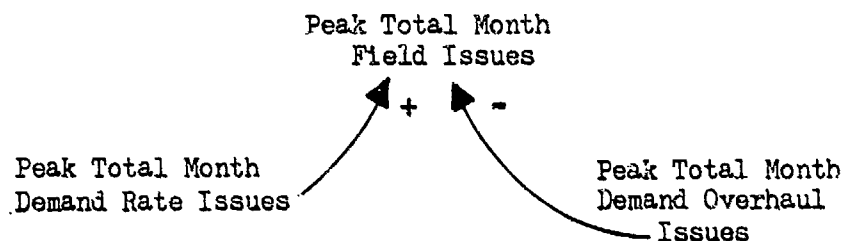


Figure 3-4. Peak Total Month Field Issues Causal-Loop

The Peak Total Month Field Issues interacts with standard support times used for Base Order and Ship Time, Base Repair Cycle, and Condemnation Percent to determine the Order and Ship Time Requirement and the Repair Cycle Requirement. Since "... initial spares procurement will be limited to new items [12:1-1]," standard support times are used because "... no actual data is available [12:2-1]."

The Order and Ship Time Requirement causal-loop is presented as Figure 3-5. Each of the variables involved, Peak Total Month

Field Issues, Base Order and Ship Time, and Condemnation Percent, have a positive effect on the Order and Ship Time Requirement. The result of these positive effects is that as either of variables increase so will the Order and Ship Time Requirement.

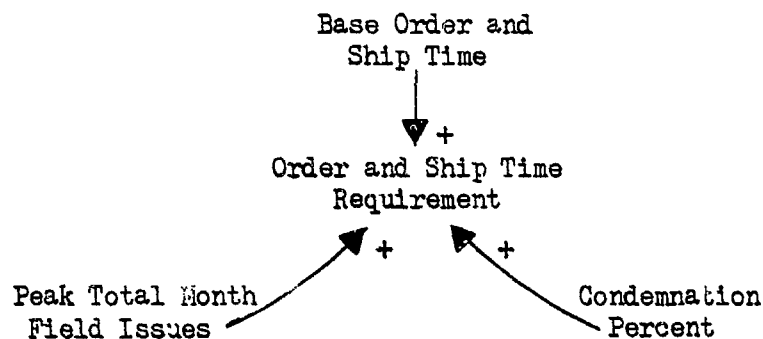


Figure 3-5. Order and Ship Time Requirement Causal-Loop

Figure 3-6 depicts the interrelationships that exist to form the Repair Cycle Requirement. In this instance the Peak Total Month Field Issues and the standard value for the Base Repair Cycle have a positive effect on the Repair Cycle Requirement. Therefore, as these variables increase so will the Repair Cycle Requirement increase. However, the Condemnation Percent has a negative effect which means that as the Condemnation Percent increases the Repair Cycle Requirement will decrease. The Condemnation Percent for EOQ items ". . . will always equal 1.00 [12:2-2];" thus, the Repair Cycle requirement is zero for EOQ items. This will be explained further in Chapter IV.

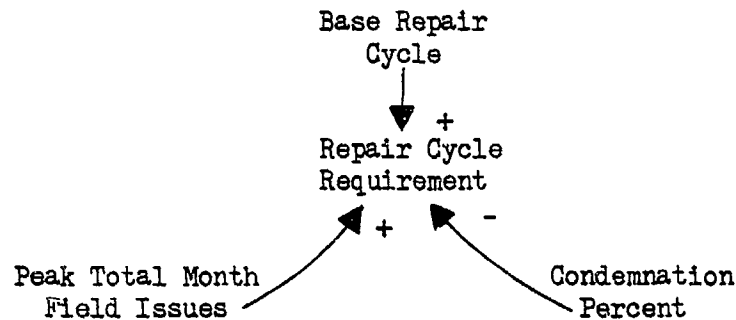


Figure 3-6. Repair Cycle Requirement Causal-Loop.

The Order and Ship Time Requirement and Repair Cycle Requirement interact as shown in Figure 3-7 on the Initial Worldwide ISSL. Both of the calculated variables have a positive effect on the ISSL. As the Order and Ship Time Requirement or Repair Cycle Requirement increases the Initial Worldwide ISSL will also increase.

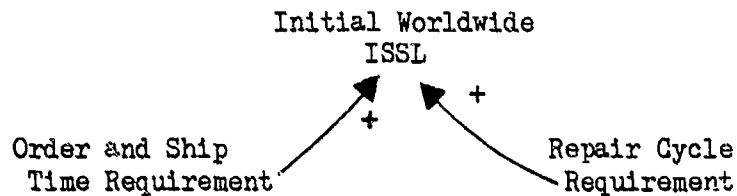


Figure 3-7. Initial Worldwide ISSL Causal-Loop.

In order to show the effects of adjustments made to the initial ISSL quantities as the system progresses through time, a new variable called Worldwide ISSL was introduced. The Worldwide ISSL variable differs from the Initial Worldwide ISSL because it takes into consideration the experience gained at those bases that have used the initial ISSL quantities in support of the weapon

system/equipment activation. In addition, the worksheets with the original computations ". . . must be available for HQ AFLC review during regularly scheduled materiel management reviews [12:2-1]." The interactions of the variables that have an impact on Worldwide ISSL are shown in Figure 3-8. It should be noted that if the ISSL is still in its initial stages of deployment and actual experiences are limited the Initial Worldwide ISSL and the Worldwide ISSL are the same.

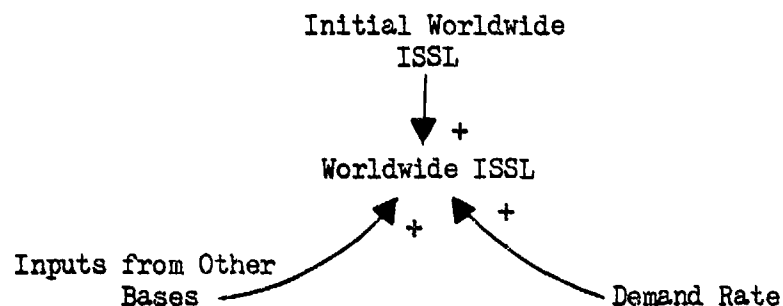


Figure 3-8. Worldwide ISSL Causal-Loop

As shown in Figure 3-8, as the Inputs From Other Bases goes up there will be an increase in the Worldwide ISSL. Similarly, as the Demand Rate experienced from actual usage of the ISSL goes up there will again be an increase in the Worldwide ISSL. As the Initial Worldwide ISSL goes up, so too will the Worldwide ISSL because they are essentially the same, differing only in time; i.e., the Initial Worldwide ISSL initializes the Worldwide ISSL to a given value, after which time the Worldwide ISSL becomes a function of actual consumption data.

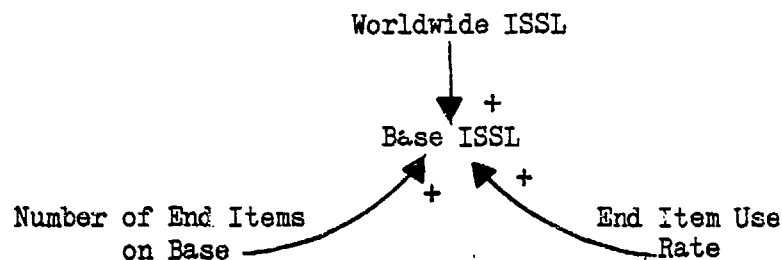


Figure 3-9. Base ISSL Causal-Loop

The Base ISSL causal-loop diagram, Figure 3-9, is the final portion of the ISSL development sector. As the Worldwide ISSL increases the Base ISSL will also increase. Further, either the Number of End Items On Base or the Base End Item Use Rate will have a positive effect on the Base ISSL. This is true because as the number of end items increase or the more the end item is used, the greater the amount of spare/replacement parts will be required to support the end item (11).

Thus, the ISSL Development Sector is composed of several interdependent causal-loops which interact to produce the quantity of items required to provide the projected end item support. The description of Base ISSL causal-loop provides a point to begin the description of the Base Inventory Sector.

Base Inventory Sector

The Base initial spares support list (ISSL) is the connecting link between the ISSL Development Sector and the Base Inventory Sector as shown in Figure 3-10. The reader should note that the

Demand Rate element is not only in the ISSL development but also in the Base Inventory Sector as well. The Demand Rate is used to calculate the Safety Level Quantity, the Order and Ship Time Quantity and the Economic Order Quantity in this Sector.

Figure 3-11 shows that as the Demand Rate goes up the Safety Level Quantity also increases. Similarly, as the Demand Rate increases, the Order and Ship Time Quantity also increase. It should be noted that a Safety Level Quantity is utilized only if the calculated safety level is greater than the demand rate multiplied by fifteen; otherwise, the Safety Level Quantity is equal to the demand rate multiplied by fifteen (17:11-13).



Figure 3-11. Safety Level Quantity and Order and Ship Time Quantity Causal-Loop

After calculating the Safety Level Quantity and the Order and Ship Time Quantity, the Base Reorder Point can be determined. The causal-loop diagram for the Base Reorder Point, Figure 3-12, reveals that the Safety Level Quantity and the Order and Ship Time Quantity each have a positive effect on the Base Reorder Point such

that as either one goes up so too will the Base Reorder Point. In addition to these two variables, the Base ISSL also has a positive effect on the Base Reorder Point which means that as the Base ISSL quantity increases the Base Reorder Point will also go up.

The Base Inventory level established by the Base ISSL receives a positive impact from not only the Base ISSL but also from Other Base Requirements as well (Figure 3-12). The established Base Inventory has an impact on the Base Reorder Point in providing a timing factor, as the reorder point used by the base is ". . . 1/3 the minimum level quantity (ISSL) or normal reorder point whichever is greater [17:11-53]." The ISSL represents the minimum level of a given item that must be on hand or on order, or a combination of the two, in order to provide adequate system support as determined by the equipment specialist (6,8,11).

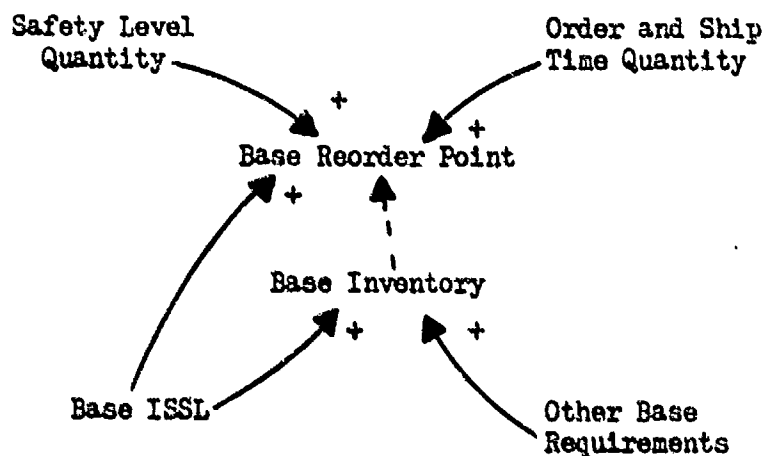


Figure 3-12. Base Reorder Point Causal-Loop

The Demand Rate variable also interacts with the Variable Stockage Objective and Unit Price in the Base Economic Order Quantity causal-loop (Figure 3-13). As the Demand Rate increases, the Base Economic Order Quantity also increases which indicates a positive effect. The Variable Stockage Objective, which represents the number of days items should be stocked to cover, also has a positive effect on the Base Economic Order Quantity (17:11-6). The Base Economic Order Quantity receives a negative effect from the Unit Price because as the Unit Price increases the Base Economic Order Quantity will have a corresponding decrease.

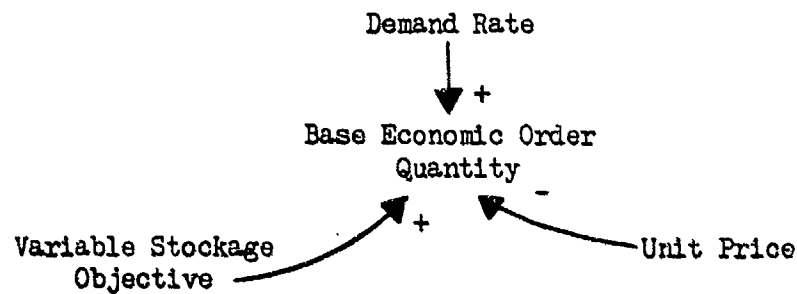


Figure 3-13. Base Economic Order Quantity Causal-Loop

Aside from the Demand Rate, the Base Reorder Point also plays an important role in the Base Inventory Sector. The Base Reorder Point is an important factor in the Base Procurement Rate causal-loop, and the actual Base Inventory causal-loop diagrams.

The Base Procurement Rate receives positive inputs from the Base Reorder Point, Base Economic Order Quantity, and from the Money

Available for Procurement (Figure 3-14). As any one of these variables increases the Base Procurement Rate will also increase. The point should be made that while a variable for Money Available for Procurement was included in the Base Procurement Rate it was done so only as a matter of completeness. The Money Available for Procurement variable represents an exogenous system to the ISSL development process and was not thoroughly researched. The inventory specialists interviewed indicated that once a requirement for additional operating and maintenance funds were made known to the Base Financial Activity, funds were made available to purchase the required items (6,8,11).

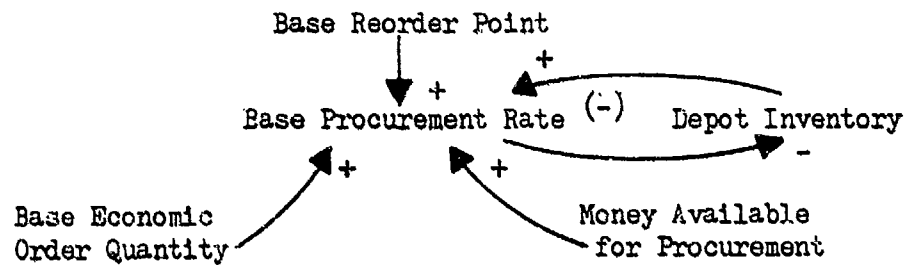


Figure 3-14. Base Procurement Rate Causal-Loop

Also depicted in Figure 3-14 is the positive effect of the Depot Inventory on the Base Procurement Rate while the Base Procurement Rate has a negative impact on the Depot Inventory. The reason for this dichotomy should be intuitive in that as the Depot Inventory has the required items, the Base is able to procure them which, in

turn, reduces the Depot Inventory. Another variable which has a dual impact on the Base Procurement Rate is the actual Base Inventory (Figure 3-15).

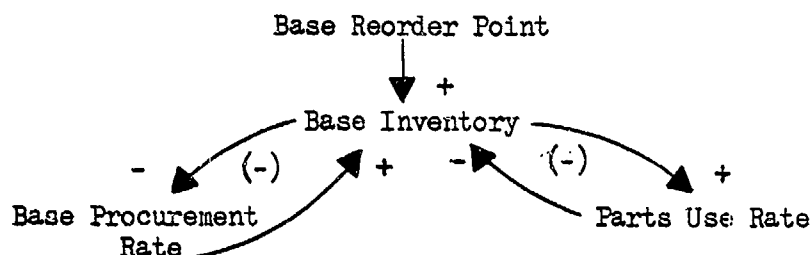


Figure 3-15. Base Inventory Causal-Loop

As the actual Base Inventory increases the Base Procurement Rate will decrease; conversely, as the Base Procurement Rate increases the actual Base Inventory will also increase. Also shown in Figure 3-15 is the positive effect of the Base Reorder Point on actual Base Inventory. This indicates that as the Base Reorder Point goes up, the actual Base Inventory will also increase.

Before completing a description of this sector a discussion of how the Base Inventory Sector is interdependent on the Consumption Sector and how it provides a means of updating other Base ISSLs is warranted. The Parts Use Rate Variable connects the Base Inventory Sector directly to the Consumption Sector as will be discussed later in this chapter, and indirectly connects the Base Inventory Sector with the Worldwide IESL through the Demand Rate.

As indicated in Figure 3-15, the Base Inventory has a positive impact on the actual Parts Use Rate which in turn has a negative

impact on the actual Base Inventory. This means that as the actual Base Inventory increases the actual Parts Use Rate can also increase; on the other hand as the Parts Use Rate increases the Base Inventory decreases.

Figure 3-16 shows that as the Parts Use Rate goes up the Cumulative Recurring Demand also goes up. The Cumulative Recurring Demand represents the accumulated total of parts used over a given period of time. Also shown by Figure 3-16 is that as the Cumulative Recurring Demand increases the Demand Rate will also increase due to the positive impact of Cumulative Recurring Demand on the established Demand Rate.

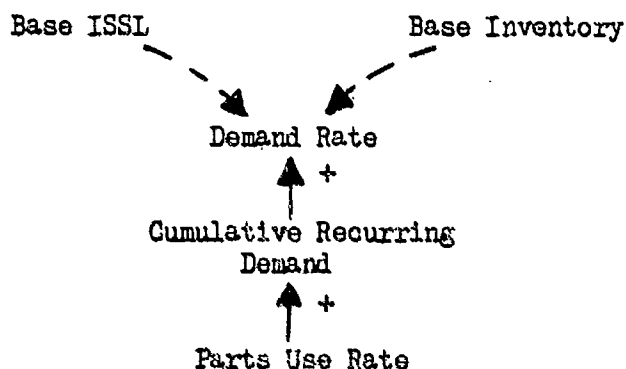


Figure 3-16. Demand Rate Causal-Loop

If the Demand Rate changes by a significant amount the Base ISSL and the established Base Inventory level must be considered in determining if a change in quantity is warranted. However, "... demand levels will be changed only when the amount of change equals or exceeds the square root of the existing level [17:11-4]."

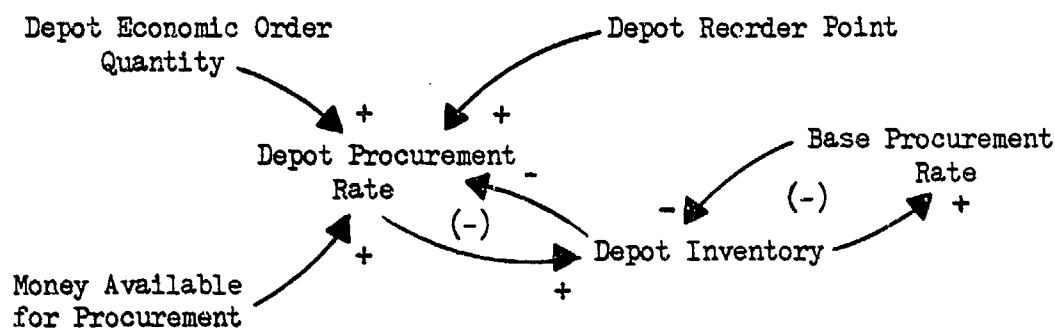


Figure 3-17. Depot Inventory Sector Causal-Loop

Depot Inventory Sector

The Depot Inventory causal-loop diagram (Figure 3-17) is interdependent with the Base Inventory Sector through the Base Procurement Rate as discussed in the Base Inventory Sector description. As was the case with the Base Inventory, the Depot Inventory has a negative effect on the Depot Procurement Rate which in turn has a positive impact on Depot Inventory. As in the similar case, this means that as the Depot Inventory goes up the Depot Procurement Rate goes down; conversely, as the Depot Procurement Rate increases the Depot Inventory also increases.

Figure 3-17 also shows that the Depot Procurement Rate is positively correlated to the Depot Economic Order Quantity, Depot Reorder Point, and Money Available for Procurement. However, since the depot inventory system is exogenous to the initial spares support list (ISSL) development process it was not thoroughly researched; research was conducted only to the extent to determine the effects

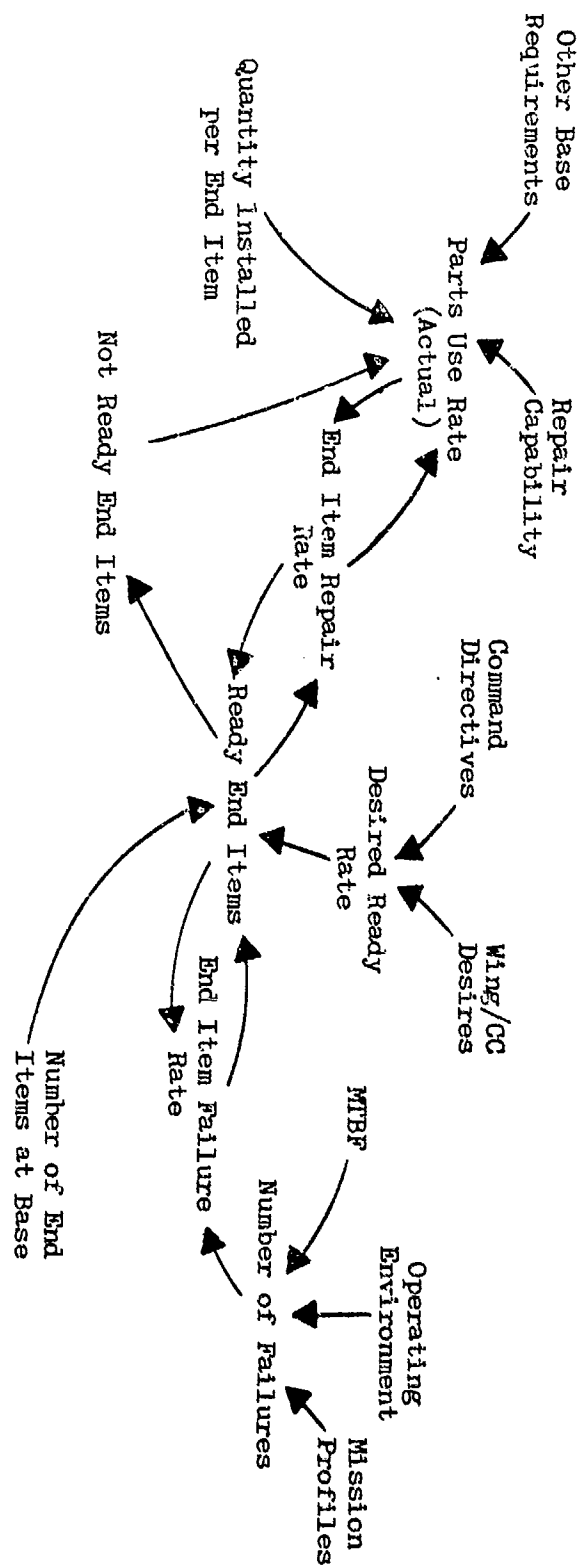


Figure 3-18. Consumption Sector Causal-Loop

of the Depot Inventory System on the Base inventory system. Thus, only the essential variables have been included.

Consumption Sector

The causal-loop diagram of the Consumption Sector is presented as Figure 3-18. One of the key elements of this sector is the Parts Use Rate. The Parts Use Rate variable represents the withdrawal of spare/replacement items from the Base inventory. The rate which the parts are removed is affected by the number of Not Ready End Items, the Quantity of item Installed per End Item, the Repair Capability, and Other Base Requirements for the items, if any exist. Figure 3-19 shows the relationship that exists between these variables and the Parts Use Rate.

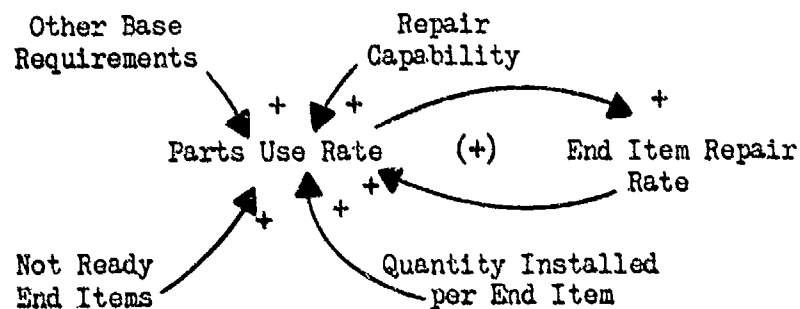


Figure 3-19. Parts Use Rate Causal-Loop

As indicated by the assigned polarity symbols, each of the variables have a positive impact on the Parts Use Rate such that as either of the variables increase there will also be a corresponding increase in the Parts Use Rate. Note also that the End Item Repair

Rate has a positive impact on the Parts Use Rate which in turn has a positive impact on the End Item Repair Rate. This means that as either the End Item Repair Rate or the Parts Use Rate increases there will be an increase in the other variable.

The End Item Repair Rate is also a factor that affects the number of Ready End Items on the Base to carry out the assigned mission (Figure 3-20). As the End Item Repair Rate goes up the number of Ready End Items will also increase. Conversely, it is intuitive that as the Ready End Items increase the End Item Repair Rate will go down because there are fewer Not Ready End Items.

