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Monterey, California

THESIS

CRITICAL ITEM IDENTIFICATION

by

June A. Bishop

September 1987

Thesis Advisor: Michael G. Sovereign

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The Joint Chiefs of Staff are concerned about the military's ability to deter enemy action and counter enemy forces. In an effort to assess capabilities and have a basis for apportioning items, the Unified Commands were asked to identify critical items. This paper looks at the various methods the Navy uses to determine critical items with the objective of finding a consistent method for critical item determination. Based on the results of research, the validity of existing programs used in critical item identification could improve if there was more communication between the Fleet Commander in Chief and his Type Commanders and Navy Supply Systems Command. Better communication would also make model results available to all for use in planning.

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Critical Item Identification

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ABSTRACT

The Joint Chiefs of Staff are concerned about the military's ability to deter enemy action and counter enemy forces. In an effort to assess capabilities and have a basis for apportioning necessary items, the Unified Commands were asked to identify critical items. This paper looks at the various methods the Navy uses to determine critical items with the objective of finding a consistent method for critical item determination. Based on the results of research, the validity of existing programs used in critical item identification could improve if there was more communication between the Fleet Commander in Chief and his Type Commanders and Navy Supply Systems Command. Better communication would also make model results available to all for use in planning.

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I. INTRODUCTION

Critical is a term that has connotations of something requiring immediate response. The word "critical" is over-used. Because of its frequent use, everyone thinks they understand what "critical" means. If asked to give a definition of "critical", everyone's definition is slightly different. For clarity and consistency, one should provide the desired definition when discussing "critical". Unfortunately, this is usually not done and results are predictably diverse. When the word "critical" is used by the military in reference to principal or secondary items, the confusion caused is the same as in the civilian sector. This thesis deals with identification of critical items which are loosely defined as items which, when not carried by the unit, affect the unit's capability to perform its assigned mission.

Efforts to identify critical items in the Navy have primarily centered around identifying which platforms and munitions are necessary to meet the threat and determining how many of these platforms and munitions are needed. Traditional efforts to determine which items on the platform were required involved looking at which items were used in the past and using that information to determine which items would be required in the future. The item with the highest demand was considered the most important (critical) and no consideration was given to the impact the item had on the unit's operational capability. Therefore, until recently, little effort had been put into trying to determine which equipment on the platform must be functioning for the platform to accomplish its mission. Recent efforts to determine critical items have been directed toward new ship and aircraft construction programs. It is relatively easy to theorize about a new ship or airplane that will accomplish a given mission. It is much harder to put theory into practice by designing, developing and producing the theorized craft with the needed capability and reliability. It is harder still to take an existing ship or aircraft and determine which systems should be improved or changed so the platform can accomplish the given mission.

The majority of the work done by the Navy with critical items has been in improving readiness rather than trying to determine which items are in short supply or have the greatest impact on availability. Efforts have been directed toward better prediction of requirements to raise the probability of being ready to face any future contingency.

This thesis will present the background on how the author became interested in this topic[1] and what is being done by the Navy today. It discusses methods used by the Navy to determine requirements (planning) and how the operational side of the Navy responds when planned requirements do not meet demands. Those times that requirements do not meet demands have the potential of providing candidates for "critical" items. The situation causing a demand for an item must be known before it can be determined that the item is "critical". One of the major problems with critical item identification is that "critical" is situation dependent. This thesis also presents:

1. Areas where planners need to do more work
2. Areas where the various echelons of command need to improve communication
3. Areas where planners and operators need to improve communication

Improvements in these three areas will facilitate critical item identification. Finally, some topics in the area of critical item determination that need further study are presented.

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[1] The author first became aware of the problems involved in critical item identification while assigned to the staff of the Commander in Chief, U. S. Naval Forces Europe as a logistics planner.

II. BACKGROUND

Because of the Defense Department's shift of attention to the Joint Commander's level of readiness, critical items, critical spares and essential sustainability are currently of concern in Department of Defense circles. The primary concerns about these items are:

1. How can we identify what is critical
2. How do we determine how stock much we need to meet the demand for the critical item
3. How do we provide the critical items in the necessary quantities
4. Is there some mix of items that will give a higher level of effectiveness in terms of criticality per dollar when funds are limited

Several attempts have been made to identify which items are critical. [Ref. 1: pgs. 2 - 4]. This is not a static set of identifiable items and it is hard to find a general consensus among military planners of what is critical. Furthermore, any set of critical items identified today may not be applicable to the world situation tomorrow.

In 1983 the Joint Chiefs of Staff tasked the Unified Commands and their components to provide a list of critical items. This list was to be included in the Logistics Annex to the Joint Strategic Capabilities Plan. The items on this list would be apportioned to the theater or service with the greatest need, by the Joint Chiefs of Staff in time of war. [Ref. 2] The items to be included were: (1) any item in short supply or (2) anything that could be classified as a "war stopper". No clarification on what constituted a "war stopper" was given. Each Unified Commander in Chief was allowed to identify no more than 500 critical items and could allocate these to his service components as he thought best. The Commander in Chief, U. S. Naval Forces Europe was allocated 120 Navy/Marine Corps critical items.

From the Navy's point of view this task was not well defined and was difficult to do. The Joint Chiefs of Staff did not provide a clear, concise description of what they expected and the tasked the service component commands, through the Unified Commanders in Chief to provide information that should come from the services.

The Fleet Commander in Chief does not have control over supply in the Navy. That function belongs to the Navy Supply Systems Command which has overall responsibility for determining requirements for material and procuring it for the entire

Navy. The Type Commanders for air, surface and subsurface also become involved in this process because they provide input to the Navy Supply Systems Command, through the Ships Parts Control Center and the Aviation Support Office, about which parts have the highest demand. The Ships Parts Control Center and the Aviation Support Office maintain usage data for the entire fleet, afloat and ashore. Identification of critical items which are "items in short supply", the first definition of critical given above, is not appropriate at the Fleet Commander in Chief level because the Fleet Commander in Chief can only identify what is in short supply in his theater. The term "short supply" refers to an item whose present stocks are less than the predicted demand for the item. Being in short supply in one theater does not necessarily mean an item is in short supply for the entire Navy. For example, it is possible for an item, such as fuel, to be in short supply in a particular theater due to lack of storage facilities in that theater but for worldwide stocks of fuel to be sufficient for total Navy demand.

The other definition of critical given above, those items classified as "war stoppers", if "war stopper" is defined as an item that keeps a platform/unit from performing its mission, is already included in the Semi-Annual Situation Report. [Ref. 3] No clarification was given by the Joint Chiefs of Staff on whether the critical items to be identified were to be in addition to those in the Situation Report.[2] Eventually the lists were prepared and submitted, along with a request for additional clarification of the Joint Chiefs of Staff definition of critical. The critical items identified by the Unified Commands included such items as ammunition, repair parts, Advanced Base Functional Components, major end items, and were published in the 1984 Joint Strategic Capabilities Plan Logistics Annex.

The philosophy of the Joint Chiefs of Staff on critical items has changed somewhat since 1983. The Staff tends to understand the lack of response in providing "lists" for the sake of providing lists, which was the only apparent purpose since no incentives were given for the Unified Commanders in Chief or for their Components to provide the lists. No additional funds to procure items identified as critical were made

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[2] Within the Navy, a Semi-Annual Situation Report is made by every command, to the command's reporting senior. This report is a review (often lengthy) of achievements, on-going programs/projects, or problems encountered by the command. The report covers the entire range of personnel, material conditions, material shortfalls, support provided, support needed, mobilization capability, readiness, intelligence, and other conditions that a command has encountered. The report also has a section for the Commander in Chief or unit Commander to identify critical items.

available, and peacetime apportionment of critical items was not discussed. The potential for wartime apportionment served as a disincentive for providing the lists requested by the Joint Chiefs of Staff. No service or Commander in Chief wants to spend its budget dollars on items it thinks it will need in time of war only to have the items taken away because another theater or service did not plan adequately. The present Joint Chiefs of Staff policy is that critical items will be identified in the Situation Reports. Once critical items are identified, the services must provide information on consumption rates and current stockage levels by theater in accordance with Reference 4 .

The critical item lists and the information from the Logistics Factors Report will eventually be used by the Logistics Capabilities Estimator module of the Joint Operational Planning and Execution System to provide a logistics capability assessment of operations plans. The Logistic Capabilities Estimator will be usable by every echelon of command that uses the Joint Operational Planning and Execution System to develop operation plans, to evaluate the Command's portion of the operation plans. The Logistics Capability Estimator will be an upgrade to the current Joint Operational Planning System Movement Requirements Generator and will do everything the Movement Requirements Generator does and more. The Movement Requirements Generator is presently used to forecast gross tonnages of lift required to move resupply. It can subdivide the requirements by class of supply, type of movement (air or surface), origin, port of embarkation, port of debarkation, and date required. The Logistics Capability Estimator uses the critical items and capabilities discussed above to match capabilities to the requirements forecasted by the Movement Requirements Generator and flag as shortfalls those requirements without corresponding capabilities. These shortfalls will then be reviewed by planners who can either (1) make adjustments to (a) requirements, (b) timing or (c) strategy as necessary to accomplish the mission or (2) advise those concerned that the mission cannot be completed and identify the critical items needed to complete the mission. [Ref. 5]

The Joint Operational Planning and Execution System is an iterative replacement for the Joint Operational Planning System. The installation of the first phase is scheduled to start in 1989. The automated logistic estimate will not be available for several years, but a manual analysis will be possible if the services submit the information for the Logistics Factors Report. [Ref. 6]

Discussions with personnel in Chief of Naval Operations (OP-401) and the Office of the Secretary of Defense, Programs, Analysis and Evaluation, Navy, regarding the analysis of the critical item lists submitted, indicate that the methods of determining critical items are as varied as the groups trying to determine what is critical. The first decision to be made in this thesis is which definition of critical to use. This thesis will combine the operational definition and the supply definition of critical resulting in critical items being defined as items which are both: (1) in short supply and (2) capable of causing the failure of the next highest component or system. Discussion will be limited to secondary items which, in Navy Supply Systems Command terminology, are repairables, consumables, and repair parts. These items are being considered because so much emphasis and study has been put into areas like munitions and weapons.

