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ABSTRACT

The U.S. Navy is planning to enter the 21st Century with a large new class of surface combatants which are to be maintained in a manner significantly different from previous procedures. This thesis, through the use of a simulator, will investigate the possible impact of those new maintenance procedures upon aggregate inventory levels. The relevant inventory aspects considered are average inventory level, completion activity and crisis response.

Thesis Supervisor: Harlan C. Meal

Title: Senior Lecturer of Management

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by

RENÉ A. SMITH

Lieutenant Commander
Supply Corps
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B.A., Michigan State University
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SUBMITTED IN PARTIAL FULFILLMENT
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(May, 1978)

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Alfred P. Sloan School of Management, May, 1978

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Most theses have comments concerning the assistance given the author and so shall this one. But here the concern is somewhat broader in scope for the author would like to appreciate herein the efforts of many over the last several years. These are persons, for reasons I have not understood fully, who went out of their way to assist me in some manner, occasionally to their own personal detriment. So to K.F. Thompson, R.D. Goben, R.H. Brown, T.J. McEnaney, and J.K. Konopik, a sincere, belated recognition of my appreciation.

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by

RENÉ A. SMITH

Submitted to the Alfred P. Sloan School of Management on May 5, 1978, in partial fulfillment of the requirements for the Degree of Master of Science.

ABSTRACT

The U.S. Navy is planning to enter the 21st Century with a large new class of surface combatants which are to be maintained in a manner significantly different from previous procedures. This thesis, through the use of a simulator, will investigate the possible impact of those new maintenance procedures upon aggregate inventory levels. The relevant inventory aspects considered are average inventory level, completion activity and crisis response.

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INTRODUCTION

. The surface forces of the United States Navy are preparing to enter the last of the 20th Century with a series of new ships and revised maintenance procedures. The last of the World War II destroyers are being retired and new warships are regularly coming down the ways. The largest class of new ships will be the Oliver Hazard Perry (FFG-7) class with upwards of seventy ships planned for delivery during the next decade.

The Perry-class that will take the surface combatant Navy into the 21st Century is unique in several respects but the principal distinction between it and its predecessors is its maintenance philosophy. Utilizing modern design achievements, it is planned that these ships will have reduced corrective maintenance by on board personnel through an increase in the quantity and a change in the nature of the preventive maintenance. The plan is to replace units at a specified frequency in anticipation of repair. This is planned to relieve a large fraction of organizational level (shipboard) corrective maintenance. It has been decided that these units, and units replaced upon failure, will be repaired by a central depot.

It is the purpose of this paper to reflect upon the implications of this repair decision for inventory management. The methodology employed will be the use of a small scale simulator (1,2,3) in an attempt to identify those aspects of inventory management that are influenced by the depot decision rather than attempt to replicate the entire Navy distribution system. A simulator was developed, not because of any belief in an intrinsically greater value to be derived from a personal modelling effort but because other, presumably applicable models in the Navy's library were unavailable.

It is recognized that the depot repair decision has already been taken (4,5) but the guiding purpose of this effort is to assist the author in his attempts to appreciate some of the complex dimensions of this problem.

CHAPTER I - THE PROBLEM

"The search for and establishment of leading principles, always few around which considerations of detail group themselves, will tend to reduce confusion of impression to simplicity and directness of thought with consequent facility of comprehension."

Alfred Thayer Mahan

Background

The surface combatant forces of the U.S. Navy have evolved through several distinct periods in the recent past to their current structure. A brief description of this process will provide background to the matter under consideration.

The destroyers and cruisers of World War II vintage were characterized by one particular trait: redundancy of equipment. The typical destroyer of that period had five sets of gun mounts, two boiler rooms, two engine rooms, and two propulsion trains. The assembly line-like manufacture of these vessels reduced the incremental cost per unit enough so that the conventional wisdom regarding the need for redundancy did not warrant challenge.

In the 1950's and 1960's, however, there were few production economies of scale to be obtained due to the limited surface combatant construction programs and the escalating costs. Guided missile systems were added to ships, further increasing production and overhaul costs. Vietnam took an aging fleet and literally exhausted it through many years of extended operating cycles.

Another significant event of this period has been the constant relative increase in personnel costs. Life cycle costs, for the first time, received significant notice in shipbuilding design.

Maintenance - Reparables

During this post-World War II period, there was a gradual movement in the manner of repair for surface ships. Nevertheless, these ships generally are repaired in a manner analogous to that of thirty years ago. Every three years, a ship enters a shipyard for extensive overhaul and modernization. These expensive activities often last upwards of six to nine months during which period, obviously, the ship is of little use to the operating Navy.

One manner in which the personnel on board these ships can be characterized is that there are many more of them required for operational duties (standing watch, service functions) than are required for maintenance. These high levels of organizational manning implied a large number of skills with relatively little cross-training. Corrective maintenance was generally performed on board thus requiring extensive test equipment and a large inventory of repair parts (the latter often exceeding 20,000 individual units). Preventive maintenance went through several generations of upgrading attempts but with mixed results (6,7).

Reparables that could not be repaired on board ship were often sent to destroyer tenders which might be considered an intermediate repair activity but normally were not of general usefulness in repairing reparables because of limited facilities. The next echelon, depot level (either organic or contractor), was the level that prepared material to a ready-for-issue (RFI) condition for reentry into the supply system.

It was, and is, a modest system with limited demands upon the repair system, external to the organizational (shipboard) level.

The aviation community, however, has preferred a substantively different reparables maintenance methodology. Because of the nature of aviation requirements, there has been a much more rapid movement into highly specialized reparable components. Because of this growth and the larger numbers of aircraft, there has been a continuing increase in the size and scope of aviation intermediate level repair activity both within the U.S. and overseas.[1] Aviation repair activities have grown in scale to the point where they employ thousands of persons and can complete micro-miniature and "clean room" environment repairs.

The aviation maintenance reporting systems, albeit imperfect, appear to provide more timely and accurate information. This could be because of qualitative differences, i.e. the aviation maintenance technician recognizes that the misapplication of his skills may have mortal consequences. But the quality of the aviation maintenance reporting is such that an exciting new extensive logistics deficiency reporting system, NORS Improvement Program (NIP)[2], may provide the necessary inventory/ maintenance management control system for intermediate maintenance activities.

Thus the aviation and surface branches have used two dissimilar approaches to maintenance procedures. It is suggested that the FFG-7 class provides an opportunity for the surface community to gain from the experience of the aviation community.

[1] While the aviation branch has a number of ex-CONUS shore intermediate maintenance activities, the surface branch apparently does not intend to increase the limited numbers they have overseas. (8)

[2] Discussed in Appendix D.

Inventory Management - Reparables

As previously indicated, the sources for RFI material are either the intermediate maintenance level or the depot level. In the surface community, the intermediate level (the tender) is of little consequence in the inventory management of reparables. Tenders perform a limited amount of repair, primarily that described as being of an emergency nature. Given the antiquated nature of these forces, i.e., they were designed to provide repair assistance to a different vintage of ship and cannot be readily redesigned, there is no reasonable expectation of a significant impact by these ships upon reparable inventories in the near term. Shore Intermediate Maintenance Activities (SIMA) are a relatively new concept and are not currently viable in the surface community in the area of repairing pools of reparable materials. Much effort and expense are being invested in establishing improved SIMA's but primarily to assist in ship repairs and not in the test and repair of reparables. Accordingly, the reparable inventories are maintained at a number of Naval Supply Centers (NSC) with stocks replenished from the depot level. This works moderately well because of the generally low levels of commonality and low demand nature of these components. Also because of the previously indicated redundancy levels, surface combatant operators are accustomed to operating with mildly impaired equipment.

The aviation community inventory management problem is vastly more complex. Many different Intermediate Maintenance Activities (IMA) support different aircraft configurations and levels of repair. The IMA's, however, are critical to the success of the aviation maintenance program since they are capable of repairing and returning to stock many reparables without the transportation, damage and other delays involved in transshipping material to depots. Perhaps the key mechanism by which this is accomplished is the use of rotatable pools of reparables. This pool serves to decouple the IMA repair process from the customer demand generation process. Nearly without exception, these pools consist of reparables that can be repaired at the IMA level. If an item is damaged beyond the capability of the IMA to repair it, then it is shipped to the depot and a replacement is ordered. The rationale is that the pool level must be maintained to accomodate the stochastic effects of depot repair and transshipment times as well as those of the demand process. That is, the buffer stock (rotatable pool) must provide a given service level by accomodating not only demand and repair vagaries but also those of the transshipment and depot administrative delays.