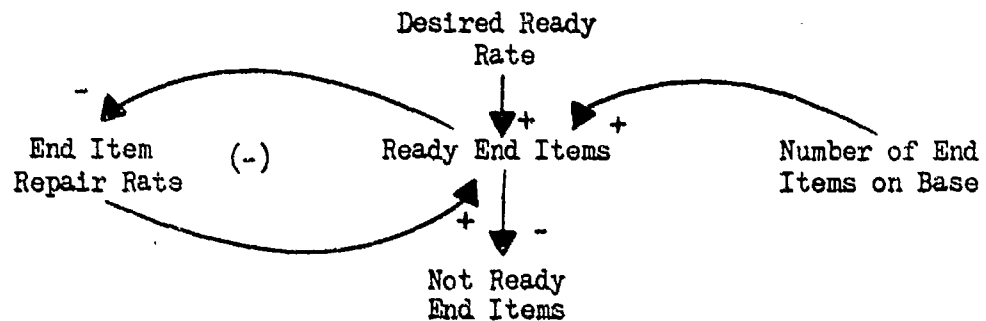


Figure 3-20. Ready End Items Causal-Loop

The concept of fewer Not Ready End Items is also illustrated in Figure 3-20 by the negative polarity given to the relationship that exists between the Ready End Items and Not Ready End Items.

Figure 3-20 also shows that the number of Ready End Items is also affected by the Desired Ready Rate and the Number of End Items

on Base. Both of these variables have a positive affect on the number of Ready End Items. The Desired Ready Rate is affected by two variables (Figure 3-21).

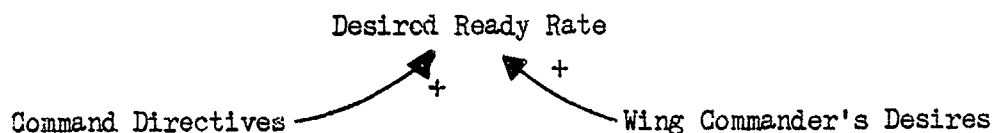


Figure 3-21. Desired Ready Rate Causal-Loop

Command Directives and the Wing Commanders Desires have a positive impact on the Desired Ready Rate. As either one goes up the Desired Ready Rate will also increase. Command Directives represent the percentage of assigned end items which must be ready to meet the assigned Base mission, the Command Directives are often-times augmented by the Wing Commander Desires to meet unforeseen emergencies or contingency operations.

Ready End Items is affected by and has an impact on the End Item Failure Rate (Figure 3-22). The number of Ready End Items has a positive relationship with End Item Failure Rate in that as the number of Ready End items increases more failures are expected. On the other side of the coin, as the End Item Failure Rate goes up the number of Ready End Items will decrease. The relationship that exists between the Number of Failures and End Item Failure Rate is also shown in Figure 3-22. As the Number of Failures increase there is also an increase in the End Item Failure Rate.

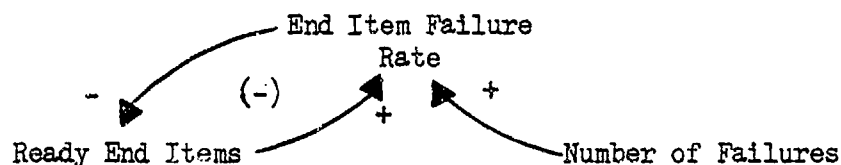


Figure 3-22. End Item Failure Rate Causal-Loop

The final variable conceptualized as being in the Consumption Sector is the Number of Failures. The three variables that interact and affect the Number of Failures are shown in Figure 3-23. All three of the variables, Mean Time Between Failure, Operating Environment, and Mission Profiles, have negative affects on the Number of Failures. This means that as the Mean Time Between Failure increases, or the Operating Environment goes up in terms of being better for end item operation, or the Mission Profile, which is how the item is used, goes up or improves the Number of Failures will decrease. Number of Failures pertains to not only end item failure but to component failure which takes the end item out of mission ready status.

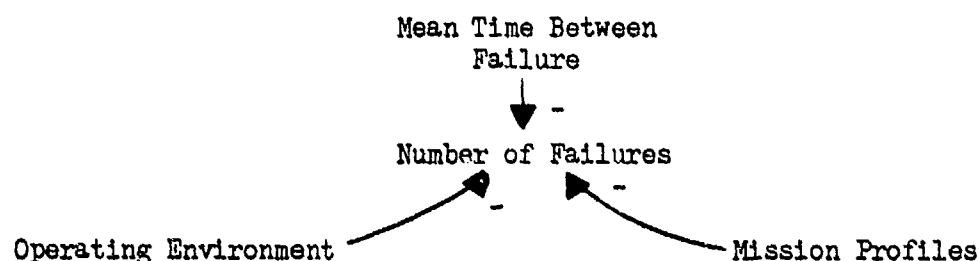


Figure 3-23. Number of Failures Causal-Loop

The four sector causal-loop diagrams can be combined to form a single causal-loop diagram of the initial spares support list (ISSL)

development process, and the interaction of the component variables would not change. While the causal-loop diagrams are useful during the conceptualization of a system because ". . . they help identify and organize principal components and feedback loops of the system under study [4:11]." However, flow diagrams are essential in ". . . model construction and equation writing [4:11]," because the causal-loop diagrams ". . . lack the precision and detail of the rate, level, and auxiliary elements found in flow diagrams [4:11]."

The causal-loop diagrams discussed in this chapter formed the basis upon which the flow diagrams of the ISSL development process were devised. The flow diagrams and the mathematical equations of the dynamic ISSL development process model are the subjects of the next chapter.

Chapter IV

FLOW DIAGRAMS AND DYNAMO EQUATIONS

Introduction

In this chapter the causal loop diagrams that were presented in Chapter III are transformed into System Dynamics flow diagrams and DYNAMO equations. Each of the four sectors is treated as an individual unit and the connections between the sectors are identified where they occur. In order to simplify explanation of the flow diagrams, they have been divided into small sections. These sections are then presented along with the corresponding DYNAMO equations. The discussion of each sector begins with a central level or auxiliary variable. The sector is then decomposed variable-by-variable until further decomposition is no longer possible; i.e., the discussion reaches a constant or a variable that has either been previously discussed or that will be discussed in another section.

To avoid continuous repetition, three concepts that appear in many of the model's equation are explained here. The first is the concept of an adjustment rate. Chapter II briefly addressed this concept in the discussion of the rate (decision) symbol and the rate equation. An adjustment rate controls the quantity of material or information in its associated level. It may be thought of as a valve that opens or closes to determine how much material or information

moves into or out of the level and at what speed (rate).

The adjustment rates are generally influenced by many factors. These adjustment rate factors have been designed to determine the magnitude of the adjustment rate and to establish the timing of the rate; i.e., at what points in time the "valve" opens or closes. These factors have been called various names throughout the system in order to identify their function. Some examples are the Base Fraction Ordered factors 1 through 5, the Worldwide ISSL Adjustment Rate Factor, and the Adjustment Timing Factor. These factors are, in turn, a function of various variables that are identified in the appropriate discussion.

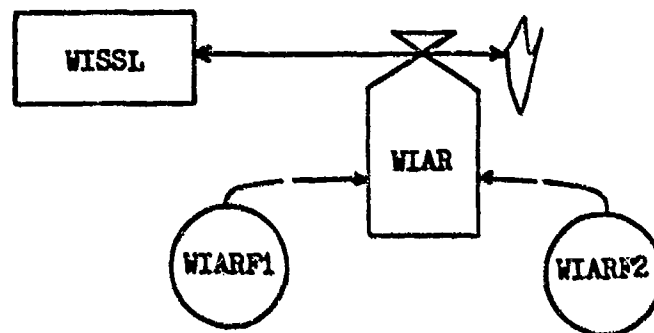
The third concept is that of Delta Time (DT). This variable appears in many equations. Its purpose is to make the model insensitive to the computation interval of the simulation. If the analyst wants a "high resolution" simulation that will indicate the minute variations in the system, he may set the computation interval equal to a day or a fraction of a day; if, on the other hand, he is interested only in the general behavior of the system, he may set the computation interval equal to a week (7 days), a month (30 days), or even a year (365 days). The variable DT automatically adjusts the various rate and auxiliary equations to the computation interval so that the model correctly simulates the operation of the system.

For reference, complete sector flow diagrams and the entire computer program listing are presented in the appendices. The first sector to be discussed is the ISSL Development Sector.

ISSL Development Sector

This sector describes the process that is involved in the initial development of the ISSL. The process has been divided into two parts: the development of the Worldwide ISSL and the development of the Base level ISSL.

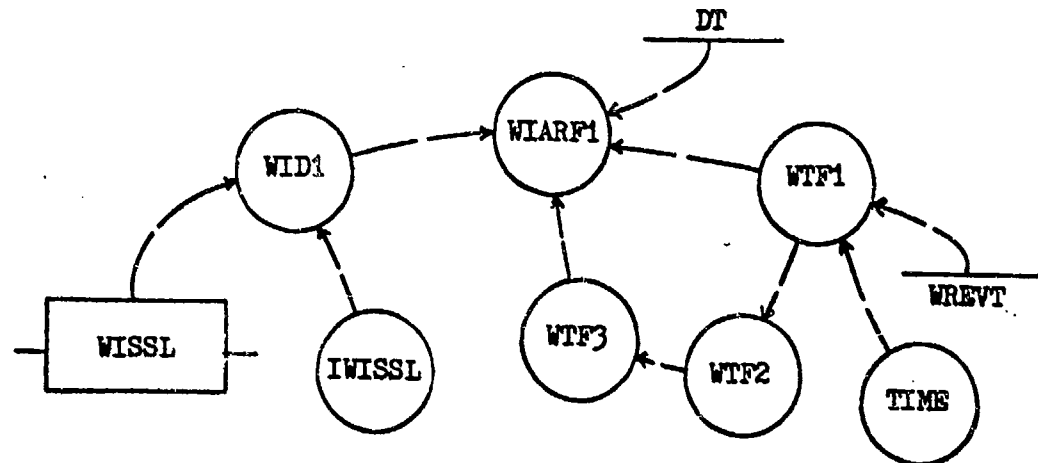
The Worldwide ISSL level is the quantity of a given item that is required per month to support the entire weapon system under study until normal demand rates can be established. Figure 4-1 illustrates that it is a function of the Worldwide ISSL Adjustment Rate. The Worldwide ISSL Adjustment Rate is the sum of two factors: the Worldwide ISSL Adjustment Rate Factor 1 and the Worldwide ISSL Adjustment Rate Factor 2.



175L $WISSL.K = WISSL.J + (DT)(WIAR.JK)$
244NOTE WISSL -WORLDWIDE ISSL
225NOTE DT -DELTA TIME
254NOTE WIAR -WORLDWIDE ISSL ADJUSTMENT RATE
275R $WIAR.KL = WIARF1.K + WIARF2.K$
300NOTE WIAR -WORLDWIDE ISSL ADJUSTMENT RATE
325NOTE WIARF1 -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 1
350NOTE WIARF2 -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 2

Figure 4-1. ISSL Development Sector Diagram 1

Figure 4-2 illustrates that the Worldwide ISSL Adjustment Rate Factor 1 is a function of the Worldwide ISSL Discrepancy 1, the timing factors 1 and 3, and Delta Time. This set of factors forces the computer program to compare the Worldwide ISSL level to the



