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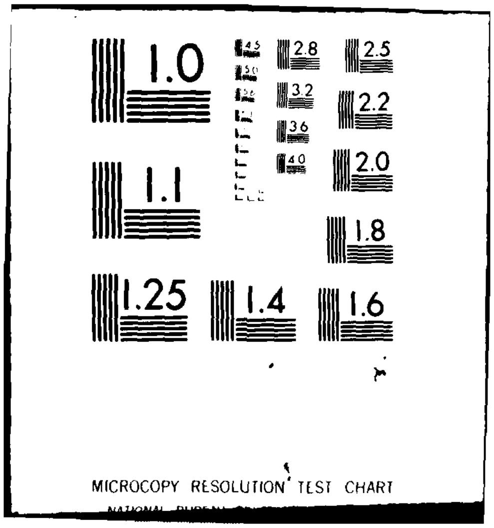
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SURVEY AND ASSESSMENT OF MODELS OR DECISION RULES DETERMINING SPARE PART LEVELS FOR NAVY ELECTRONICS EQUIPMENTS

Prepared for

Naval Electronics Systems Command
Headquarters
Washington, D. C.

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Approved

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7 September 1979

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Table of Contents

Section		Page
I	Introduction	I-1
II	Task Statement	II-1
III	Scope of Effort	III-1
	Area of Logistics	III-1
	Area of Task	III-1
IV	Approach	IV-1
V	Description and Evaluation of Applicable Models	V-1
	Kinds of Models	V-1
	Scope of Models	V-2
	Navy Models (Current and Proposed)	V-2
	Normal Model	V-6
	Negative Binomial	V-8
	Poisson	V-10
VI	Rank of Applicable Models	VI-1
VII	Conclusions and Recommendations	VII-1
VIII	Literature Evaluations (Forms A, B, and C)	VIII-1
IX	Glossary	IX-1
X	Bibliography	X-1
Appendix A -- Applicable Literature Source List		A-1

Section I

Introduction

The primary objective of sparing procedures as applicable to the task assignment is to maintain an acceptable level of spare parts input into a system while keeping within prescribed boundaries of cost. The aforementioned objective, simple as a goal, assumes a greater complexity with the imposition of conditions and restrictions.

For this task there is the necessity to comply with the Navy's supply procedures for spare parts. This requires as a minimum, abiding by the requirements set up for items or components that are classified as critical, demand and insurance items. Maintenance policy such as repairability at the source must be considered in addition to the possibility of other constraints such as weight and cube. Stocking at various levels of supply (ship, mobile support forces and depot), and compliance with mission time and mission function have to be considered.

The function of the sparing models or methodologies for electronic equipments for this task should have the following criteria:

1. compliance with the Navy's supply procedures
2. maintaining levels of spare parts
3. abiding by cost constraints
4. administrative ease.

Methodologies for spare part procedures are abundant. However, they span the spectrum of the area of logistics ranging from those that are all encompassing to those that apply to specific areas. It will be necessary to separate the methods that are applicable to this task from those that are not.

It should be emphasized that it is not so much a case of new sparing models or methodologies that are needed as the application of those that exist. However, the existing models often have to be adapted to the criteria or goals that are specified.

Section II

Task Statement

~~The~~ task ~~for Contract N00039-79-C-0187~~ requires a survey and assessment of models or decision rules applicable to the determination of spare parts levels for Navy electronic equipment be made. This survey agreed to include a search of pertinent literature published subsequent to 1 January 1974, together with such other sources deemed appropriate by contractor to establish a list of available sparing models.

Models are to be evaluated and ranked according to criteria to be jointly determined by procuring activity and contractor.

A report is to be furnished, in ten (10) copies, detailing:

1. Those models determined to be appropriate for use, listed in order of desirability
2. The criteria used to evaluate and rank the models,
3. Copies of descriptive material on the top ten ranked models,
4. List of sources investigated.

The models determined to be appropriate for use, listed in order of desirability are contained in Section VI. The criteria for evaluating and ranking applicable models are contained in Section III (Area of Task). Copies of descriptive material on the top ten ranked models are listed in Appendix A and the list of sources are listed in the Bibliography and Literature Evaluation Form A.

Section III

Scope of Effort

Area of Logistics

This task falls into the broad area of logistics. In order to gain a perspective of the task in relation to the area of logistics, it would be feasible to specify some of these areas.

The following are functions associated with the process of logistics:

1. budget decisions
2. procurement
3. acquisition
4. distribution
5. maintenance
6. management.