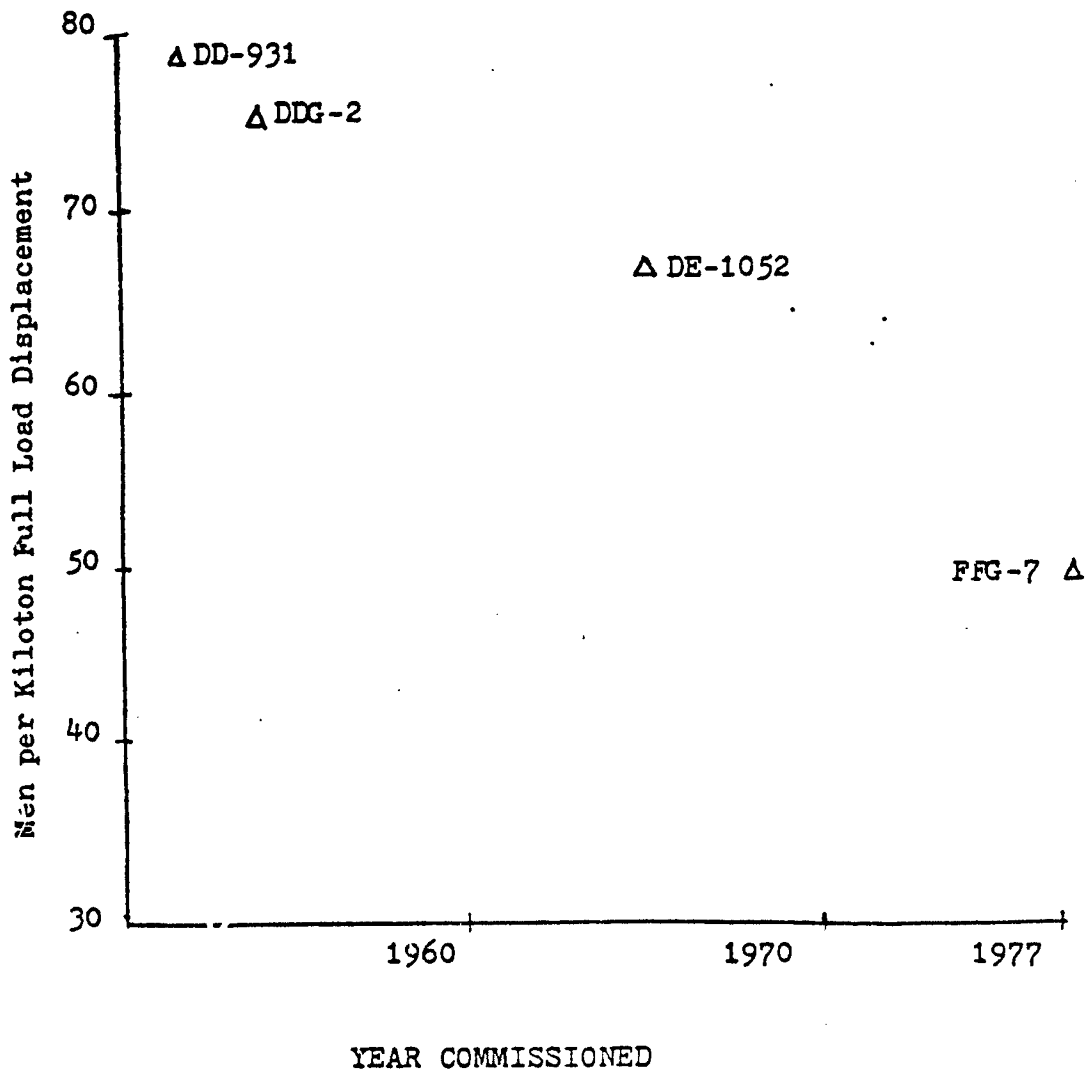
Surface Combatants- The Future

Beginning with the Spruance (DD-963) class of destroyers, the surface Navy initiated a maintenance philosophy change that will continue to be important through the remainder of this century. Subsequent ship types that extend this philosophy include the Perry (FFG-7) class of frigates which will not enter the fleet in substantial numbers for several years. The DDG-47 and PHM classes will not enter the fleet until several years later. But it is the Perry class that is of critical importance to the viability of the surface combatant forces of the late 20th Century since they will constitute nearly 40% of these forces. Because of the magnitude of the construction project for this class, the repair methodology implemented with this class of ship will, of necessity, be followed by these later ship classes.

The figure below indicates the shift in personnel manning levels for these new ships. (9) The operator/ maintenance relationship may finally be changed, i.e. the numbers of required operator manhours may not provide sufficient latitude to perform required maintenance. The implication of this for future combatants is that reparables will have to be readily available at major fleet sites if acceptable levels of operational availability are to be

FIGURE 1

TRENDS IN MANNING DENSITY



maintained since organizational level repair may not be practicable. To ensure a high degree of availability, the aviation branch has moved the repair site to the operational area. The surface branch apparently intends to use remote repair facilities and sufficiently high inventories to obtain comparable availability levels.

Recognizing this, a revised maintenance concept was prepared. No longer would ships go to shipyards for triennial overhauls. Rather, a new concept, the Engineered Operating Cycle (EOC) calls for a 21 day repair period, an IMA(V), at the IMA level every six months with a more extensive 28 day depot repair period (SRA) replacing every fourth IMA(V). But little in the manner of reparables repair can be accomplished in so short a period. Accordingly, the concept requires a specific set of repair actions to be completed each cycle. These are different from those in common practice currently. Reparable components will be removed, prior to failure and replaced during these repair periods. These components will be transshipped to the central depot for possible reentry into the supply system. (Central is perhaps an incorrect term since only an approximate 20% of the FFG-7 class will be located within 3,000 miles of either of the two major depot sites.)

The currently approved plan is that neither tenders nor SIMA's will have a significant repair capability for these approximately 1400 reparables. In fact, it appears as though neither will have the capability even to test many of these "failed" items to determine their actual condition. This latter aspect becomes crucial when material is returned to storage as not ready for issue (NRFI) when, in fact, the material does not need repair and is ready for issue (RFI). There are many events that cause this to happen including overworked personnel, insufficient technical documentation and faulty or incorrect test equipment/procedures. Whatever the cause, the result is the same: RFI material enters the pipeline to the depot repair process greatly increasing the risk that it will be damaged in transit or lost, in addition to being unavailable for issue during the pipeline delay.

There are, of course, good reasons for opting for a depot only repair system. The first is that the system is easier to control. Dedicated repair facilities can be identified and controlled. Second, the variable repair cost at the depot is probably less than it would be at the various SIMA's. It is unlikely that any, much less all, of several major FFG-7 class homeports, would be able to maintain the production efficiencies of one or two large depots.

Summary

The logistics control issues of the surface maintenance picture for the remainder of the 20th Century are coming into sharper focus. They are immensely complex and this introduction has certainly not been intended to relate that complexity. Rather it has served to identify what the author considers to be some critical factors in current and proposed maintenance and, derivatively, inventory management methodology. To the extent that the requirements of these newer classes of ships can be seen as being in some sense similar in nature to the complex aviation maintenance structure, a juxtaposition of practices in use in each arena has been discussed.

In this thesis, I wish to examine the inventory required to support this remote depot configuration. Whether a centralized or decentralized approach is taken, there are control and inventory level issues. The systems discussed above will be represented in a simulation model to assess varying impacts upon the different systems caused by changing operational characteristics.

CHAPTER II - THE MODEL

He had brought a large map representing the sea
Without the least vestige of land;
And the crew were much pleased when they found it to be
A map they could all understand.

Lewis Carroll in
The Hunting of the Snark. Fit the Second.

Introduction

There are many ways systems with a SIMA can be compared with those containing only depots. None is entirely satisfactory since each examines only certain, limited aspects of the logistics chain influenced by the configurational choice.

The Model

Chapter I presented the basic configuration of the currently approved system for the surface branch and an alternative configuration. In this chapter, there follows a description of how these systems operate and how the model has been created to represent these systems.

Description of the Systems

The currently approved system configuration for the FFG-7 class is as shown in Figure 2. Upon the generation of a demand for a reparable assembly, if there is NSC stock, an issue is made and the carcass is forwarded to the depot for repair or replacement from the vendor. If there were no stock at the NSC, the issue would be made from depot stock immediately if there were inventory available. In the event of no initial depot inventory, the issue would be made after depot repair. In either event, the inventory of the issuing activity is incremented when a regeneration into stock is completed. (See Figure 2)

With the addition of a SIMA, the basic flow is altered in only one significant manner, as indicated in Figure 3. In the event that there is no NSC stock, the SIMA might attempt to repair the carcass for issue to the ship. Whenever units are repaired by the SIMA, they are transferred to the NSC for issue to backlogged demands or placed in NSC stock. On those occasions when the SIMA is incapable of completing repair upon the carcass, it is forwarded to the depot and the procedures described above for the depot only system are utilized.

FIGURE 2

MATERIAL FLOW DIAGRAM WITHOUT A SIMA

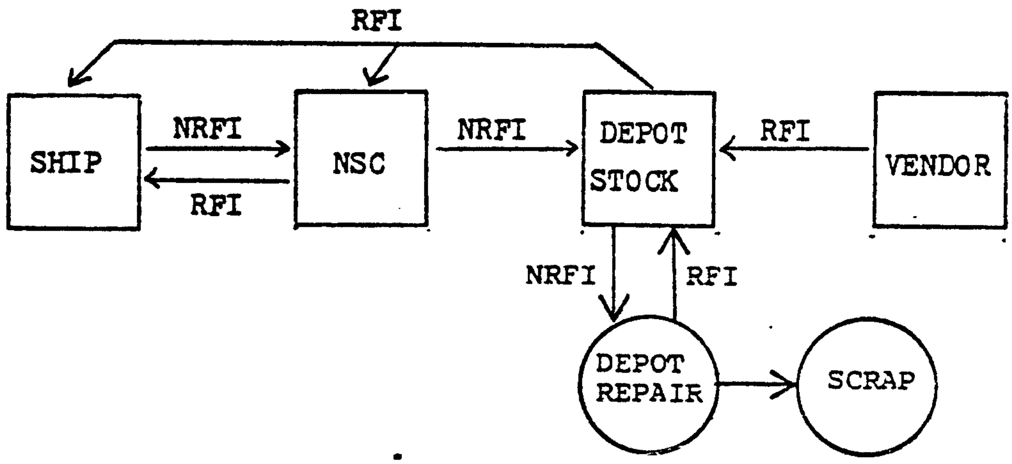
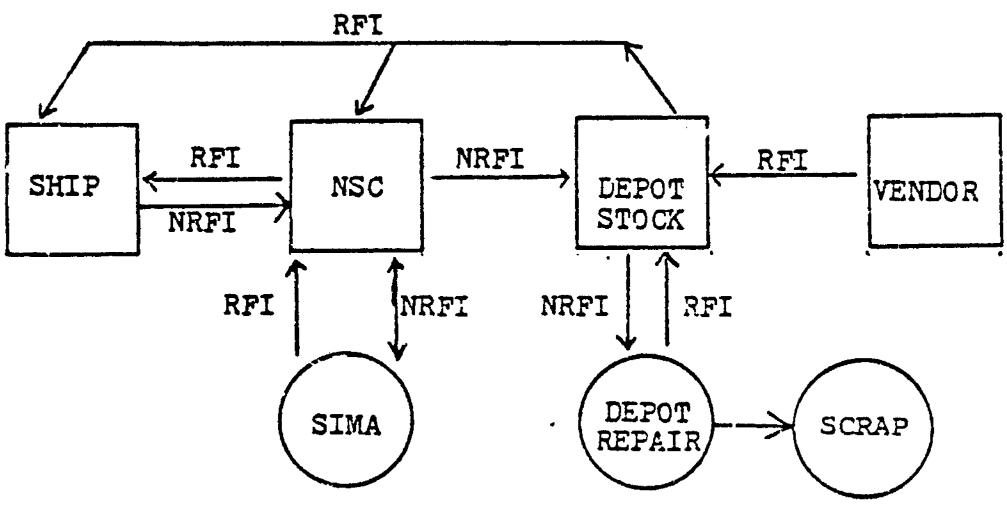


FIGURE 3

MATERIAL FLOW DIAGRAM WITH A SIMA



Description of the Model

The model discussed herein will not be a global description of the problem. Rather, it will consider the problem from a typical supply vantage point: impact upon inventory levels, transshipment and queuing implications. The function of inventories in this model is to decouple the repair cycle from the demand process. Accordingly, a model has been developed that attempts to assess the inventory changes under differing demand generation rates. More elaborate and perhaps more realistic models have been built but were not available to the author.

The Framework

The model of the logistics network is constructed to describe the system described earlier in this chapter. The model definition then is one similar to Figures 2 and 3 with a comparison of the aggregate inventory levels, completion rates and queuing implications of a repair system with and without a SIMA. The SIMA trunk was removed during those runs with only a depot, as in the currently planned distribution system. The reason for this was as expressed earlier: there can be two definitions of an IMA. In the aviation community, it serves to a very great extent as a repair facility for carcass regeneration into inventory.

As presently planned in the surface community, its function will be to satisfy requirements of either an emergency nature or to provide equipment or manpower to assist in ships repairs. This analysis will attempt to determine the benefit from increasing the capability of the SIMA.

Assumptions

The inventory control policy implied by the model is an (S,s) policy. This is maintained in the model through the use of a technique that tests to determine whether the NSC has issued material for which a carcass regeneration has not been made. This "open to buy" procedure ensures that if there are no backlogged demands at the depot level, an RFI carcass is transferred to the NSC if it is in an "open to buy" position. This is directly analogous to the standard Navy reparables policy of one-for-one replacement.