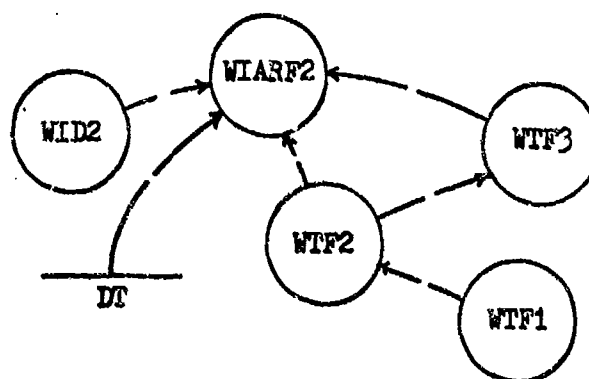
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375A WIARF1.K=(WID1.K)*(WTF1.K)*(WTF3.K)*(1/DT)
400NOTE    WIARF1  -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 1
425NOTE    WID1    -WORLDWIDE ISSL DISCREPANCY 1
450NOTE    WTF1    -WORLDWIDE ISSL TIMING FACTOR 1
475NOTE    WTF3    -WORLDWIDE ISSL TIMING FACTOR 3
500NOTE    DT      -DELTA TIME
525A WID1.K=IWISSL.K-WISSL.K
550NOTE    WID1    -WORLDWIDE ISSL DISCREPANCY 1
575NOTE    IWISSL  -INITIAL WORLDWIDE ISSL
600NOTE    WISSL   -WORLDWIDE ISSL
625A WTF1.K=CLIP(0,1,TIME.K,WREVT)
650NOTE    WTF1    -WORLDWIDE ISSL TIMING FACTOR 1
675NOTE    TIME    -TIME
700NOTE    WREVT   -WORLDWIDE ISSL REVIEW TIME
725A WTF2.K=CLIP(0,1,WTF1.K,0.5)
750NOTE    WTF2    -WORLDWIDE ISSL TIMING FACTOR 2
775NOTE    WTF1    -WORLDWIDE ISSL TIMING FACTOR 1
800A WTF3.K=CLIP(0,1,WTF2.K,0.5)
825NOTE    WTF3    -WORLDWIDE ISSL TIMING FACTOR 3
850NOTE    WTF2    -WORLDWIDE ISSL TIMING FACTOR 2
  
```

Figure 4-2. ISSL Development Sector Diagram 2

Initial Worldwide ISSL until the point in time established by the Worldwide ISSL Review Time. In other words, they force the Worldwide ISSL level to equal the Initial Worldwide ISSL until the Worldwide ISSL Review Time is reached. Figure 4-2 also illustrates that the Worldwide ISSL Discrepancy 1 is simply the difference between the current Worldwide ISSL level and the Initial Worldwide ISSL.

The second factor that controls the Worldwide ISSL Adjustment Rate is the Worldwide ISSL Adjustment Rate Factor 2. Figure 4-3 illustrates that it is also a function of four factors: the Worldwide ISSL Discrepancy 2, Timing Factors 2 and 3, and Delta Time.



$$875A \text{ WIARF2.K} = (\text{WID2.K}) (\text{WTF2.K}) (\text{WTF3.K}) (1/\text{DT})$$

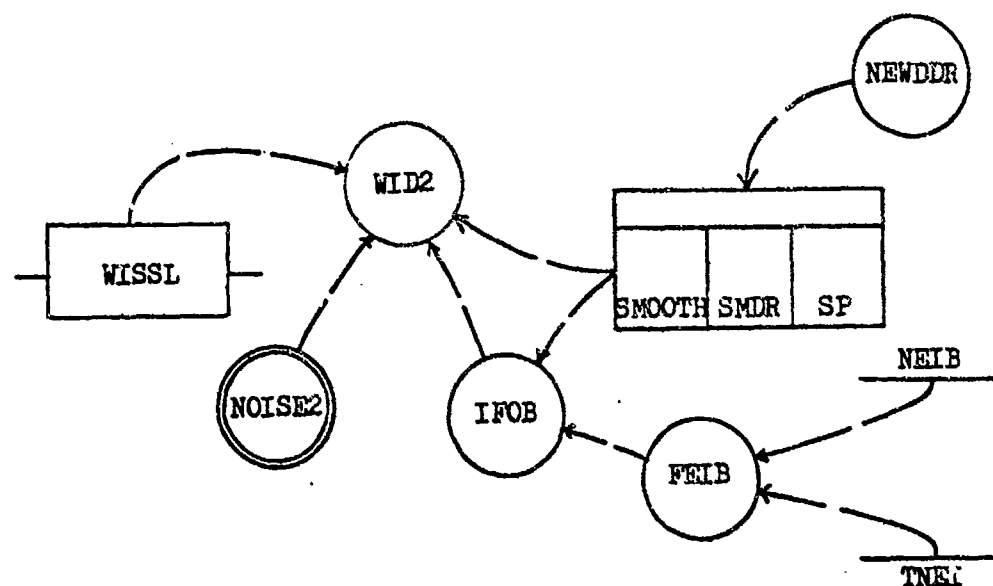
988NOTE	WIARF2	-WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 2
923NOTE	WID2	-WORLDWIDE ISSL DISCREPANCY 2
939NOTE	WTF2	-WORLDWIDE ISSL TIMING FACTOR 2
975NOTE	WTF3	-WORLDWIDE ISSL TIMING FACTOR 3
1884NOTE	DT	-DELTA TIME

Figure 4-3. ISSL Development Sector Diagram 3

These factors force the program to compare the Worldwide ISSL level to the Worldwide ISSL Discrepancy 2 at the point in time that is determined by the Worldwide ISSL Review Time. At that time the Worldwide ISSL level is revised if necessary. Since command directives require that ISSL reviews be kept to a minimum, the model was designed to review the Worldwide ISSL only once during each simulation.

The Worldwide ISSL Discrepancy 2 is the difference between the Worldwide ISSL level and the smoothed worldwide total monthly demand rate for the item under study. It is a function of four factors as illustrated in Figure 4-4. The Smoothed Monthly Demand Rate is a function of the actual demand rate for an item that has been established through experience at a single base for the weapon system under study for a period of time that is determined by the Smoothing Period. The Input From Other Bases is estimated from the Smoothed Monthly Demand Rate and the Fraction of End Items at the one Base. The weapon system's total monthly demand rate is calculated and then multiplied by a noise factor to simulate reporting errors (see Chapter I). This figure is then compared to the current Worldwide ISSL level to determine the Worldwide ISSL Discrepancy 2.

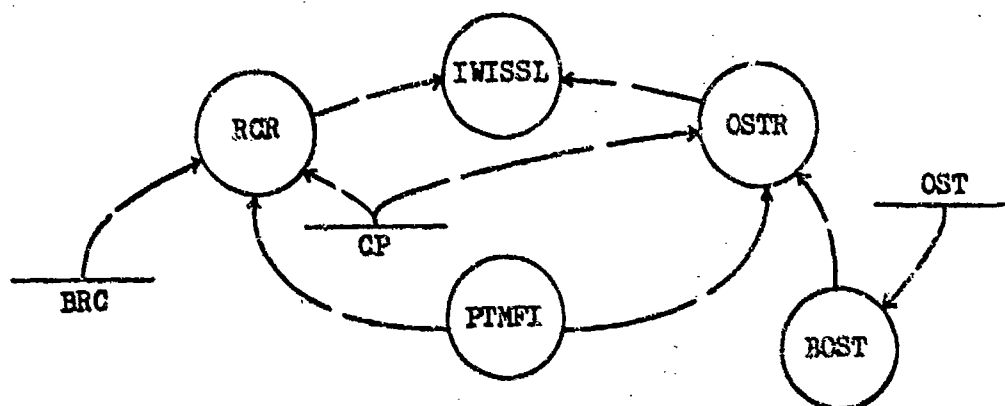
The Initial Worldwide ISSL is the second factor that is used to calculate the Worldwide ISSL Discrepancy (see Figure 4-2). It is the original AFLC estimate of the quantity of an item that will be required to support the weapon system during its activation period.



1025A $WID2.K = (IFOB.K + SMDR.K - WISL.K) (NOISE2.K)$
 1050NOTE WID2 -WORLDWIDE ISSL DISCREPANCY 2
 1075NOTE IFOB -INPUT FROM OTHER BASES
 1100NOTE SMDR -SMOOTHED MONTHLY DEMAND RATE
 1125NOTE WISL -WORLDWIDE ISSL
 1150NOTE NOISE2 -NOISE 2
 1175A $SMDR.K = (30) (SMOOTH(NEWDDR.K, SP))$
 1200NOTE SMDR -SMOOTHED MONTHLY DEMAND RATE
 1225NOTE NEWDDR -NEW DAILY DEMAND RATE
 1250NOTE SP -SMOOTHING PERIOD
 1275A $IFOB.K = (SMDR.K / FEIB.K) - SMDR.K$
 1300NOTE IFOB -INPUT FROM OTHER BASES
 1325NOTE SMDR -SMOOTHED MONTHLY DEMAND RATE
 1350NOTE FEIB -FRACTION OF END ITEMS ON BASE
 1375A $FEIB.K = NEIB / TNEI$
 1400NOTE FEIB -FRACTION OF END ITEMS ON BASE
 1425NOTE NEIB -NUMBER OF END ITEMS ON BASE
 1450NOTE TNEI -TOTAL NUMBER OF END ITEMS
 1475A $NOISE2.K = NORMRN(1, 0, 0.2)$
 1500NOTE NOISE2 -NOISE 2

Figure 4-4. ISSL Development Sector Diagram 4

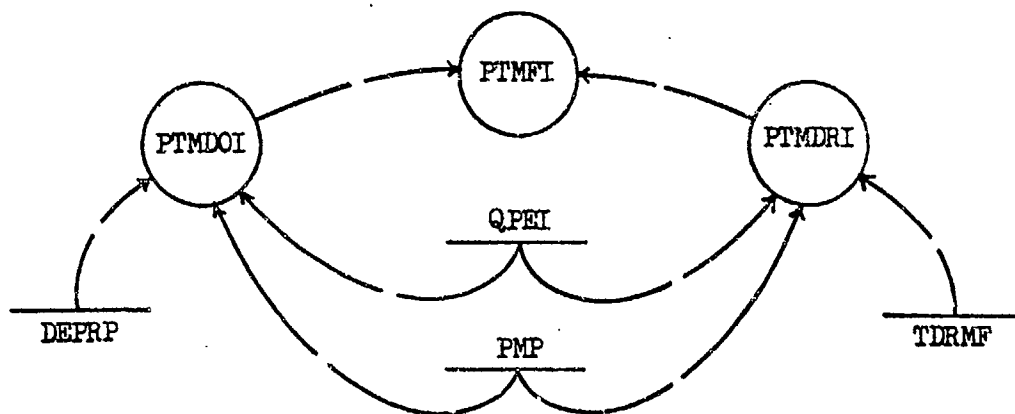
It is calculated on the AFLC Form 997, EOQ Initial Provisioning Worksheet, using the equations in Chapter 2 of AFLCR 57-27, Initial Requirements Determination. The data used in the calculations are obtained from the provisioning documents and was discussed in Chapter III. Figure 4-5 illustrates that the Initial Worldwide ISSL is the sum of the Order and Ship Time Requirement and the Repair Cycle



1525A $IWISSL.K = OSTR.K + RCR.K$
 1550NOTE IWISSL -INITIAL WORLDWIDE ISSL
 1575NOTE OSTR -ORDER AND SHIP TIME REQUIREMENT
 1600NOTE RCR -REPAIR CYCLE REQUIREMENT
 1625A $OSTR.K = (BOST.K) (PTMFI.K) (CP.K)$
 1650NOTE OSTR -ORDER AND SHIP TIME REQUIREMENT
 1675NOTE BOST -BASE ORDER AND SHIP TIME
 1700NOTE PTMFI -PEAK TOTAL MONTH FIELD ISSUES
 1725NOTE CP -CONDEMNATION PERCENT
 1750A $BOST.K = OST/30$ MONTHS
 1775NOTE BOST -BASE ORDER AND SHIP TIME
 1800NOTE OST -ORDER AND SHIP TIME
 1825A $RCR.K = (BRC.K) (PTMFI.K) (1.00 - CP.K)$
 1850NOTE RCR -REPAIR CYCLE REQUIREMENT
 1875NOTE BRC -BASE REPAIR CYCLE
 1900NOTE PTMFI -PEAK TOTAL MONTH FIELD ISSUES
 1925NOTE CP -CONDEMNATION PERCENT

Figure 4-5. ISSL Development Sector Diagram 5

Requirement. The Order and Ship Time Requirement is the product of three factors: the Base Order and Ship Time, the Peak Total Month Field Issues, and the Condemnation Percent. The Base Order and Ship Time equals the Order and Ship Time divided by thirty.



1950A $PTMFI.K = PTMDRI.K - PTMDOI.K$
 1975NOTE PTMFI -PEAK TOTAL MONTH FIELD ISSUES
 2000NOTE PTMDRI -PEAK TOTAL MONTH DEMAND RATE ISSUES
 2025NOTE PTMDOI -PEAK TOTAL MONTH DEPOT OVERHAUL ISSUES
 2050A $PTMDOI.K = (DEPRP.K) (QPEI) (PMP.K)$
 2075NOTE PTMDOI -PEAK TOTAL MONTH DEPOT OVERHAUL ISSUES
 2100NOTE DEPRP -DEPOT REPLACEMENT PERCENT
 2125NOTE QPEI -QUANTITY OF PARTS PER END ITEM
 2150NOTE PMP -PEAK MONTH PROGRAM
 2175A $PTMDRI.K = (TDRMF.K) (QPEI) (PMP.K)$
 2200NOTE PTMDRI -PEAK TOTAL MONTH DEMAND RATE ISSUES
 2225NOTE TDRMF -TOTAL DEMAND RATE MAINTENANCE FACTOR
 2250NOTE QPEI -QUANTITY OF PARTS PER END ITEM
 2275NOTE PMP -PEAK MONTH PROGRAM

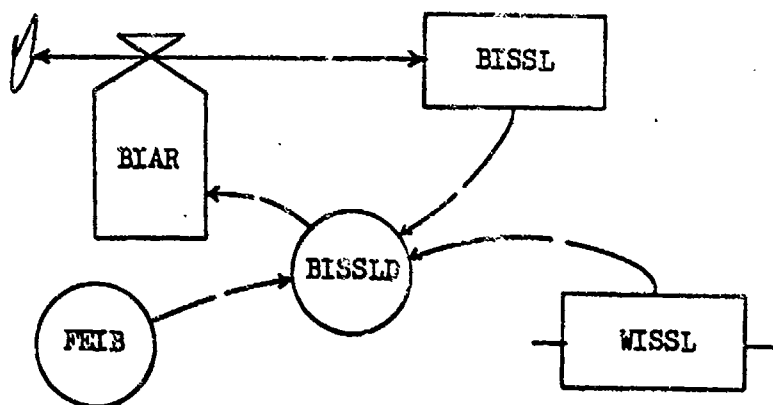
Figure 4-6. ISSL Development Sector Diagram 6

The Repair Cycle Requirement is also the product of three factors; the Base Repair Cycle, the Peak Total Month Field Issues, and one minus the Condemnation Percent.

Figure 4-6 shows that the Peak Total Month Field Issues is a function of two factors: the Peak Total Month Depot Overhaul

Issues and the Peak Total Month Demand Rate Issues. The Peak Total Month Depot Overhaul Issues is the product of the Depot Replacement Percent, the Total Quantity Installed per End Item, and the Peak Month Program. The Peak Month Demand Rate Issues is the product of the Total Demand Rate Maintenance Factor, the Total Quantity Installed per End Item, and the Peak Month Program.

The Base level ISSL is the second part of the ISSL development sector. It is the quantity of an item that is required at base level to support a weapon system until normal demand rates are established.



2300L $BISSL.K = BISSL.J + (DT)(BIAR.JK)$
 2325NOTE BISSL -BASE ISSL
 2350NOTE DT -DELTA TIME
 2375NOTE BIAR -BASE ISSL ADJUSTMENT RATE
 2400R $BIAR.KL = BISSLD.K$
 2425NOTE BIAR -BASE ISSL ADJUSTMENT RATE
 2450NOTE BISSLD -BASE ISSL DISCREPANCY
 2475A $BISSLD.K = (WISSL.K)(FEIB.K) - BISSL.K$
 2500NOTE BISSLD -BASE ISSL DISCREPANCY
 2525NOTE WISSL -WORLDWIDE ISSL
 2550NOTE FEIB -FRACTION OF END ITEMS ON BASE
 2575NOTE BISSL -BASE ISSL

Figure 4-7. ISSL Development Sector Diagram 7

It is a function of the Base ISSL Adjustment Rate as shown in Figure 4-7.

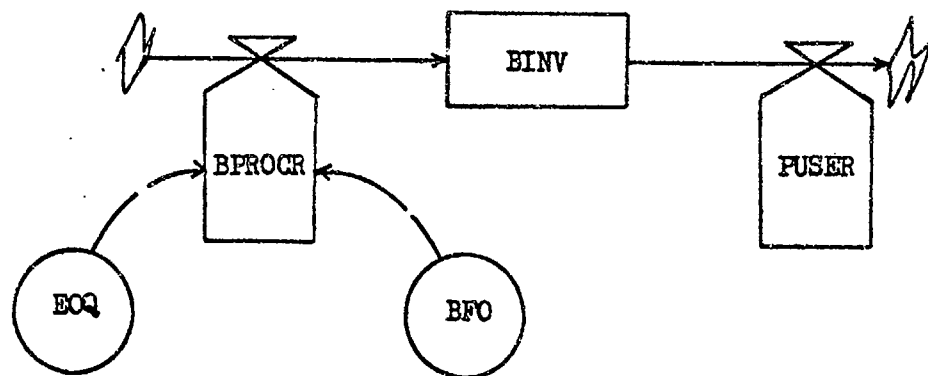
The Base ISSL Adjustment Rate is a function of the Base ISSL Discrepancy; i.e., the difference between the current Base ISSL level and the updated Base ISSL. The three factors that determine the value of the Base ISSL Discrepancy (the Worldwide ISSL level, the Base ISSL level, and the Fraction of End Items on Base) have all previously been discussed in this section.

This concludes the discussion of the ISSL development sector. The Base Inventory sector is discussed next.

Base Inventory Sector

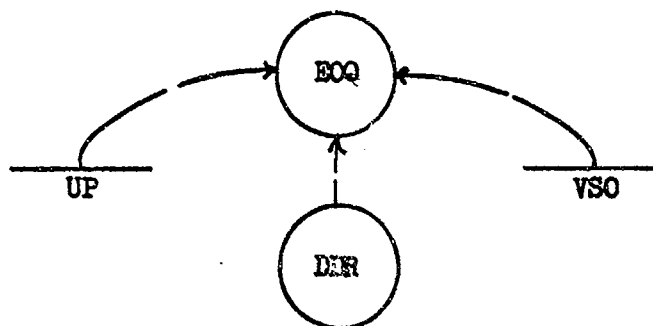
For purposes of discussion, the Base Inventory Sector has been divided into two subsectors: the Inventory Subsector which describes the actual movement of items through the base, and the Daily Demand Rate Adjustment Subsector which is concerned with the flow of information about the movement of those items and how that information is used. The Inventory Subsector will be discussed first.

Inventory Subsector. The central variable in this sector is the level of the Base Inventory. This level is the quantity of the item under study that is actually in stock in base supply. Figure 4-8 illustrates that this level is determined by the Parts Use Rate and the Base Procurement Rate. Parts Use Rate is a part of the Consumption Sector and will be discussed later in this chapter. The Base Procurement Rate is a function of the Base Economic Order Quantity and the Base Fraction Ordered.



3925L $BINV.K = BINV.J + (DT) (BPROCR.JK - PUSER.JK)$
 3950NOTE BINV -BASE INVENTORY
 3975NOTE BPROCR -BASE PROCUREMENT RATE
 4000NOTE PUSER -PARTS USE RATE
 4025R $BPROCR.KL = (EQQ.K) (BFO.K)$
 4050NOTE BPROCR -BASE PROCUREMENT RATE
 4075NOTE EQQ -BASE ECONOMIC ORDER QUANTITY
 4100NOTE BFO -BASE FRACTION ORDERED

Figure 4-8. Base Inventory Sector Diagram 1



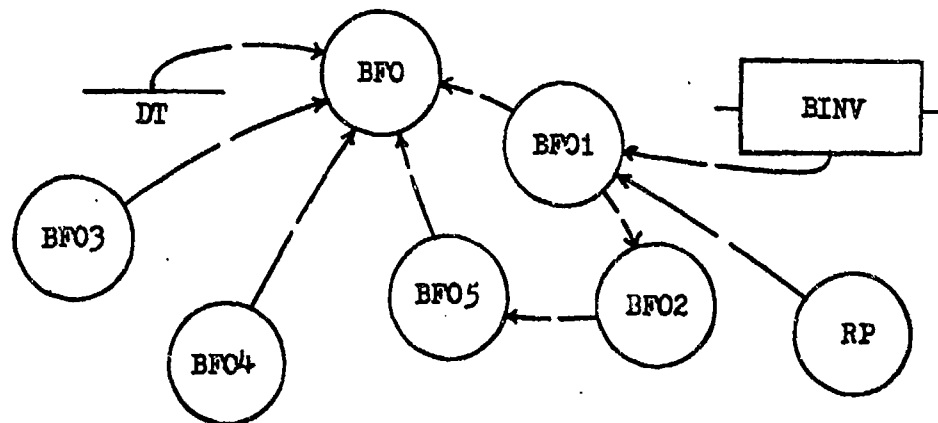
4125A $EOQ.K = ((4.4) (\text{SQRT}((DDR.K) (VSO) (UP)))) / (UP)$
 4150NOTE EOQ -BASE ECONOMIC ORDER QUANTITY
 4175NOTE DDR -DAILY DEMAND RATE
 4200NOTE VSO -VARIABLE STOCKAGE OBJECTIVE
 4225NOTE UP -UNIT PRICE

Figure 4-9. Base Inventory Sector Diagram 2

As illustrated in Figure 4-9, the Base Economic Order Quantity is a function of three factors; the Unit Price of the item being procured, the Variable Stockage Objective, and the Daily Demand Rate. These three factors are combined in the following manner to yield the Economic Order Quantity: $EOQ = \frac{4.4 \sqrt{(DDR)(VSO)(UP)}}{UP}$.

Both the Variable Stockage Objective and the Unit Price are constants that are peculiar to the particular item under study. The Daily Demand Rate will be discussed later.

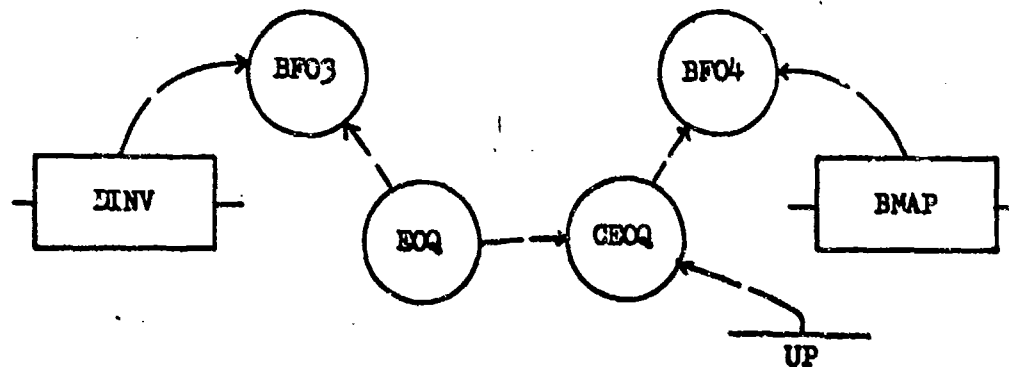
The Base Fraction Ordered is a combination of five factors: Delta Time and the Base Fraction Ordered factors 1,3,4, and 5. This is illustrated in Figure 4-10. Base Fraction Ordered factors 1 and 5 are timing factors that "order" parts from the Depot whenever the Base Inventory is depleted to the extent that it reaches the Base Reorder Point.



4250A BFO.K=(BFO1.K)(BFO5.K)(MIN(BFO3.K,BFO4.K))(1/DT)
 4275NOTE BFO -BASE FRACTION ORDERED
 4300NOTE BFO1 -BASE FRACTION ORDERED 1
 4325NOTE BFO5 -BASE FRACTION ORDERED 5
 4350NOTE BFO3 -BASE FRACTION ORDERED 3
 4375NOTE BFO4 -BASE FRACTION ORDERED 4
 4400NOTE DT -DELTA TIME
 4425A BFO1.K=CLIP(0,1,BINV.K,RP.K)
 4450NOTE BFO1 -BASE FRACTION ORDERED 1
 4475NOTE BINV -BASE INVENTORY
 4500NOTE RP -BASE REORDER POINT
 4525L BFO2.K=CLIP(0,1,BFO1.J,0.5)
 4550NOTE BFO2 -BASE FRACTION ORDERED 2
 4575NOTE BFO1 -BASE FRACTION ORDERED 1

Figure 4-10. Base Inventory Sector Diagram 3

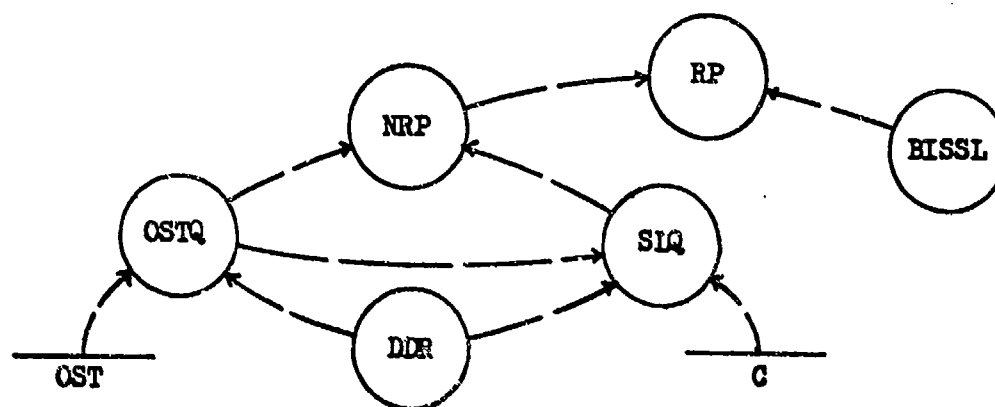
Figure 4-11 illustrates that factor 3 limits the quantity of parts that are "shipped" to the base to the number of parts that are available from the Depot. This factor prevents the Depot Inventory from going negative if a situation should develop in which an order from the Base exceeds the current Depot Inventory. Factor 4 is a function of the Cost of the Economic Order Quantity and the amount of money that the base has available for the procurement of parts. This factor prevents the base from ordering more parts than it can pay for. The Cost of the Base Economic Order Quantity is equal to the Base Economic Order Quantity times the Unit Price of the item being procured.



4675A $BFO3.K = CLIP(1, (DINV.K/EOQ.K), (DINV.K - EOQ.K), 0)$
4700NOTE BFO3 -BASE FRACTION ORDERED 3
4725NOTE DINV -DEPOT INVENTORY
4750NOTE EOQ -BASE ECONOMIC ORDER QUANTITY
4775A $BFO4.K = CLIP(1, (BMAP.K/CEOQ.K), (BMAP.K - CEOQ.K), 0)$
4800NOTE BFO4 -BASE FRACTION ORDERED 4
4825NOTE BMAP -BASE MONEY AVAILABLE FOR PROCUREMENT
4850NOTE CEOQ -COST OF BASE ECONOMIC ORDER QUANTITY
4875A $CEOQ.K = (EOQ.K)(UP)$
4900NOTE CEOQ -COST OF BASE ECONOMIC ORDER QUANTITY
4925NOTE EOQ -BASE ECONOMIC ORDER QUANTITY
4950NOTE UP -UNIT PRICE

Figure 4-11. Base Inventory Sector Diagram 4

Figure 4-12 illustrates that the Base Reorder Point is equal to either the Base ISSL divided by three or the Normal Reorder point, whichever is greater (see Chapter III). The Base ISSL was discussed in the ISSL Development Sector. The Normal Reorder Point is the sum of the Order and Ship Time Quantity and the Safety Level Quantity.

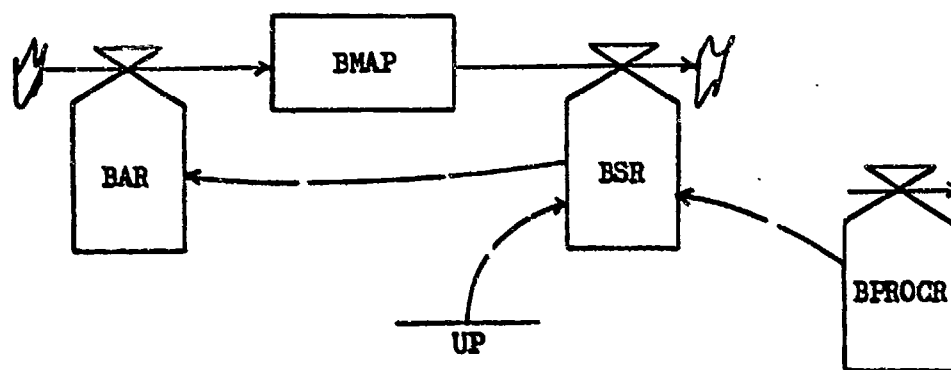


4975A $RP.K = \text{MAX}((BISSL.K/3), NRP.K)$
 5000NOTE RP -BASE REORDER POINT
 5025NOTE BISSL -BASE INITIAL SPARES SUPPORT LIST
 5050NOTE NRP -NORMAL REORDER POINT
 5075A $NRP.K = OSTQ.K + SLQ.K$
 5100NOTE NRP -NORMAL REORDER POINT
 5125NOTE OSTQ -ORDER AND SHIP TIME QUANTITY
 5150NOTE SLQ -SAFETY LEVEL QUANTITY
 5175A $OSTQ.K = (DDR.K) (OST)$
 5200NOTE OSTQ -ORDER AND SHIP TIME QUANTITY
 5225NOTE DDR -DAILY DEMAND RATE
 5250NOTE OST -ORDER AND SHIP TIME
 5275A $SLQ.K = \text{MAX}((C) (\text{SQRT}((3) (OSTQ.K))), (DDR.K) (15))$
 5300NOTE SLQ -SAFETY LEVEL QUANTITY
 5325NOTE C -CONSTANT
 5350NOTE OSTQ -ORDER AND SHIP TIME QUANTITY
 5375NOTE DDR -DAILY DEMAND RATE

Figure 4-12. Base Inventory Sector Diagram 5

The Order and Ship Time Quantity equals the Order and Ship Time multiplied by the Daily Demand Rate. The Safety Level Quantity is equal to either C times the square root of three times the Order and Ship Time Quantity ($C \sqrt{3}(\text{OSTQ})$), or fifteen times the Daily Demand Rate, whichever is greater. C is a constant determined by Headquarters United States Air Force that is normally equal to 1. The Daily Demand Rate is discussed in the Daily Demand Rate Adjustment Subsector.

Figure 4-13 illustrates how the money that is available for the procurement of ISSL items flows through the base. As was



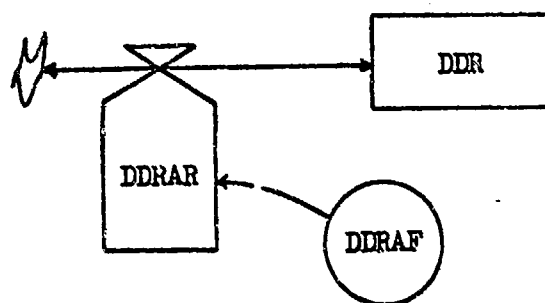
5444L BMAP.K=BMAP.J+(DT)(BAR.JK-BSR.JK)
 5425NOTE BMAP -BASE MONEY AVAILABLE FOR PROCUREMENT
 5450NOTE DT -DELTA TIME
 5475NOTE BAR -BASE APPROPRIATION RATE
 5500NOTE BSR -BASE SPENDING RATE
 5525R BAR.KL=BSR.JK
 5550NOTE BAR -BASE APPROPRIATION RATE
 5575NOTE BSR -BASE SPENDING RATE
 5600R BSR.KL=(BPROCR.JK)(UP)
 5625NOTE BSR -BASE SPENDING RATE
 5650NOTE BPROCR -BASE PROCUREMENT RATE
 5675NOTE UP -UNIT PRICE

Figure 4-13. Base Inventory Sector Diagram 6

discussed in Chapter III, this money is generally made available to the base supply system and seldom presents anything more than a temporary problem. For this reason, the model was constructed to ensure that the base always has adequate funds to purchase ISSL items. The amount of Money Available for Procurement is a function of the Base Appropriation Rate and the Base Spending Rate. The Base Appropriation Rate was made equal to the Base Spending Rate. The Base Spending Rate equals the Base Procurement Rate times the Unit Price of the item being procured. The Base Procurement Rate was discussed earlier in this section and the Unit Price is a constant that is peculiar to the item being procured.

This concludes the discussion of the Base Inventory Subsector. The Daily Demand Rate Adjustment Subsector will be discussed next.

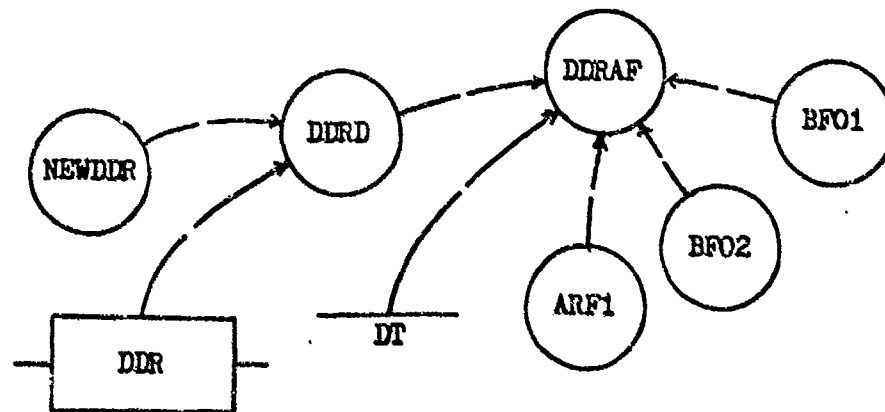
Daily Demand Rate Adjustment Subsector. The variable "Daily Demand Rate" is the periodically updated average daily demand for the item under study. It is the central variable of this subsector. Figure 4-14 illustrates that it is controlled by the Daily Demand Rate Adjustment Rate. The Daily Demand Rate Adjustment Rate is, in turn, controlled by the Daily Demand Rate Adjustment Factor.



635#L $DDR.K = DDR.J + (DT) (DDRAR.JK)$
 6375NOTE DDR -DAILY DEMAND RATE
 6376NOTE DT -DELTA TIME
 6377NOTE DDRAR -DAILY DEMAND RATE ADJUSTMENT RATE
 6400R $DDRAR.KL = DDRAF.K$
 6425NOTE DDRAR -DAILY DEMAND RATE ADJUSTMENT RATE
 6450NOTE DDRAF -DAILY DEMAND RATE ADJUSTMENT FACTOR

Figure 4-14. Base Inventory Sector Diagram 7

Figure 4-15 identifies the five factors that determine the value of the Daily Demand Rate Adjustment Factor. They are: the Daily Demand Rate Discrepancy, Base Fraction Ordered factors 1 and 2, Adjustment Rate Factor 1, and Delta Time. The Daily Demand Rate Discrepancy is the difference between the Daily Demand Rate, which is an information level that is updated periodically, and the New Daily Demand Rate which is an auxiliary variable that is updated continually and will be explained later.



6475A DDRAF.K=(DDRD.K)(BFO1.K)(BFO2.K)(ARF1.K)(1/DT)
 6500NOTE DDRAF -DAILY DEMAND RATE ADJUSTMENT FACTOR
 6525NOTE DDRD -DAILY DEMAND RATE DISCREPANCY
 6550NOTE BFO1 -BASE FRACTION ORDERED 1
 6575NOTE BFO2 -BASE FRACTION ORDERED 2
 6600NOTE ARF1 -ADJUSTMENT RATE FACTOR 1
 6625NOTE DT -DELTA TIME
 6650A DDRD.K=NEWDDR.K-DDR.K
 6675NOTE DDRD -DAILY DEMAND RATE DISCREPANCY
 6700NOTE NEWDDR -NEW DAILY DEMAND RATE
 6725NOTE DDR -DAILY DEMAND RATE

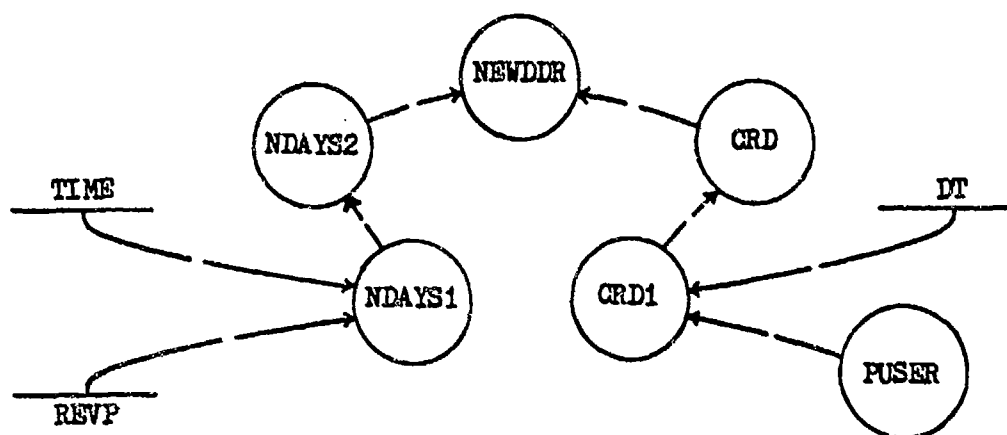
Figure 4-15. Base Inventory Sector Diagram 8

Base Fraction Ordered factors 1 and 2 and the Adjustment Rate Factor 1 are timing factors that permit the adjustment of the Daily Demand Rate only at specific times and only if certain conditions are satisfied. Base Fraction Ordered factors 1 and 2 were discussed in the Base Inventory Subsector. They are used here to limit the adjustment of the Daily Demand Rate to the points in time immediately prior to the depot filling orders for parts from the base.

Adjustment Rate Factor 1 allows adjustment of the Daily Demand Rate only if the magnitude of the adjustment meets certain criteria that are discussed later in this section. Both the timing conditions imposed by the Base Fraction Ordered factors and the magnitude of change conditions imposed by the Adjustment Rate Factor must be satisfied before the Daily Demand Rate can be adjusted.

If the base places an order for parts and the Daily Demand Rate is adjusted, the Base Economic Order Quantity and Reorder Point are immediately revised and the order is filled based on the revised Economic Order Quantity. Subsequent orders are filled based on the revised Reorder Point and Economic Order Quantity.

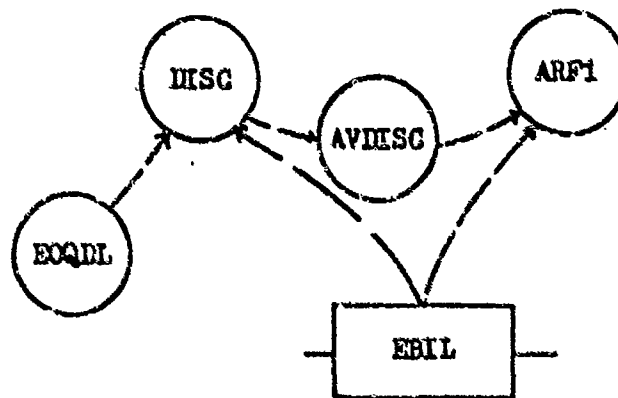
The New Daily Demand Rate in Figure 4-15 is an average Daily Demand Rate that is updated daily. It is equal to the Cumulative Recurring Demand over a given review period divided by the length of the review period (REVP). Figure 4-16 illustrates the variables that are required to make the program properly compute and update the New Daily Demand Rate.



6758A NEWDDR.K=CRD.K/NDAYS2.K
 6775NOTE NEWDDR -NEW DAILY DEMAND RATE
 6800NOTE CRD -CUMULATIVE RECURRING DEMAND
 6825NOTE NDAYS2 -NUMBER OF DAYS 2
 6850C REVPI=45 DAYS
 6875NOTE REVPI -REVIEW PERIOD (INITIAL)
 6900FOR I=1,REVPI
 6925NOTE I -REVIEW PERIOD COUNTER
 6950NOTE REVPI -REVIEW PERIOD (INITIAL)
 6975A CRD.K=SUN(CRD1.K)
 6976NOTE CRD -CUMULATIVE RECURRING DEMAND
 7000NOTE CRD1 -CUMULATIVE RECURRING DEMAND 1
 7025L CRD1.K(1)=(PUSER.JK)(DT)+CRD1.J(1)
 7050NOTE CRD1 -CUMULATIVE RECURRING DEMAND 1
 7075NOTE PUSER -PARTS USE RATE
 7100NOTE DT -DELTA TIME
 7125A NDAYS2.K=CLIP(NDAYS1.K,1,NDAYS1.K,1)
 7150NOTE NDAYS2 -NUMBER OF DAYS 2
 7175NOTE NDAYS1 -NUMBER OF DAYS 1
 7200A NDAYS1.K=CLIP(REVP.K,TIME.K,TIME.K,REVPI.K)
 7225NOTE NDAYS1 -NUMBER OF DAYS 1
 7250NOTE REVPI -REVIEW PERIOD
 7275NOTE TIME -TIME

Figure 4-16. Base Inventory Sector Diagram 9

The Adjustment Rate Factor 1 is the final variable that influences the Daily Demand Rate Adjustment Factor. It is the timing factor that determines whether or not the Daily Demand Rate (and thus the Base Economic Order Quantity and Base Reorder Point) is updated when the base places an order for parts. Figure 4-17 shows that two variables act to determine the value of the Adjustment Rate Factor 1: the Established Base Inventory Level and the absolute value of the difference between the Economic Order Quantity Demand Level and the Established Base Inventory Level. If the difference is greater than the square root of the Established Base Inventory Level, both the Daily Demand Rate and the Established Base Inventory Level are updated; if not, no change is permitted (see Chapter III).

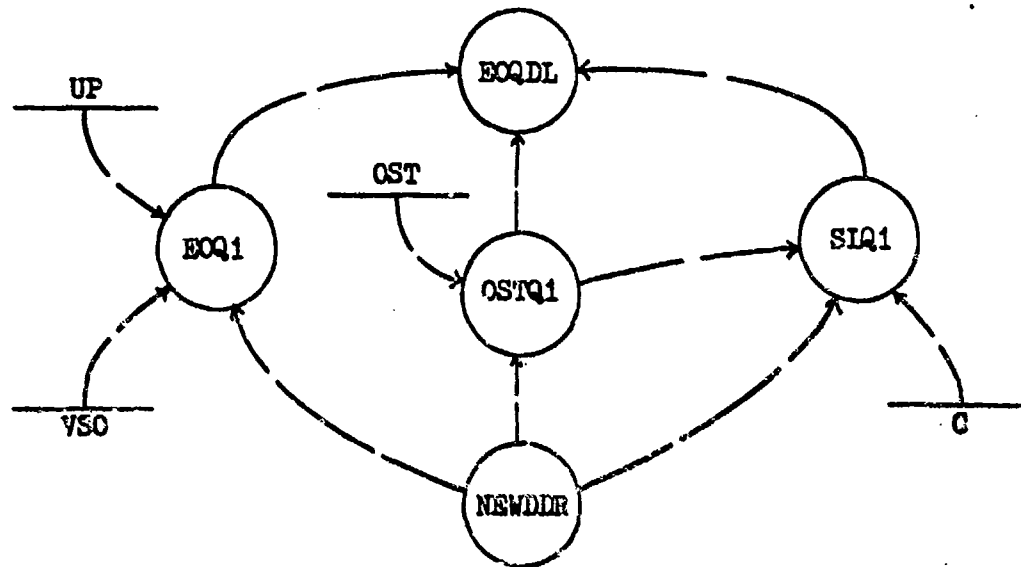


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7340A ARF1.K=(CLIP(1.0,(AVDISC.K-SQRT(EBIL.K)),0))
7325NOTE  ARF1  -ADJUSTMENT RATE FACTOR 1
7350NOTE  AVDISC -ABSOLUTE VALUE OF DISC
7375NOTE  EBIL  -ESTABLISHED BASE INVENTORY LEVEL
7400A DISC.K=EQDL.K-EBIL.K
7425NOTE  DISC  -DISCREPANCY
7450NOTE  EQDL  -BASE EOQ DEMAND LEVEL
7475NOTE  EBIL  -ESTABLISHED BASE INVENTORY LEVEL
7500A AVDISC.K=MAX(DISC.K,-DISC.K)
7525NOTE  AVDISC -ABSOLUTE VALUE OF DISC
7550NOTE  DISC  -DISCREPANCY
  