The Secretary of Defense is quoted in Reference 1 as saying ". . . If we do not have adequate munitions to execute our plans to destroy enemy targets, there is little point in possessing sustainability for other items . . . " [Ref. 1: pg. 5]. What the Secretary of Defense did not say was that if we do not have the operational platforms and weapons systems from which to launch those munitions, there is little point in having the munitions. A balance must be achieved. Having just operational availability or sustainability, without the other, is of little benefit.

A problem exists in knowing which items are in short supply today that may be needed in time of war. The Joint Chiefs of Staff want the Services and the Unified Commanders in Chief to identify their wartime requirements and the existing capabilities to meet those requirements. This thesis will discuss the methods the Navy uses to determine requirements, which is a major portion of the planning process. It will look at the impact of the recent shift from a demand based method to an availability based method for determining requirements for spare parts. Since planned requirements do not always match actual operational demands and the times when planning does not match demands are the times items potentially become critical, options available when shortfalls occur will be discussed. Some topics, which have not been discussed in the reports of current work in requirements determination, are presented as areas which need further study for planning procedures to be complete.

Since critical items are both nebulous and temporal, expending a lot of effort to define and identify what is critical is not the most productive use of time or money. Our efforts would be better rewarded by trying to make our planning efforts more closely relate to operations. The better our planning is, the less we will have to rely on back-up measures, such as critical item identification, to see us through when the plans fall short.

III. REQUIREMENTS DETERMINATION

Imagine yourself as a naval power. You own a fleet of ships, with each ship in a given state of readiness. You also have standard levels of readiness you would like each ship to achieve. What can be done to bring those ships not at the specified level of readiness up to standards? What can be done to maintain the ships at the specified levels of readiness? These questions are being dealt with routinely in the U. S. Navy, both from a planning viewpoint and from an operational/execution viewpoint. This chapter will look at three programs in use to accomplish the above tasks from the planning perspective of requirements determination (forecasting demand).[3] For each program, there will be a discussion of the theory used, how the program calculates requirements and the program's general effectiveness.[4] The execution aspects of these programs will be looked at in Chapter IV.

In 1982 the Secretary of the Navy and the Chief of Naval Operations established operational availability as the new measure of effectiveness for logistics support [Refs. 7,8,9]. The prior measure of effectiveness the Navy used for logistic support was percentage of demands satisfied. The method of determining requirements must be changed to fit the new measure of effectiveness. Therefore some initiatives, sponsored at the Chief of Naval Operations staff level, which address readiness improvement are receiving attention by the Navy Supply Systems Command and Navy Contractors. The two methods of determining requirements that will be discussed in this thesis are the demand based method and the availability improvement method.

A. DEMAND BASED STOCKAGE COMPUTATIONS

Determining requirements deserves some comments at this point. Demands can be classified as either deterministic or probabilistic. A deterministic demand has a constant usage rate which is assumed to be known with certainty. A probabilistic

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[3] Requirements determination will be used throughout this thesis when referring to the planning process of forecasting demands. The phrase "requirements determination" is used to avoid the inherent confusion involved in trying to keep forecast demand and actual demand straight.

[4] None of the models or programs presented will determine criticality. Based on the definition of critical used in this thesis, no item is inherently critical nor is any item universally critical. Criticality is scenario dependent.

demand has a usage rate that varies according to a probability distribution which is assumed to be known and continuous. [Ref. 10: pgs. 78, 126]

Predicting spare parts for an item whose demand is deterministic does not present much of a challenge. If the usage rate is known with certainty, providing adequate spare parts is a straight forward process.

When demand is probabilistic, the use of a demand based model allows room for error. Knowing the probability distribution of demand doesn't give the exact demand at any given time. It only gives an estimate that is similar to the actual demand. Predicting the number of spares required becomes harder because the demand distribution must also be predicted. If the probability distribution of demand is known, it is possible to determine a number of spares that will meet close to 100 percent of demand for a given period of time. Figure 3.1 is the cumulative density function for a Poisson demand with rate 10. From the figure it can be seen that nearly 100 percent of demand (actually 99.84%) would be met if 20 items were stocked. This will give total protection against downtime due to unavailability of spare parts. It will also cost a lot in terms of capital invested in inventory and space for storage. The military is generally not allowed the luxury of 100 percent protection. What is sought is a lower level of protection for a decrease in capital expenditure and a decrease in the storage space required. Finding the appropriate mix of items to accomplish this is extremely difficult.

Requirements determination, using demand based methodology, uses the best replacement factor for an item. The best replacement factor (usually referred to as BRF) is a demand rate derived from reliability studies, contractor predicted usage or Navy history of failure data from similar items. The best replacement factor is updated annually by the Ships Parts Control Center using a weighted function based on the demand for that item during the previous year and the existing best replacement factor for that item. The equation for the best replacement factor recomputation is:

$$\begin{aligned}\text{New BRF} = \alpha \times &(\text{New Average Rate of Demand}) \\ &+ (1 - \alpha) \times (\text{Old BRF})\end{aligned} \qquad \text{(eqn 3.1)}$$

where α is the weighting factor assigned by Ships Parts Control Center. [Ref. 11: pg. 4-37] Those familiar with inventory theory or inventory modeling will recognize this equation as an exponentially weighted moving average. The platform's overall annual demand for an item is determined by multiplying the best replacement factor by the number of installations of that item on the platform [Ref. 12: pg. 6].

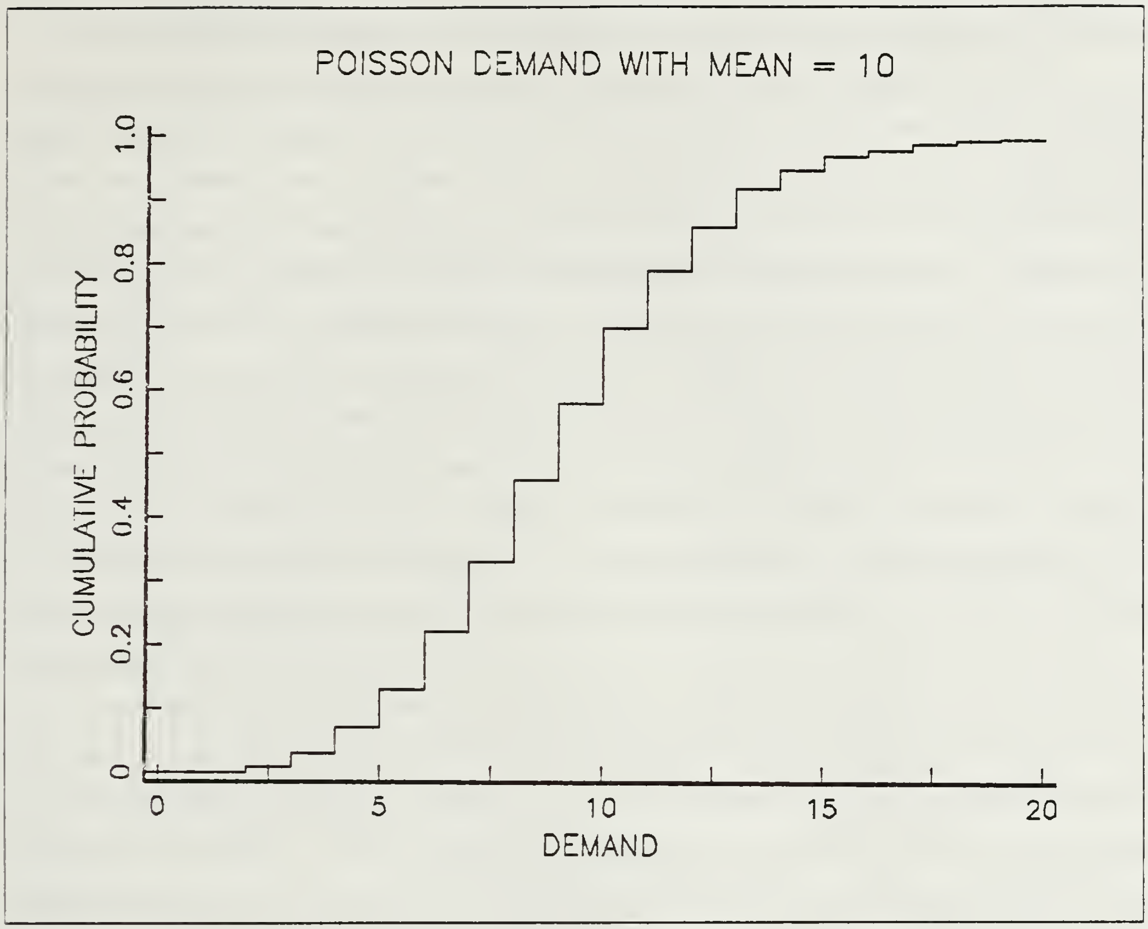

Figure 3.1 Probability of Demand.

Determining the number of spares needed is a straight-forward mathematical calculation using the best replacement factor method. The α used by the Ships Parts Control Center varies depending on the number of items in the population and on whether the demand is increasing or decreasing. The new average demand rate is the failure rate just observed and the old BRF is the exponentially weighted average of previous demands. The results with this method are good for items which have been in use by the Navy for three or more years and have a fairly constant demand rate. Roughly 50 percent of the items used by the Navy can have spare parts determined by the demand based methodology and achieve the Navy's goal of meeting at least 65 percent of demands [Ref. 13]. For items which have been in use for less than three years or have a fluctuating demand rate, the demand based method does not provide adequate protection against downtime due to unavailability of parts. Ships Parts

Control Center has found that it takes roughly three years for a newly introduced item to develop a demand history and for consumption rates to level out [Ref. 14].