The model is concerned with aggregate inventory levels not the inventory levels of any specific item. This appears to be reasonable for a number of reasons. First, repair capability is rarely established for any single item but rather for groups of items. If a computer module consisted of several electronically similar although non-identical sub-assemblies, it is reasonable to expect that the repair capability established would be for the set of sub-assemblies.

Second, at any place where demands are generated there are several nearly identical originators of these demands.[1] That is, there are separate units which can place demands for components of a similar nature. This view is similar to the Navy's previous modelling efforts in which hull, mechanical, electrical and ordnance material are treated differently from electronic material (13).

The model randomly determines carcasses to be scrapped. These are "regenerated" by creation by a vendor after a specified period of time. This corresponds to Navy practice in that inventory levels are, generally, maintained at a specific level for a given demand rate and replacement is made principally for those items that are scrapped or lost.

It is recognized that this is a generalization that might not universally hold, particularly in a period of increasing demand. However, this model is attempting to assess the environment in a world where there are not sufficient funds to solve all problems by continually procuring additional inventory. It is perhaps merely anecdotal but one of the pervasive logistics shortcomings that the NORS Improvement Program (NIP) is attempting to overcome is the

[1] This is particularly true of the FFG-7 class where contractual incentives have been established to ensure production consistency among equipments on the ships. (10,11,12)

classification of all problems as variants of the same symptom: NIP identifies the specific logistics element that is causing the shortfall. As an example of this problem, consider a pipeline that proves to be nearly infinite. This often occurs during new weapons system introduction when items fail more rapidly than anticipated while new fleet introductions at different locations demand separate pipelines that must be filled. Centralized repair may compound the problem because the increase in user activities, both in number and disposition, is such that by the time material leaves the pipeline, the demand requirements are greater than the material levels. For a given configuration, it may be inordinately expensive to ensure sufficient availability by increasing the amount of inventory in the pipelines in reasonable periods of time. Perhaps with increasing demand, a different configuration may be more effective than increasing inventory.

The model was constructed to employ a conservative structure. One example is the estimate used for overhead and transshipment times. These times were taken to be normally distributed with a constant mean. During periods of increased demand, these times will increase faster in the depot only configuration than in the SIMA configuration.

periods of increased activity these two areas are particularly subject to increasing times that might be characterized differently.

Modelling of Operational Characteristics

Demand Rate. The demand distribution was assumed to be Poisson. A random number generator[1] was utilized to select an interarrival period around a given mean value. Specifically, mean interarrival periods of 30, 20, 15, 10, 5 and 3 days were tested with the first three periods being characterized as low demand items and the second three as high demand items.

Repair Length. The repair time distribution was assumed to be exponential. In the simulation a random number generator was used to determine the repair time required by each demand. The rationale employed is as follows: If the repair process were truly exponential, and if the SIMA, in those runs where it was employed, were perfectly capable and desirous of selecting its' carcass percentages from the most easily repaired, then a simple truncation of the exponential curve would be appropriate.

---

1 A different random number generator was utilized for each random variable.

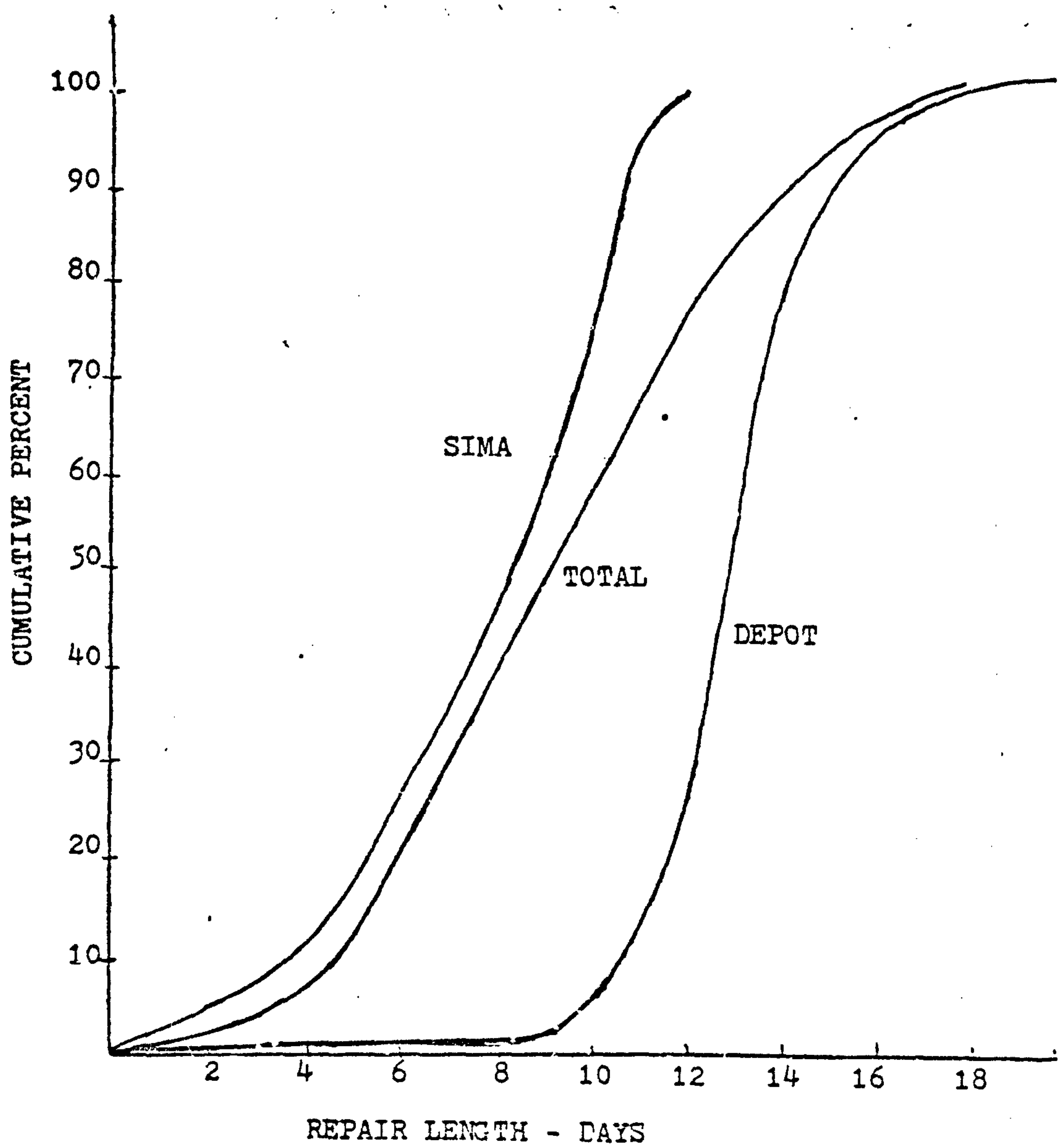
However, given that the totality of repair actions follows a given repair time distribution,[1] it appeared reasonable to attempt to generally separate this cumulative distribution into component functions as indicated in Figures 4 and 5. Accordingly, in the depot only characterization, the total time distribution was utilized (q.v. Figures 4 and 5). In the characterizations where some percentage of repair was completed by the SIMA, different component distributions were utilized depending upon the parameter value for allocation amount to SIMA. That is, different partitionings were made of the total distribution depending upon whether 90% or 60% went to SIMA as indicated in Figures 4 and 5 respectively. The partitioning was made in such a manner that the average and standard deviations of the repair times were maintained regardless of the allocation to the depot.

Flow Charts. The following flow charts reflect the manner in which the simulation program was constructed. A detailed program listing is included in Appendix A. The important point to consider during a review of the flow charts is the distinction maintained between the demand process and the repair process. The model was constructed

[1] It should be emphasized that what is utilized in the repair length process generator is the total repair time distribution with allowances for differing overhead and transshipment times accounted for separately.

FIGURE 4

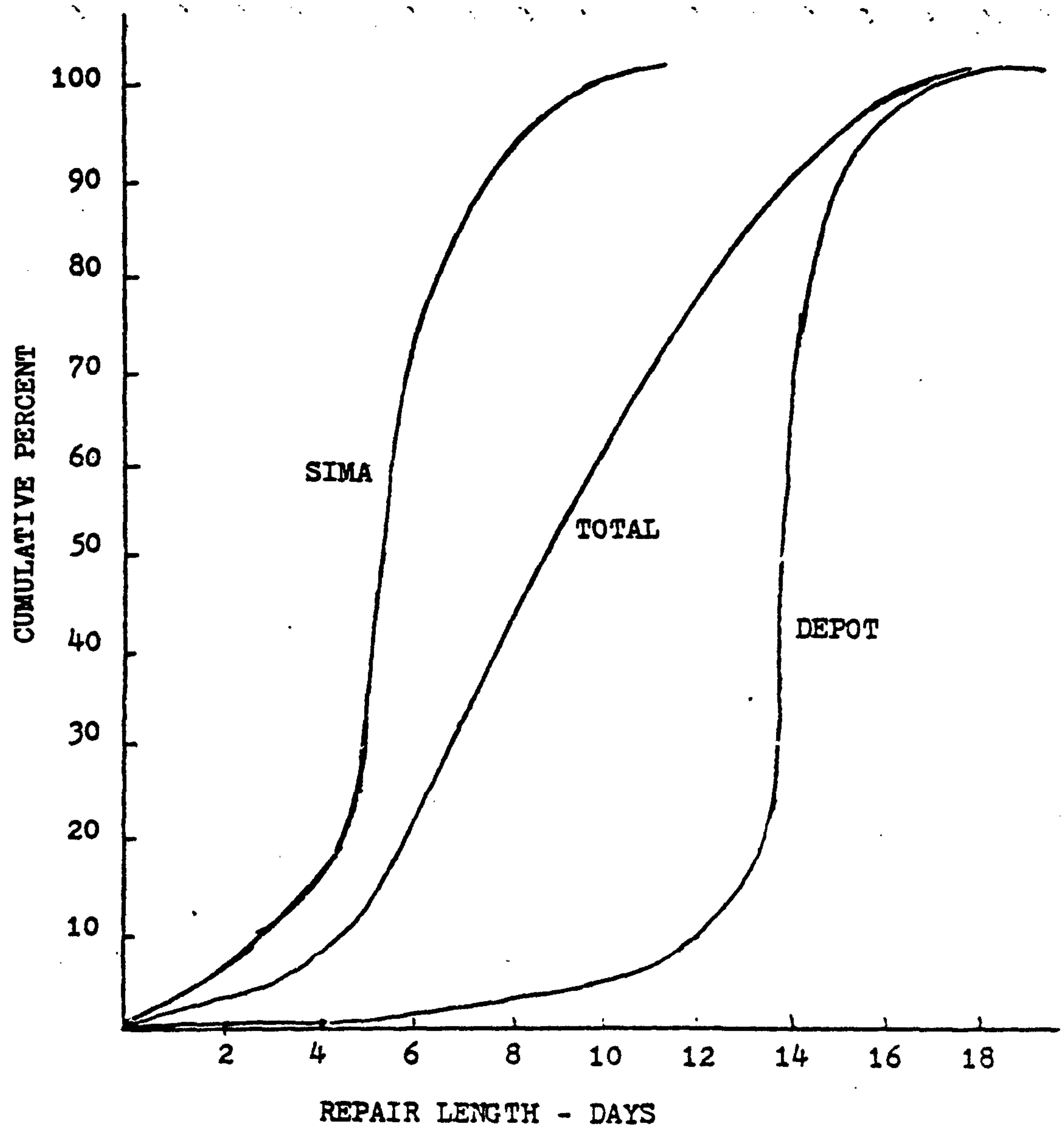
REPAIR DISTRIBUTION - 10% DEPOT ALLOCATION



NOTE: Total represents 100% depot allocation

FIGURE 5

REPAIR DISTRIBUTION - 40% DEPOT ALLOCATION



NOTE: Total represents 100% depot allocation.

in such a way that there would be interfaces between the two processes but that each would maintain its own integrity, just as materiel and requisitions are not interchangeable in any physical sense.