```

Figure 4-17. Base Inventory Sector Diagram 10

Figure 4-18 illustrates that the Economic Order Quantity Demand Level is equal to the sum of the Economic Order Quantity 1, the Order and Ship Time Quantity 1, and the Safety Level Quantity 1.

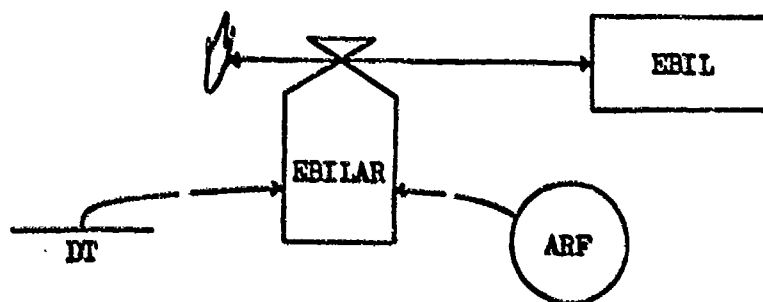


7575A $EOQDL.K = EOQ1.K + OSTQ1.K + SLQ1.K$
7600NOTE EOQDL -BASE EOQ DEMAND LEVEL
7625NOTE EOQ1 -BASE ECONOMIC ORDER QUANTITY 1
7650NOTE OSTQ1 -ORDER AND SHIP TIME QUANTITY 1
7675NOTE SLQ1 -SAFETY LEVEL QUANTITY 1
7700A $EOQ1.K = ((4.4) (\text{SQRT}((NEWDDR.K) (VSO) (UP)))) / (UP)$
7725NOTE EOQ1 -BASE ECONOMIC ORDER QUANTITY 1
7750NOTE NEWDDR -NEW DAILY DEMAND RATE
7775NOTE VSO -VARIABLE STOCKAGE OBJECTIVE
7800NOTE UP -UNIT PRICE
7825A $OSTQ1.K = (NEWDDR.K) (OST)$
7850NOTE OSTQ1 -ORDER AND SHIP TIME QUANTITY 1
7875NOTE NEWDDR -NEW DAILY DEMAND RATE
7900NOTE OST -ORDER AND SHIP TIME
7925A $SLQ1.K = \text{MAX}((C) (\text{SQRT}((3) (OSTQ1.K))), (NEWDDR.K) (15))$
7950NOTE SLQ1 -SAFETY LEVEL QUANTITY 1
7975NOTE C -CONSTANT
8000NOTE OSTQ1 -ORDER AND SHIP TIME QUANTITY 1
8025NOTE NEWDDR -NEW DAILY DEMAND RATE

Figure 4-18. Base Inventory Sector Diagram 11

These three factors are determined in the same manner as the Economic Order Quantity, the Order and Ship Time Quantity, and the Safety Level Quantity that were previously discussed in the Inventory Subsector, except that the New Daily Demand Rate, not the Daily Demand Rate, is used in the calculation.

The Established Base Inventory Level is the second factor that is used to calculate the discrepancy in Figure 4-17. It serves as a point of reference for determining when to revise the Daily Demand Rate. Figure 4-19 illustrates that it is a function of the Established Base Inventory Level Adjustment Rate. The adjustment rate is, in turn, a function of the Adjustment Rate Factor and Delta Time.



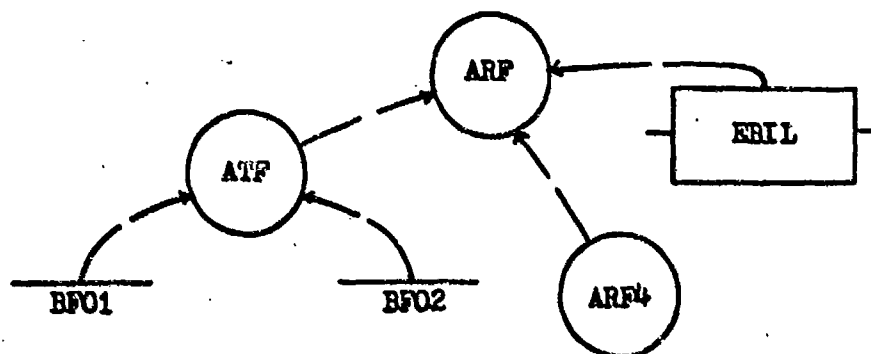
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8450L EBIL.K=EBIL.J+(DT)(EBILAR.K)
8473NOTE    EBIL    -ESTABLISHED BASE INVENTORY LEVEL
8164NOTE    DT      -DELTA TIME
8125NOTE    EBILAR  -EBIL ADJUSTMENT RATE
8156R EBILAR.KL=(1/DT)(ARF.K)
8173NOTE    EBILAR  -EBIL ADJUSTMENT RATE
8264NOTE    DT      -DELTA TIME
8225NOTE    ARF     -ADJUSTMENT RATE FACTOR

```

Figure 4-19. Base Inventory Sector Diagram 12

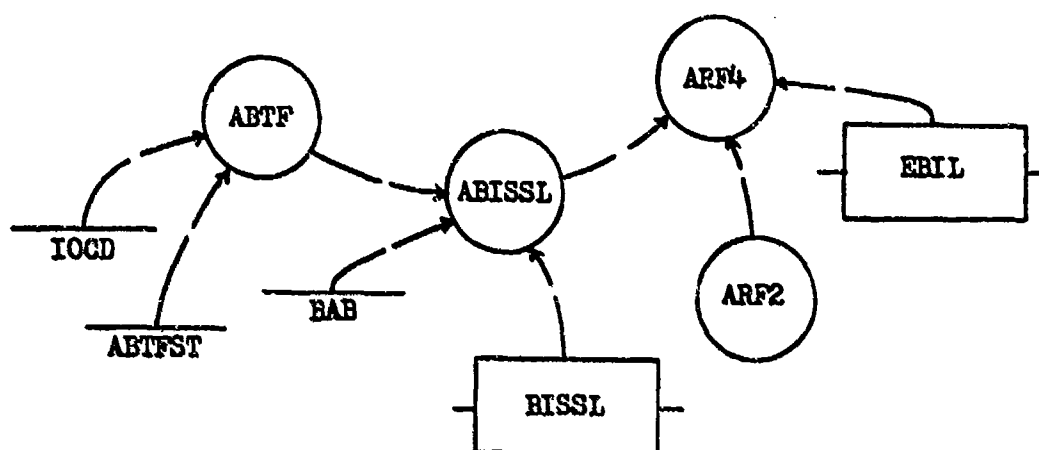
The Adjustment Rate Factor is the amount of the change to be made in the Established Base Inventory Level at any given point in time. It is composed of the three elements that are illustrated in Figure 4-20. The Adjustment Timing Factor is the product of Base Fraction Ordered factors 1 and 2 and permits the Established Base Inventory Level to be adjusted only when the base submits an order for parts from the depot. Adjustment Rate Factor 4 is the value that the Established Base Inventory Level "should be" at a given point in time.



8250A $ARF.K = (ARF4.K - EBIL.K) (ATF.K)$
 8275NOTE ARF -ADJUSTMENT RATE FACTOR
 8340NOTE ARF4 -ADJUSTMENT RATE FACTOR 4
 8325NOTE EBIL -ESTABLISHED BASE INVENTORY LEVEL
 8350NOTE ATF -ADJUSTMENT TIMING FACTOR
 8375A $ATF.K = (BFO1.K) (BFO2.K)$
 8450NOTE ATF -ADJUSTMENT TIMING FACTOR
 8425NOTE BFO1 -BASE FRACTION ORDERED 1
 8450NOTE BFO2 -BASE FRACTION ORDERED 2

Figure 4-20. Base Inventory Sector Diagram 13

Figure 4-21 illustrates that the Adjustment Rate Factor 4 is a function of three elements: the Established Base Inventory Level, the Adjusted Base ISSL, and the Adjustment Rate Factor 2. The equation selects the maximum of the adjusted currently Established Base Inventory Level or the Adjusted Base ISSL as the desired future Established Base Inventory Level.



```

8475A ARF4.K=SWITCH((ARF2.K*EBIL.K),
8500X (MAX(ARF2.K*EBIL.K,ABISSL.K)),ABISSL.K)
8525NOTE    ARF4    -ADJUSTMENT RATE FACTOR 4
8550NOTE    ARF2    -ADJUSTMENT RATE FACTOR 2
8575NOTE    EBIL    -ESTABLISHED BASE INVENTORY LEVEL
8600NOTE    ABISSL   -ADJUSTED BASE ISSL
8625A ABISSL.K=(BAB)(BISSL.K)(ABTF.K)
8650NOTE    ABISSL   -ADJUSTED BASE ISSL
8675NOTE    BAB      -BASE ADJUSTMENT TO THE BASE ISSL
8676NOTE    BISSL    -BASE ISSL
8700NOTE    ABTF     -ADJUSTED BASE ISSL TIMING FACTOR
8725A ABTF.K=STEP(1,ABTFST)+STEP(-1,IOCD+730)
8750NOTE    ABTF     -ADJUSTED BASE ISSL TIMING FACTOR
8775NOTE    ABTFST   -ABTF STEP TIME
8800NOTE    IOCD     -INITIAL OPERATION CAPABLE DATE

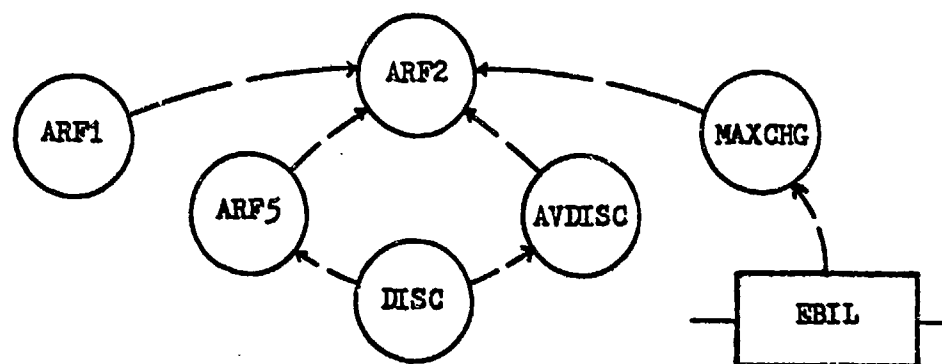
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Figure 4-21. Base Inventory Sector Diagram 14

The Adjusted Base ISSL equals the Base ISSL (as discussed in the ISSL Development Sector) multiplied by the Base Adjustment to the Base ISSL and the Adjusted Base ISSL Timing Factor. The Base Adjustment to the Base ISSL is a modification to the Base ISSL level that is jointly determined by the using organization and its parent major command. The Adjusted Base ISSL Timing Factor determines the point in time at which the ISSL requirement is levied on the base. It also removes the ISSL requirement from the base 730 days after the Initial Operation Capable Date of the weapon system at that base.

The Adjustment Rate Factor 2 in Figure 4-21 is the numerical value of the desired change in the Established Base Inventory Level. Figure 4-22 illustrates that it is composed of four factors: Adjustment Rate Factors 1 and 5, the absolute value of the difference between the Established Base Inventory Level and the Economic Order Quantity Demand Level, and the maximum permitted change. The equation compares the absolute value of the difference between the Established Base Inventory Level and the Economic Order Quantity Demand Level with the maximum allowable change in the Established Base Inventory Level, multiplies this by the Adjustment Rate Factor 5 to obtain the proper algebraic sign, and finally, multiplies the change by the Adjustment Rate Factor 1 to obtain the proper timing.

The Adjustment Rate Factor 5 establishes the proper sign of the Adjustment Rate Factor 2. It is a function of the difference between the Economic Order Quantity Demand Level and the Established



8825A $ARF2.K = (MIN(AVDISC.K, MAXCHG.K)) (ARF1.K) (ARF5.K)$
 8850NOTE ARF2 -ADJUSTMENT RATE FACTOR 2
 8875NOTE AVDISC -ABSOLUTE VALUE OF DISC
 8900NOTE MAXCHG -MAXIMUM CHANGE
 8925NOTE ARF1 -ADJUSTMENT RATE FACTOR 1
 8950NOTE ARF5 -ADJUSTMENT RATE FACTOR 5
 8975A $ARF5.K = CLIP(1, -1, DISC.K, 0)$
 9000NOTE ARF5 -ADJUSTMENT RATE FACTOR 5
 9025NOTE DISC -DISCREPANCY
 9050A $MAXCHG.K = SQRT(EBIL.K)$
 9075NOTE MAXCHG -MAXIMUM CHANGE
 9100NOTE EBIL -ESTABLISHED BASE INVENTORY LEVEL

Figure 4-22. Base Inventory Sector Diagram 15

Base Inventory Level. If the demand level is greater than the established inventory, Adjustment Rate Factor 5 is positive; if the demand level is less than the established inventory, Adjustment Rate Factor 5 is negative. The absolute value of the difference between the Economic Order Quantity demand level and the established base level is the mathematical absolute value of the difference. The maximum allowable change for the Established Base Inventory Level is equal to the square root of the level at that point in time (see Chapter III).

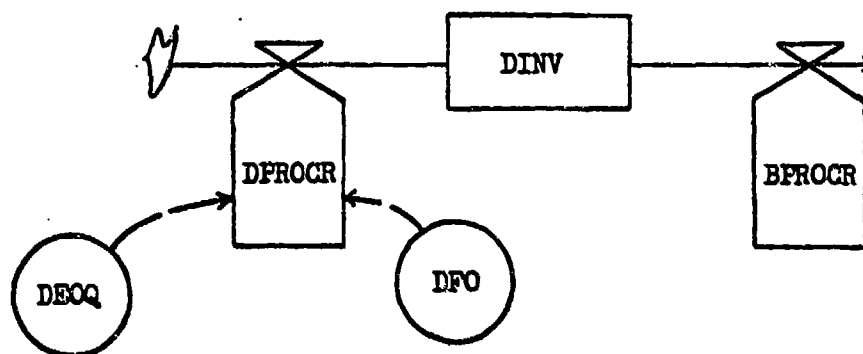
This concludes the discussion of the Base Inventory Sector. The Depot Inventory Sector is described next.

Depot Inventory Sector

The function of this sector is to briefly describe the process of acquiring parts and providing them to the Base Inventory Sector. The sector did not have to be thoroughly developed in order to accomplish this function and it was designed to satisfy all demands from the base.

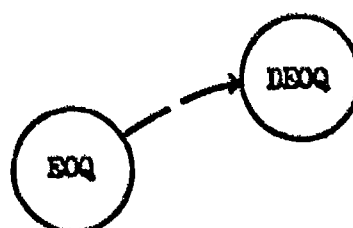
The central variable in the sector is the level of Depot Inventory. Figure 4-23 illustrates that it is determined entirely by the Base Procurement Rate (which was described in the Base Inventory Sector) and the Depot Procurement Rate. The Depot Procurement Rate is a function of the Depot Economic Order Quantity and the Depot Fraction Ordered.

Figure 4-24 illustrates that the Depot Economic Order Quantity is a function of the Base Economic Order Quantity. It is the number of items that the depot orders each time it places an order for the items under study. It was set to equal five times the Base Economic Order Quantity in order to ensure that the Depot Inventory Sector would always be able to satisfy requirements imposed by the base.



9875L $DINV.K = DINV.J + (DT) (DPROCR.JK - BPROCR.JK)$
 9966NOTE DINV -DEPOT INVENTORY
 9925NOTE DPROCR -DEPOT PROCUREMENT RATE
 9936NOTE BPROCR -BASE PROCUREMENT RATE
 9975R $DPROCR.KL = (DEOQ.K) (DFO.K)$
 10066NOTE DPROCR -DEPOT PROCUREMENT RATE
 10025NOTE DEOQ -DEPOT ECONOMIC ORDER QUANTITY
 10036NOTE DFO -DEPOT FRACTION ORDERED

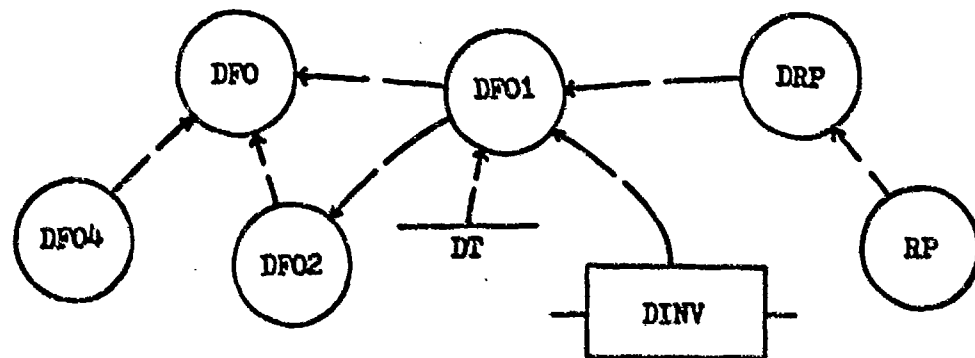
Figure 4-23. Depot Inventory Sector Diagram 1



10073A $DEOQ.K = (5) (EOQ.K)$
 10166NOTE DEOQ -DEPOT ECONOMIC ORDER QUANTITY
 10125NOTE EOQ -BASE ECONOMIC ORDER QUANTITY

Figure 4-24. Depot Inventory Sector Diagram 2

The Depot Fraction Ordered is the second factor that affects the Depot Procurement Rate in Figure 4-23. Figure 4-25 illustrates that it is composed of three factors: Depot Fraction Ordered factors 1, 2, and 4. Factors 1 and 2 are timing factors that "order" parts for the Depot Inventory when the inventory level reaches the Depot Reorder Point. The Depot Reorder Point, like the Depot Economic Order Quantity, was set to equal five times the Base Reorder Point to ensure that the depot sector could always fill the demands of the base sector.