The Coordinated Shipboard Allowance List is a demand based requirements list of items, both consumable and repairable, which are to be carried on board a ship to meet day to day operating requirements. This list is created when the ship is commissioned and is originally based on manufacturer provided data on reliability and maintenance. The Coordinated Shipboard Allowance List is recomputed each time the ship goes through overhaul, using actual usage/consumption data and is updated whenever major equipment changes are made. Coordinated Shipboard Allowance Lists are usually determined using the Fleet Logistics Support Improvement Program (FLSIP). The FLSIP methodology is as follows: any item installed on the ship which can be replaced by ship's maintenance personnel is a candidate for the ship's Coordinated Shipboard Allowance List. Once candidate items are determined, a predicted demand rate is generated using the item's best replacement factor and the number of installations of the item on the ship. Using the Fleet Logistics Support Improvement Program methodology, if the predicted demand rate is .25 per year or greater, the item is allowed in the ships Coordinated Shipboard Allowance List. The number of spares carried for each item in the Coordinated Shipboard Allowance List is dependent on the demand rate. One spare is carried for items which are classified as "vital" (98% of candidate items are classified as vital) and have a forecasted demand between .25 per year and 4.0 per year. Items with demand of 4 or more per year carry enough spares to provide a 90 percent protection against stockout, under the assumption that demand has a Poisson distribution [Ref. 12: pg. 7].

This method proved unsatisfactory because the Navy's goal is to meet at least 65 percent of demands on-board the ship using the Coordinated Shipboard Allowance List. Coordinated Shipboard Allowance Lists generated by the FLSIP method were meeting only 49 percent of such demands [Ref. 12: pg. 1]. Planning was clearly not supporting execution. A modified version of the Coordinated Shipboard Allowance List generating program, known as the Modified Fleet Logistics Ship Improvement Program (Mod-FLSIP), was developed. The Modified Fleet Logistics Support Improvement Program methodology lowers the minimum demand rate for inclusion in the Coordinated Shipboard Allowance List to .1 per year if the item has an Item Mission Essentiality Code of 3 or 4. (Item Mission Essentiality Codes will be explained and discussed later in this chapter.) One spare is carried for items with a demand between .1 per year and 2.0 per year and two spares are carried for items with demand between 2.0 per year and 4.0 per year. The spare parts stockage for items with demand greater than 4.0 per year is the same stockage computed using the Fleet Logistics Support Improvement Program method. Figure 3.2 shows the probability of being out of stock at the end of one year, as a function of the yearly demand, if no spares, one spare or two spares are available. For items with annual demand between 2 and 4, the probability of stockout is still high. The FLSIP and Mod-FLSIP policies are based on annual demand. In actual operations, resupply occurs more frequently. It makes more sense to look at probability of stockout during a resupply leadtime. The average leadtime used by the Navy is 90 days. Figure 3.3 shows the probability of stockout for the given leadtime demands. The larger yearly demands in Figure 3.2 were converted to leadtime demands in Figure 3.3 and the respective probabilities computed. Reference 15, discussing the impact of the Mod-FLSIP policy changes, states that "Since implementation began in 1982, CASREP downtime for parts has been decreasing." [Ref. 15: pg. slide 5.1].

In 1985 the Navy Fleet Material Support Office did a study to compare the protection provided by the FLSIP and Mod-FLSIP stockage policies. For the study, the Fleet Material Support Office ran a simulation using various ship types and generated "demands" for parts. From this simulation it was found that the stockage policy computed using the Fleet Logistics Support Improvement Program methodology would satisfy 53.5[5] percent of the total demands that were capable of causing Casualty Reports, while the Modified Fleet Logistics Support Improvement Program methodology would satisfy 63 percent of such demands [Ref. 16: pgs. 9 - 10].

The Item Mission Essentiality Code was developed by the Navy Supply Systems Command and is a method of combining an item's importance to its applicable end item (Military Essentiality) with its end item's importance to mission completion (Mission Criticality). To determine the Item Mission Essentiality Code for an item, both of the following questions must be considered. How will the failure of the item affect the end item it supports? How will the failure of the end item affect successful mission completion? The Modified Fleet Logistics Support Improvement Program was one of the earliest programs to recognize that basing stockage policies purely on demand was insufficient to ensure a ship's operational capability. The ship's mission

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[5] This differs from the 49 percent referenced in the Bagby study because the FLSIP study looked only at CASREP causing items and the Bagby study looked at all items.

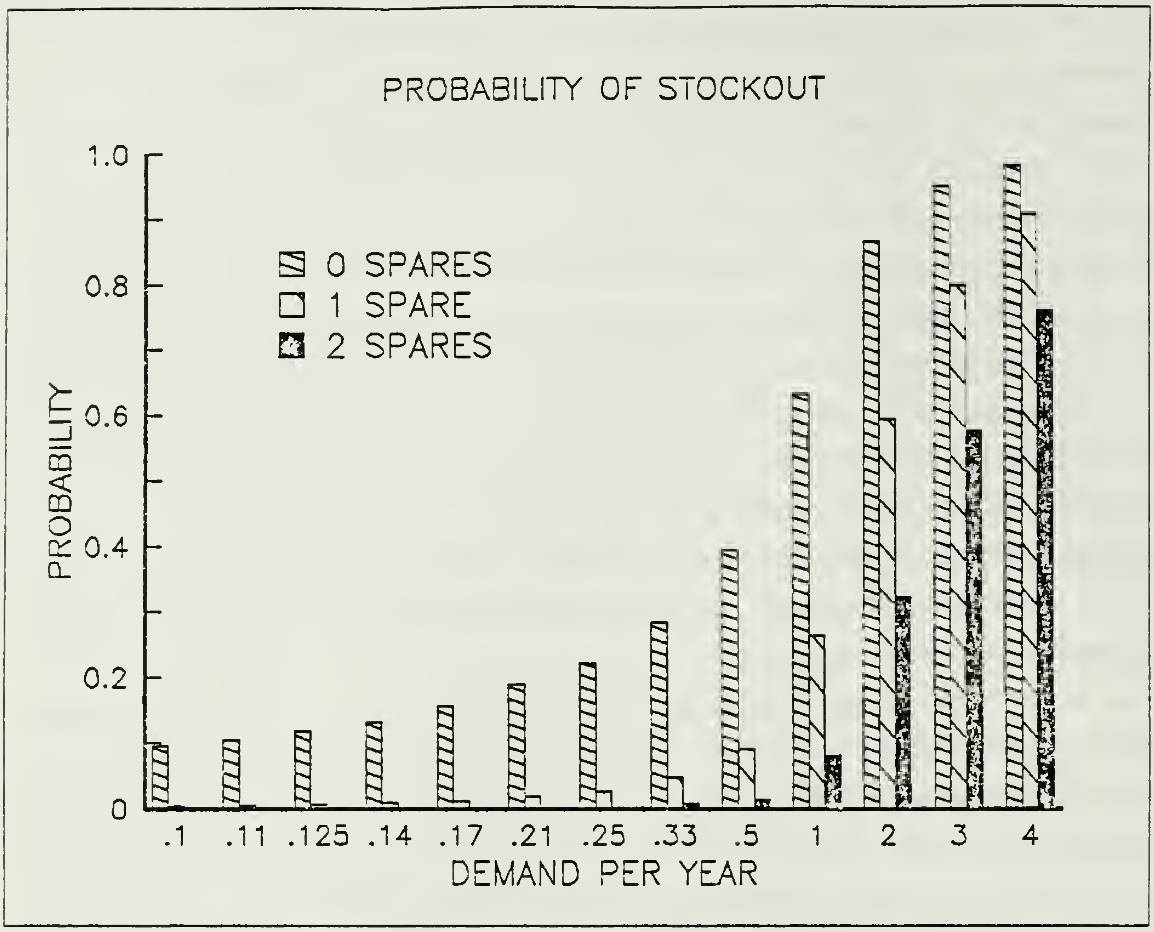

Figure 3.2 Probability of Stockout Per Year.

must be considered and the item's impact on mission completion taken into account. The Item Mission Essentiality Code was the way developed to do this.

An Item Mission Essentiality Code has been assigned to all items on the Weapons System File at Aviation Support Office and Ships Parts Control Center. For those items which the program managers have not done the necessary computations to generate Item Mission Essentiality Codes, default codes have been assigned. Consequently, some Item Mission Essentiality Code data is incorrect. Another problem with Item Mission Essentiality Codes is that an Item Mission Essentiality Code ranks the items on a given platform, but has no corresponding ranking among platforms. Items which are common to different classes of platform must necessarily have a generic Item Mission Essentiallity Code assigned, one which may underestimate the importance of the item on one platform, while overestimating the importance of