These functions are interrelated and compounded by problems such as modes of transportation, facilities, man power, duplication, supply level, economical management, producibility, performance, centralization, and safety.

The area of logistics is broad and multifaceted while the task assignment is limited in scope. In order to cope with the task assignment, the area of logistics will be arbitarily partitioned by a procedure depicted under Approach (Section IV) in order to classify models and eliminate those that do not pertain to the task assignment.

Area of Task

Provisioning, excluding the various facets of spare management such as storage, transportation, and reordering policies, reduces to providing adequate levels of spare parts at reasonable cost. Therefore, the sparing procedure should take into consideration

1. provisioning effectiveness
2. cost evaluation (weight and cube could be considered).

The methodologies or model required to achieve the above ends could be done by hand, the use of tables, or computerized calculations or combination of these procedures. Additionally, the model must be capable of complying with the Navy's supply procedures, that is; the model should be capable of providing for the requirements of criticality, demand insurance items, and infrequently used items. The model should be mission oriented while abiding by a normal usage concept. The model should be what is called a static in contrast to a dynamic one, that is; the time interval under consideration within the model would not be partitioned and the methodologies for the time intervals would not change. In addition, it would be feasible to have spare support at three levels:

1. organizational level of supply -- spares carried aboard ship or at the equipment site
2. intermediate level of resupply -- spares carried aboard the mobile logistics support force and selected shore activity
3. depot -- spares located at the depot.

Section IV

Approach

The approach to the task involved a review of literature sources to determine whether the material was applicable. In order to accomplish this, it had to be determined what kind of models were being considered, the scope of the models and whether they were applicable to the task. This was accomplished through the use of three forms which subsequently will be described.

Initially, the breakdown of the approach to the logistics problem can be categorized as follows:

1. stochastic (probabilistic, statistical)
2. deterministic (algorithms, mathematical)
3. empirical (rule of thumb, historically practical).

Many models have features of more than one of the above categories. The one that is most pertinent will be the one under which the approach will be classified. Essentially, the task would be concerned with the stocastic approach in that, in general, uncertainity underlies the sparing process. The stochastic procedures involved would depend upon underlying processes and assumed distributions. For provisioning models input distributions could be exponential, negative binomial, Poisson, Weibull, or possibly some other type. Feasible deterministic procedures will be reviewed as well as empirical procedures.

The problems of logistics for this task can be broken down into five general areas:

1. forecasting
2. inventory control and procurement procedures
3. distribution
4. maintainability
5. availability

Not considered are areas such as producibility, safety and technical performance.

The area of <u>forecasting</u> generally involves stochastic processes and procedures and would have a bearing on the other four above mentioned areas. The stochastic procedures would depend upon the distribution of the underlying random variable such as the Poisson, normal and negative binomial distribution. Algorithms or procedures that constitute methodologies would fall in this area.

The areas of inventory control and procurement procedures which encompass management budget decisions and acquisition are embedded in the economics of ordering quantities of items. The approaches or methodologies depict various processess which are classified as: queing models or systems, game theory, optimality theory, operations research, and markov processes (see References in bibliography).

The area of distribution would involve problems such as transporting, lead times for ordering and location of distribution points. Methodologies concerned with such problems are linear programming, network theory, dynamic programming and various specialized algorithms.

The area of maintainability would involve the determination of type, quantity, and extent of maintenance which must be incorporated in the logistics system as well as factors such as manpower, test equipment and technical support. Basically, a system is considered maintainable within allowable time and personnel skills. The objective is to keep the system in operational condition. There are many papers in the literature concerning the multitude of problems involved in the area of maintainability. Analytic methods could be in the areas of renewal theory, operations research or the Bayesian approach.

The area of availability involves the satisfactory operation in time of equipment(s)/system(s) when used under state conditions. Involved in this concept are operating time, active repair time, administrative time and logistic time. Provisioning effectiveness contributes to availability.

The five areas depicted above represent a general breakdown of the logistic process. Some of the methodologies described under these areas could and do span more than one area and in some cases serve as models for an entire logistic system. It is not necessary or desirable to get involved in the various aspects and details of the methods that are applicable to the problems of logistics. The purpose it to layout the framework of logistics into which the task statement under consideration could fall.