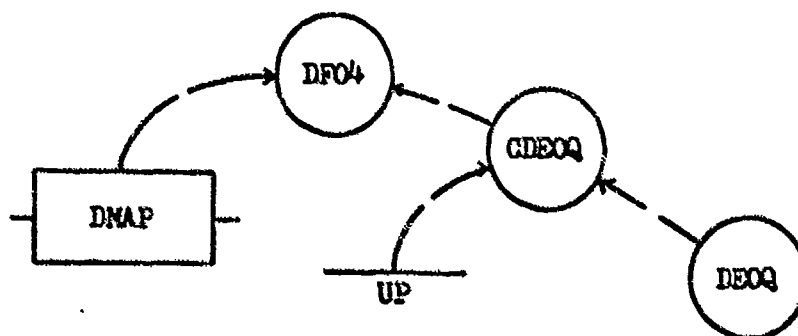
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10150A DFO.K=(DFO1.K)(DFO2.K)(DFO4.K)
10175NOTE DFO -DEPOT FRACTION ORDERED
10200NOTE DFO1 -DEPOT FRACTION ORDERED 1
10225NOTE DFO2 -DEPOT FRACTION ORDERED 2
10250NOTE DFO4 -DEPOT FRACTION ORDERED 4
10275A DFO1.K=CLIP(0,(1/DT),DINV.K,DRP.K)
10300NOTE DFO1 -DEPOT FRACTION ORDERED 1
10325NOTE DT -DELTA TIME
10350NOTE DINV -DEPOT INVENTORY
10375NOTE DRP -DEPOT REORDER POINT
10400A DFO2.K=CLIP(0,1,DFO1.J,0.5)
10425NOTE DFO2 -DEPOT FRACTION ORDERED 2
10450NOTE DFO1 -DEPOT FRACTION ORDERED 1
10475A DRP.K=(5)(RP.K)
10500NOTE DRP -DEPOT REORDER POINT
10525NOTE RP -BASE REORDER POINT

```

Figure 4-25. Depot Inventory Sector Diagram }

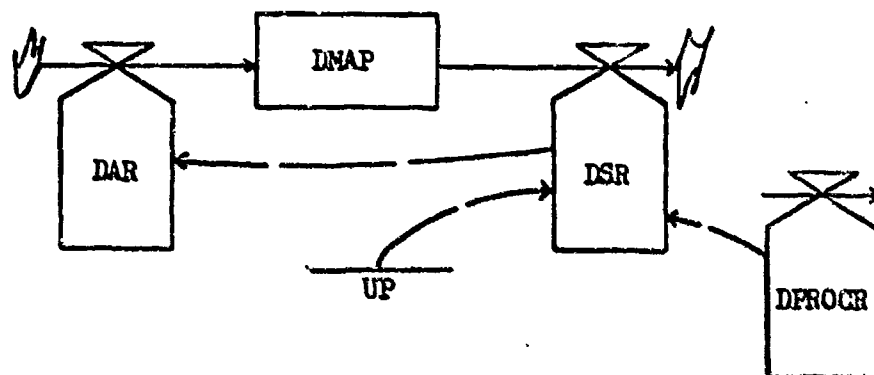
Figure 4-26 illustrates that the Depot Fraction Ordered factor 4 is a function of the Cost of the Depot Economic Order Quantity and the amount of money that the depot has available for the procurement of spare parts. Factor 4 limits the size of the order that the depot places with its vendors to the amount of money that it has available to spend. An implicit assumption of the Depot Fraction Ordered is that the depot's suppliers can always completely fill the depot's orders. The Cost of the Depot Economic Order Quantity is equal to the Depot Economic Order Quantity times the Unit Price of the item being procured.



10550A DFO4.K=CLIP(1,(DMAP.K/CDEOQ.K),(DMAP.K-CDEOQ.K),0)
 10575NOTE DFO4 -DEPOT FRACTION ORDERED 4
 10600NOTE DMAP -DEPOT MONEY AVAILABLE FOR PROCUREMENT
 10625NOTE CDEOQ -COST OF DEPOT ECONOMIC ORDER QUANTITY
 10650A CDEOQ.K=(DEOQ.K)(UP)
 10675NOTE CDEOQ -COST OF DEPOT ECONOMIC ORDER QUANTITY
 10700NOTE DEOQ -DEPOT ECONOMIC ORDER QUANTITY
 10725NOTE UP -UNIT PRICE

Figure 4-26. Depot Inventory Sector Diagram 4

Figure 4-27 illustrates the flow of money through the depot sector. The level of Depot Money Available for Procurement is a function of the Depot Appropriation Rate and the Depot Spending Rate. In order to insure that the depot always has adequate funds to purchase parts so that it can meet the base's demands, the Depot Appropriation Rate is set to equal the Depot Spending Rate. The Depot Spending Rate is a function of the Depot Procurement Rate and the Unit Price of the items purchased.



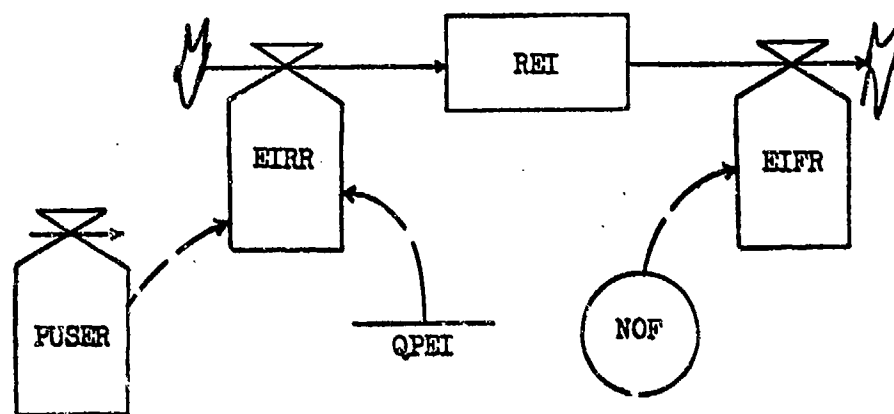
10750L DMAP.K=DMAP.J*(DT)*(DAR.JK-DSR.JK)
 10773NOTE DMAP -DEPOT MONEY AVAILABLE FOR PROCUREMENT
 10844NOTE DT -DELTA TIME
 10825NOTE DAR -DEPOT APPROPRIATION RATE
 10858NOTE DSR -DEPOT SPENDING RATE
 10875R DAR.KL=DSR.JK
 10944NOTE DAR -DEPOT APPROPRIATION RATE
 10925NOTE DSR -DEPOT SPENDING RATE
 10954R DSR.KL=(DPROCR.JK)*(UP)
 10975NOTE DSR -DEPOT SPENDING RATE
 11044NOTE DPROCR -DEPOT PROCUREMENT RATE
 11025NOTE UP -UNIT PRICE

Figure 4-27. Depot Inventory Sector Diagram 5

This concludes the discussion of the Depot Inventory Sector. The next section discusses the consumption of parts by the base.

Consumption Sector

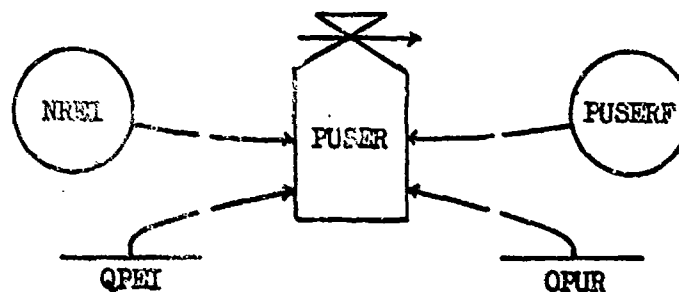
This sector discusses the factors that influence the use of spare parts by the base level organization. The number of Ready End Items is the central variable in this sector. Figure 4-28 illustrates that the number of Ready End Items is a function of the End Item Repair Rate and the End Item Failure Rate. The End Item Repair Rate is a function of the Parts Use Rate and the Quantity of Parts per End Item; the End Item Failure Rate is a function of the Number of Failures of the end item that are due to the component under study. The next several paragraphs discuss the factors that determine the Parts Use Rate.



11375L REI.K=REI.J+(DT) (EIRR.JK-EIFR.JK)
 11400NOTE REI -READY END ITEMS
 11425NOTE DT -DELTA TIME
 11450NOTE EIRR -END ITEM REPAIR RATE
 11475NOTE EIFR -END ITEM FAILURE RATE
 11500R EIRR.KL=(PUSER.JK/QPEI)
 11525NOTE EIRR -END ITEM REPAIR RATE
 11550NOTE PUSER -PARTS USE RATE
 11575NOTE QPEI -QUANTITY OF PARTS PER END ITEM
 11600R EIFR.KL=NOF.K
 11625NOTE EIFR -END ITEM FAILURE RATE
 11650NOTE NOF -NUMBER OF FAILURES

Figure 4-28. Consumption Sector Diagram 1

Figure 4-29 illustrates that the Parts Use Rate is a function of four factors: the Quantity of Parts per End Item, the Parts Use Rate generated by weapon systems at the base other than the one under study, the number of Not Ready End Items due to malfunction of the component under study, and the Parts Use Rate Factor.

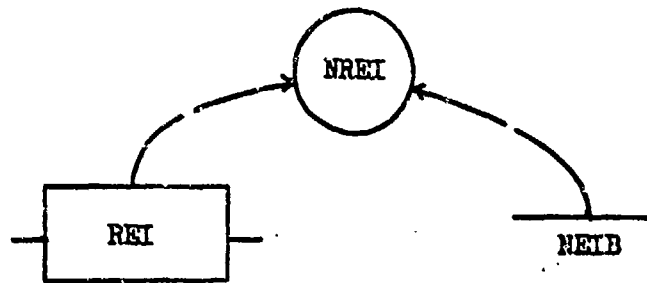


11675R PUSER.KL=(NREI.K)(QPEI)(PUSERF.K)+OPUR
 1170#NOTE PUSER -PARTS USE RATE
 11725NOTE NREI -NOT READY END ITEMS
 11750NOTE QPEI -QUANTITY OF PARTS PER END ITEM
 11775NOTE PUSERF -PARTS USE RATE FACTOR
 1180#NOTE OPUR -OTHER PARTS USE RATE

Figure 4-29. Consumption Sector Diagram 2

The Quantity of Parts per End Item is a constant that is extracted from the weapon system provisioning document. It is the quantity of the particular part under study that is used each time an end item is repaired. The Other Parts Use Rate requirement is the total demand for the item at the base by all other weapon systems except the one that requires the ISSI.

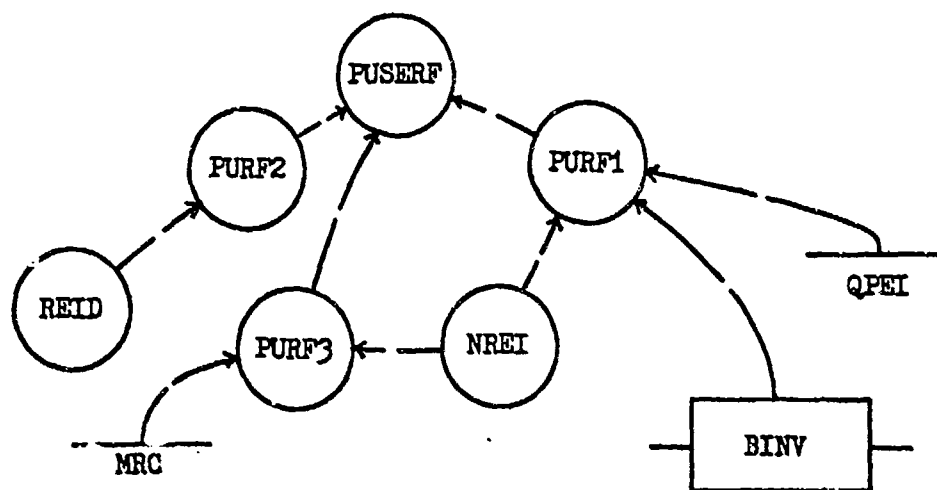
As illustrated in Figure 4-30, the number of Not Ready End Items is simply the difference between the Number of End Items on the Base and the number of Ready End Items.



11825A $NREI.K = NEIB - REI.K$
 11850NOTE NREI -NOT READY END ITEMS
 11875NOTE NEIB -NUMBER OF END ITEMS ON BASE
 11900NOTE REI -READY END ITEMS

Figure 4-30. Consumption Sector Diagram 3

Figure 4-31 illustrates that the Parts Use Rate Factor is a function of three elements: Parts Use Rate Factors 1, 2, and 3. Parts Use Rate Factor 1 limits the Parts Use Rate at the base to the number of parts that are available in the base inventory. Parts Use Rate Factor 2 is a table function that relates the amount of emphasis that is placed by the base on the repair of Not Ready End Items to the number of Not Ready End Items and the Required Number of Ready End Items. This relationship was developed intuitively and is plotted in Figure 4-32. It states that as the actual number of Ready End Items exceeds the required number of Ready End



11925A PUSERF.K=(MIN(PURF1.K,PURF3.K))(PURF2.K)
 11950NOTE PUSERF -PARTS USE RATE FRACTION
 11975NOTE PURF1 -PARTS USE RATE FRACTION 1
 12000NOTE PURF3 -PARTS USE RATE FRACTION 3
 12025NOTE PURF2 -PARTS USE RATE FRACTION 2
 12050A PURF1.K=CLIP(1,(BINV.K/(NREI.K)(QPEI)),(BINV.K-
 12075) (NREI.K)(QPEI)),0)
 12100NOTE PURF1 -PARTS USE RATE FRACTION 1
 12125NOTE BINV -BASE INVENTORY
 12150NOTE NREI -NOT READY END ITEMS
 12175NOTE QPEI -QUANTITY OF PARTS PER END ITEM
 12200A PURF2.K=TABLE(PURF2T,REID.K,-10,1,1)
 12225NOTE PURF2 -PARTS USE RATE FRACTION 2
 12250NOTE PURF2T -PARTS USE RATE FRACTION 2 TABLE
 12275NOTE REID -READY END ITEM DISCREPANCY
 12300A PURF3.K=CLIP(1,(MRC/NREI.K),(MRC-NREI.K),0)
 12325NOTE PURF3 -PARTS USE RATE FRACTION 3
 12350NOTE MRC -MAINTENANCE REPAIR CAPABILITY
 12375NOTE NREI -NOT READY END ITEMS

Figure 4-31. Consumption Sector Diagram 4

Items, there is less pressure at the base to repair the defective items. Conversely, it states that as the number of defective end items approaches or becomes less than the required number of end items, there is an increased effort placed on repairing the defective units. Parts Use Rate Factor 3 prevents the Parts Use Rate from exceeding the Maintenance Repair Capability of the organization (as determined by unit manning, facilities, tools, etc.).

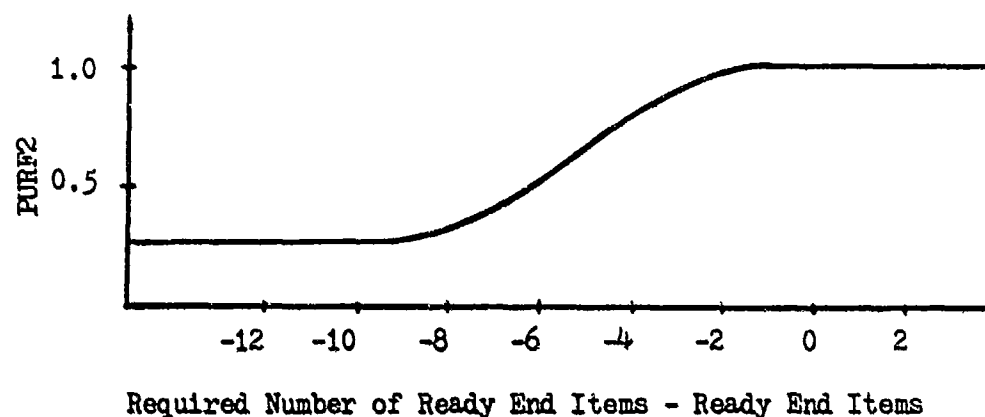
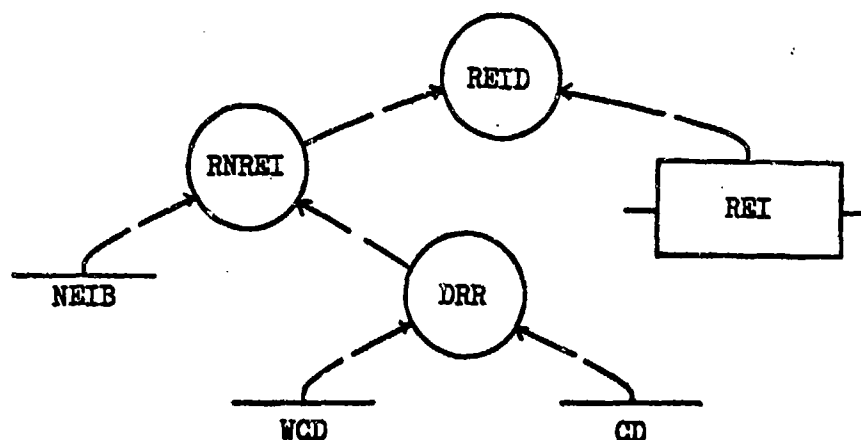


Figure 4-32. Parts Use Rate Factor 2 Graph

Figure 4-33 illustrates that the Ready End Item Discrepancy is the difference between the Required Number of Ready End Items and the actual number of Ready End Items. The Required Number of Ready End Items is simply the number of end items at the base multiplied by the Desired Ready Rate. The Desired Ready Rate is the ready rate



12400A $REID.K = RNREI.K - REI.K$
 12425NOTE REID -READY END ITEM DISCREPANCY
 12450NOTE RNREI -REQUIRED NUMBER OF READY END ITEMS
 12475NOTE REI -READY END ITEMS
 12500A $RNREI.K = (DRR.K) (NEIB)$
 12525NOTE RNREI -REQUIRED NUMBER OF READY END ITEMS
 12550NOTE DRR -DESIRED READY RATE
 12575NOTE NEIB -NUMBER OF END ITEMS ON BASE
 12600A $DRR.K = CD + WCD$
 12625NOTE DRR -DESIRED READY RATE
 12650NOTE CD -COMMAND DIRECTIVES
 12675NOTE WCD -WING COMMANDER'S DESIRES

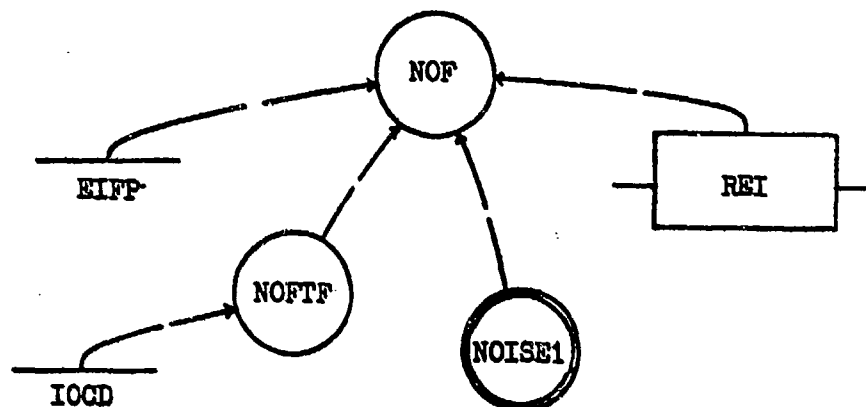
Figure 4-33. Consumption Sector Diagram 5

required by Command Directives as modified by the unit commander's desires.

This completes the discussion of the factors that influence the End Item Repair Rate and Parts Use Rate, the left-hand side of Figure 4-28. The next several paragraphs discuss the End Item Failure Rate, the right-hand side of Figure 4-28.

It was already stated that the End Item Failure Rate is a function of the Number of Failures of the end item that are due to

the component under study. Figure 4-34 illustrates that the Number of Failures is a function of four factors: the number of Ready End Items, the timing factor, the End Item Failure Parameter, and a noise factor.



12700A NOF.K=(REI.K)(EIFP)(NOISE1.K)(NOFTF.K)
 12725NOTE NOF -NUMBER OF FAILURES
 12750NOTE REI -READY END ITEMS
 12775NOTE EIFP -END ITEM FAILURE PARAMETER
 12800NOTE NOISE1 -NOISE 1
 12825NOTE NOFTF -NUMBER OF FAILURES TIMING FACTOR
 12850A NOFTF.K=STEP(1,IOCD)
 12875NOTE NOFTF -NUMBER OF FAILURES TIMING FACTOR
 12900NOTE IOCD -INITIAL OPERATION CAPABLE DATE
 12925A NOISE1.K=NORMRN(1.0,0.2)
 12950NOTE NOISE1 -NOISE 1

Figure 4-34. Consumption Sector Diagram 6

The timing factor is a function of the Initial Operational Capable Date of the weapon system under study. It prevents the model from simulating any end item failures before that date, and after that date it permits the model to simulate the number of failures that are determined by the other three factors.

The End Item Failure Parameter is a constant that is dependent on such factors as weapon system operating environment, use rate, and mission profile. It was fully discussed in Chapter III.

The noise factor was added to the number of failure equation to simulate the random fluctuations in the number of failures that are due to factors that are not considered by the model.

This concludes the discussion of the flow diagrams and DYNAMO equations that were developed to permit computer simulation of the ISSL model. The chapter consisted of a variable-by-variable discussion of all four sectors of the model. It identified all the variables in the model and discussed the mathematical relationships among them. Chapter V addresses the validity of these hypothesized relationships and the parameters that were used to run the model on the computer.

Chapter V

MODEL VALIDATION

Introduction

In his book Industrial Dynamics Jay Forrester stated that model validity ". . . depends on how well it [the model] serves its purpose [3:115]." He continued to say that a model ". . . should be judged by its suitability for a particular purpose. A model is sound and defensible if it accomplishes what is expected of it [3:115]." Therefore, the model which was constructed is valid if it fulfills the objectives established by the analysts at the beginning of the research effort.

The importance of establishing objectives in model development and validation were stated by Forrester when he said:

. . . the absolute worth of a model can be no greater than the worth of its objectives.

The value of the objective transcends all other considerations in determining the utility of a model [3:116].

Therefore, the analyst must choose an objective which is significant. In order to choose a significant objective the analyst must have a ". . . keen perception of symptoms [of system behavior] and, ability to relate them to the probable causes [3:116]." For this research effort, the objective of the model was to simulate the process involved in the development of the initial spares support list (ISSL).

Through the construction of a valid model which satisfies the research objectives, the Air Force will be provided with a device to be used in reaching a decision concerning initial provisioning; i.e., ISSL quantity decisions.

With the establishment of significant and meaningful objectives the effectiveness of the model must be established. Model effectiveness depends ". . . first on the system boundaries it encompasses, second on the pertinence of selected variables, and last on the numerical values of the parameters [3:115-117]." In determining the effectiveness of the model, confidence is developed in the model. This chapter examines the dynamic model of the ISSL development process to determine its validity in terms of the boundaries established for the system, the interaction of the variables identified as components of the system, and finally the results obtained from the values assigned as the model parameters.

System Boundaries

Establishing the system boundaries is the ". . . first and most important question about detailed model design . . . [3:117]" which must be answered. The selection of system boundaries is directly related to the objectives that are established by the analyst because they guide the study of the system in question. Forrester noted the importance of establishing sound system

objectives and boundaries when he said:

. . . . Suitable boundaries are related to objectives.
. . . . If the boundaries range unnecessarily far, the model
will be distracting and may lead to such confusion that
the project is abandoned [3:117].

Applying these principles delineated by Forrester, the ISSL development process was conceptualized as being composed of four interdependent sectors, with each sector consisting of several variables. The interactivity of the variables and the interdependence of the sectors was discussed in Chapter III.

The variables within a given sector aggregated information and resources independent of the activity of another given sector. Therefore, each sector was free to act upon the information and resources based upon its own internal decision structure. From this independence of action it was concluded that the system boundaries were properly conceptualized and established correctly for the model of the ISSL development process. Once the system boundaries were established a check had to be performed to ensure that all pertinent variables and their proper interrelationships were included as part of the model.

Pertinence of Selected Variables

After establishing the boundaries of the system the next step was to identify the variables which interact within these boundaries to form the model of the system. Forrester pointed out

the significance of variable identification when he said