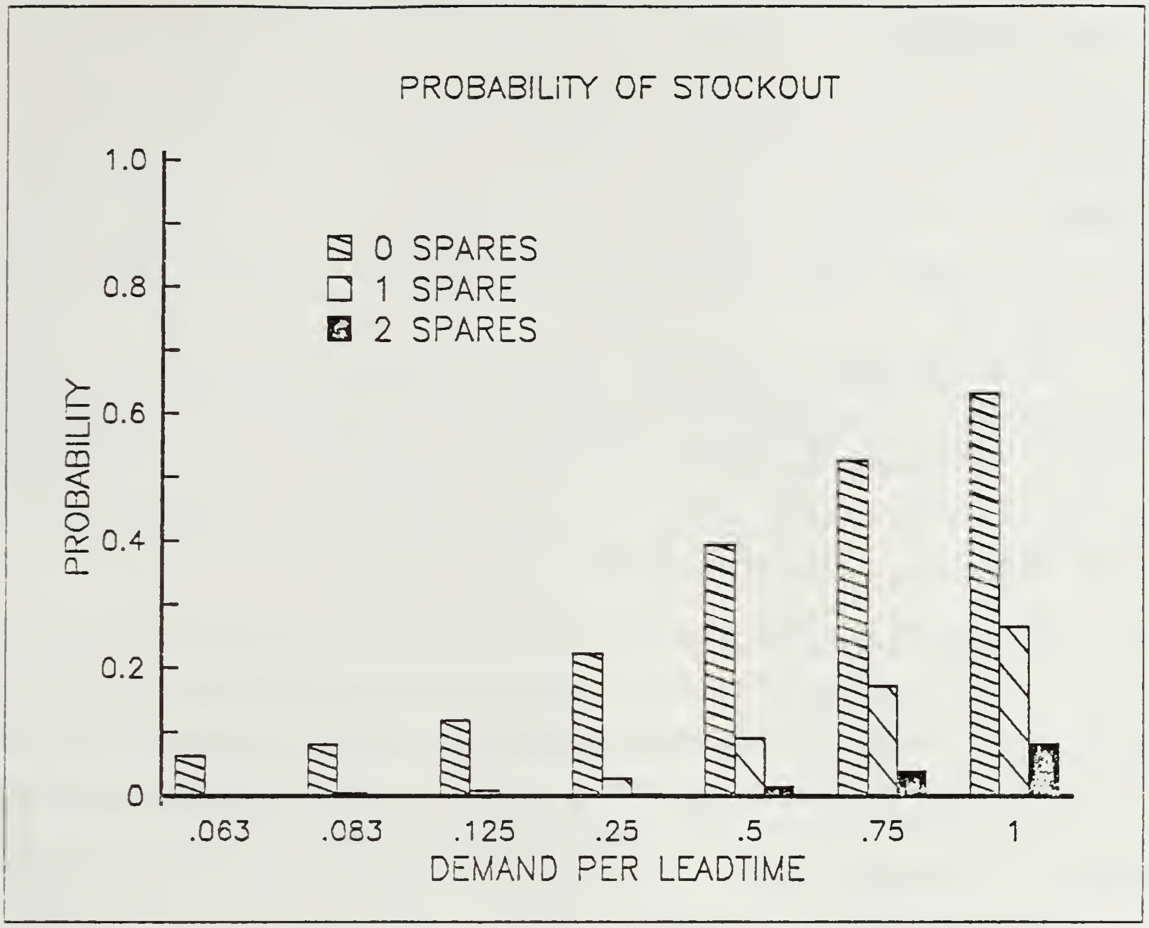

Figure 3.3 Probability of Stockout Per Leadtime.

the item for the other platforms. Therefore, Item Mission Essentiality Codes will tell what the most important items on a ship are but will not tell what the most important items in the Task Organization or Fleet are. The upper echelon commanders should have their own procedures for determining relative importance between units and platform types. Since there are no analytical models available, Commanders at the higher echelons of command must make a subjective determination if an airplane is more important than a destroyer or an auxiliary ship is more important than an aircraft carrier or submarine, etc.

Another deficiency in Item Mission Essentiality Codes is a direct result of a deficiency in the FLSIP and Mod-FLSIP programs. This deficiency exists because none of the models take into account the effect that the platform's mission can have on failure rates. FLSIP and Mod-FLSIP used a fixed failure rate to determine stockage policies. In actuality, the failure rate is not fixed. The failure rate varies from mission to mission and is affected by the mission. The impact an item has on the platform's capability to complete a mission is also dependent on the mission. It is possible for an item to be critical for one mission, but not for other missions. Thus, the demand and criticality for an item will change from mission to mission. These problems are mentioned because they are deficiencies in the present systems. Discussion of these problems will be limited to suggestions for further study contained in Chapter V.

The demand based system which is presently in use clearly has some flaws. The time necessary to determine valid demand rates is increasing as parts reliability increases. The demand rate does not consider the impact the item has on the ship's operational availability. These problems led to the development of programs that look at the impact each part has on the operational availability of a unit.

B. OPERATIONAL AVAILABILITY BASED STOCKAGE COMPUTATIONS

In 1984, as stated in Reference 9, the measure of effectiveness for the Navy Supply System changed to operational availability from the old measure of percent of demands satisfied. The most important characteristic of an item is no longer just reliability but rather reliability and essentiality to the platform's mission completion capability. The determination of what is critical is no longer by number of demands in a given time period but rather by the amount of operational availability improvement provided by carrying that item as a spare.

Operational availability is determined by:

$$A_0 = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR} + \text{MLDT}} \qquad \text{(eqn 3.2)}$$

where:

1. MTBF is Mean Time Between Failure (reliability)
2. MTTR is Mean Time To Repair (maintainability)
3. MLDT is Mean Logistic Delay Time (supportability)

[Ref. 17: pg. 1]. MTBF is the time the system is up and the sum of MTTR and MDLT is the time the system is down.

Mean Logistic Delay Time is similar to Mean Supply Response Time. Mean Supply Response Time generally refers to the average waiting time for spare parts.

The Mean Logistic Delay Time used by Hall, et al. includes nine other "logistic elements", which are not elaborated upon, in addition to the average waiting time for spare parts [Ref. 17: pg. 1]. If observing operations on a ship, two times will be observed. One time will be the time necessary to get the needed part from the ship's storeroom. The other time will be the time necessary to get the needed part from an external source. Obviously, these times will vary from part to part, but in general an average time for parts held in inventory and an average time for parts not carried in inventory can be determined. The Mean Supply Response Time represents the average length of time required to satisfy a demand. The actual computation of Mean Supply Response Time also includes the probability of item failure. The equation used by Navy Supply Systems Command for computation of Mean Supply Response Time is:

$$D = 1/\lambda \, \Sigma_{X > S} \, (x - S) \, p(x) \qquad \text{(eqn 3.3)}$$

where:

1. D = Mean Supply Response Time
2. λ = expected number of demands per time unit
3. S = number of items in stock
4. p(x) = probability of requiring x units

[Ref. 11: pg. 4-J-3].

Using an availability model to determine requirements is more complex than using the demand based FLSIP method. More input information must be known and often it is difficult to obtain the necessary data. The mean time between failure is a measure of an item's reliability. The mean time to repair is treated as a constant, but is actually influenced by the training required by the personnel doing the repairs, the number of repair facilities and the queueing discipline used at the repair facilities. The mean logistic delay time takes into consideration the availability of trained personnel as well as the availability of spares, the time necessary to get a spare, the probability a spare will be needed, and the expected number of spares needed which are included in the mean supply response time. Of the three times described above, mean logistic delay time is the hardest to determine. It has the most variables, some of which are not always the result of objective mathematical computations.

From Equations 3.2 and 3.3 it is apparent that, theoretically at least, the availability improvement provided by any item will not be constant with regard to the number of spares that are carried for an item. Adding one spare of a component may increase availability by ten percent, but two spares will not usually give a twenty percent improvement in availability. The improvement gained depends on the probability of having X failures in a given time, the number of spares in inventory and the time necessary to get another spare through procurement or repair. So the current models go through each item on the platform, adding spares one at a time until the specified availability level is reached.

Two programs developed to determine requirements based on operational availability are the Readiness Improvement Program and the Readiness Based Spares program. Both programs have availability improvement as their measure of effectiveness and both are designed to work within a budget constraint. Many factors affect readiness. These factors can be separated into three basic categories: reliability, maintainability, and supportability. Readiness Based Spares primarily addresses the supportability factors while the Readiness Improvement Program addresses all factors.

1. Readiness Improvement Program

The Readiness Improvement Program looks at a platform's current level of readiness. If the platform is not at a specified level of readiness, the program tries to determine how readiness can be improved. Some methods for improvement include redesign or design modification of some of the platform's components, modification of maintenance procedures and/or schedules, a different mix of spares or different numbers of spares. This program can be used on new construction using design estimates for reliability or on existing platforms using historical data on downtime and failures.

The two models used by the Readiness Improvement Program are TIGER and the Availability Centered Inventory Model. The Readiness Improvement Program first uses TIGER to determine which items should be considered critical. The Availability Centered Inventory Model is then used to determine the spare parts necessary to achieve specified levels of availability. TIGER is then run again using the spares generated by the Availability Centered Inventory Model to see if the critical items from the first run are still critical or if the spares recommended by the Availability Centered Inventory Model are sufficient to meet predicted demand.

a. TIGER

TIGER is a simulation model developed by Navy Sea Systems Command. A flow diagram of inputs and outputs is given in Figure 3.4 [Ref. 18: pg. 2-3]. Input data includes mean time between failures, mean time to repair, duty cycle, allowable downtime, mission timeline, reliability data, maintenance policy, and number of spares at each level of maintenance. Output data includes system reliability, system availability, readiness and critical equipment. Critical equipment output is specified in two categories:

1. Critical equipment due to unavailability
2. Critical equipment due to unreliability

Tiger uses item availability and reliability to determine which item is responsible for system failure. The items responsible for system failure or downtime are classified as critical. [Ref. 18: pg. 9-13]. The model can be used on the entire range of equipment from single components through complex systems. The model uses simulation rather than analytical techniques due to the complexity of computations for intricate systems. [Ref. 18: pg. 1-1].