In order to facilitate a review of the flow charts, the following explanation is provided for the procedures and terms that were employed.

Figure 6. This represents the creation (Generate) of a demand for repair at a time (randomly generated) after the last demand. In order to distinguish between materiel and demands (requisitions), the generated demand is "split" with the remainder of this figure replicating the flow of the requisitions. The demand enters the NSC queue where it remains until there is NSC stock available or a predetermined delay period has passed. (If there is stock available when the demand enters the NSC queue, it then has a zero delay time.) If the delay period is excessive, the requisition is transferred to the depot storage facility (Figure 7). Otherwise, an issue is made from the NSC stock. The "open to buy" is an inventory control mechanism that flags the repair facility(ies) that there has been a reduction in the allocated material at the NSC. When a carcass has been repaired, this flag is checked to determine where the material should be provided, i.e. NSC or depot stock.

Figure 7. Upon receipt of the requisition by the depot, the depot inventory is checked for stock. It stock is available, an issue is made. If stock is not available, the requisition is backlogged in the depot queue until stock is available.

Figure 8. This figure is the first of two flow charts representing the flow of materiel in the model. The first decision represents the repair decision based upon a random selection at the pre-determined allocation rate (i.e. 10%, 40% and 100% to depot). If the decision is to have the carcass repaired by the SIMA, Figure 9 applies. If the item is transferred to the depot, a low percentage of items are randomly scrapped[1] and subsequently regenerated by means of vendor procurement. Next, the item is inducted into depot repair where the delay is a function of the repair time randomly determined from the partitioned repair distribution descussed earlier. If the depot queue is greater than zero or the NSC open-to-buy equals zero, the material is transferred to depot stock. Otherwise the material is transferred to the NSC to satisfy the "open to buy" requirement.

[1] Note: This procedure is in accordance with Navy procedures for similar items in which the scrap decision is made by the depot.

Figure 9. The carcass flow in the SIMA is straight forward, consisting of the repair distribution described earlier and the transfer to NSC stock procedure.

FIGURE 6

BASIC FLOW

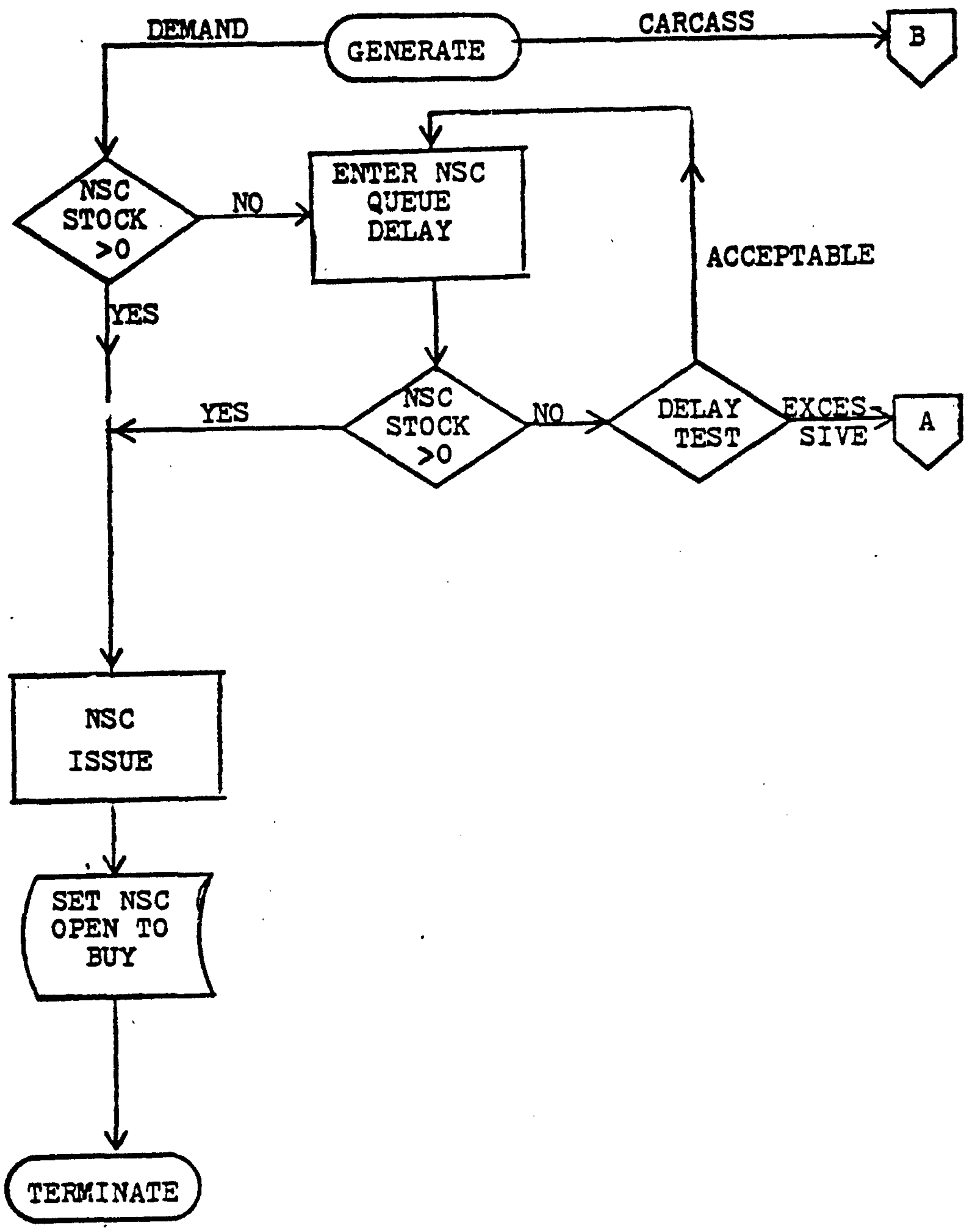


FIGURE 7

CUSTOMER DEMAND FLOW DEPOT

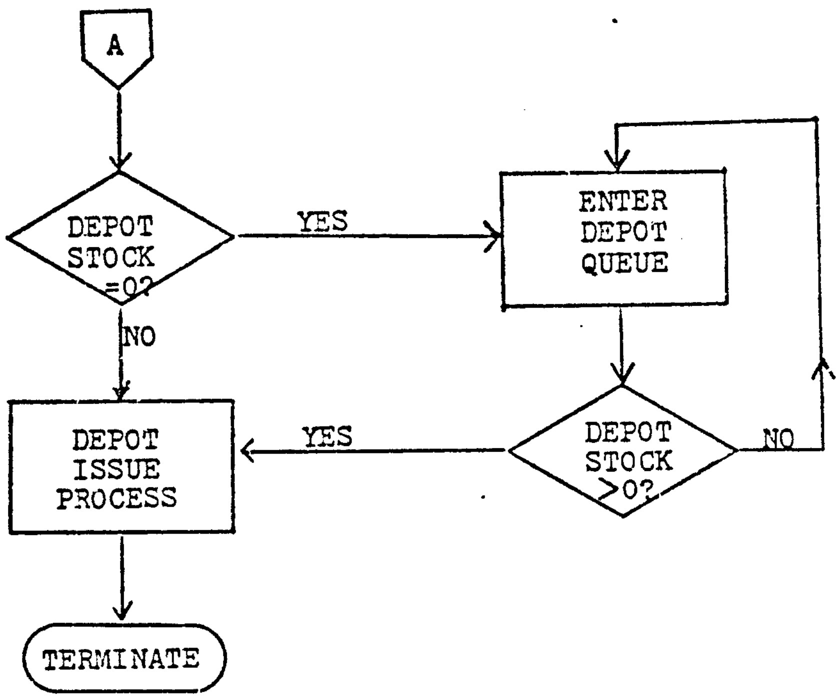
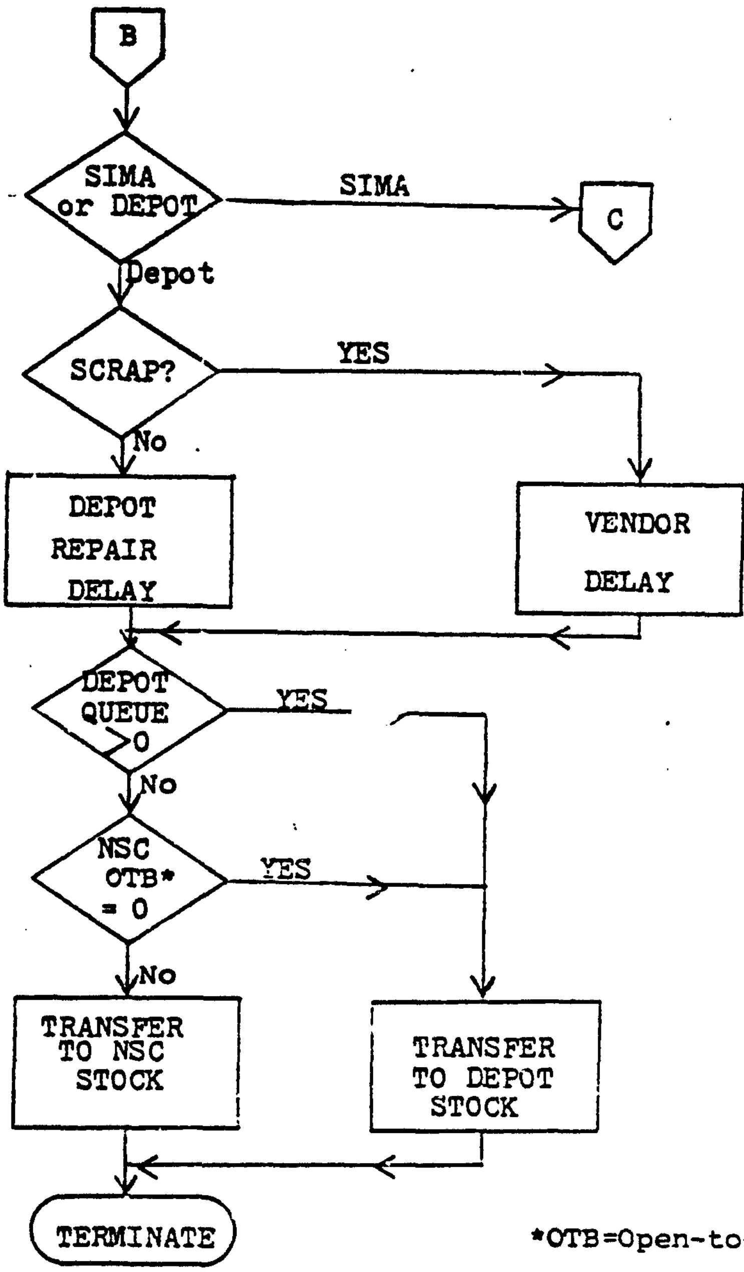


FIGURE 8

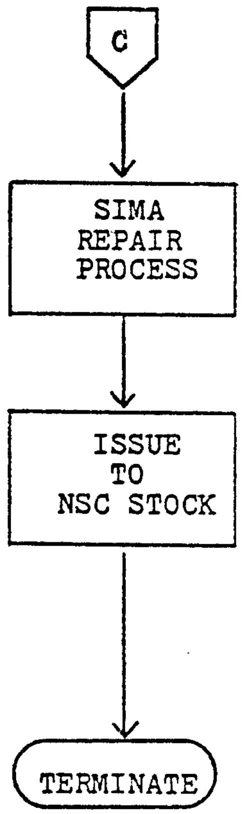
CARCASS FLOW GENERAL



*OTB=Open-to-Buy

FIGURE 9

CARCASS FLOW SIMA



Process Generators

The principal parameter was that which governed the allocation of the carcass to either the SIMA or the depot. Three classes of allocation, as indicated above, were utilized: 100% to depot, 40% to depot, and 10% to depot. It is considered that for most items, some level of repair will be maintained at a depot, thus there was no review made with a 100% allocation to SIMA.