The second most important question of model design is to ask if the model contains an effective choice of variables, properly interconnected. . . . Failure to include the proper system variables in a model can destroy the utility of the model as a design tool [3:118].

In determining and establishing the variables which are contained within a system the ". . . most difficult choices will be in the decision functions of the model [3:118]," because these variables ". . . exist largely within the information networks where policies are informal [3:118]." Hence, the model was constructed from the interacting variables, which were derived from the current information policies.

For the most part the current policy guidance was contained in the assorted Department of Defense; Headquarters, Air Force; and Headquarters, Air Force Logistics Command directives and regulations governing the actions and activities which comprise the initial spares support list development process. Thus, the variables which form the formal portion of the ISSL development process were somewhat easily discerned. However, in order for the model to accurately replicate the current system's structure the informal policy variables had to be included as well.

The informal policy variables were discerned from interviews with specialists responsible for the computations and adjustments made to the range and depth of support/replacement items included on the ISSL. These informal policy variables were combined with the

formal policy variables and together they made up the causal-loop diagrams discussed in chapter III. From the research into the formal and informal policy formulation process the relationships that exist between the variables in each sector and the interdependence between the sectors were identified. This research into the variables also revealed that the model did conform to the actions and activities which combine to form the initial spares support list (ISSL) development process.

With the system boundaries established and the interacting variables identified the next action was to test the interaction of the variables to verify the reasonableness of the model. Prior to testing the variable interaction values were assigned to initiate model activity.

Parameter Values

Having determined that the system boundaries were properly established and that all pertinent variables had been captured by these boundaries it was time to perform the third model validity check, which was to assign numerical values to the parameters within which the model will operate. The assignment of these parameter values was also discussed by Forrester when he said

The third and least important aspect of a model to be considered in judging its validity concerns the values for its parameters. . . They may be chosen anywhere within a plausible range [3:119].

Forrester considered the parameters chosen for the numerical values of the variables to be least important because of the sensitivity of the variables. Forrester noted that a few variables will be insensitive to the values assigned; however, a ". . . few sensitive parameters will be identified by model tests. . . [3:119]."

Since this research effort was directed towards the development of a model of initial spares support for new items coming into the Air Force inventory, standard values were assigned to many of the variables. For the most part these standard values are contained within the governing directives and regulations. These standard values are applicable to the ISSL Development Sector and are used in conjunction with the computation parameters established by the equipment specialist to determine the initial spare/replacement parts quantity level.

The other parameters that have an impact on the variables which make up the ISSL development process are those established by the using Major Command. The using command establishes the number of end items to be assigned to the base and the mission profiles for the end item which are the parameters with the greatest impact on the remaining three sectors of Base Inventory, Depot Inventory, and Consumption, as the demand levels for the spare/replacement parts are projected based on anticipated end item usage.

With the three phases of model validity established by Forrester satisfied, the remaining task was to reproduce system

behavior by simulation. The reproduction of system behavior through model simulation is the subject of the final section of this chapter.

Reproducing System Behavior

The true test of how well the analyst designed his model to represent the system under study is demonstrated when the model is utilized. Once again it was Forrester who provided the insight into the importance of the model duplicating the system when he said the model

. . . should generate time patterns of behavior that do not differ in any significant way (judged within the framework of the objectives of the study) from the real system. . . . the more indistinguishable the over-all model performance is from a typical history of the actual system, the better our confidence in the model is apt to be [3:119].

Using these guidelines it was assumed that the value of the ISSL development process model would be shown in the model's ability to represent the behavior of the real system.

In order to verify the model's ability to simulate the performance of the ISSL development process, a hypothetical situation was created. Input values were developed based on information obtained during the research effort. These values were input into the model, and the model was run on the computer. The results of the simulation for selected variables are shown in the following figures.

Figure 5-1 illustrates the model's ability to generate the Base Inventory level pattern that is consistent with the Parts Use

Figure 5-2 illustrates the model's capability to simulate the adjustment of the Established Base Inventory Level. The Established Base Inventory Level is adjusted when orders are placed until the level reaches a value that is in equilibrium with the Parts Use Rate. As was discussed in Chapters III and IV, adjustments can be made to the Base Inventory level only if the magnitude of the adjustment meets certain criteria that are specified in Air Force directives.

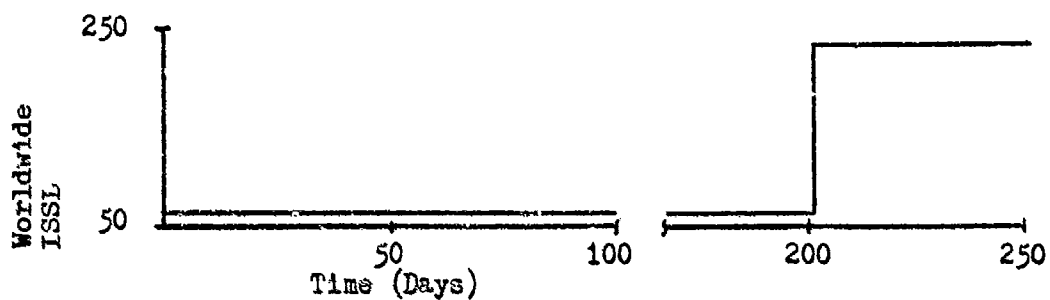


Figure 5-3. Simulation Results Graph 3

Figure 5-3 illustrates that the model simulates the adjustments of the Worldwide ISSL level at the Worldwide ISSL Review Time. At the review time the Worldwide ISSL level is adjusted, if required, to make it consistent with actual parts consumption data that has been generated by using organizations.

During the course of research into the validity of the model, varying lengths of simulation and different parameter values were input into the system. In all cases similar results were

obtained. Thus the model demonstrated its ability to stabilize and adjust quantity levels based on actual demand generated from actual parts use rate. Therefore, it was concluded that the system boundaries were properly established, the pertinent variables had been included in the model design, and the numerical values assigned as the variable parameters were accurate. Since all three validity factors were satisfied, the model appears to be valid and capable of reproducing expected system behavior.

The foregoing served to verify the internal validity of the model; i.e., it demonstrated to the authors that the model simulates the behavior of the ISSL development process as they conceptualized the system to be. Verification of the external validity of the model, i.e., that the model actually simulates the behavior of the real-world system, requires the input of actual historical data.

A summary of the research effort, recommendations for further study, and the conclusions that were drawn from the research project are the subjects of the next chapter.

Chapter VI

SUMMARY, RECOMMENDATIONS, AND CONCLUSIONS

Six objectives were established at the beginning of this project. A summary of the research effort is presented by addressing how well each of the objectives was accomplished. The summary is followed by recommendations for further study and the conclusions that were reached as a result of the study.

Summary

Dynamic Interrelationships. The first objective of this research was to determine pertinent dynamic interrelationships that comprise the ISSL development process. This was a three step process that involved setting the boundaries of the system, identifying pertinent variables, and determining the relationships among them. This was successfully accomplished and permitted investigation of the cause and effect relationships.

Cause and Effect. The second research objective was to trace the cause and effect of the relationships among the variables of the system. Causal loop analysis, as described in Chapters II and III, was used to logically investigate the specific nature of the relationships of the ISSL development process. This analysis led to investigation of the system's control process.

Control Process Formulation. Description of how decisions resulted from available information streams, through formulation of the control process of the system was the third research objective. This objective was accomplished by creating the sector flow diagrams that were presented in Chapter IV. The flow diagrams formally identified the decision points, information flows, and resource flows within the ISSL development process. Completion of the system flow diagrams permitted the construction of a mathematical model of the system.

Construction of the Mathematical Model. The fourth research objective was to construct a mathematical model of the ISSL development process. The DYNAMO simulation language was used as the framework for model construction. The model was completed using the flow diagrams that were presented in Chapter IV as an outline. Parameters were extracted from currently available data sources or intuitively developed. Completion of the mathematical model made it possible to simulate the behavior of the hypothetical ISSL development process.

Simulation of Behavior. The fifth objective of the research was to operate the model. Each operation of the model generated one simulation of the system. Numerous simulations were accomplished and, after each simulation, the model behavior was analyzed to determine if the expected behavior was present. If, in fact, it was not, the model

was analyzed to determine the cause of the unexpected behavior. Once the cause was discovered, the model was modified and the simulation repeated. This iterative process led to internal validation of the model.

Validation Testing. The final objective of the research was to test the validity of the model with historical data. As outlined in Chapter V, validation is twofold: internal and external. The internal validity of the model was demonstrated by the system behavior patterns that the model generated for the values of the parameters that were used during numerous simulations. External validation of the model was prevented due to a lack of historical parts consumption data and the inability to measure the human factors that influence the inputs to the ISSL development process. Until this information is developed, full model validation is impossible. Partly as a result of this inability to externally validate the model, recommendations for further study have been formulated.

Recommendations for Further Study

The authors feel that four areas need further research. First, the model that was developed in the project needs to be externally validated. Real world data needs to be collected, inserted into the model, and the model run to ensure that it indeed accurately simulates the behavior of the ISSL development process.

During the course of the research project, it was discovered that ISSL reviews are kept to an absolute minimum and that the accuracy of the actual parts consumption data that is available for use during these ISSL review meetings is, at best, questionable. The second recommendation is that the model be used to investigate the effectiveness of various ISSL review policies and to determine the sensitivity of the system to the inaccurate data that is used in the ISSL review process.

Also discovered during the course of the research was the fact that the base level ISSL is prorated from the worldwide ISSL based on the fraction of the total number of end items that the base receives and the projected end item use rate. No consideration is given to the different environmental conditions that exist at different bases. By not considering the end item operating environment, one base may be overstocked with an item whereas another base may be understocked. This leads to the third recommendation; the model should be used to investigate the effects of considering environmental variables on the effectiveness of the base level ISSL.

The last recommendation follows from the stock level imbalances that were just described. It is more general and is beyond the scope of the present model. The authors recommend that other ISSL distribution policies be investigated. During the course of the research, three options were discussed with various AFLC officials: contractor provided support, regional ISSLs, and centralized support.

Under the contractor provided support option, the contractor would provide the initial support for an end item for a designated period of time. Then, based on actual parts consumption data, the stock levels required for system support would be determined. By using actual data, predicting future needs for support becomes more precise and funds for procurement can be spent more effectively and efficiently. Also, more accurate ISSLs could be developed that would provide better support to base level units.

The regional ISSL concept would be predicated on the anticipated operating environment in the area that the weapon system is to be employed. Under this concept the effect of different environments on end item failure rates would have to be determined and the projected support requirements for each environment calculated. To illustrate this point, tests might show that more failures occur in a hot, humid environment than in a more temperate environment; thus, more parts would be required in the hot, humid region. Under this concept, a larger portion of the worldwide ISSL would be given to bases in the hot, humid areas than in the temperate areas. Prior to adopting this concept, the costs of conducting the environmental tests should be compared to the anticipated benefits of the concept; however, the regional concept has the potential of providing more effective and efficient ISSLs.

The centralized support concept is an extension of the regional ISSL concept. Under this concept, a single base within a