The objective of the TIGER model is to predict how well a system performs in the areas of reliability, maintainability, and availability [Ref. 18: pg. 2-1]. Since TIGER is a simulation model, it operates differently from the computational models to be discussed later in this chapter. The way TIGER works is for the user to specify the details of the mission the platform is to perform, the equipment on-board the platform (including the mean time before failure, mean time to repair, and duty cycle), the operational rules (which equipment must be operational for the platform to be operational, which components of a piece of equipment must be operational for the equipment to be operational), and logistic information (which spare parts are carried on-board or at a depot-level maintenance facility, resupply times). When all the necessary parameters are provided, TIGER simulates the specified operation and produces the appropriate reports. It is necessary to remember that multiple repetitions of a program must be run and that program results are in terms of means and standard deviations resulting from the multiple simulations. The TIGER documentation advises users on the number of times a simulation should be run to obtain a specified level of statistical confidence. [Ref. 18: pgs. 2-2 - 2-7]

b. Availability Centered Inventory Model

The Availability Centered Inventory Model was developed by Consolidated Analysis Centers, Incorporated for the Naval Sea Systems Command. The Availability Centered Inventory Model is a computer program which uses design-stage characteristics of reliability, maintainability, and supportability to determine stock

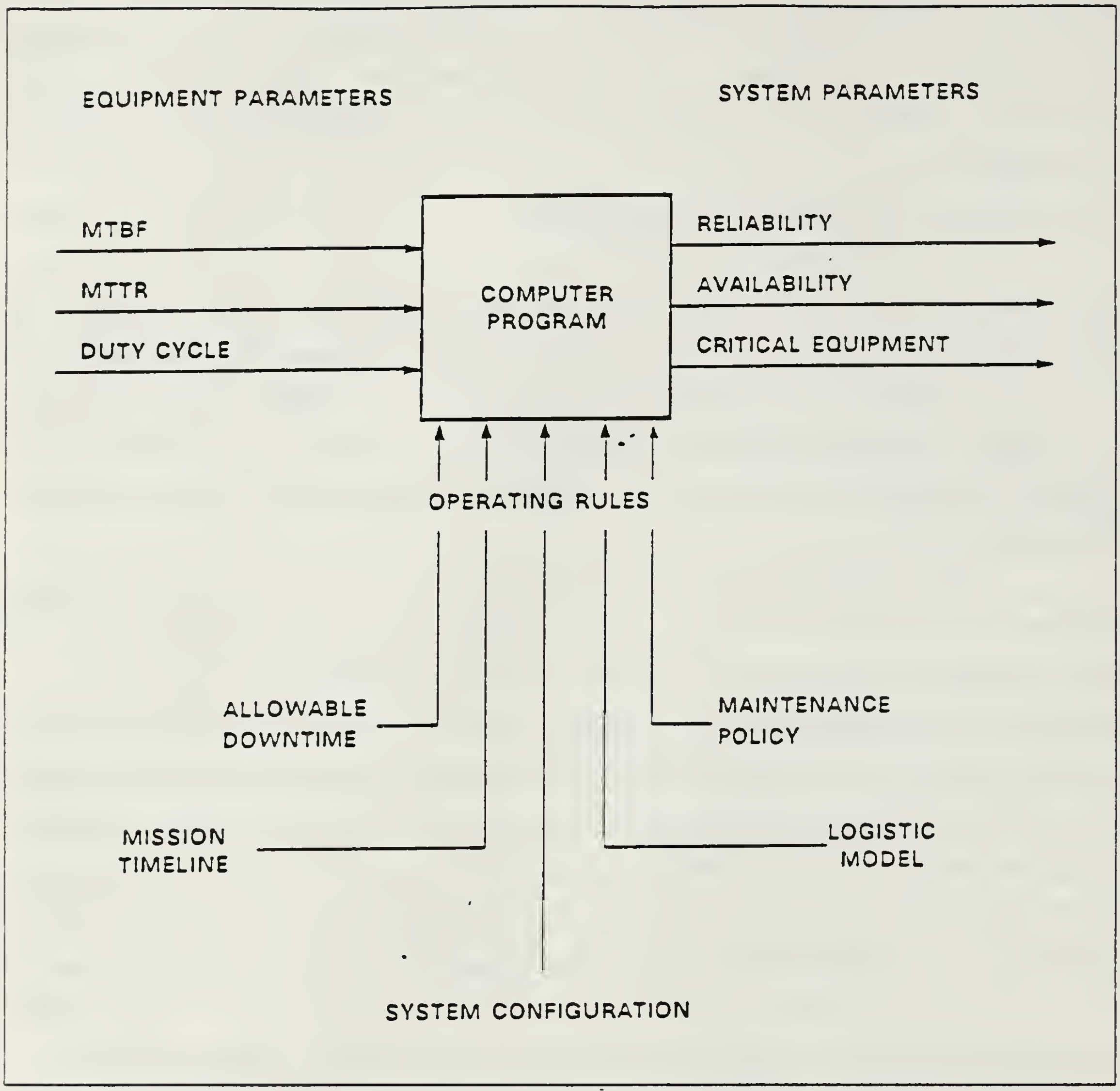

Figure 3.4 TIGER Computer Program Flow.

levels at all stockage facilities for a particular platform in order to maximize the platform's operational availability subject to a given budget constraint. An alternative use of the program is to minimize inventory costs subject to a specified availability constraint. [Ref. 19: pg. 12]

The Availability Centered Inventory Model assumes that a system is subject to failures only the amount of time prescribed by its availability. This means that if a piece of radar equipment is scheduled to operate 50 hours a week and has an availability of 85 percent, spare parts will be based on a work week of 42.5 hours because that is all the time the equipment can be expected to be operational based on its availability level. The Availability Centered Inventory Model also assumes that system unavailability is due to failure of only one component, i.e. no multiple failures can occur. There are no failures when the system is unavailable, either. Thus, when a failed component is replaced, the system is again available. If a component is common to two or more systems on a platform, the Availability Centered Inventory Model treats each component as a different item, i.e. it does not consider commonality of parts. The Availability Centered Inventory Model assumes that availability is the probability that all components considered are available. [Ref. 20: pgs 2-10 - 2-11]

The Availability Centered Inventory Model is the only "sparing to availability" model currently approved for use on U. S. shipboard systems [Ref. 17: p. 1]. What sparing to availability does is look at all components of a system and the impact each one has on the overall availability of the platform. The model goes through each component of the platform and determines the availability improvement provided by stocking another spare for that component. The spare which provides the greatest improvement to platform availability is the next spare added to the shipboard stockage list.

An added feature of this model is that it is designed to work within a budget constraint, so if a specified amount of money is available, the model will tell you which spares to buy to get the best availability improvement for that budget amount. The program is designed to compute stockage policies for all components of a platform at all levels of support, i.e. for shipboard systems, the model computes the number of spares carried on board, the number of spares to be stocked at the intermediate maintenance activity and the number of spares to be stocked at the depot level maintenance activity. To assist in analyzing shipboard spares, the model computes two sets of output, one based on the Availability Centered Inventory Model parameters and one based on a current sparing policy (Fleet Logistics Support Improvement Program, Modified Fleet Logistics Support Improvement Program, or Maintenance Criticality Oriented Coordinated Shipboard Allowance List). The model gives the planner lists of spares generated by the Availability Centered Inventory Model and by the current sparing policy so he can compare stock levels and inventory performance from both models without having to rerun the program and possibly introduce errors when changing parameters. [Ref. 17: pg. 2]

The Availability Centered Inventory Model is used in new procurement programs by the contractors to determine initial spares purchases. Initial Coordinated Shipboard Allowance Lists are prepared by the Ships Parts Control Center using FLSIP and Mod-FLSIP as usual. These initial Coordinated Shipboard Allowance Lists are then updated with the contractor's stockage list. The results have been encouraging with improved availability for the same cost or the same level of availability for a reduced cost. Unfortunately, the time and cost necessary for recomputing stockage policies for existing shipboard systems have resulted in the Chief of Naval Operation's staff limiting use of the Readiness Improvement Program to new construction or selected existing programs.

So far the Readiness Improvement Program has only been used on the DD 963 and the FFG 7 classes of ships with a mixture of different spares and design modifications being used to improve readiness [Ref. 21: pgs. 49-9, 49-15]. For the DD 963 class, hardware modifications to improve reliability were predicted to improve availability by eleven percent at a cost of $5.371 million per ship [Ref. 21: pg. 49-22]. For the FFG 7 Class, it was found that the MK-92 Fire Control System caused 28 percent of the downtime. The failure rate of the MK-92 was higher than predicted, resulting in on-board spares unavailability. The short term solution was to increase the number of spares on-board at a cost of $245,000 per ship. The long term solution was to modify the hardware to improve reliability at a cost of $18 million per ship. Total ship availability was expected to increase by twelve percent by June 1987 and the number of spares needed in the future is expected to decline. [Ref. 21: pg. 49-10]

2. Readiness Based Spares

The Readiness Based Spares program looks only at the readiness improvement achievable through a different mix of spares, which is just one of the options used by the Readiness Improvement Program. Readiness Based Spares addresses location of spares (are spares aboard ship or not) and availability of spares (how much is in stock). To run the Readiness Based Spares models, the component/subcomponent interrelationships must be included in the input parameters. Types of information required are:

1. Are the components in series or parallel
2. Which subcomponents make up each of the components
3. Are the subcomponents in series or parallel
4. What is the reliability of each subcomponents
5. Will the component or the subcomponent be replaced upon failure

6. What is the essentiality of each item, by application

The Readiness Based Spares program is used to maximize availability within a cost constraint or to minimize a cost within an availability constraint. [Ref. 15: pgs. slide 6.1, slide 12.1]

The Readiness Based Spares program uses the Availability Centered Inventory Model for shipboard spares determination and the Multi-Item Multi-Echelon model for aviation spares determination. Because of the similarities of the Readiness Based Spares Program to the Readiness Improvement Program, to the point of using some of the same models, the Readiness Based Spares program can be considered a subset of the Readiness Improvement Program.