Another parameter was vendor regenerations to represent that portion of carcasses scrapped or lost. To maintain a reasonably consistent impact across the various characterizations, a constant mean regeneration period was utilized.

Storage Contents

Storage contents were initialized at one of two levels depending upon whether the demand rate was greater than once in ten days. If more frequent than this, the NSC and the depot were provided ten units each. If less frequent than this, each was provided with two units each. When an issue is made, an "open to buy" record is established against the appropriate issuing inventory. The first available unit of inventory regenerated from repair or vendor replacement is used to satisfy this requirement if there are no backlogged demands.

Storage and Transshipment Times

In order to ensure that specific changes could be monitored, these times were established in such a manner that they remained constant throughout the series of runs. That is,specific mean time frames were established for each category around a normal distribution. A random number generator was then employed in the selection of the particular time utilized during each transaction.

CHAPTER III - OUTPUT ANALYSIS

"For every complex problem, there is
a quick, simple and incorrect solution."

Attributed to H.L. Mencken

Results Analysis

This chapter will deal with those portions of the data that are considered particularly relevant to the matter under discussion. The data collected from the entire series of runs is presented in Appendix B.

There are three general areas of concern. One is the average inventory level in each of the two inventory/repair systems (i.e.,with or without a SIMA) under the same demand generation rate. The significance of these levels is that a comparison of relative inventory investment costs can be performed. The average inventory levels (AIL) indicate the residual inventory that is available on average to satisfy customer demands and this allows a comparison of inventory investment levels.

Another issue is that of the completion rates for demand satisfaction by the servicing supply center versus the completion rates for the central depot. Without entering into a direct transportation cost tradeoff analysis, a comparison is made of the percentage of demands satisfied by either source and an analysis is made of the manner in which these percentages change as demand generation rates change.

A third concern is the effect upon the system of a crisis overload which has been called a "thrombosis" condition (14). This situation is analyzed to determine the reaction of the system as saturation is approached in the repair process.

Each of these issues will be reviewed in turn in an effort to assess the relative tradeoffs inherent in the SIMA/depot repair question from an inventory control standpoint.

Average Inventory Levels

These are important as relative indicators of the expense due to inventory investment since they represent the inventory available for issue.[1] In the model, initial inventory levels were set at two units for low demand items (q.v. page 39) and ten units for high demand items at both the servicing supply center and central depot. Thus, there is a caveat required at this point because any nonweighted

[1] Concomitantly, they provide a relative measure of the service level possible with a given inventory level.

intergroup comparisons between demand rate groups may be inaccurate because of the difference in the initial inventory levels.

Another issue that requires discussion is that of the total system inventory including that of the demand generators. If there is an infinite customer population, it is possible that the actual inventory in the system is not consistent for different demand rates.[1] The differences that were found did not appear to be significant enough to alter any of the conclusions presented in this chapter. This is principally because the conclusions reached are based on significant variances in the comparable output between the two systems and the minor changes in inventory levels should not affect these comparisons.

Finally, it is considered critical that the repair process assignment methodology be clearly understood. As discussed earlier, the sigmoidal repair time distribution was not mearly truncated. Rather, the distribution was partitioned on the basis of the repair allocation (0%, 60%, or 90% to SIMA). Thus, to ensure comparability among runs, the constructs with a SIMA were created by removing random segments of the depot repair distribution so as to create

[1] This is because the AIL in the storage points might be impacted by the migration of units from the customer into the storage points.

the curves presented earlier. There was then a division of the same total workload as indicated in Figure 4.

As indicated earlier, two groupings by demand rate characterization were made and these are reflected in Tables 1A and 1B which show the total inventory levels at the inventory points (NSC and Depot) available for issue. The configuration with a SIMA has a higher level of inventory available for issue. Considering the low demand rate items, it is apparent that in both allocations as the demand rate increases, the average inventory level (AIL) decreases. This, of course, is to be anticipated given the nature of material movement. What is worthy of note is the rapidity of decrease in AIL for the allocation without a SIMA as opposed to that with a SIMA. The increase in demand rate from once every thirty days to once every fifteen days results in a reduction in available inventory by 32% with a SIMA and 76% without a SIMA or a 2.4 times faster decrease in available inventory without a SIMA. For the high demand items, the same relationship was found to exist although the higher initial inventories provide a less dramatic relative change.

Another manner in which this can be discussed is from the implied service level changes. As indicated in column four in Tables 1A and 1B, given the same initial inventory

TABLE 1A - LOW DEMAND

AIL COMPARISON - DEPOT ONLY VERSUS WITH SIMA

MEAN TIME BETWEEN DEMANDS	AVERAGE INVENTORY LEVEL WITH SIMA	WITHOUT SIMA	% GREATER AIL AVAILABLE FOR ISSUE WITH SIMA *
30 days	3.50	2.78	18%
20 days	2.91	1.92	25%
15 days	2.39	.67	43%

NOTE: As demand rate increases, AIL decreased 2.4 times as fast without a SIMA compared to with a SIMA. Initial inventory total was four.

TABLE 1B - HIGH DEMAND

AIL COMPARISON - DEPOT ONLY VERSUS WITH SIMA

MEAN TIME BETWEEN DEMANDS	AVERAGE INVENTORY LEVEL WITH SIMA	WITHOUT SIMA	% GREATER AIL AVAILABLE FOR ISSUE WITH SIMA *
10 days	18.83	18.38	2%
5 days	19.14	17.33	9%
3 days	17.31	14.91	12%

NOTE: Again, AIL decreased 2.4 times as fast without a SIMA compared to with a SIMA. Initial inventory was twenty.

* This value is derived by taking the difference between the AIL in the two cases over the initial inventory, i.e.

$$\frac{AIL_{SIMA} - AIL_{NO\ SIMA}}{INITIAL\ INVENTORY}$$

there is always a greater inventory available for issue with a SIMA and as the demand rate increases, the SIMA is better able to accommodate this increase.

These data indicate that with a SIMA, as the demand rate increases there is less of an impact on AIL than in the depot only construct and thus a greater degree of flexibility to respond to exogenous shocks. This not only means that the probability of satisfying a demand is greater but also that if the issue rate for the depot is considered satisfactory, a similar issue rate could be obtained with a SIMA and a lower investment level for inventory.

Completion Rates

The question here is of the ability to respond to a customer's demand within a "reasonable" period of time. Completion rates thus provide a proxy that is useful at looking at response times. What is examined here are the relationships found to exist between the total percentages supplied by either the NSC or the depot in comparison with the relative changes in total completion times. Table 2 provides such a comparison of output results from various runs with similar repair time distributions. There are qualifications that must be presented with this analysis. A problem with any physical structure issue such as this is thatt key factors may be incommensurable. The SIMA is established as being closer to the customers and is simulated accordingly. Thus, the transportation costs will be less. Also, the SIMA should be prepared to maintain those items requiring the most frequent repair. (Pareto's distribution law may apply here, i.e., that there is a small percentage of items that will constitute the significant percentage of total repair actions.)

TABLE 2

COMPARISON OF RESPONSE TIMES AND COMPLETION RATES

DEPOT ONLY VERSUS WITH SIMA

MEAN TIME BETWEEN DEMANDS	MEAN TOTAL RESPONSE TIMES		FRACTION OF TOTAL RESUPPLY FROM NSC	
	WITH SIMA (days)	WITHOUT SIMA (days)	WITH SIMA	WITHOUT SIMA
30 days	3.4	8.1	.95	.17
20 days	3.4	10.8	.94	.27
15 days	3.8	22.9	.88	.07

The following results are of particular note. For each allocation scenario, the total response time increased as the demand interarrival period shortened. This is, of course, to be expected. The results presented in Table 2 indicate that increased demand rates have less of an impact when there is a SIMA. Also, a higher percentage of issues come from the NSC when there is a SIMA thus providing a decreased transportation expense for the reparable items. There is another matter worthy of comment in addition to the question of flexibility that has just been raised. That is, the material tied up in the pipeline is greater if all maintenance must be done by the depot. This explains the increased response times noted in Tables 1A and 1B which was reflected in a reduced AIL during comparable periods.

Table 2 indicates two things. First, with a SIMA, the total mean repair time can be greater than in a depot only situation and still yield comparable response times to the user. Stated differently, there appears to be a greater flexibility in the SIMA arrangement to absorb an increase in repair times. Second, maintaining a SIMA increases the number of demands satisfied by the servicing NSC thus reducing the overall inventory and transportation costs.

The "Thrombosis" Concern

The reaction of the systems to overload was studied. We may expect, given the very nature of national defense, large increases in demand under certain conditions and thus steady state environments are of lesser concern. As evidenced by the work done on airport cargo handling (14), it is clear that downtime or overload of 1% can have significantly greater long range effects than might be implied from the overload time.

Table 3 shows the results of comparable runs that rapidly reach a steady state. (The other data presented in this report are also of this nature except as indicated below.) Table 4 reports data from a particular set of runs specifically designed not to stabilize. The mean repair time was set such that it exceeded the mean time between demands. It is obvious that these runs are in, and would continue in, transience. They will have queues that grow without limit. The purpose was to assess the impact of an exogenous shock, some occurrence that caused the system to be out of balance for the period under review. It was considered important to assess the responses of the depot only versus the "with SIMA" configurations to conditions of this nature.