given region would be designated as the central supply point for system support. This base would maintain the ISSL inventory for the region and would ship items to customer bases on an as-required basis. This procedure would have the effect of smoothing demand and would improve efficiency by minimizing the problem of one base being "overstocked" while another was "understocked."

Conclusions

Two conclusions can be drawn from this project. First, it is possible to develop a mathematical model that simulates the management and decision structures that constitute the ISSL development process. If this model is validated with real world data, it could become a very useful tool for improving the ISSL development process.

The second conclusion is that the present ISSL development process is not efficiently supporting Air Force weapon systems. In many cases too many, too few, or the incorrect spare parts are procured. This results in either needless expenditure of funds or unnecessary equipment down time. There appear to be two reasons for this inefficiency.

The first reason is that AFLC is using a piecemeal approach for providing end item support. While all parties involved seek to provide adequate support, there is no one person who oversees the entire process. For example, all of the inventory management

specialists that were interviewed were knowledgeable in their own individual areas and had a working knowledge of an Air Logistics Center, but none of them had a complete picture of ISSL development.

A second reason for the inefficiency appears to be an over dependence on the computer. While the computer does provide a valuable service in management, care must be taken to make sure that the managers understand and maintain control over their system. The analysts discovered two cases in which the computer is "controlling" the managers. First, AFLC has developed a program to provide the headquarters with information about parts use rates so that ISSL levels can be adjusted. This program is not working because of a computer interface problem that requires manual recoding of data. Because the managers in the ALCs do not have the time to recode the data, i.e., to properly "feed" the computer, the data is lost, and the program thus far has not worked. The second case that the analysts discovered was in the local base supply activity. The managers that were interviewed there relied entirely on the computer to calculate their reorder points and reorder quantities; they had no idea what kind of calculations the computer used to determine the numbers that they use to manage their system.

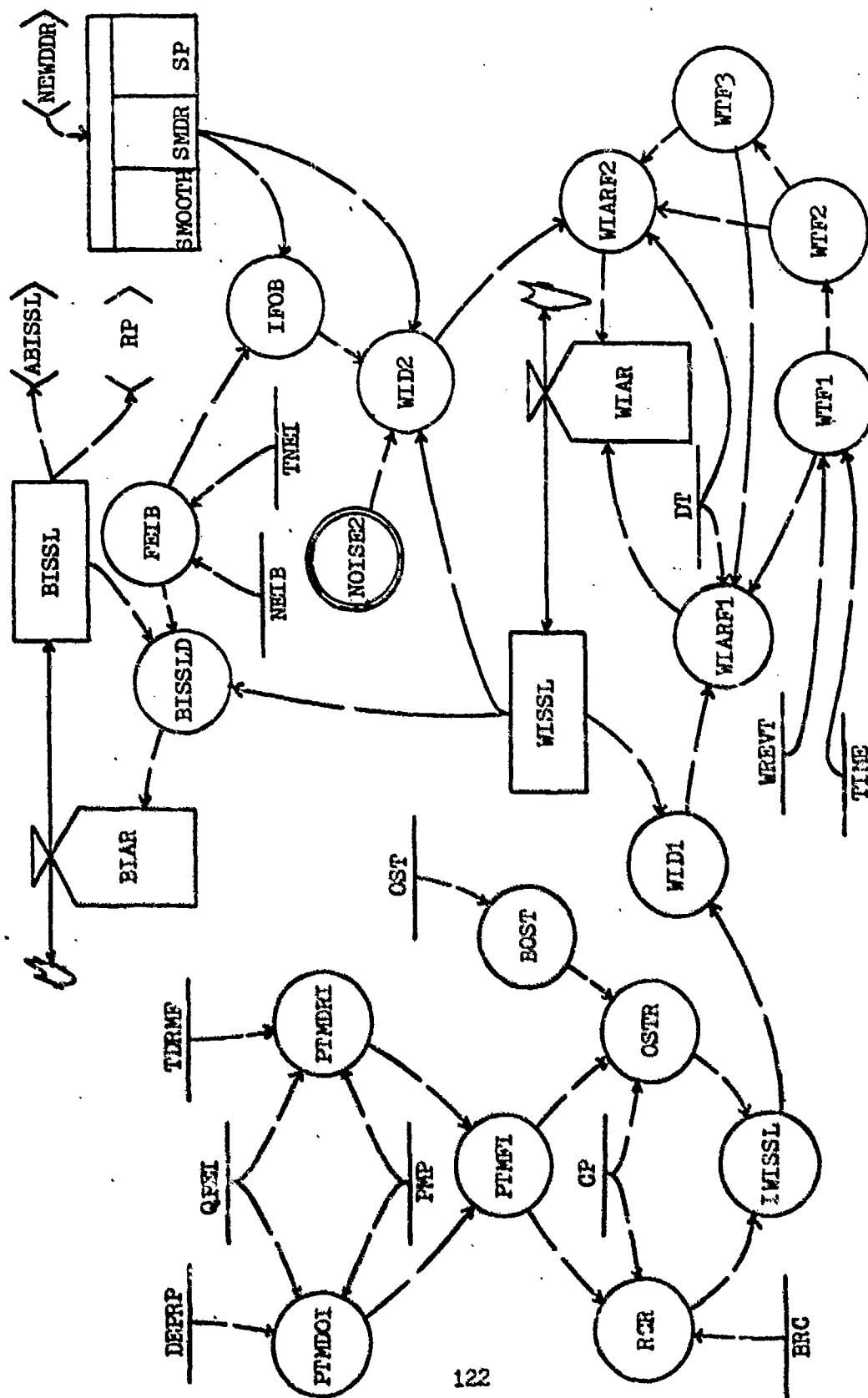
If a manager is to make his organization both effective and efficient, he must be able to control it. In order for him to control his organization, he must be aware of the variables that influence the behavior of his system and he must understand how

those variables interact to produce the behavior of the system. Perhaps the greatest value of the model that was developed for this project is that it can provide a means to gain that understanding for the complex set of interactions that make up the ISSL development process.

APPENDICES

APPENDIX A

ISSL DEVELOPMENT SECTOR FLOW DIAGRAM AND VARIABLE LIST



23C*****

50C

75C VARIABLE LIST FOR THE ISSL DEVELOPMENT SECTOR

100C

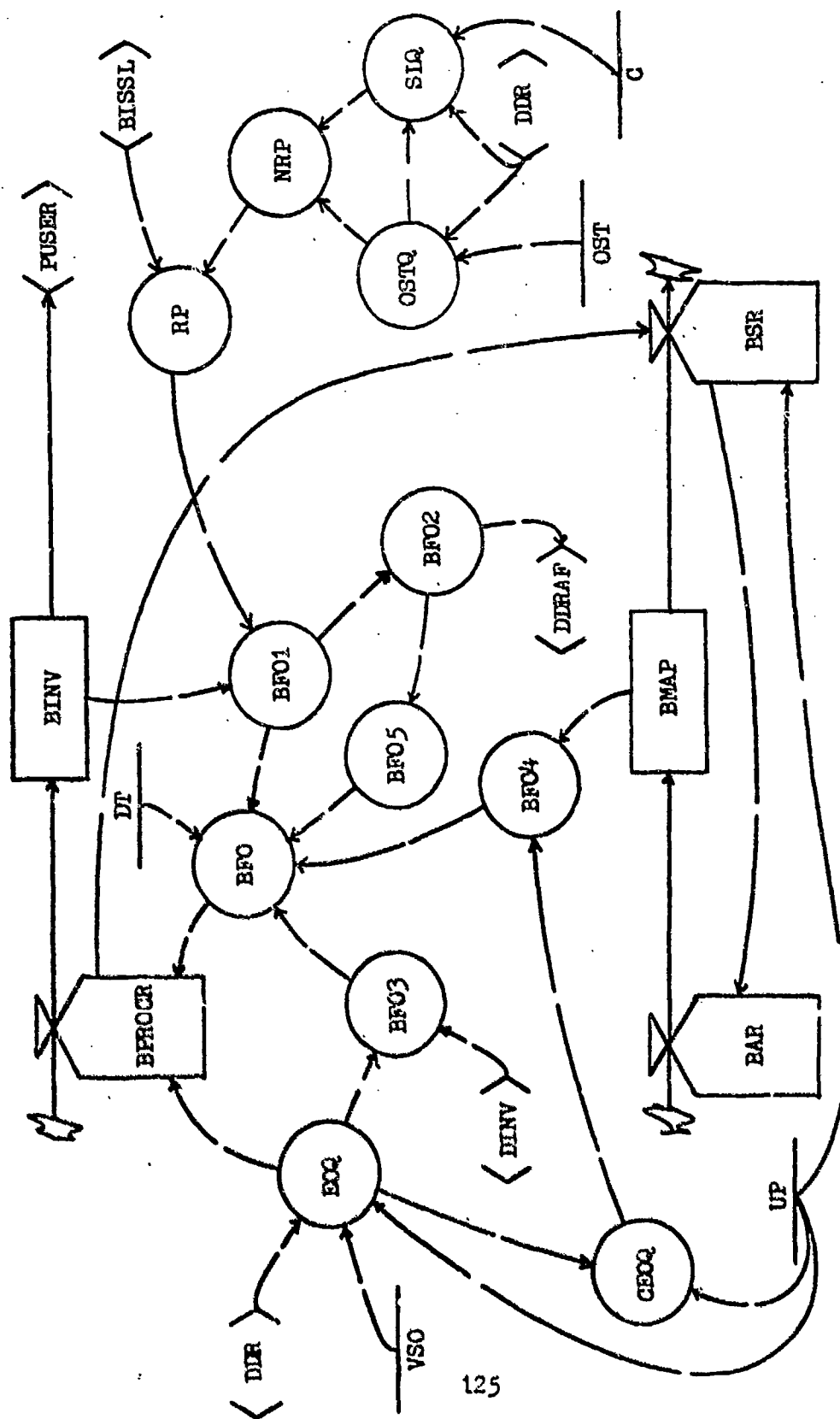
125C ABISL ADJUSTED BASE ISSL
150C BIAR BASE ISSL ADJUSTMENT RATE
175C BISSL BASE ISSL
200C BISSLD BASE ISSL DISCREPANCY
225C BRC BASE REPAIR CYCLE
250C BOST BASE ORDER AND SHIP TIME
275C CP CONDEMNATION PERCENT
300C DEPRP DEPOT REPLACEMENT PERCENT
325C DT DELTA TIME
350C FEIB FRACTION OF END ITEMS ON BASE
375C IFOB INPUT FROM OTHER BASES
400C INISSL INITIAL WORLDWIDE ISSL
425C NEIB NUMBER OF END ITEMS ON BASE
450C NEWDDR NEW DAILY DEMAND RATE
475C NOISE2 NOISE 2
500C OST ORDER AND SHIP TIME
525C OSTR ORDER AND SHIP TIME REQUIREMENT
550C PMP PEAK MONTH PROGRAM
575C PTMDOI PEAK TOTAL MONTH DEPOT OVERHAUL ISSUES
600C PTMDRI PEAK TOTAL MONTH DEMAND RATE ISSUES
625C PTMFI PEAK TOTAL MONTH FIELD ISSUES
650C QPEI QUANTITY OF PARTS PER END ITEM
675C RCR REPAIR CYCLE REQUIREMENT
700C RP BASE REORDER POINT
725C SMNR SMOOTHED MONTHLY DEMAND RATE
750C SP SMOOTHING PERIOD
775C TDRMF TOTAL DEMAND RATE MAINTENANCE FACTOR
800C TIME TIME
825C TNEI TOTAL NUMBER OF END ITEMS
850C WJAR WORLDWIDE ISSL ADJUSTMENT RATE
875C WJARF1 WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 1
900C WJARF2 WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 2
925C WID1 WORLDWIDE ISSL DISCREPANCY 1
950C WID2 WORLDWIDE ISSL DISCREPANCY 2
975C WISSL WORLDWIDE ISSL
1000C WTF1 WORLDWIDE ISSL TIMING FACTOR 1
1025C WTF2 WORLDWIDE ISSL TIMING FACTOR 2
1050C WTF3 WORLDWIDE ISSL TIMING FACTOR 3
1075C WREVT WORLDWIDE ISSL REVIEW TIME

1100C

1125C*****

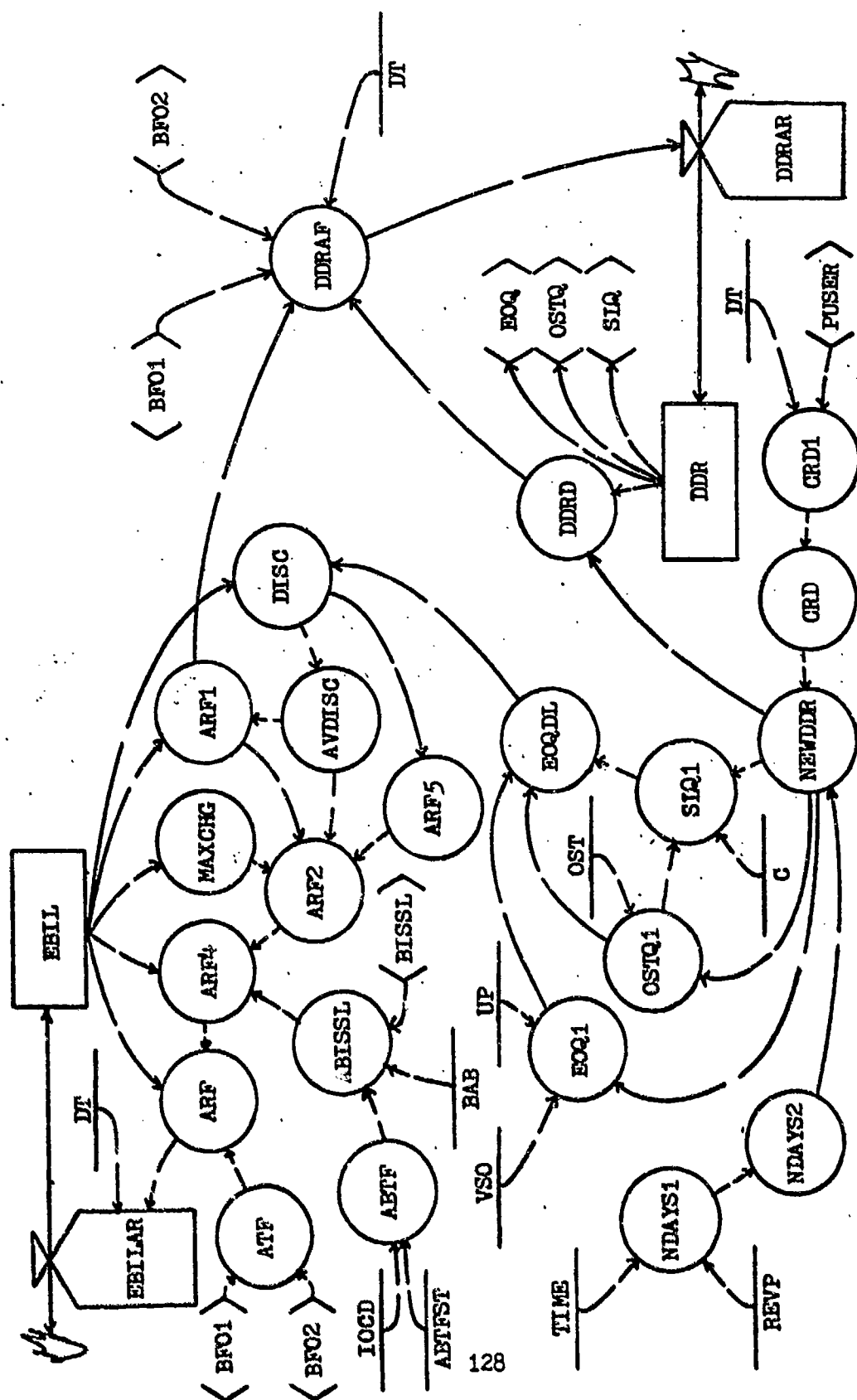
APPENDIX 3

BASE INVENTORY SUBSECTOR FLOW DIAGRAM AND VARIABLE LIST



25C*****
50C
75C VARIABLE LIST FOR THE BASE INVENTORY SUBSECTOR
100C
125C BAR BASE APPROPRIATION RATE
150C BFO BASE FRACTION ORDERED
175C BFO1 BASE FRACTION ORDERED 1
200C BFO2 BASE FRACTION ORDERED 2
225C BFO3 BASE FRACTION ORDERED 3
250C BFO4 BASE FRACTION ORDERED 4
275C BFO5 BASE FRACTION ORDERED 5
300C BINV BASE INVENTORY
325C BISSL BASE ISSL
350C BNAP BASE MONEY AVAILABLE FOR PROCUREMENT
375C BPROCR BASE PROCUREMENT RATE
400C BSR BASE SPENDING RATE
425C C CONSTANT
450C CEDQ COST OF BASE ECONOMIC ORDER QUANTITY
475C DDR DAILY DEMAND RATE
500C DDRAF DAILY DEMAND RATE ADJUSTMENT FACTOR
525C DINV DEPOT INVENTORY
550C DT DELTA TIME
575C EOQ BASE ECONOMIC ORDER QUANTITY
600C NRP NORMAL REORDER POINT
625C OST ORDER AND SHIP TIME
650C OSTQ ORDER AND SHIP TIME QUANTITY
675C PUSER PARTS USE RATE
700C RP BASE REORDER POINT
725C SLQ SAFETY LEVEL QUANTITY
750C UP UNIT PRICE
775C VSO VARIABLE STOCKAGE OBJECTIVE
800C
825C*****

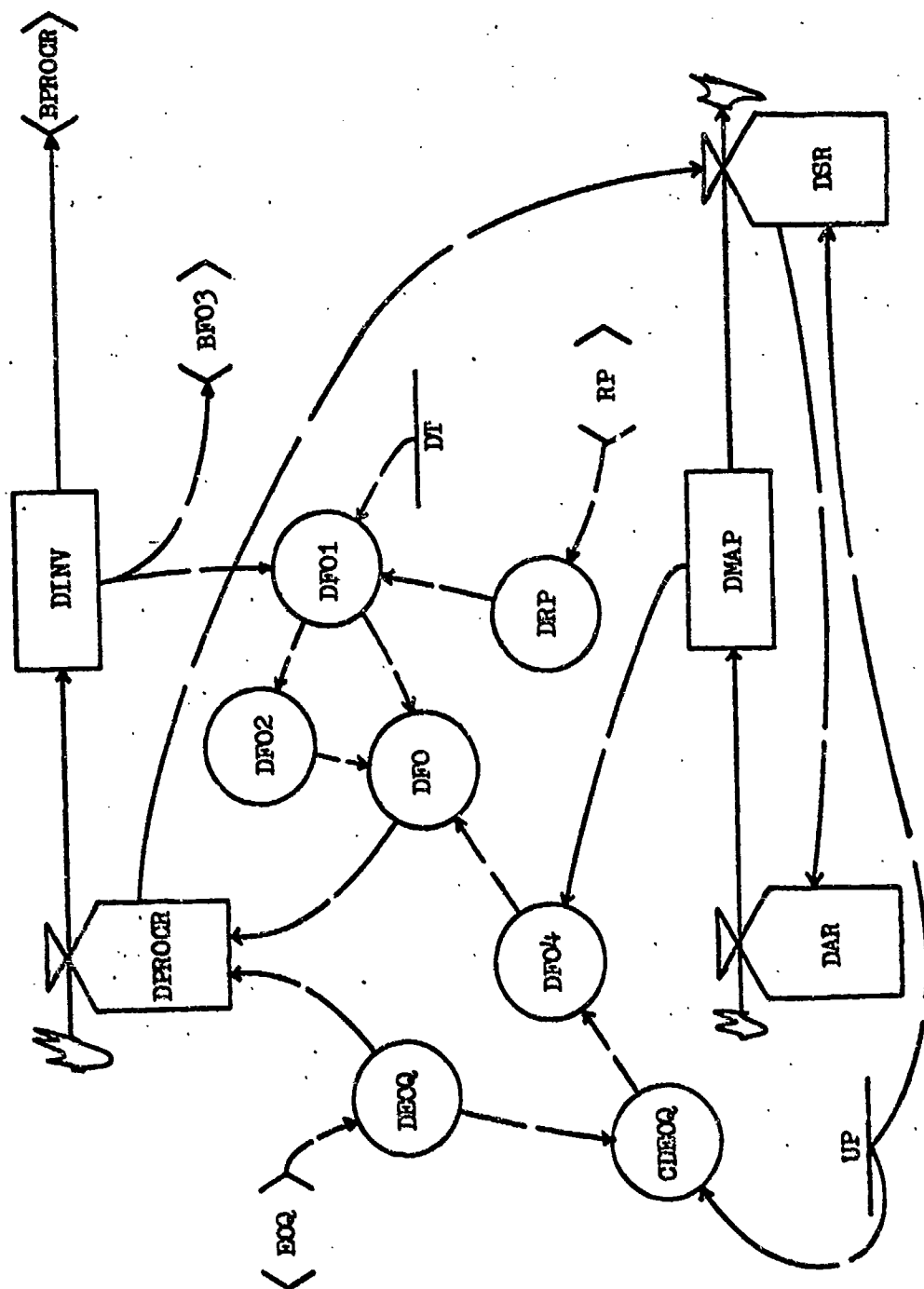
APPENDIX C
DAILY DEMAND RATE ADJUSTMENT SUBSECTOR FLOW DIAGRAM AND VARIABLE LIST



25C*****
 50C
 75C VARIABLE LIST FOR THE DAILY DEMAND RATE ADJUSTMENT SUBSECTOR
 100C
 125C ABISL ADJUSTED BASE ISL
 150C ABTF ADJUSTED BASE ISL TIMING FACTOR
 175C ABTFST ABTF STEP TIME
 200C ARF ADJUSTMENT RATE FACTOR
 225C ARF1 ADJUSTMENT RATE FACTOR 1
 250C ARF2 ADJUSTMENT RATE FACTOR 2
 275C ARF4 ADJUSTMENT RATE FACTOR 4
 300C ARF5 ADJUSTMENT RATE FACTOR 5
 325C ATF ADJUSTMENT TIMING FACTOR
 350C AVDISC ABSOLUTE VALUE OF DISC
 375C BAB BASE ADJUSTMENT TO THE BASE ISL
 400C BF01 BASE FRACTION ORDERED 1
 425C BF02 BASE FRACTION ORDERED 2
 450C BISSL BASE ISL
 475C C CONSTANT
 500C CRD CUMULATIVE RECURRING DEMAND
 525C CRD1 CUMULATIVE RECURRING DEMAND 1
 550C DDR DAILY DEMAND RATE
 575C DDRAF DAILY DEMAND RATE ADJUSTMENT FACTOR
 600C DDRAR DAILY DEMAND RATE ADJUSTMENT RATE
 625C DDRD DAILY DEMAND RATE DISCREPANCY
 650C DISC DISCREPANCY
 675C DT DELTA TIME
 700C EBIL ESTABLISHED BASE INVENTORY LEVEL
 725C EBILAR EBIL ADJUSTMENT RATE
 750C EQQ BASE ECONOMIC ORDER QUANTITY
 775C EQQDL BASE EQQ DEMAND LEVEL
 800C EQQ1 BASE ECONOMIC ORDER QUANTITY 1
 825C IOCD INITIAL OPERATION CAPABLE DATE
 850C MAXCHG MAXIMUM CHANGE
 875C NDAYS1 NUMBER OF DAYS 1
 900C NDAYS2 NUMBER OF DAYS 2
 925C NEWDDR NEW DAILY DEMAND RATE
 950C OST ORDER AND SHIP TIME
 975C OSTQ ORDER AND SHIP TIME QUANTITY
 1000C OSTQ1 ORDER AND SHIP TIME QUANTITY 1
 1025C PUSER PARTS USE RATE
 1050C REVP REVIEW PERIOD
 1075C SLQ SAFETY LEVEL QUANTITY
 1100C SLQ1 SAFETY LEVEL QUANTITY 1
 1125C TIME TIME
 1150C UP UNIT PRICE
 1175C VSO VARIABLE STOCKAGE OBJECTIVE
 1200C
 1225C*****

APPENDIX D

DEPOT INVENTORY SECTOR FLOW DIAGRAM AND VARIABLE LIST



250C*****

50C

75C VARIABLE LIST FOR THE DEPOT INVENTORY SECTOR

100C

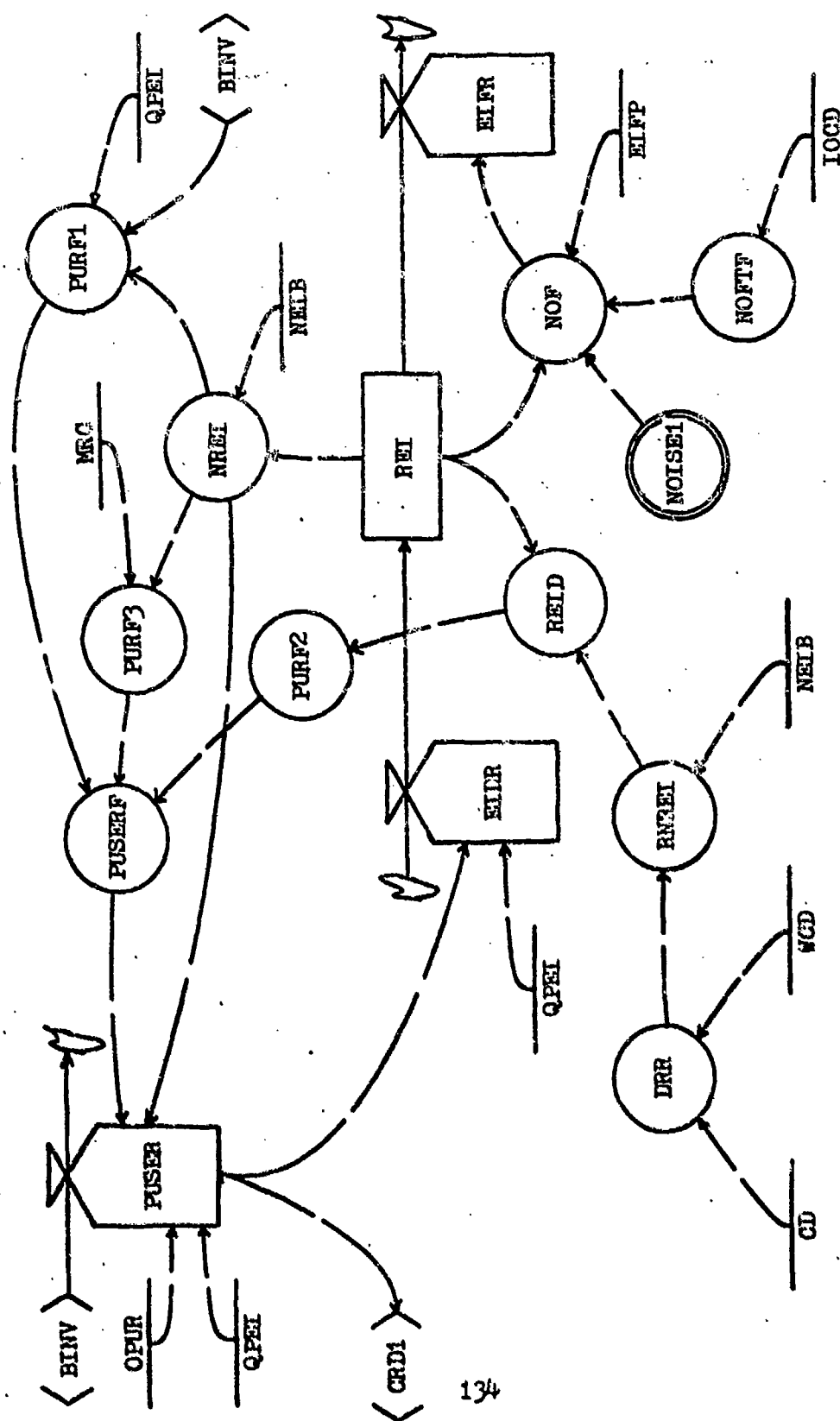
125C BF03 BASE FRACTION ORDERED 3
150C BPROCR BASE PROCUREMENT RATE
175C CDE00 COST OF DEPOT ECONOMIC ORDER QUANTITY
200C DAR DEPOT APPROPRIATION RATE
225C DE00 DEPOT ECONOMIC ORDER QUANTITY
250C DF0 DEPOT FRACTION ORDERED
275C DF01 DEPOT FRACTION ORDERED 1
300C DF02 DEPOT FRACTION ORDERED 2
325C DF04 DEPOT FRACTION ORDERED 4
350C DINV DEPOT INVENTORY
375C DMAP DEPOT MONEY AVAILABLE FOR PROCUREMENT
400C DPROCR DEPOT PROCUREMENT RATE
425C DRP DEPOT REORDER POINT
450C DSR DEPOT SPENDING RATE
475C DT DELTA TIME
500C E00 BASE ECONOMIC ORDER QUANTITY
525C RP BASE REORDER POINT
550C UP UNIT PRICE

575C

600C*****

APPENDIX E

CONSUMPTION SECTOR FLOW DIAGRAM AND VARIABLE LIST



250*****
 500
 750 VARIABLE LIST FOR THE CONSUMPTION SECTOR
 1000
 1250 BINV BASE INVENTORY
 1500 CD COMMAND DIRECTIVES
 1750 CRD1 CUMULATIVE RECURRING DEMAND 1
 2000 DRR DESIRED READY RATE
 2250 EIFP END ITEM FAILURE PARAMETER
 2500 EIFR END ITEM FAILURE RATE
 2750 ETRR END ITEM REPAIR RATE
 3000 IOCD INITIAL OPERATION CAPABLE DATE
 3250 MRC MAINTENANCE REPAIR CAPABILITY
 3500 NEIB NUMBER OF END ITEMS ON BASE
 3750 NOF NUMBER OF FAILURES
 4000 NOFTF NUMBER OF FAILURES TIMING FACTOR
 4250 NOISE1 NOISE 1
 4500 NREI NOT READY END ITEMS
 4750 OPUR OTHER PARTS USE RATE
 5000 PURF1 PARTS USE RATE FRACTION 1
 5250 PURF2 PARTS USE RATE FRACTION 2
 5500 PURF3 PARTS USE RATE FRACTION 3
 5750 PUSER PARTS USE RATE
 6000 PUSERF PARTS USE RATE FRACTION
 6250 UPEI QUANTITY OF PARTS PER END ITEM
 6500 REI READY END ITEMS
 6750 REID READY END ITEM DISCREPANCY
 7000 RNREI REQUIRED NUMBER OF READY END ITEMS
 7250 WCD WING COMMANDER'S DESIRES
 7500
 7750*****

APPENDIX F
PROGRAM LISTING

25+ A DYNAMIC MODEL OF THE ISSL DEVELOPMENT PROCESS
 50NOTE
 75NOTE
 100NOTE ISSL DEVELOPMENT SECTOR
 125NOTE
 150NOTE
 175L $WISSL.K = WISSL.J + (DT) (WIAR.JK)$
 200NOTE WISSL -WORLDWIDE ISSL
 225NOTE DT -DELTA TIME
 250NOTE WIAR -WORLDWIDE ISSL ADJUSTMENT RATE
 275R $WIAR.KL = WIARF1.K + WIARF2.K$
 300NOTE WIAR -WORLDWIDE ISSL ADJUSTMENT RATE
 325NOTE WIARF1 -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 1
 350NOTE WIARF2 -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 2
 375A $WIARF1.K = (WID1.K) (WTF1.K) (WTF3.K) (1/DT)$
 400NOTE WIARF1 -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 1
 425NOTE WID1 -WORLDWIDE ISSL DISCREPANCY 1
 450NOTE WTF1 -WORLDWIDE ISSL TIMING FACTOR 1
 475NOTE WTF3 -WORLDWIDE ISSL TIMING FACTOR 3
 500NOTE DT -DELTA TIME
 525A $WID1.K = IWISSL.K - WISSL.K$
 550NOTE WID1 -WORLDWIDE ISSL DISCREPANCY 1
 575NOTE IWISSL -INITIAL WORLDWIDE ISSL
 600NOTE WISSL -WORLDWIDE ISSL
 625A $WTF1.K = CLIP(0,1,TIME.K,WREV.T)$
 650NOTE WTF1 -WORLDWIDE ISSL TIMING FACTOR 1
 675NOTE TIME -TIME
 700NOTE WREV.T -WORLDWIDE ISSL REVIEW TIME
 725A $WTF2.K = CLIP(0,1,WTF1.K,0.5)$
 750NOTE WTF2 -WORLDWIDE ISSL TIMING FACTOR 2
 775NOTE WTF1 -WORLDWIDE ISSL TIMING FACTOR 1
 800L $WTF3.K = CLIP(0,1,WTF2.K,0.5)$
 825NOTE WTF3 -WORLDWIDE ISSL TIMING FACTOR 3
 850NOTE WTF2 -WORLDWIDE ISSL TIMING FACTOR 2
 875A $WIARF2.K = (WID2.K) (WTF2.K) (WTF3.K) (1/DT)$
 900NOTE WIARF2 -WORLDWIDE ISSL ADJUSTMENT RATE FACTOR 2
 925NOTE WID2 -WORLDWIDE ISSL DISCREPANCY 2
 950NOTE WTF2 -WORLDWIDE ISSL TIMING FACTOR 2
 975NOTE WTF3 -WORLDWIDE ISSL TIMING FACTOR 3
 1000NOTE DT -DELTA TIME
 1025A $WID2.K = (IFOB.K + SMDR.K - WISSL.K) (NOISE2.K)$
 1050NOTE WID2 -WORLDWIDE ISSL DISCREPANCY 2
 1075NOTE IFOB -INPUT FROM OTHER BASES
 1100NOTE SMDR -SMOOTHED MONTHLY DEMAND RATE
 1125NOTE WISSL -WORLDWIDE ISSL
 1150NOTE NOISE2 -NOISE 2

1175A SMDR.K=(30)(SMOOTH(NEWDDR.K,SP))
 1200NOTE SMDR -SMOOTHED MONTHLY DEMAND RATE
 1225NOTE NEWDDR -NEW DAILY DEMAND RATE
 1250NOTE SP -SMOOTHING PERIOD
 1275A IF08.K=(SMDR.K/FEIB.K)-SMDR.K
 1300NOTE IF08 -INPUT FROM OTHER BASES
 1325NOTE SMDR -SMOOTHED MONTHLY DEMAND RATE
 1350NOTE FEIB -FRACTION OF END ITEMS ON BASE
 1375A FEIB.K=NEIB/TNEI
 1400NOTE FEIB -FRACTION OF END ITEMS ON BASE
 1425NOTE NEIB -NUMBER OF END ITEMS ON BASE
 1450NOTE TNEI -TOTAL NUMBER OF END ITEMS
 1475A NOISE2.K=NORMRN(1.0,0.2)
 1500NOTE NOISE2 -NOISE 2
 1525A IWISL.K=OSTR.K+RCR.K
 1550NOTE IWISL -INITIAL WORLDWIDE ISL
 1575NOTE OSTR -ORDER AND SHIP TIME REQUIREMENT
 1600NOTE RCR -REPAIR CYCLE REQUIREMENT
 1625A OSTR.K=(BOST.K)(PTNFI.K)(CP.K)
 1650NOTE OSTR -ORDER AND SHIP TIME REQUIREMENT
 1675NOTE BOST -BASE ORDER AND SHIP TIME
 1700NOTE PTNFI -PEAK TOTAL MONTH FIELD ISSUES
 1725NOTE CP -CONDEMNATION PERCENT
 1750A BOST.K=OST/30 MONTHS
 1775NOTE BOST -BASE ORDER AND SHIP TIME
 1800NOTE OST -ORDER AND SHIP TIME
 1825A RCR.K=(BRC.K)(PTNFI.K)(1.00-CP.K)
 1850NOTE RCR -REPAIR CYCLE REQUIREMENT
 1875NOTE BRC -BASE REPAIR CYCLE
 1900NOTE PTNFI -PEAK TOTAL MONTH FIELD ISSUES
 1925NOTE CP -CONDEMNATION PERCENT
 1950A PTNFI.K=PTNDRI.K-PTND01.K
 1975NOTE PTNFI -PEAK TOTAL MONTH FIELD ISSUES
 2000NOTE PTNDRI -PEAK TOTAL MONTH DEMAND RATE ISSUES
 2025NOTE PTND01 -PEAK TOTAL MONTH DEPOT OVERHAUL ISSUES
 2050A PTND01.K=(DEPRP.K)(QPEI)(PHP.K)
 2075NOTE PTND01 -PEAK TOTAL MONTH DEPOT OVERHAUL ISSUES
 2100NOTE DEPRP -DEPOT REPLACEMENT PERCENT
 2125NOTE QPEI -QUANTITY OF PARTS PER END ITEM
 2150NOTE PHP -PEAK MONTH PROGRAM
 2175A PTNDRI.K=(TDRMF.K)(QPEI)(PHP.K)
 2200NOTE PTNDRI -PEAK TOTAL MONTH DEMAND RATE ISSUES
 2225NOTE TDRMF -TOTAL DEMAND RATE MAINTENANCE FACTOR
 2250NOTE QPEI -QUANTITY OF PARTS PER END ITEM
 2275NOTE PHP -PEAK MONTH PROGRAM

2300L BISSL.K=BISSL.J+(DT)(BIAR.JK)
 2325NOTE BISSL -BASE ISSL
 2350NOTE DT -DELTA TIME
 2375NOTE BIAR -BASE ISSL ADJUSTMENT RATE
 2400R BIAR.KL=BISSLD.K
 2425NOTE BIAR -BASE ISSL ADJUSTMENT RATE
 2450NOTE BISSLD -BASE ISSL DISCREPANCY
 2475A BISSLD.K=(WISSL.K)(FEIB.K)-BISSL.K
 2500NOTE BISSLD -BASE ISSL DISCREPANCY
 2525NOTE WISSL -WORLDWIDE ISSL
 2550NOTE FEIB -FRACTION OF END ITEMS ON BASE
 2575NOTE BISSL -BASE ISSL
 2600N BISSL=BISSLI
 2625NOTE BISSL -BASE ISSL
 2650NOTE BISSLI -BASE ISSL (INITIAL)
 2675C BISSLI=10
 2700NOTE BISSLI -BASE ISSL (INITIAL)
 2725C NEIB=100
 2750NOTE NEIB -NUMBER OF END ITEMS ON BASE
 2775C TNEI=500
 2800NOTE TNEI -TOTAL NUMBER OF END ITEMS
 2825N WISSL=WISSLI
 2850NOTE WISSL -WORLDWIDE ISSL
 2875NOTE WISSLI -WORLDWIDE ISSL (INITIAL)
 2900C WREVT=200
 2925NOTE WREVT -WORLDWIDE ISSL REVIEW TIME
 2950C WISSLI=50
 2975NOTE WISSLI -WORLDWIDE ISSL (INITIAL)
 3000N WTF3=1
 3025NOTE WTF3 -WORLDWIDE ISSL TIMING FACTOR 3
 3050C SP=90
 3075NOTE SP -SMOOTHING PERIOD
 3100C OST=12 DAYS
 3125NOTE OST -ORDER AND SHIP TIME
 3150A TDRMF.K=TDRNFI
 3175NOTE TDRMF -TOTAL DEMAND RATE MAINTENANCE FACTOR
 3200NOTE TDRNFI -TDRMF (INITIAL)
 3225C TDRNFI=1.0
 3250NOTE TDRNFI -TDRMF (INITIAL)
 3275A PHP.K=PNPI
 3300NOTE PHP -PEAK MONTH PROGRAM
 3325NOTE PNPI -PHP (INITIAL)
 3350C PNPI=63
 3375NOTE PNPI -PHP (INITIAL)
 3400A DEPRP.K=DEPRPI
 3425NOTE DEPRP -DEPOT REPLACEMENT PERCENT
 3450NOTE DEPRPI -DEPOT REPLACEMENT PERCENT (INITIAL)

3475C DEPRPI=0
 3500NOTE DEPRPI -DEPOT REPLACEMENT PERCENT (INITIAL)
 3525A CP.K=CPI
 3550NOTE CP -CONDEMNATION PERCENT
 3575NOTE CPI -CONDEMNATION PERCENT (INITIAL)
 3600C CPI=1.8
 3625NOTE CPI -CONDEMNATION PERCENT (INITIAL)
 3650A BRC.K=BRCI
 3675NOTE BRC -BASE REPAIR CYCLE
 3700NOTE BRCI -BASE REPAIR CYCLE (INITIAL)
 3725C BRCI=0
 3750NOTE BRCI -BASE REPAIR CYCLE (INITIAL)
 3775NOTE
 3800NOTE
 3825NOTE BASE INVENTORY SECTOR
 3850NOTE (INVENTORY SUBSECTOR)
 3875NOTE
 3900NOTE
 3925L BINV.K=BINV.J+(DT)(BPROCR.JK-PUSER.JK)