a. Multi-Item Multi-Echelon Model

The Multi-Item Multi-Echelon model is similar to the Availability Centered Inventory Model in methodology and output. The Multi-Item Multi-Echelon model objective function is to minimize inventory costs subject to a given availability requirement. The Multi-Item Multi-Echelon model has alternative of maximizing availability subject to an inventory cost constraint. [Ref. 19: pg. 12] The assumptions used in the optimization are slightly different from the assumptions made by the Availability Centered Inventory Model. The Multi-Item Multi-Echelon model assumes that the failure rate does not depend on the tempo of operations. The Multi-Item Multi-Echelon model also allows the system to have multiple, simultaneous component failures and for failures to occur when the system is unavailable. The Multi-Item Multi-Echelon model also does not consider commonality of parts between end items. The Multi-Item Multi-Echelon model assumes that availability is the probability that all parts are available at an arbitrary point in time. [Ref. 20: pgs. 2-10 - 2-11]

The Multi-Item Multi-Echelon model was developed by the Center for Naval Analyses at about the same time as the Availability Centered Inventory Model. The Multi-Item Multi-Echelon model was designed to work specifically with multiple indentured inventory systems. Since the two models were developed by different organizations, to accomplish different functions, it is not unusual that they are based on different assumptions. Under the Multi-Item Multi-Echelon model, the number of days which an individual component is subject to failures is determined by the component's operational availability. This means that different components may be subject to failures for differing lengths of time. In essence, components can fail when the overall system is down. The Multi-Item Multi-Echelon model allows the system to still be down once the failed part is replaced, i.e. multiple failures or failures when the system is down. The Multi-Item Multi-Echelon model and the Availability Centered Inventory Model therefore generate the same type of information but the number of spares stocked for a particular component may not be identical for the two models because of these differences in assumptions. [Ref. 20: pgs. 2-10 - 2-11]

b. ARROWS Model

Another readiness based model is the Aviation Readiness Requirements Oriented to Weapon Replaceable Assemblies (ARROWS). ARROWs is mentioned because it was developed about the same time the Multi-Item Multi-Echelon model and does essentially the same things. ARROWS makes the same assumptions about availability rates and multiple failures as does the Multi-Item Multi-Echelon model. ARROWS was developed by the Fleet Material Support Office for the Aviation Support Office to use in determining aviation spares at the consumer level (carried on-board ships with aircraft embarked) for high cost, mission-essential items which can be removed at the organizational level. ARROWS can be used for a single aircraft or an entire deckload of aircraft to determine the optimum stockage policy for a specified availability. It handles multiple aircraft on a sequential basis and takes into account commonality of parts. This differs from the Availability Centered Inventory Model and the Multi-Item Multi-Echelon model in which duplicate items are spared as separate or individual items. Model availability results can be based strictly on high cost, mission-essential items, or all items. The Fleet Material Support Office has recommended that ARROWS be designated as the Readiness Based Spares model for aircraft because it was designed to do readiness based sparing and it was designed to run on the Aviation Support Office computer system and interface with the necessary Aviation Support Office files. [Ref. 22: pg. 23]

c. Readiness Based Spares Test

The Readiness Based Spare program was tested during the 1986 USS Enterprise deployment. The purpose of the Readiness Based Spares Test was to determine the feasibility of using Readiness Based Spares models to build full air-wing Aviation Consolidated Allowance Lists and to estimate the improvement in aircraft performance resulting from use of the Readiness Based Spares models. [Ref. 23: pg. 1] The test was conducted using the Readiness Based Spares Aviation Consolidated Allowance List for the F-14s embarked on the USS Enterprise during the 1986 deployment. The cost of the readiness based AVCAL was constrained to be the same as the traditional demand based AVCAL.

Since the Enterprise is an aircraft carrier, it has both an Aviation Consolidated Allowance List and a Coordinated Shipboard Allowance List. Aviation Consolidated Allowance Lists are computed for all ships with aircraft assigned. An Aviation Consolidated Allowance List is similar to a Coordinated Shipboard Allowance List in that it is a list of items necessary to support the embarked aircraft and it must provide a specified level of coverage. The demands used in the Aviation Consolidated Allowance List production are based on 90 days instead of the annual demands seen in the Coordinated Shipboard Allowance List, because Aviation Consolidated Allowance Lists are recomputed prior to each deployment. This is necessary because the mix of aircraft generally changes with each deployment and the Aviation Consolidated Allowance List is designed to support the embarked aircraft.

For the 1986 test, the Enterprise Aviation Consolidated Allowance List was computed twice, once using the traditional Aviation Consolidated Allowance List generation method and once using the Readiness Based Spares method. The data base used to produce the Aviation Consolidated Allowance Lists was based on 3-M data from the 1984 Enterprise deployment and included only items which had one or more failures during the deployment. Therefore the data base was not as extensive as that used for normal Aviation Consolidated Allowance List provisioning. [Ref. 23: pg. 2] Consumable items are most noticeably missing. As expected, the models produced different sets of spares within the same budget amount. The traditional Aviation Consolidated Allowance List for F-14s is 30 percent consumable items. The Readiness Based Spares model did not specify spares be stocked at the depot level but the simulation program assumed peacetime resupply rates for these items, thus using items that the Readiness Based Spares model didn't stock. There were more than 400 items which experienced a single failure on the 1984 cruise. The Readiness Based Spares model treated these items as if they were always in the Aviation Consolidated Allowance List and generated higher levels of spares for these items than would normally occur. Generally, one demand for an item is insufficient to guarantee its inclusion in the Aviation Consolidated Allowance List.

The Center for Naval Analyses, which conducted the test, attempted to predict mission capable rates and fully mission capable rates based on the spares forecast and then compare the mission capable/fully mission capable rates to the 1984 Enterprise deployment mission capable/fully mission capable rates. In presenting results of the test to OP-91, the Center for Naval Analyses added the caveat that the results cannot be considered conclusive because the aircraft mix for the 1984 deployment was not the same as for the 1986 deployment and weather conditions were not the same either (1986 encountered a typhoon). Since the aircraft mix was different, the data base from 1984 was not a good basis for the 1986 Aviation Consolidated Allowance List.

Mr. P. Evanovich, of the Center for Naval Analyses, states in Reference 23 that a 2.1 percent to 12.2 percent increase over the 1984 mission capable rates and a 1.1 percent to 6.8 percent increase over the 1984 number of sorties flown were experienced during the test. He feels that the improvements shown are understated because of limitations in the data base and in the Center for Naval Analyses model used to simulate and analyze the deployment. [Ref. 23: pg. 16]

C. COMPARISON

Figure 3.5 [Ref. 15: pg. slide 13.1] is a conceptual representation relating item reliability and system complexity to stockage policies. Complexity refers to the technology involved in the development of the part. A pump is an example of a low complexity system while a radar is an example of a high complexity system. No matter what level of reliability a part has, it can have sufficient spares to meet demand determined by traditional demand based models if the part is used in a medium to low complexity system. Readiness Based Spares chooses spare parts based on availability improvement per dollar spent. Highly reliable parts used in highly complex systems have the best results when spares are determined using the methodology of the Readiness Based Spares program. The Readiness Improvement Program will determine if a different mix of spare parts will improve availability or if redesign/system modification is necessary. Parts with low reliability used in highly complex systems achieve the best results when spares are determined by the Readiness Improvement Program. The Readiness Improvement Program works best on these parts because more or different spares have little impact on availability improvement, so the program then looks for alternate methods of availability improvement. Design modifications or redundancy need to be included and the Readiness Improvement Program will identify which parts need to be modified.

The programs discussed above are examples of our capability to determine requirements. The Navy has just started looking at the effects the mission and tempo of operations have on demand. The Navy has realized that the items with the highest demand are not necessarily the most important (most critical) to mission completion.

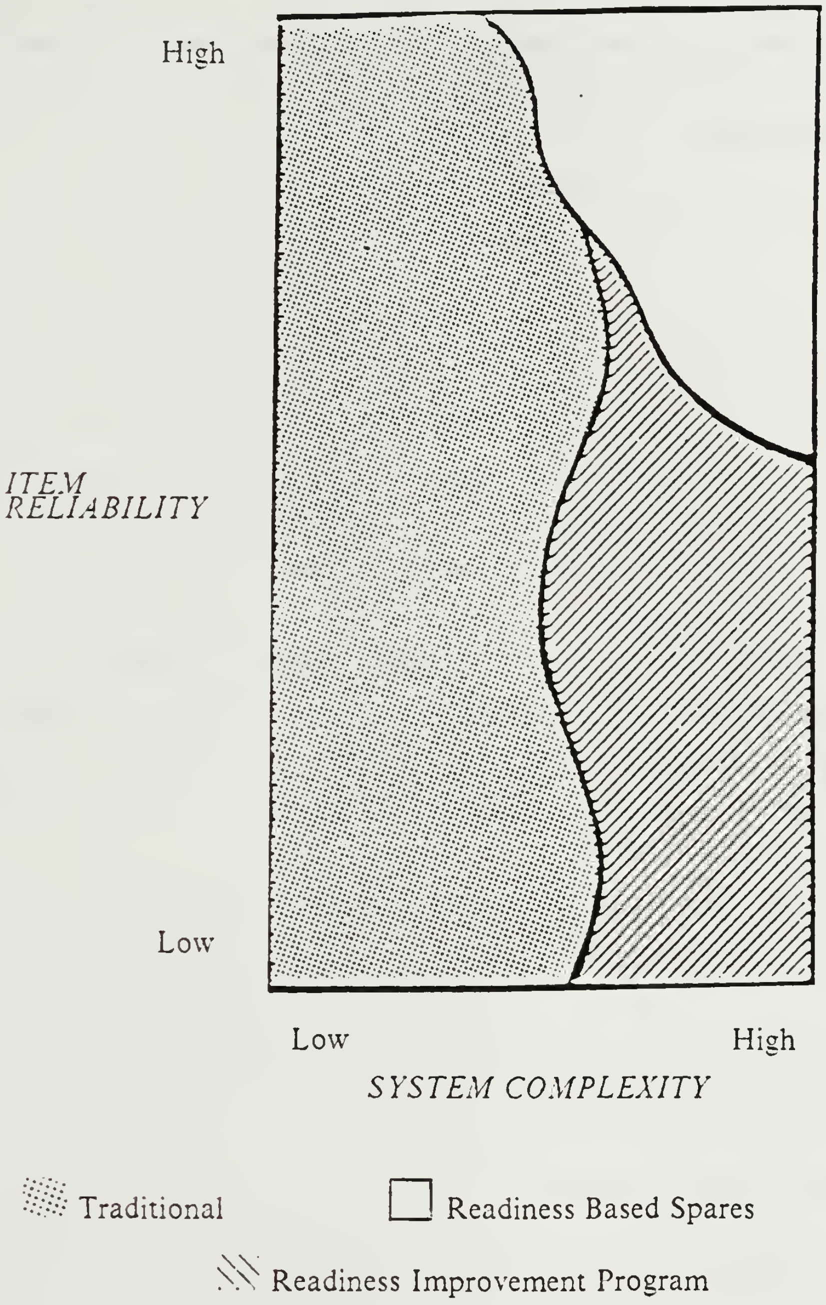

Figure 3.5 Sparing Model Selection Criteria.