Table 3 shows that the rate of growth in both queue

TABLE 3

QUEUE SIZE AS A FUNCTION OF REPAIR LENGTH/ALLOCATION

STEADY STATE CASE *

MEAN TIME BETWEEN DEMANDS	DEPOT ALLOCATION	AVERAGE UNITS IN REPAIR QUEUE	AVERAGE TIME IN QUEUE
20 days	100%	.43	12.9 days
	10%	.48	11.5 days
10 days	100%	1.0	13.5
	10%	.77	8.21

TABLE 4

QUEUE SIZE AS A FUNCTION OF REPAIR LENGTH/ALLOCATION

TRANSIENT CASE**

MEAN TIME BETWEEN DEMANDS	DEPOT ALLOCATION	AVERAGE UNITS IN REPAIR QUEUE	AVERAGE TIME IN QUEUE
15 days	100%	6.3	91.0 days
	10%	1.2	21.9 days
5 days	100%	26.7	124.0 days
	10%	14.8	76.0 days

** Mean repair times are similar within each demand rate category and greater than the mean time between demands.

* Mean repair times are similar within each demand rate category and less than the mean time between demands.

size and queue wait time increases in a significantly greater amount for the depot only configuration when there is an increase in the demand rate. It should be noted that in all cases of Table 3, the mean repair time/mean time between demands ratio has been held constant.

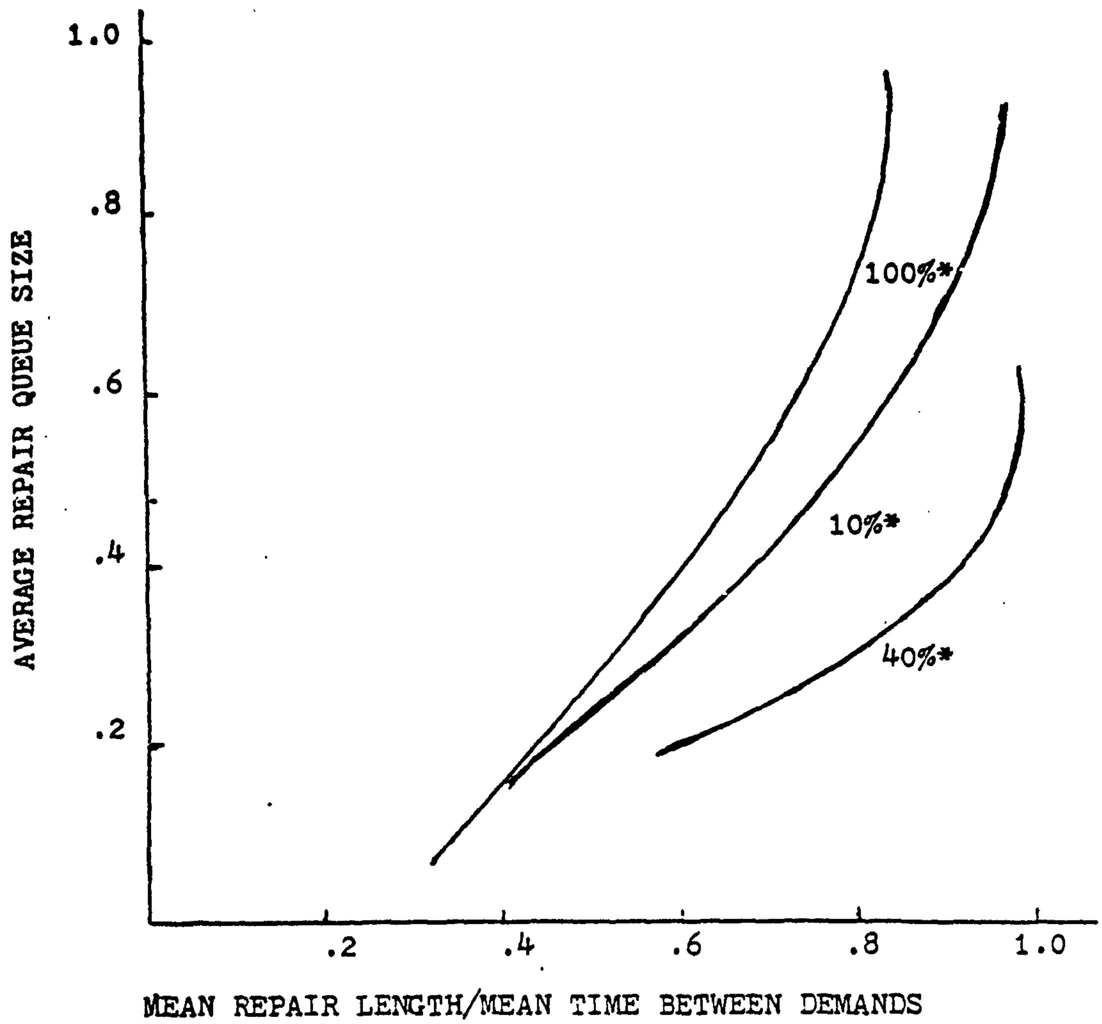
It should be noted that the comparison between 100% and 10% allocations is the more conservative of the two comparisons that could have been made. The reason for this is that the SIMA begins to encounter queuing problems and capacity limitations analogous to those experienced by the depot. In the case where the depot receives 40% of the demands, there is a balancing that takes place between the two queues with a more efficient utilization of resources. This can be seen through the results expressed in Figure 10.

Table 4 shows the results as the mean repair/mean time between demands ratio rises above 1.0. With two queues operating, there is a much less rapid deterioration in the ability to satisfy customer demands as witnessed by the fact that even after a tripling of the demand rate, the SIMA construct queue length is still only one-half the size of the depot only queue length.

The values in Table 3 are more clearly explained with reference to Figure 10 which reflects the data from a larger series of runs. This figure has as its horizontal axis the ratio of the mean repair time and mean time between demands as its vertical axis the average repair queue size. This shows the impact upon the system's ability to respond, on average, to a change in the demand rate relative to the repair length. Albeit a crude measure, it does provide an indication of the degree of flexibility inherent in each allocation methodology to respond to changes in the demand rate. The results would appear to indicate that there is a much less dramatic impact by demand rate changes upon either SIMA configuration than there is upon the depot only configuration. That is, the depot only configuration was much more sensitive to changes in the demand rate and the queue grew much more rapidly than in either other configuration.

FIGURE 10

QUEUE SIZE AS A FUNCTION OF REPAIR LENGTH/DEMAND



* Depot Allocation

CHAPTER IV - CONCLUSIONS

"The true strength of a prince does not consist so much in his ability to conquer his neighbors as in the difficulty they find in attacking him."

de Montesquieu, The Spirit of the Laws

The model's output has been utilized principally to address three facets of inventory control decision rules. The results addressed in Chapter III will be expanded upon here to form the basis of this report's conclusions.

Average inventory level is of concern because it is a lifetime cost. After the ships are purchased, the major cost is the operation and upkeep over the projected lifetime. Given the complexity of current technology and the rapidity of change much inventory becomes outmoded. There are two major concerns with the average inventory levels (AIL): iventory levels rachet upwards as more ships enter the fleet, and the larger this inventory the greater the cost of obsolescent inventory. On site (SIMA) repair of the rotatable pools requires much less inventory than the current plan to repair rotatables only at depot. Use of a SIMA in this way, therefore, provides an opportunity to reduce the cost of supporting the new fleet.

The servicing supply activity is another concern. The issue raised earlier was principally one of the magnitude of pipeline fill and transportation cost inherent in either configuration (with or without SIMA).

There are a number of other concerns that are raised by this configurational issue. Admiral Zumwalt has written about the "unions" (15) in the Navy: the hegemonies that are the aviation, surface and submarine fields. It would appear that this issue might be raised here. There is the painful experience of the aviation community over the last several years as it has attempted, with mixed success at best, to come to grips with the supply/maintenance interface question. It has become clear that making the "supply types" custodians of material far removed from the scene of the demand has caused many problems--fractionalization being a major one.

The FFG-7 reparables system is institutionalizing the supposed differences in the maintenance problems of aviation and surface by establishing a different maintenance philosophy. Perhaps it is doing the same in the surface community by not allowing for the similarities that are to be found in the Spruance class and the DDG-47 class. The aviation community has attempted to move maintenance and supply together by expanding repair capability at the customer site while striving to retain centralized control through the use of the NORS Improvement Program (NIP) and the Individually Consolidated Repair List (ICRL).[1] The work reported here indicates the surface Navy should do the same in supporting the new fleet units.

The "thrombosis" concern has been raised in the form of the airport cargo handling problem but it is not nearly so limited in scope. Deterrence, as indicated by the earlier quote, is one's effectiveness in peacetime in convincing potential enemies that one is capable of responding well and quickly in the event of conflict. To be convincing, the supply and repair support system should be able to respond to a greatly increased load with only minimal performance degradation. The system should not become choked and unable to respond at all.

This paper cannot address the marginal cost of shipping in wartime particularly the incremental cost of shipping from the Mediterranean litorral to a west coast site versus

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[1] These are briefly described in Appendix D and although they are only now coming to fruition, they provide powerful tools for not only centralized management of IMA's but also the capability to identify which logistics element is causing equipment degradation. An interesting recent effort discussing the shortcomings of the surface maintenance data collection system and another localized attempt to repair it is given in reference 7.

an east coast site.[1] It is clear, however, that the capacity of those supply lines will be exceeded by the demand.

These concerns are expansions on the "supply type" concern over inventory into a logisticians concern over support capability during an emergency. The model's output suggests that the inventory problem alone is serious enough to cause concern. The overload cases tested suggest that the systems with local repair capability are much less vulnerable to saturation or congestion problems.

Restructuring the surface combatant forces is a monumental undertaking and one aspect of it, depot level repair, has not been decided lightly.

There are strong arguments in favor of the depot only position, principally the ability to concentrate labor and capital investment. But the arguments have not, at least as far as the author has been made aware of them, addressed the magnitude of the impact upon inventory control levels and decision rules.

There is great concern these days in the Armed Services over life-cycle costs (18) and one is constantly

[1] The Navy's refusal to maintain surface repair capability in Europe, even given apparent airlift constraints in case of emergency, have been dealt with elsewhere. Interesting aspects of this issue are raised in references 8, 16, and 17.

reminded of these factors during all program development stages. This life-cycle cost concern is the crux of the issue raised here. The author is aware of the current and near term manning shortfalls in skilled trades. The author is equally cognizant of the historical basis for the current SIMA's. This basis was derived more from a need to provide shore duty for technical ratings that were suffering retention problems due to excessive sea duty rather than a concern over the establishment of a generalized industrial repair base. But the author's concern is that the shortcomings of the past and immediate future may be used as the rationale for the solutions applied to new problems.

An additional comment relative to the aviation maintenance procedure may be in order. Repeated experience has shown that many items are removed that are not, in themselves faulty. The ability, locally, to readily detect this saves not only transportation and depot repair time and,concomitantly, dollars, but also the damage that ensues from multiple handling. The author believes it is impractical to maintain a rotatable pool at the fleet sites without local repair capability. In aviation, only the most expensive items with failure free warranties and complex, separate system shipping and control procedures were ever able to satisfy, generally, pool demands for items not reparable locally.

It is the author's opinion based on prior experience and the results described above that the Navy will be unable to meet CNO imposed standards of operational availability (14) unless the SIMA concept is expanded to include a significant check and test and repair capability at each of the fleet sites.