 3950NOTE BINV -BASE INVENTORY
 3975NOTE BPROCR -BASE PROCUREMENT RATE
 4000NOTE PUSER -PARTS USE RATE
 4025R BPROCR.KL=(EQQ.K)(BFO.K)
 4050NOTE BPROCR -BASE PROCUREMENT RATE
 4075NOTE EQQ -BASE ECONOMIC ORDER QUANTITY
 4100NOTE BFO -BASE FRACTION ORDERED
 4125A EQQ.K=((4.4)(SQRT((DDR.K)(VSO)(UP))))/(UP)
 4150NOTE EQQ -BASE ECONOMIC ORDER QUANTITY
 4175NOTE DDR -DAILY DEMAND RATE
 4200NOTE VSO -VARIABLE STOCKAGE OBJECTIVE
 4225NOTE UP -UNIT PRICE
 4250A BFO.K=(BFO1.K)(BFO5.K)(MIN(BFO3.K,BFO4.K))(1/DT)
 4275NOTE BFO -BASE FRACTION ORDERED
 4300NOTE BFO1 -BASE FRACTION ORDERED 1
 4325NOTE BFO5 -BASE FRACTION ORDERED 5
 4350NOTE BFO3 -BASE FRACTION ORDERED 3
 4375NOTE BFO4 -BASE FRACTION ORDERED 4
 4400NOTE DT -DELTA TIME
 4425A BFO1.K=CLIP(0,1,BINV.K,RP.K)
 4450NOTE BFO1 -BASE FRACTION ORDERED 1
 4475NOTE BINV -BASE INVENTORY
 4500NOTE RP -BASE REORDER POINT
 4525L BFO2.K=CLIP(0,1,BFO1.J,0.5)
 4550NOTE BFO2 -BASE FRACTION ORDERED 2
 4575NOTE BFO1 -BASE FRACTION ORDERED 1
 4600L BFO5.K=CLIP(0,1,BFO2.J,0.5)
 4625NOTE BFO5 -BASE FRACTION ORDERED 5
 4650NOTE BFO2 -BASE FRACTION ORDERED 2

4675A $BF03.K = CLIP(1, (DINV.K/EOQ.K), (DINV.K - EOQ.K), 0)$
 4700NOTE BF03 -BASE FRACTION ORDERED 3
 4725NOTE DINV -DEPOT INVENTORY
 4750NOTE EOQ -BASE ECONOMIC ORDER QUANTITY
 4775A $BF04.K = CLIP(1, (BMAP.K/CEQ.K), (BMAP.K - CEQ.K), 0)$
 4800NOTE BF04 -BASE FRACTION ORDERED 4
 4825NOTE BMAP -BASE MONEY AVAILABLE FOR PROCUREMENT
 4850NOTE CEQ -COST OF BASE ECONOMIC ORDER QUANTITY
 4875A $CEQ.K = (EOQ.K) (UP)$
 4900NOTE CEQ -COST OF BASE ECONOMIC ORDER QUANTITY
 4925NOTE EOQ -BASE ECONOMIC ORDER QUANTITY
 4950NOTE UP -UNIT PRICE
 4975A $RP.K = MAX((BISSL.K/3), NRP.K)$
 5000NOTE RP -BASE REORDER POINT
 5025NOTE BISSL -BASE INITIAL SPARES SUPPORT LIST
 5050NOTE NRP -NORMAL REORDER POINT
 5075A $NRP.K = OSTQ.K + SLQ.K$
 5100NOTE NRP -NORMAL REORDER POINT
 5125NOTE OSTQ -ORDER AND SHIP TIME QUANTITY
 5150NOTE SLQ -SAFETY LEVEL QUANTITY
 5175A $OSTQ.K = (DDR.K) (OST)$
 5200NOTE OSTQ -ORDER AND SHIP TIME QUANTITY
 5225NOTE DDR -DAILY DEMAND RATE
 5250NOTE OST -ORDER AND SHIP TIME
 5275A $SLQ.K = MAX((C) (SQRT((3) (OSTQ.K))), (DDR.K) (15))$
 5300NOTE SLQ -SAFETY LEVEL QUANTITY
 5325NOTE C -CONSTANT
 5350NOTE OSYQ -ORDER AND SHIP TIME QUANTITY
 5375NOTE DDR -DAILY DEMAND RATE
 5400A $BMAP.K = BMAP.J + (DT) (BAR.JK - BSR.JK)$
 5425NOTE BMAP -BASE MONEY AVAILABLE FOR PROCUREMENT
 5450NOTE DT -DELTA TIME
 5475NOTE BAR -BASE APPROPRIATION RATE
 5500NOTE BSR -BASE SPENDING RATE
 5525A $BAR.KL = BSR.JK$
 5550NOTE BAR -BASE APPROPRIATION RATE
 5575NOTE BSR -BASE SPENDING RATE
 5600A $BSR.KL = (EPROCR.JK) (UP)$
 5625NOTE BSR -BASE SPENDING RATE
 5650NOTE EPROCR -BASE PROCUREMENT RATE
 5675NOTE UP -UNIT PRICE
 5700A $DINV = DINVI$
 5725NOTE DINV -BASE INVENTORY
 5750NOTE DINVI -BASE INVENTORY (INITIAL)
 5775C $DINV = 200$
 5800A $DINV = DINVI$ -BASE INVENTORY (INITIAL)

5825C VSO=188
 5850NOTE VSO -VARIABLE STOCKAGE OBJECTIVE
 5875C C=1
 5900NOTE C -CONSTANT
 5925M BF02=1
 5950NOTE BF02 -BASE FRACTION ORDERED 2
 5975M BF05=0
 6000NOTE BF05 -BASE FRACTION ORDERED 5
 6025M BMAP=BMAPI
 6050NOTE BMAP -BASE MONEY AVAILABLE FOR PROCUREMENT
 6075NOTE BMAPI -BASE MONEY AVAILABLE FOR PROCUREMENT (INITIAL)
 6100C BMAPI=500
 6125NOTE BMAPI -BASE MONEY AVAILABLE FOR PROCUREMENT (INITIAL)
 6150C UP=.5
 6175NOTE UP -UNIT PRICE
 6200NOTE
 6225NOTE
 6250NOTE
 6275NOTE BASE INVENTORY SECTOR
 6300NOTE (DAILY DEMAND RATE ADJUSTMENT SUBSECTOR)
 6325NOTE
 6350L DDR.K=DDR.J+(DT)(DDRAR.JK)
 6375NOTE DDR -DAILY DEMAND RATE
 6376NOTE DT -DELTA TIME
 6377NOTE DDDR -DAILY DEMAND RATE ADJUSTMENT RATE
 6400R DDDR.KL=DDRAF.K
 6425NOTE DDDR -DAILY DEMAND RATE ADJUSTMENT RATE
 6450NOTE DDRAF -DAILY DEMAND RATE ADJUSTMENT FACTOR
 6475A DDRAF.K=(DDRD.K)(BF01.K)(BF02.K)(ARF1.K)(1/DT)
 6500NOTE DDRAF -DAILY DEMAND RATE ADJUSTMENT FACTOR
 6525NOTE DDRD -DAILY DEMAND RATE DISCREPANCY
 6550NOTE BF01 -BASE FRACTION ORDERED 1
 6575NOTE BF02 -BASE FRACTION ORDERED 2
 6600NOTE ARF1 -ADJUSTMENT RATE FACTOR 1
 6625NOTE DT -DELTA TIME
 6650A DDRD.K=NEWDDR.K-DDR.K
 6675NOTE DDRD -DAILY DEMAND RATE DISCREPANCY
 6700NOTE NEWDDR -NEW DAILY DEMAND RATE
 6725NOTE DDR -DAILY DEMAND RATE
 6750A NEWDDR.K=CRD.K/NDAYS2.K
 6775NOTE NEWDDR -NEW DAILY DEMAND RATE
 6800NOTE CRD -CUMULATIVE RECURRING DEMAND
 6825NOTE NDAYS2 -NUMBER OF DAYS 2
 6850C REVPI=45 DAYS
 6875NOTE REVPI -REVIEW PERIOD (INITIAL)

6900FOR I=1,REVP
 6925NOTE I -REVIEW PERIOD COUNTER
 6950NOTE REVP -REVIEW PERIOD (INITIAL)
 6975A CRD.K=SUN(CRD1.K)
 6976NOTE CRD -CUMULATIVE RECURRING DEMAND
 7000NOTE CRD1 -CUMULATIVE RECURRING DEMAND 1
 7025L CRD1.K(1)=(PUSER.JK)(DT)+CRD1.J(1)
 7050NOTE CRD1 -CUMULATIVE RECURRING DEMAND 1
 7075NOTE PUSER -PARTS USE RATE
 7100NOTE DT -DELTA TIME
 7125A NDAYS2.K=CLIP(NDAYS1.K,1,NDAYS1.K,1)
 7150NOTE NDAYS2 -NUMBER OF DAYS 2
 7175NOTE NDAYS1 -NUMBER OF DAYS 1
 7200A NDAYS1.K=CLIP(REVP.K,TIME.K,TIME.K,REVP.K)
 7225NOTE NDAYS1 -NUMBER OF DAYS 1
 7250NOTE REVP -REVIEW PERIOD
 7275NOTE TIME -TIME
 7300A ARF1.K=CLIP(1,0,(AVDISC.K-SQRT(EBIL.K)),0)
 7325NOTE ARF1 -ADJUSTMENT RATE FACTOR 1
 7350NOTE AVDISC -ABSOLUTE VALUE OF DISC
 7375NOTE EBIL -ESTABLISHED BASE INVENTORY LEVEL
 7400A DISC.K=EQDL.K-EBIL.K
 7425NOTE DISC -DISCREPANCY
 7450NOTE EQDL -BASE EOQ DEMAND LEVEL
 7475NOTE EBIL -ESTABLISHED BASE INVENTORY LEVEL
 7500A AVDISC.K=MAX(DISC.K,-DISC.K)
 7525NOTE AVDISC -ABSOLUTE VALUE OF DISC
 7550NOTE DISC -DISCREPANCY
 7575A EQDL.K=EQO1.K+OSTQ1.K+SLQ1.K
 7600NOTE EQDL -BASE EOQ DEMAND LEVEL
 7625NOTE EQO1 -BASE ECONOMIC ORDER QUANTITY 1
 7650NOTE OSTQ1 -ORDER AND SHIP TIME QUANTITY 1
 7675NOTE SLQ1 -SAFETY LEVEL QUANTITY 1
 7700A EQO1.K=((4.4)(SQRT((NEWDDR.K)(VSO)(UP))))/(UP)
 7725NOTE EQO1 -BASE ECONOMIC ORDER QUANTITY 1
 7750NOTE NEWDDR -NEW DAILY DEMAND RATE
 7775NOTE VSO -VARIABLE STOCKAGE OBJECTIVE
 7800NOTE UP -UNIT PRICE
 7825A OSTQ1.K=(NEWDDR.K)(OST)
 7850NOTE OSTQ1 -ORDER AND SHIP TIME QUANTITY 1
 7875NOTE NEWDDR -NEW DAILY DEMAND RATE
 7900NOTE OST -ORDER AND SHIP TIME
 7925A SLQ1.K=MAX((C)(SQRT((3)(OSTQ1.K))), (NEWDDR.K)(15))
 7950NOTE SLQ1 -SAFETY LEVEL QUANTITY 1
 7975NOTE C -CONSTANT
 8000NOTE OSTQ1 -ORDER AND SHIP TIME QUANTITY 1
 8025NOTE NEWDDR -NEW DAILY DEMAND RATE

8050L EBIL.K=EBIL.J+(DT)(EBILAR.JK)
 8075NOTE EBIL -ESTABLISHED BASE INVENTORY LEVEL
 8100NOTE DT -DELTA TIME
 8125NOTE EBILAR -EBIL ADJUSTMENT RATE
 8150R EBILAR.KL=(1/DT)(ARF.K)
 8175NOTE EBILAR -EBIL ADJUSTMENT RATE
 8200NOTE DT -DELTA TIME
 8225NOTE ARF -ADJUSTMENT RATE FACTOR
 8250A ARF.K=(ARF4.K-EBIL.K)(ATF.K)
 8275NOTE ARF -ADJUSTMENT RATE FACTOR
 8300NOTE ARF4 -ADJUSTMENT RATE FACTOR 4
 8325NOTE EBIL -ESTABLISHED BASE INVENTORY LEVEL
 8350NOTE ATF -ADJUSTMENT TIMING FACTOR
 8375A ATF.K=(BFO1.K)(BFO2.K)
 8400NOTE ATF -ADJUSTMENT TIMING FACTOR
 8425NOTE BFO1 -BASE FRACTION ORDERED 1
 8450NOTE BFO2 -BASE FRACTION ORDERED 2
 8475A ARF4.K=SWITCH((ARF2.K+EBIL.K),
 8500X (MAX(ARF2.K+EBIL.K,ABISSL.K)),ABISSL.K)
 8525NOTE ARF4 -ADJUSTMENT RATE FACTOR 4
 8550NOTE ARF2 -ADJUSTMENT RATE FACTOR 2
 8575NOTE EBIL -ESTABLISHED BASE INVENTORY LEVEL
 8600NOTE ABISSL -ADJUSTED BASE ISSL
 8625A ABISSL.K=(BAB)(BISSL.K)(ABTF.K)
 8650NOTE ABISSL -ADJUSTED BASE ISSL
 8675NOTE BAB -BASE ADJUSTMENT TO THE BASE ISSL
 8676NOTE BISSL -BASE ISSL
 8700NOTE ABTF -ADJUSTED BASE ISSL TIMING FACTOR
 8725A ABTF.K=STEP(1,ABTFST)+STEP(-1,IOCD+730)
 8750NOTE ABTF -ADJUSTED BASE ISSL TIMING FACTOR
 8775NOTE ABTFST -ABTF STEP TIME
 8800NOTE IOCD -INITIAL OPERATION CAPABLE DATE
 8825A ARF2.K=(MIN(AVDISC.K,MAXCHG.K))(ARF1.K)(ARF5.K)
 8850NOTE ARF2 -ADJUSTMENT RATE FACTOR 2
 8875NOTE AVDISC -ABSOLUTE VALUE OF DISC
 8900NOTE MAXCHG -MAXIMUM CHANGE
 8925NOTE ARF1 -ADJUSTMENT RATE FACTOR 1
 8950NOTE ARF5 -ADJUSTMENT RATE FACTOR 5
 8975A ARF5.K=CLIP(1,-1,DISC.K,0)
 9000NOTE ARF5 -ADJUSTMENT RATE FACTOR 5
 9025NOTE DISC -DISCREPANCY
 9050A MAXCHG.K=SQRT(EBIL.K)
 9075NOTE MAXCHG -MAXIMUM CHANGE
 9100NOTE EBIL -ESTABLISHED BASE INVENTORY LEVEL
 9125N DDR=DDR1
 9150NOTE DDR -DAILY DEMAND RATE
 9175NOTE DDR1 -DAILY DEMAND RATE (INITIAL)

9200C DDRI=3
 9225NOTE DDRI -DAILY DEMAND RATE (INITIAL)
 9250A REVP.K=REVPI
 9275NOTE REVP -REVIEW PERIOD
 9300NOTE REVPI -REVIEW PERIOD (INITIAL)
 9325N CRD1(I)=0
 9350NOTE CRD1 -CUMULATIVE RECURRING DEMAND 1
 9375A OUT.K=SHIFTL(CRD1.K,INTVL)
 9400NOTE OUT -DISCRETE OUTPUT OF CRD1 ARRAY
 9425NOTE CRD1 -CUMULATIVE RECURRING DEMAND 1
 9450NOTE INTVL -CRD1 ARRAY SHIFT INTERVAL
 9475C ABTFST=0
 9500NOTE ABTFST -ABTF STEP TIME
 9525C BAB=1
 9550NOTE BAB -BASE ADJUSTMENT TO THE BASE ISSL
 9575C INTVL=1
 9600NOTE INTVL -INTERVAL
 9625N EBIL=EBILI
 9650NOTE EBIL -ESTABLISHED BASE INVENTORY LEVEL
 9675NOTE EBILI -ESTABLISHED BASE INVENTORY LEVEL (INITIAL)
 9700C EBILI=200
 9725NOTE EBILI -ESTABLISHED BASE INVENTORY LEVEL (INITIAL)
 9750NOTE
 9775NOTE
 9800NOTE DEPOT INVENTORY SECTOR
 9825NOTE
 9850NOTE
 9875L DINV.K=DINV.J+(DT)(DPROCR.JK-BPROCR.JK)
 9900NOTE DINV -DEPOT INVENTORY
 9925NOTE DPROCR -DEPOT PROCUREMENT RATE
 9950NOTE BPROCR -BASE PROCUREMENT RATE
 9975R DPROCR.KL=(DEOQ.K)(DFO.K)
 10000NOTE DPROCR -DEPOT PROCUREMENT RATE
 10025NOTE DEOQ -DEPOT ECONOMIC ORDER QUANTITY
 10050NOTE DFO -DEPOT FRACTION ORDERED
 10075A DEOQ.K=(5)(EOQ.K)
 10100NOTE DEOQ -DEPOT ECONOMIC ORDER QUANTITY
 10125NOTE EOQ -BASE ECONOMIC ORDER QUANTITY
 10150A DFO.K=(DFO1.K)(DFO2.K)(DFO4.K)
 10175NOTE DFO -DEPOT FRACTION ORDERED
 10200NOTE DFO1 -DEPOT FRACTION ORDERED 1
 10225NOTE DFO2 -DEPOT FRACTION ORDERED 2
 10250NOTE DFO4 -DEPOT FRACTION ORDERED 4

10275A DFO1.K=CLIP(0,(1/DT),DINV.K,DRP.K)
 10300NOTE DFO1 -DEPOT FRACTION ORDERED 1
 10325NOTE DT -DELTA TIME
 10350NOTE DINV -DEPOT INVENTORY
 10375NOTE DRP -DEPOT REORDER POINT
 10400L DFO2.K=CLIP(0,1,DFO1.J,0.5)
 10425NOTE DFO2 -DEPOT FRACTION ORDERED 2
 10450NOTE DFO1 -DEPOT FRACTION ORDERED 1
 10475A DRP.K=(5)(RP.K)
 10500NOTE DRP -DEPOT REORDER POINT
 10525NOTE RP -BASE REORDER POINT
 10550A DFO4.K=CLIP(1,(DMAP.K/CDEOQ.K),(DMAP.K-CDEOQ.K),0)
 10575NOTE DFO4 -DEPOT FRACTION ORDERED 4
 10600NOTE DMAP -DEPOT MONEY AVAILABLE FOR PROCUREMENT
 10625NOTE CDEOQ -COST OF DEPOT ECONOMIC ORDER QUANTITY
 10650A CDEOQ.K=(DEOQ.K)(UP)
 10675NOTE CDEOQ -COST OF DEPOT ECONOMIC ORDER QUANTITY
 10700NOTE DEOQ -DEPOT ECONOMIC ORDER QUANTITY
 10725NOTE UP -UNIT PRICE
 10750L DMAP.K=DMAP.J+(DT)(DAR.JK-DSR.JK)
 10775NOTE DMAP -DEPOT MONEY AVAILABLE FOR PROCUREMENT
 10800NOTE DT -DELTA TIME
 10825NOTE DAR -DEPOT APPROPRIATION RATE
 10850NOTE DSR -DEPOT SPENDING RATE
 10875R DAR.KL=DSR.JK
 10900NOTE DAR -DEPOT APPROPRIATION RATE
 10925NOTE DSR -DEPOT SPENDING RATE
 10950R DSR.KL=(DPROCR.JK)(UP)
 10975NOTE DSR -DEPOT SPENDING RATE
 11000NOTE DPROCR -DEPOT PROCUREMENT RATE
 11025NOTE UP -UNIT PRICE
 11050N DINV=(5)(BINVI)
 11075NOTE DINV -DEPOT INVENTORY
 11100NOTE BINVI -BASE INVENTORY (INITIAL)
 11125N DFO2=1
 11150NOTE DFO2 -DEPOT FRACTION ORDERED 2
 11175N DMAP=(5)(EMAPI)
 11200NOTE DMAP -DEPOT MONEY AVAILABLE FOR PROCUREMENT
 11225NOTE BMAPI -BASE MONEY AVAILABLE FOR PROCUREMENT (INITIAL)

11250NOTE
 11275NOTE
 11300NOTE CONSUMPTION SECTOR
 11325NOTE
 11350NOTE
 11375L $REI.K = REI.J + (DT)(EIRR.JK - EIFR.JK)$
 11400NOTE REI -READY END ITEMS
 11425NOTE DT -DELTA TIME
 11450NOTE EIRR -END ITEM REPAIR RATE
 11475NOTE EIFR -END ITEM FAILURE RATE
 11500R $EIRR.KL = (PUSER.JK/QPEI)$
 11525NOTE EIRR -END ITEM REPAIR RATE
 11550NOTE PUSER -PARTS USE RATE
 11575NOTE QPEI -QUANTITY OF PARTS PER END ITEM
 11600R $EIFR.KL = NOF.K$
 11625NOTE EIFR -END ITEM FAILURE RATE
 11650NOTE NOF -NUMBER OF FAILURES
 11675R $PUSER.KL = (NREI.K)(QPEI)(PUSERF.K) + OPUR$
 11700NOTE PUSER -PARTS USE RATE
 11725NOTE NREI -NOT READY END ITEMS
 11750NOTE QPEI -QUANTITY OF PARTS PER END ITEM
 11775NOTE PUSERF -PARTS USE RATE FACTOR
 11800NOTE OPUR -OTHER PARTS USE RATE
 11825A $NREI.K = NEIB - REI.K$
 11850NOTE NREI -NOT READY END ITEMS
 11875NOTE NEIB -NUMBER OF END ITEMS ON BASE
 11900NOTE REI -READY END ITEMS
 11925A $PUSERF.K = (MIN(PURF1.K, PURF3.K))(PURF2.K)$
 11950NOTE PUSERF -PARTS USE RATE FRACTION
 11975NOTE PURF1 -PARTS USE RATE FRACTION 1
 12000NOTE PURF3 -PARTS USE RATE FRACTION 3
 12025NOTE PURF2 -PARTS USE RATE FRACTION 2
 12050A $PURF1.K = CLIP(1, (BINV.K/(NREI.K)(QPEI)), (BINV.K -$
 12075I $(NREI.K)(QPEI)), 0)$
 12100NOTE PURF1 -PARTS USE RATE FRACTION 1
 12125NOTE BINV -BASE INVENTORY
 12150NOTE NREI -NOT READY END ITEMS
 12175NOTE QPEI -QUANTITY OF PARTS PER END ITEM
 12200A $PURF2.K = TABHL(PURF2T, REID.K, -10, 1, 1)$
 12225NOTE PURF2 -PARTS USE RATE FRACTION 2
 12250NOTE PURF2T -PARTS USE RATE FRACTION 2 TABLE
 12275NOTE REID -READY END ITEM DISCREPANCY
 12300A $PURF3.K = CLIP(1, (NRC/NREI.K), (NRC - NREI.K), 0)$
 12325NOTE PURF3 -PARTS USE RATE FRACTION 3
 12350NOTE NRC -MAINTENANCE REPAIR CAPABILITY
 12375NOTE NREI -NOT READY END ITEMS

12400A REID.K=RNREI.K-REI.K
 12425NOTE REID -READY END ITEM DISCREPANCY
 12450NOTE RNREI -REQUIRED NUMBER OF READY END ITEMS
 12475NOTE REI -READY END ITEMS
 12500A RNREI.K=(DRR.K)(NEIB)
 12525NOTE RNREI -REQUIRED NUMBER OF READY END ITEMS
 12550NOTE DRR -DESIRED READY RATE
 12575NOTE NEIB -NUMBER OF END ITEMS ON BASE
 12600A DRR.K=CD+WCD
 12625NOTE DRR -DESIRED READY RATE
 12650NOTE CD -COMMAND DIRECTIVES
 12675NOTE WCD -WING COMMANDER'S DESIRES
 12700A NOF.K=(REI.K)(EIFP)(NOISE1.K)(NOFTF.K)
 12725NOTE NOF -NUMBER OF FAILURES
 12750NOTE REI -READY END ITEMS
 12775NOTE EIFP -END ITEM FAILURE PARAMETER
 12800NOTE NOISE1 -NOISE 1
 12825NOTE NOFTF -NUMBER OF FAILURES TIMING FACTOR
 12850A NOFTF.K=STEP(1,IOCD)
 12875NOTE NOFTF -NUMBER OF FAILURES TIMING FACTOR
 12900NOTE IOCD -INITIAL OPERATION CAPABLE DATE
 12925A NOISE1.K=NORMRN(1.0,0.2)
 12950NOTE NOISE1 -NOISE 1
 12975N REI=REII
 13000NOTE REI -READY END ITEMS
 13025NOTE REII -READY END ITEMS (INITIAL)
 13050C REII=98
 13075NOTE REII -READY END ITEMS (INITIAL)
 13100C OPEI=2
 13125NOTE OPEI -QUANTITY OF PARTS PER END ITEM
 13150C OPUR=0
 13175NOTE OPUR -OTHER PARTS USE RATE
 13200T PURF2T=.3/.3/.35/.4/.5/.66/.8/.9/.98/1./1./1.
 13225NOTE PURF2T -PARTS USE RATE FRACTION 2 TABLE
 13250C IOCD=0
 13275NOTE IOCD -INITIAL OPERATION CAPABLE DATE
 13300C EIFP=.0167 PER DAY
 13325NOTE EIFP -END ITEM FAILURE PARAMETER
 13350C MRC=4
 13375NOTE MRC -MAINTENANCE REPAIR CAPABILITY
 13400C CD=.85
 13425NOTE CD -COMMAND DIRECTIVES
 13450C WCD=.05
 13475NOTE WCD -WING COMMANDER'S DESIRES

13560NOTE
 13525NOTE
 13550NOTE CONTROL CARDS
 13575NOTE
 13680NOTE
 13625PLOT DINV=I/DPROCR=P/DRP=R/DEOQ=E/DF01=1/DF02=2/DF04=4/DF0=+
 13650PLOT BINV=I/BPROCR=P/RP=R/EOQ=E/BF01=1/BF02=2/BF03=3/BF04=4/
 13675X BF05=5/BF0=+
 13700PLOT DDR=D/CRD=C/NEWDDR=N/SHDR=S/NDAYS2=2
 13725PLOT EBITL=E/ARF1=1/ARF2=2/ARF4=4/ARF5=5/ARF=A/EOQDL=Q/
 13750X DISC=X/MAXCHG=M
 13775PLOT BISSL=B/WISSL=W/WIARF1=1/WIARF2=2/WIAR=A/
 13800X IWISSL=+/SHDR=S/WTF1=X/WTF2=Y/WTF3=Z
 13825PLOT PUSER=P/EIRR=R/EIFR=F/REI=+/NREI=N/PURF1=1/
 13850X PURF2=2/PURF3=3/PUSERF=U
 13875SPEC DT=1/LENGTH=360/PLTPER=1
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