It has been realized that for execution/operations to go smoothly, planning must be done accurately. The more accurately that planning is done, the fewer the number of critical items in existance. The Navy is improving its predictive capabilities but still falls short at times. The next chapter discusses some of the measures taken when planned requirements are insufficient to meet demand. Actions taken by various echelons of command to counter the negative effects of not having a needed item in stock are also presented.

IV. WHEN REQUIREMENTS DO NOT MEET DEMANDS

In Chapter III the planning methods used by the Navy to predict demand were discussed. It is impossible to plan for every situation that can occur. The recent shift within the Navy to operational availability is an attempt to be better prepared for the situations most damaging to a platforms operational status. What needs to be discussed now are the Navy's methods for handling situations in which the planned requirements do not satisfy demand.

At the unit level, there is little flexibility. Storage space on board ship is limited, requiring only essential spares be carried on board. This necessitates a thorough understanding of the ship and the problems most likely to arise, the impact each may have on operational availability and the number of spares required to correct the problem. The Coordinated Shipboard Allowance List establishes the types and quantities of each item to be carried on board the ship. Deviations from these set standards are frowned upon but do occur. Experienced supply officers or department heads will stock unauthorized spares if they know a certain component tends to fail more often than the Coordinated Shipboard Allowance List authorized stockage level would indicate. Otherwise, the only recourse in the event of the failure of a critical item is to submit a Casualty Report and a requisition and wait for the needed part to arrive.

There are procedures established, called Allowance Change Requests, where a ship/unit can request that its Coordinated Shipboard Allowance List be changed. Such a request may be made for the following reasons:

1. The failure rates of an item are greater than or less than estimated
2. The unit is in a new operating area or operating under conditions that require different support
3. A change in mission assignments has been made which requires additional equipment or repair parts
4. Technical improvements in equipment/systems and repair parts have been made which can provide additional capability

The Supply Officer is expected to check the Coordinated Shipboard Allowance Lists on his supporting tender to ensure that the desired changes have not already been made and simply have not reached him yet. [Ref. 24] The allowance Change Request process is not a rapid action. A lot of time is involved in filling out forms, providing justification for the change and obtaining authorization for submitting the Allowance Change Request. The Allowance Change Request goes from the unit to the unit's Type Commander (for information) and to the Ships Parts Control Center. The Ships Parts Control Center takes appropriate action and notifies the unit. If the change has been approved, the unit can requisition the desired part.

There is hope that the recent implementation of the Shipboard Non-Tactical Automatic Data Processing Program II (SNAP II) on smaller ships will reduce the amount of paperwork and the time necessary to process Allowance Change Requests. Since implementation of SNAP II on smaller ships, the correlation has increased between the equipment actually on the ship and the equipment the Ships Parts Control Center thinks is on the ship. With SNAP II, it is a quicker, easier process to notify Ships Parts Control Center of parts/equipment changes and the automated system rejects requisitions for items not in the allowable parts/equipments data base of SNAP II. It is hoped that Ships Parts Control Center will start comparing requisitions actually submitted to planning data and start making adjustments to Coordinated Shipboard Allowance Lists without waiting for the unit to realize planning data doesn't match operational demand and request a change. The Ships Parts Control Center cannot provide a definitive answer on when this will occur until resystemization[6] is complete in the late 1989 timeframe.

At the unit level, not much thought is given to critical item determination or non-critical item determination. Day to day operations do not leave much time for speculating about future requirements. Naval operations and the supply system are theoretically structured so this is not necessary. Based on the type of operation, the shipboard Supply Officer has guidelines and procedures that tell him how much of which items to order at what time to keep the ship running. Since things do not always work as designed, other precautions are taken and the Fleet Type Commanders and the Navy Supply System organizations monitor daily operations to ensure minor problems do not become major.

The Fleet Type Commanders monitor all platforms under their command. The Type Commanders are responsible for keeping their platforms at their highest level of readiness. Therefore the Type Commanders closely monitor Casualty Reports for ships

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[6] Resystemization is the term used when discussing installation if new computer hardware at Ships Parts Control Center and the Fleet Material Support Office and the conversion of the existing software to be compatible with the new hardware.

and Not Mission Capable/Partial Mission Capable reports for aircraft and keep track of systems and parts causing failures. The Type Commanders work with the Ships Parts Control Center and the Aviation Support Office to have the deficiencies corrected. The Type Commanders provide information on system failures to Ships Parts Control Center and the Aviation Control Office. They also provide repair or procurement priorities for the various items and recommendations on whether the corrective measure should include redesign or modification of the item or if more spares will solve the problem. The deficiencies can be either in the item/system not meeting design reliability standards, the planned level of stocks being insufficient to meet demand or the design reliability standard being inadequate. Type Commanders have been known to keep their own stocks of certain troublesome items in order to expedite replacement parts to ships when Casualty Reports occur.

Fleet Commanders and Fleet Commanders in Chief are also interested in Casualty Reports. The Fleet Commanders each have specific missions which they must accomplish. These missions may require all of their assigned forces or just a part of them. In either case the Commander must know the status of all his units in order to make decisions rapidly. These Commanders, too, have been known to have their own stocks of items to expedite repairs in units within their area of responsibility. Having a second level of support improves the probability of having certain required parts. It must be remembered that the Type Commanders and Fleet Commanders are subject to the same problems with predicting requirements that are faced by the Navy Supply System. Fleet Commanders in Chief, while not maintaining their own stocks of items, are interested in expediting Casualty Reported related repairs. Frequently, the Fleet Commander in Chief will increase shipping priorities to reduce transit time of a Casualty Reported spare.

The Fleet Type Commanders, Fleet Commanders, and Fleet Commanders in Chief, all of whom have planning staffs, are monitoring the day to day material condition of units in their command. In 1983, the planning staffs for the Fleet Type Commanders were asked by the Fleet Commander in Chief to provide input for the "Critical Items" lists and did so. Unfortunately, the volume of data provided by the Type Commanders was so great that is caused a problem for the Commanders in Chiefs' staffs to integrate the data based on their interpretation of the threat and understanding of the impact specific repair parts have on the mission completion capability of specific platforms.

In order to accurately determine which items are critical, the threat must be explicitly understood so the decision maker will know which mix of forces (air, surface, and subsurface) are necessary to effectively counter the threat. Once the forces are defined, determinations can be made as to which parts have the greatest impact on availability and are in short supply.

Planning staffs are responsible for planning the operations carried out by the units. The logistic support required by a unit is not tailored to the operation but rather of a generic nature designed to fit any situation any time. The various echelons of command have not yet found it necessary to devote much planning to the logistic support required by an operation. In order to improve logistic support for specific operations, one thing that could be done by the planning staffs is to determine the Coordinated Shipboard Allowance List for a specific deployment. Using the availability improvement methodology, they could augment the regular (generic) Coordinated Shipboard Allowance List, as appropriate, to reflect changes related to the deployment specific requirements. Another option would be to consider the entire Battle Group as a unit and generate a scenario specific Coordinated Shipboard Allowance List for the Battle Group. The generated requirements would then need to be compared with the individual Coordinated Shipboard Allowance Lists of each ship in the Battle Group and either have the items not carried prepositioned or added to the Coordinated Shipboard Allowance Lists of any of the units in the Battle Group that have available space. This option could also provide stockage levels for items not carried by the smaller units in the Battle Group because of space limitations, thus improving supply support for the smaller units. Items with insufficient demand to be carried on individual units may be included in an aggregate Coordinated Shipboard Allowance List, thus reducing the probability of downtime due to unavailability of parts. The last two changes would require the Battle Group to work together logistically as well as operationally. This is often done by individual supply officers as a matter of survival, but not as a matter of Navy policy. Navy policy emphasizes unit integrity and self-sufficiency.

A Casualty Report signals a failure of the planning system. The Navy Supply Systems Command, through its subordinate Supply Centers and Supply Depots worldwide, can only react once Casualty Report requisitions occur. If the needed part is not held at the center/depot receiving the requisition, other depots in the area are checked. If the part is still unavailable, the requisition is forwarded to the next Supply

Center. Much work is in progress to automate supply centers and depots so they can more rapidly locate items. Work is also being done to network the supply center and supply depot computers worldwide so it will be possible from any supply location around the world to locate a needed item. [Ref. 25]

This chapter is not meant to imply that the Navy Supply System has failed to do its job. The objective the Navy Supply System is trying to accomplish in determining requirements is very broad and general. The supply system planners must define requirements for all platforms to meet all contingencies in all parts of the world. When the mission statement is that broad and general, the spare parts determined by the models tend to be the ones most likely to fail in any given situation. For planning to more closely match day to day operations, a generic solution cannot be used. What is being presented in this chapter are alternate methods used in peacetime to speed up procedures when planning does not match demand. The time delays inherent in normal resupply operations can be too long for situations when items become "critical". Consequently, different levels of command maintain their own stockpiles of certain items in order to get a part where it is needed within a specified amount of time. What is needed is more effort to ensure that planning scenarios match the likely world situations the Navy will be involved in or needs to be prepared for.