APPENDIX A

MODEL PROGRAM LISTING

```
*LOC    OPERATION  A,B,C,D,E,F,G             COMMENTS
*       ************************************************************
*       *************************************************************
*
*
*       *      * *****  *       * *   *     *  ****** ****  **** *
*       **     * *    * *      *   * *     ** **  *     *   * *  *
*       * *  * * *****   *    *     *      * ** * *     *   * ***  *
*       *   ** * *    *   *  *      *      *    * *     *   * *    *
*       *    *** *    *    **       *      *    * *     *   * *    *
*       *     ** *    *     *       *      *    * ****** ****  **** *****
*
*
*       *************************************************************
*       ************************************************************
 REPRD FUNCTION   RN5,C11      DEPOT REPAIR TIME 7EAN=14.2
0.0,0.0/0.01,8.0/0.02,9.0/0.05,10.4/0.1,11.8/0.2,13.4/0.3,14.0/
0.85,14.6/0.9,14.8/0.95,15.6/0.999,18.0
 REPRS FUNCTION   RN4,C11      SIMA REPAIR TIME FUNCTION MEAN=5.5
0.0,0.0/0.02,1.0/0.05,2.6/0.1,3.6/0.2,4.4/0.5,5.5/0.8,6.6/0.9,7.6/
0.95,8.4/0.98,9.0/0.999,11.0
 NINTY FUNCTION   RN7,C13      SIMA REPAIR TIME(NINTY PERCENT) MEAN=8.6
0.0,0.0/0.03,2.0/0.05,3.0/0.1,4.0/0.18,5.0/0.5,8.6/0.6,9.6/0.7,10.2/
0.8,10.6/0.9,10.8/0.95,11.0/0.98,11.4/0.999,12.0
 TEN   FUNCTION   RN2,C13      DEPOT REPAIR TIME(TEN PERCENT) MEAN=12.6
0.0,0.0/0.01,8.8/0.02,9.2/0.05,10.0/0.1,10.8/0.25,12.0/0.5,12.6/
0.7,13.0/0.8,13.8/0.9,14.8/0.95,15.0/0.98,15.4/0.999,18.0
 REPRT FUNCTION   RN6,C11      TOTAL REPAIR TIME FUNCTION MEAN=9
0.0,0.0/0.02,2.0/0.04,3.0/0.08,4.0/0.16,5.0/0.5,9.0/0.84,13.0/
0.92,14.0/0.96,15.0/0.98,16.0/0.999,18.0
 POISS FUNCTION   RN1,C16      POISSON INTERARRIVAL GENERATION FCN
0.003,8.0/0.007,5.0/0.018,4.0/0.05,3.0/0.14,2.0/0.37,1.0/0.41,0.9/
0.45,0.8/0.497,0.7/0.55,0.6/0.61,0.5/0.67,0.4/0.74,0.3/0.819,0.2/
0.905,0.1/0.9997,0.001
 DISCR FUNCTION   RN3,C3       DISCRETE DISTRIBUTION FUNCTION
0.,0./.87,1.0/.999,1.0
 EXPON FUNCTION   RN8,C24      EXPON DISTRIBUTION MEAN=1
0.,0/0.1,0.104/0.2,0.222/0.3,0.355/0.4,0.509/0.5,0.69/
0.6,0.915/0.7,1.2/0.75,1.38/0.8,1.6/0.84,1.83/0.88,2.12/
0.9,2.3/0.92,2.52/0.94,2.81/0.95,2.99/0.96,3.2/0.97,3.5/
0.98,3.9/0.99,4.6/0.995,5.3/0.998,6.2/0.999,7.0/0.9997,8.0
*                              *************************
*                              * STORAGE INITIALIZATION *
*                              *************************
        STORAGE    S$QTR1,361
        STORAGE    S$QTR3,361
        STORAGE    S$QTR5,361
        STORAGE    S$QTR7,361
        STORAGE    S$QTR9,361
        STORAGE    S$NSCST,100
        STORAGE    S$DEPST,150
        STORAGE    S$WAIT,100
        GENERATE   1,,,1
 NLOAD  ENTER      NSCST,11
        LEAVE      NSCST          NSC INITIAL STORAGE=2
 DLOAD  ENTER      DEPST,11
```

```
      LEAVE       DEPST
      TERMINATE
INTRO GENERATE    10,FN$POISS
*                            ************************
*                            * POINT OF ENTRY ROUTINE *
*                            ************************
FIRST SPLIT       1,DORS
*******************DEMAND*******************
      ASSIGN      5,C1          PLACE RELATIVE CLOCK TIME IN P5
WAIT  ENTER       WAIT
      ADVANCE     1
    1 VARIABLE    (C1-P5)
      TEST LE     V1,K3,DEP
      LEAVE       WAIT
GTE1  GATE SNE    NSCST,WAIT
NSCST ENTER       NSCST
      SAVEVALUE   3+,1          INC NSC OPEN TO BUY
      LEAVE       NSCST,2
      ADVANCE     2,1
      TABULATE    6
    6 TABLE       M1,0,1,20
      TERMINATE
*                               ************************
*                               *  DEPOT STORAGE ISSUE  *
*                               ************************
DEP   QUEUE       2
    2 QTABLE      2,10,10,40
      ASSIGN      4,S7
GTE2  TEST G      P4,0
DEPST ENTER       DEPST         DECREMENT DEPOT STOCK
      LEAVE       DEPST,2
      ADVANCE     2,1
*                               ************************
*                               * DEPOT STORAGE DELIVERY*
*                               ************************
      ADVANCE     3,2
      TABULATE    8
    8 TABLE       M1,5,5,40
      TERMINATE
*******************CARCASS*******************
*                                ***********************
*                                * SIMA REPAIR ROUTINE *
*                                ***********************
DORS  TRANSFER    .1,SIMA,SCRAP
SIMA  QUEUE       3
    3 QTABLE      3,10,5,40
      SEIZE       SIMA          SEIZE FACILITY NAMED SIMA
      DEPART      3
SIMRP ADVANCE     1,FN$NINTY
      RELEASE     SIMA
      TABULATE    9
    9 TABLE       M1,10,5,20
NSCSD ENTER       NSCST,2
      SAVEVALUE   3-,1          DECREMENT NSC OPEN TO BUY
      LEAVE       NSCST
      ADVANCE     1
      TERMINATE
```

```
                                             *******************
*                                            *  SCRAP DECISION  *
*                                            *******************
*
SCRAP  ASSIGN     7,FNSDISCR                 SCRAP TEST
       TEST E     P7,0,VENDR                 TEST IF P7 E 0 ELSE GO TO VENDOR DELAY
DEPOT  QUEUE      4
     4 QTABLE     4,10,5,40
       SEIZE      DEPOT                      FACILITY--DEPOT
       DEPART     4
DEPRP  ADVANCE    1,FNSTEN
       RELEASE    DEPOT
       TABULATE   10
    10 TABLE      M1,50,10,20
DPSIN  TEST G     Q2,0,OTBNS
*                                            TEST DEPOT Q-IF LE 0 GO TO OPEN TO BUY
*                                            NSC. IF OTBNS LE 0 INCREMENT DEPOT INV.
       ENTER      DEPST,2
       LEAVE      DEPST
       TERMINATE
                                             **********************
*                                            *  VENDOR REPAIR LOOP  *
*                                            **********************
*
VENDR  ENTER      VENDR
       LEAVE      VENDR
       ADVANCE    200,FNSEXPON
       TABULATE   11
    11 TABLE      M1,200,20,20
       TRANSFER   ,DPSIN
                                             *******************
*                                            *  NSC OPEN TO BUY  *
*                                            *******************
*
OTBNS  TEST LE    X3,0,NSCSD                 IF X3 LE 0,ISSUE TO DEPOT STOCK.
*                                            ELSE GO TO NSCSD
       ENTER      DEPST,2
       ADVANCE    9,2
       LEAVE      DEPST
       TABULATE   12
    12 TABLE      M1,50,10,40
       TERMINATE
```

APPENDIX B

MODEL OUTPUT

... [illegible] Poisson

Run Nr.	Mean Repair Time		Depot %	Number of Demands	Inventory Avg. Contents		Demands Satisfied		Demands Satisfied	
	SIMA	Depot			NSC	Depot	NSC	Avg. Time	Depot	Avg. Time
2A	----	18.0	100	25	.68	2.1	4	3.3	20	9.1
2B	11.0	28.4	40	15	.98	2.9	14	3.1	1	10.0
2C	17.2	25.2	10	19	2.0	1.5	18	3.1	1	8.0

Interarrival Period 30 days - Poisson

Run Nr.	Mean Repair Time		Depot %	Repair Queue Avg. Contents		Avg. Time of Wait		Fraction of Time Occupied		Avg. Time per Occupying Transaction	
	SIMA	Depot		SIMA	Depot	SIMA	Depot	SIMA	Depot	SIMA	Depot
2A	---	18.0	100	---	.35	---	12.1	---	.471	---	17.0
2B	11.0	28.4	40	---	---	---	---	.054	.12	4.9	12.4
2C	17.2	25.2	10	.23	---	8.6	---	.386	---	14.7	---

Interarrival Period 20 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Number of Demands	Inventory Avg. Contents		Demands Satisfied		Demands Satisfied	
	SIMA	Depot			NSC	Depot	NSC	Avg.Time	Depot	Avg.Time
1A	---	11.0	100	30	.45	2.51	4	3.25	25	8.76
3	---	18.0	100	33	.21	1.71	9	3.33	24	13.63
4	11.0	28.4	40	28	1.23	2.13	20	3.2	7	9.14
5	11.0	28.4	40	33	1.21	1.91	24	3.04	9	9.0
6	17.2	25.2	10	31	1.87	1.04	29	3.03	2	8.0

Interarrival Period 20 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Repair Queue Avg. Contents		Avg. Time of Wait		Fraction of Time Occupied		Avg. Time per Occupying Transaction	
	SIMA	Depot		SIMA	Depot	SIMA	Depot	SIMA	Depot	SIMA	Depot
1A	---	11.0	100	---	.22	---	6.1	---	.374	---	10.4
3	---	18	100	---	.43	---	12.9	---	.55	---	17.3
4	11.0	28.4	40	.051	.07	1.9	5.67	.264	.314	10.1	25.2
5	11.0	28.4	40	.1	.08	3.1	7.63	.355	.267	10.7	24.1
6	17.2	25.2	10	.485	---	11.6	---	.615	.037	15.9	27.0

Interarrival Period 15 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Number of Demands	Inventory Avg. Contents		Demands Satisfied		Demands Satisfied	
	SIMA	Depot			NSC	Depot	NSC	Avg. Time	Depot	Avg. Time
1B	---	5.5	100	44	.34	2.5	12	3.75	31	9.2
7	---	18.0	100	57	.07	.6	3	3.3	43	24.3
5A	---	25.2	100	51	.08	1.4	5	3.0	29	9.21
5B	11.0	28.4	40	49	.61	2.27	24	3.08	23	9.0
4A	11.0	28.4	40	41	.71	1.92	26	2.96	14	8.64
4B	17.2	25.2	10	43	1.7	.69	36	3.03	5	9.6
8	8.6	12.6	10	54	1.31	1.95	48	3.15	6	8.83

Interarrival Period 15 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Repair Queue Avg. Contents		Avg. Time of Wait		Fraction Time Occupied		Avg. Time per Occupying Transaction	
	SIMA	Depot		SIMA	Depot	SIMA	Depot	SIMA	Depot	SIMA	Depot
1B	---	5.5	100	---	.05	---	.5	---	.259	---	5.1
7	---	18.0	100	---	6.3	---	91.0	---	.941	---	17.4
5A	---	25.2	100	---	10.7	---	161.0	---	.988	---	23.8
5B	11.0	28.4	40	.1	.55	2.3	18.8	.360	.785	10.8	27.0
4A	11.0	28.4	40	.5	.264	1.6	11.9	.323	.597	10.1	26.9
4B	17.2	25.2	10	1.2	---	21.9	---	.880	.061	16.7	22.0
8	8.6	12.6	10	.3	---	3.8	---	.493	.094	7.4	11.3

Interarrival Period 10 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Number of Demands	Inventory Avg. Contents		Demands Satisfied		Demands Satisfied	
	SIMA	Depot			NSC	Depot	NSC	Avg. Time	Depot	Avg. Time
5C	---	5.0	100	63	.33	3.25	10	3.4	51	9.37
5D	---	5.0	100	84	.15	3.13	13	3.1	64	8.84
4C	---	5.0	100	64	7.38	11.0	63	3.0	---	---
5E	---	28.4	100	61	.12	1.05	5	3.0	33	9.15
5F	---	25.2	100.	84	.02	.45	2	3.5	33	9.21
4D	---	28.4	100	56	.4	4.12	13	3.46	43	9.21
1C	---	5.5	100	74	6.35	9.99	74	3.2	---	---
3A	---	9.0	100	65	.24	.95	4	3.5	57	14.2

NOTE: The series of runs numbered 3 and 5 have initial inventory equal to number 2, all others equal 10.

Interarrival Period 10 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Repair Queue Avg. Contents		Avg. Time of Wait		Fraction Time Occupied		Avg. Time per Occupying Transaction	
	SIMA	Depot		SIMA	Depot	SIMA	Depot	SIMA	Depot	SIMA	Depot
5C	---	5.0	100	---	.191	---	2.42	---	.371	---	4.7
5D	---	5.0	100	---	.208	---	2.05	---	.392	---	4.0
4C	---	5.0	100	---	.228	---	2.75	---	.313	---	3.8
5E	---	28.4	100	---	9.0	---	132.0	---	.975	---	27.1
5F	---	25.2	100	---	24.8	---	242.0	---	.988	---	24.6
4D	---	28.4	100	---	13.35	---	209.0	---	.997	---	26.63
1C	---	5.5	100	---	.12	---	1.3	---	.436	---	4.9
3A	---	9.0	100	---	1.0	---	13.5	---	.635	---	8.8

NOTE: The series of runs numbered 3 and 5 have initial inventory equal 2, all others equal 10.

Interarrival Period 10 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Number of Demands	Inventory Avg. Contents		Demands Satisfied		Demands Satisfied	
	SIMA	Depot			NSC	Depot	NSC	Avg. Time	Depot	Avg. Time
5E	5.5	14.2	40	65	.81	1.46	37	3.16	25	9.76
4E	5.5	14.2	40	83	6.91	10.93	83	3.0	---	---
4F	17.2	25.2	10	105	1.04	2.86	58	3.17	45	9.65
4G	2.0	5.0	10	72	8.84	9.99	72	3.0	---	---
5H	8.6	12.6	10	76	7.49	10.86	75	3.05	---	---

NOTE: The series of runs numbered 5 have an initial inventory equal 2, all others equal 10.

Interarrival Period 10 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Repair Queue Avg. Contents		Avg. Time of Wait		Fraction Time Occupied		Avg. Time per Occupying Transaction	
	SIMA	Depot		SIMA	Depot	SIMA	Depot	SIMA	Depot	SIMA	Depot
5G	5.5	14.2	40	.06	.27	1.4	6.7	.219	.536	4.94	13.3
4E	5.5	14.2	40	.31	.06	3.8	2.19	.410	.361	4.93	12.43
4F	17.2	25.2	10	24.1	---	177.0	---	.997	.194	14.67	23.3
4G	2.0	5.0	10	.04	.005	.41	.799	.138	.067	1.56	9.8
5H	8.6	12.6	10	.77	---	8.21	---	.685	.085	7.37	10.3

NOTE: The series of runs numbered 5 have an initial inventory equal 2, all others equal 10.

Interarrival Period 5 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Number of Demands	Inventory Avg. Contents		Demands Satisfied		Demands Satisfied	
	STMA	Depot			NSC	Depot	NSC	Avg. Time	Depot	Avg. Time
1D	---	10.0	100	85	6.33	11.0	84	3.0	---	---
2D	---	9.0	100	133	.64	3.16	16	3.06	70	9.2
5I	---	5.5	100	72	.05	4.39	3	3.3	61	9.05
5J	---	12.6	100	56	.13	1.16	5	3.4	29	9.45
4H	---	5.5	100	77	5.34	10.14	67	3.07	10	8.8

NOTE: The series of runs numbered 5 have an initial inventory equal 2, all others equal 10.

Interarrival Period 5 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Repair Queue Avr. Contents		Avg. Time of Wait		Fraction Time Occupied		Avg. Time per Occupying Transactions	
	SIMA	Depot		SIMA	Depot	SIMA	Depot	SIMA	Depot	SIMA	Depot
1D	---	10.0	100	---	.33	---	1.6	---	.368	---	1.73
2D	---	9.0	100	---	26.7	---	124.0	---	.977	---	8.6
5I	---	5.5	100	---	1.6	---	9.4	---	.786	---	4.73
5J	---	12.6	100	---	5.4	---	132.0	---	.972	---	12.54
4H	---	5.5	100	---	2.26	---	11.5	---	.925	---	4.99

NOTE: The series of runs numbered 5 have an initial inventory equal 2, all others equal 10.

Interarrival Period 5 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Number of Demands	Inventory Avg.Contents		Demands Satisfied		Demands Satisfied	
	SIMA	Depot			NSC	Depot	NSC	Avg.Time	Depot	Avg.Time
4I	2.0	5.0	40	73	8.02	9.97	73	2.95	---	---
3B	5.5	14.2	40	98	1.76	12.1	98	3.34	43	9.2
8A	2.0	5.0	10	74	9.17	9.97	74	3.2	---	---
9A	8.6	12.6	10	95	1.74	3.2	95	3.31	20	29.15
4J	8.6	12.6	10	58	1.09	4.09	58	3.1	22	9.0

Interarrival Period 5 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Repair Queue Avg. Contents		Avg. Time of Wait		Fraction Time Occupied		Avg. Time per Occupying Transaction	
	SIMA	Depot		SIMA	Depot	SIMA	Depot	SIMA	Depot	SIMA	Depot
4I	2.0	5.0	40	.19	.07	1.3	1.6	.235	.199	1.6	4.5
3B	5.5	14.2	40	.8	2.96	7.1	37.4	.563	.957	5.0	13.3
8A	2.0	5.0	10	.4	2.1	.03	2.4	.315	.069	1.65	8.3
9A	8.6	12.6	10	25.0	.04	126.0	1.7	.941	.143	7.45	10.9
4J	8.6	12.6	10	14.46	.3	66.9	9.1	.977	.415	7.2	12.5

Interarrival Period 3 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Number of Demands	Inventory Avg.Contents		Demands Satisfied		Demands Satisfied	
	SIMA	Depot			NSC	Depot	NSC	Avg.Time	Depot	Avg.Time
8B	---	2.0	100	72	4.65	10.26	56	3.25	12	8.92
8C	2.0	5.0	40	61	5.91	10.75	56	3.02	4	8.75
10A	8.6	12.6	10	73	2.3	4.3	13	3.23	13	9.23
8D	2.0	5.0	10	64	8.78	8.53	58	2.95	5	9.4

Interarrival Period 3 days-Poisson

Run Nr.	Mean Repair Time		Depot %	Repair Queue Avg. Contents		Avg. Time of Wait		Fraction Time Occupied		Avg. Time per Occupying Transactions	
	SIMA	Depot		SIMA	Depot	SIMA	Depot	SIMA	Depot	SIMA	Depot
8B	---	2.0	100	---	1.0	---	3.07	---	.486	---	1.63
8C	2.0	5.0	40	.22	1.62	1.11	12.74	.309	.541	1.6	5.76
10A	8.6	12.6	10	23.5	---	57.7	---	.856	.071	35.8	6.0
8D	2.0	5.0	10	2.24	---	6.76	---	.502	.038	1.52	2.3

APPENDIX C

ABBREVIATIONS

ABBREVIATIONS

AIL - Average Inventory Level

A_o - Operational Availability

CNO - Chief of Naval Operations

EOC - Engineered Operating Cycle

ICRL - Individual Component Repair Lists

IMA - Intermediate Maintenance Activity

IMA(V) - Intermediate Maintenance Availability

I_o - Initial Inventory

NIP - NORS Improvement Programs

NRFI - Not Ready for Issue

NSC - Naval Supply Center

RFI - Ready for Issue

SIMA - Shore Intermediate Maintenance Activity

SRA - Selected Restricted Availability

APPENDIX D

.ORS IMPROVEMENT PROGRAM

The NORS Improvement Program was created as a joint project of the maintenance and supply organizations within the naval aviation community. The primary impetus was the realization that logistics shortcomings were much more complicated than the generalized symptom they presented: lack of parts. Accordingly, an effort was established to identify the specific cause of inoperable equipments.

The key in this process is the reporting procedures at the IMA level when used in conjunction with organizational level data. Thus, there is the capability to specifically identify the cause of the problem. This program not only highlights the true nature of logistics support problems but also purifies the reporting data necessary to identify actual material requirements.

Prior to this program, the Navy inventory managers established material levels on the basis of supply data in limited conjunction with often poor maintenance data. With NIP, the two sources of data, maintenance and supply, are carefully melded into a product of use to both communities. But most important, the results are synergistically greater than the sum of the inputs. Through the data purification and interface programs, changes in logistics procedures can be determined and controlled at the headquarters level. For the supply community, the program can provide trade-off curves detailing the degree of expected equipment degradation as a function of procurement funds available. For the maintenance community, the specific logistics element and its impact can be identified and plans for rectifying the problem can be employed.

The importance of this information cannot be overemphasized. Too often, even in the author's limited experience, funds have been spent purchasing more parts when another element (publications, training, facilities, etc.) was the cause of the degradation. This clearly amounts to chasing bad money with good as in the example given earlier of the nearly infinite pipeline.

The author is aware that there is no panacea for complex logistics problems such as those to be experienced on the FFG-7 class program. What is suggested, however, is that reliance on current surface systems for the control of the supply/maintenance interface will probably not work as well as other tools that are available. And the author sees no reason why the best tools available cannot be utilized by the surface forces. It is feared that the SIMA's, whether they do a large amount of reparable regeneration or not, will prove to be the opening at the end of the long pipeline that cannot be centrally controlled unless a program such as NIP is implemented.

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NOTE:

All material utilized in this thesis has been drawn from unclassified sources in keeping with the Massachusetts Institute of Technology's policy regarding the use of classified material in the preparation of theses. Any classified references have not been utilized but are provided as final source documents.