What this chapter has examined are the existing methods the operational Navy uses when the predictions made by the planning Navy turn out to be wrong. One of the biggest problems faced by the Navy, both in planning and in operations, is that "official" doctrine lags "operational" doctrine. What we do, as defined by publications and instructions, is not necessarily what we will do in the "heat of the battle". There will always be some differences, but the sooner we accept that some things listed as Navy policy just will not be done in a crisis, the easier the job will be for the planners. Planners are restricted to work within the confines of "official doctrine", even if it is known that "official doctrine" would be inappropriate in a given situation. When planners are allowed to plan for specific situations, in a realistic manner, planning will more closely match execution.

V. CONCLUSIONS

A. ANALYSIS RESULTS

In looking at the Navy planning systems and models and the operation of the Navy Supply System, it became apparent that deficiencies exist but the deficiencies are not the cause of the difficulty involved in providing the Joint Chiefs of Staff a list of critical items. The first problem to be solved was the determination of the appropriate definition of "critical item". The next problem was how to select items, which fit the definition of critical, from the many items that are needed on a daily basis. At this point it was realized that "critical" has a relationship to the situation in which an item is needed. Consequently, there is no universal list of critical items that can be provided to the Joint Chiefs of Staff.

What would be feasible to provide to the Joint Chiefs of Staff is a list of items that would be candidates for critical items under specified scenarios. Unfortunately, the Navy cannot do this because their planning systems do not allow scenario specific planning on a routine basis. It is a workable problem, and one that is probably not too difficult. The existing programs could be used, but new consumption factors for specific areas would need to be developed to replace the general consumption factors presently in use.

B. FURTHER STUDY

An area that needs future study is wartime demand. Demand rates in wartime are likely to be higher because of higher operating levels, but how much higher and will the increase be the same for all items? Forecasting of wartime demand has not appeared in any of the discussions of the Readiness Based Spares Program or the Readiness Improvement Program in this paper or in any of the references. This thesis has addressed requirements determination, but only from the viewpoint of peacetime consumption. Peacetime consumption rates are not too difficult to determine compared to wartime rates. Previous consumption rates used by the Joint Operational Planning System were supposed to be based on peacetime consumption with a wartime factor based on information on consumption during World War II, the Korean conflict and the Viet Nam police action. The latest planning figures are based on a study sponsored by the Chief of Naval Operations (OP - 40) which looked at consumption for all deploying ship for a two year period. From this data, the current consumption rates of pounds per man per day of each class of supply for each ship type were determined. The study also looked at ships involved in high intensity deployments and computed consumption factors for them. The study found that there was not a significant difference between the lift assets necessary to support the two intensities. Information on significant differences in consumption levels was not given but could not be great because it was stated that peacetime consumption rates had to be doubled to require an additional Mobile Logistics Support Force Ship. [Ref. 26] Operation plans used to multiply peacetime consumption rates by a set factor to arrive at estimated wartime consumption rates. There are no longer different consumption rates for wartime and peacetime. The affect of the availability improvement methodology under wartime conditions has not yet been tested. It has already been stated that just because one spare is good it does not follow that two spares are better. The effect wartime tempo has on consumption of items whose spares are determined by the Readiness Based Spares Program or the Readiness Improvement Program must be considered. The mix of spares will not necessarily be simply a multiple of peacetime demand. We have to determine what level above peacetime consumption we need to support.

Another area that needs work at the Fleet Commander in Chief level is cost/benefit analysis. This thesis has looked at methods used for determining requirements and pointed out that there needs to be a way to match capabilities to requirements. If a Commander knows what shortfalls exist, other options or strategies can be used. When operations plans are developed, the Commander in Chief's staff takes the forces allocated to the Commander in Chief and assigns them to the geographic area necessary to counter the threat. The forces list, with destinations, is turned over to the logisticians to compute "resupply". The "resupply" that is computed is purely a guess at gross tonnage of items within each supply class/subclass that will need to be transported within a given timeframe. What is not generated is how many of which items are needed to support an operational unit for a specified timeframe under wartime conditions.

Since we do not determine needs below the gross tonnage level we are not able to do any comparative analysis. Using the current planning methodology, the Fleet Commander in Chief does not have the capability to determine courses of action based on the varying levels of support he is likely to receive. It would be beneficial for a

Fleet Commander in Chief to be able to do comparative analysis of how long a particular force could be sustained in combat under different levels of resupply or with differing levels of particular items. The current planning system does not have this capability because it can only provide the tons of a particular class of resupply due to arrive at a given port in a specified timeframe. The method of employment will be determined by the state of materiel readiness at the beginning of employment and by the supportability of the forces. The capability for comparative analysis does not exist on Fleet Commander in Chiefs' staffs. Very little logistic capability analysis is being done at higher echelons of command. To this end, it is important that each Fleet Commander in Chief identify potential critical items and existing quantities of those items. The Logistics Capabilities Estimator is a first attempt by the joint community to do some analysis in this area. The benefits provided to the Navy will be proportional to the amount of effort the Navy is willing to put into building the necessary data files and as good as the data put into those files.

C. SUMMARY

This thesis has discussed the problems faced by the Fleet Commander in Chiefs', the Fleet Type Commanders' and the Navy Supply Systems Command's staffs when trying to determine critical items in accordance with the Joint Chief of Staff requirement. Since the Joint Chiefs of Staff do not provide a definition of the term "critical item" each Navy staff must make its own definition and proceed from there. The term "critical item" was defined in this thesis to be an item which contributes the most to a platform's operational availability and is in short supply. Also presented are some of the computer programs and models in use at the various levels of command to determine shipboard requirements for spare parts. In summary, requirements are determined by staff planners, based on historical data and observed trends. These requirements are placed aboard ship in the form of the Consolidated Shipboard Allowance List. If day to day operations prove the Consolidated Shipboard Allowance List insufficient to meet demand, then those items which are unavailable are considered critical items. Shipboard personnel can submit a request to have the Consolidated Shipboard Allowance List changed or they can carry unauthorized stocks of spare parts.

The models described in this thesis present different methods for determining the stockage policies in a Consolidated Shipboard Allowance List. Until recently the spares requirements for all parts were computed using the same methodology. This proved unsatisfactory because the stockage policy was not meeting its own objective, so different computational methods were sought. There are now three basic procedures in existance which give improved results if used in the right situation. The traditional demand based method, represented in the Fleet Logistics Support Improvement Program and the Modified Fleet Logistics Support Improvement Program models works best on simple, low complexity items. For highly reliable components of highly complex systems, an availability improvement approach works the best. In order to meet performance objectives, less reliable components of highly complex systems need a combination of component redesign/design modification and a different mix and or quantity of spares than is currently carried.

Determining what is critical is hard. Critical items are always changing and depend on the current situation and on the future. The Commanding Officer of a ship in the yards undergoing overhaul probably will not be too concerned if he must do without one of his main engines for two weeks because it is being replaced. But the Commanding Officer of a ship in the Mediterranean Sea or the Persian Gulf could become very anxious if he does not have spare fuses for the radar or spare circuit boards for the fire control system. What is critical is relative. Trying to predict what will be critical at some point in the future, not knowing if that point is ten days or ten years away is almost impossible. Having confidence in that prediction is even more difficult. The best we have been able to do so far is identify current problem areas and give a best guess of how long it will take to solve them. We have also looked at systems in the test or development phases and tried to predict future problems based on past experience. Beyond that, everything is a "best guess".

In the requirements determination/identification area, one possible improvement is in the area of communications between the Fleet Commander in Chief and his Type Commanders. Each Fleet Commander in Chief is supported by Type Commanders for air, surface and subsurface. These Type Commanders are responsible for the materiel condition of all platforms under their purview. They track, and often intensively manage, the items which cause the most problems and keep ships or aircraft from being fully mission capable. Sometimes even items which only cause partial mission degradation are included. Experience shows that, unfortunately, there is little information exchanged between the Fleet Commander in Chief's staff and his Type Commanders' staffs during any planning phase, i.e. Joint Operational Plan development, exercise development, wargame development, and Program Objectives

Memorandum (POM) development. Communication generally occurs only when something breaks, when a ship is down, awaiting parts. Possibly, if more communication occurred during the planning for deployment, there would be less need for communication during execution.

Two major problems encountered in planning are time available and personnel trained to do planning. There is never enough time and there are seldom enough people trained to use the planning systems efficiently or who even have a basic knowledge of the purpose and functions of the planning system. Furthermore, planning has traditionally had a low priority in the Navy so only major staffs have had billets specifically for planning. Since the Fleet Commanders in Chief and the Fleet Type Commanders both have planners on their staffs, half of the problem is taken care of. What remains is for the staffs to coordinate their efforts and ensure time is available for adequate communication between the staffs. In the rush to meet deadlines, staff planners often neglect to ask their subordinates for information relative to the problem being dealt with. The staff planner will make his "best guess" as to the answer and forget that there is probably someone on a subordinate staff who has the answer. The initiative will have to come from the senior command. The senior command will need to provide the subordinate command with a description of the situation and the information that the senior command needs to make its plans or decisions. The subordinate commands will then be able to provide the senior command the required information, using all information available to them. This allows the lower level managers to manage the necessary details and the senior Commander to take care of the overall strategy and not lose efficiency due to lack of attention to detail.

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