In order to classify the material which comes under review, three forms for literature review have been developed (see Forms A, B, and C, pages IV-5 through IV-7):

1. Form A -- This form provides for the listing of the (a) literature sources investigated, (b) whether the material is applicable to the task, (c) the three types of analysis depicted above (stochastic, deterministic and empirical), and (d) the five general categories depicted under areas of logistics above.
2. Form B -- This form is more detailed and supplementary to form A. Listed is a description of the purpose, background, model, inputs and outputs, as well as comments concerning the literature source.
3. Form C -- This form is a supplement to forms A and B. It lists the literature sources that are appropriate to the task assignment. It describes the provisioning model, the mode of calculation (hand, tables, computer), details the kinds of inputs and outputs.

If the literature source material does not fit the requirements of the task statement, in general, only form A will be completed. If the literature source investigated meets the requirements of the task statement or partially meets the requirements, the material will be reviewed further and the results will be summarized according to the layout of form B. If the literature source has an applicable model, it will be listed on form C. Form C as well as forms A and B are used to describe and evaluate models that are found applicable to the task statement.

The approach to the task would be to review the literature sources based upon the above procedures and to classify the reviewed logistics models as follows:

1. not part of the task assignment
2. part of the task assignment
3. related to the task assignment.

The feasibility of following such an approach would be that areas not germane to the task assignment can readily be eliminated while those that are pertinent can be reviewed in detail.

TITLE	FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS

FORM A

Subject:

Literature Source:

Purpose:

Background:

Model:

Input:

Output:

Comments:

FORM B

TITLE	PROVISIONING MODEL	MODE OF CALCULATION			INPUTS												OUTPUTS								COMMENTS
										RATES			PROVISION LEV.									TOTAL			
		HAND	TABLES	COMPUTER	PART DATA	PRICE	CUBE	WEIGHT	APPLICATIONS PER PART	REPL'CMENT	DEMAND	FAILURE	EQUIP'T	EQUIP'TS	SUB-DEPOT	DEPOT	PART TYPE	STAGES PER PART TYPE	PRICE/SPARE	WEIGHT/SPARE	CUBE/SPARE	PRICE	WEIGHT	CUBE	

FORM C

Section V

Description and Evaluation of Applicable Models

Kinds of Models

Numerous abstracts were examined for source material (see bibliography for material reviewed). There were over 125 articles that appeared to be related to the task assignment that were procured through the abstracts, only 74 articles were found to be pertinent. The number that were found to be most related to the assignment was approximately 20. In addition, several texts were reviewed that contributed to the general concepts that are incorporated in this report.

Most of the methodologies that were found applied to the areas of inventory control, procurement procedures, distribution and maintenance. Many of the approaches were economic models which emphasized cost minimization in the areas of ordering, procurement, shipping, holding and shortages. Other models were time oriented with emphasis being placed upon resupply time, ordering times, and lead times and associated with some of these times were various echelons of supply (i.e., ship, tender, depot) and stocking levels. Still other models provide solutions to specific types of problems such as shelf life deterioration, canabalization and handling parts that have demand rates over one (1) year.

The models that relate to the requirements as specified in the Scope of Effort of Section III are listed below. The models incorporated probabilistic functions, namely; the normal, negative binomial, compound Poisson, and the Poisson:

Probabilistic Function	Title Number (Form A)
Navy Model (normal and Poisson)	
Current (FMSO, OPNAV 4441.12A, APL, FLSIP)	9, 40, 15, 61
Proposed (Tender)	10
Proposed (Low Usage Items)	14

Probabilistic Function	Title Number (Form A)
Normal	13, 30, 32, 60
Negative Binomial	36, 37, 38
Poisson (Compound)	8
Poisson (Monte Carlo)	31
Poisson	20, 26, 18, 7, 11

Scope of Models

The evaluation of the applicable models must be done in terms of criteria of this task. Under Scope of Effort in Section III, the criteria for a model would be:

1. provisioning effectiveness
2. cost evaluation (cube and weight should be considered)
3. compliance with the Navy's supply procedures
4. provisioning at three levels of supply:
   a. organizational (equipment/system or ship)
   b. intermediate (mobile logistics support force or tender)
   c. depot.

The selected models will be matched against the above criteria and evaluated in terms of whether they meet the criteria, and if not, what the shortcomings are.

Navy Models (current and proposed)

The first probabilistic model to be evaluated, as depicted in Section V under Kinds of Models, will be the Navy Models (curent and proposed). The current FMSO model is simple: If the average demand rate for a part application ($\overline{D}_{RP}$) for a three (3) month period (based essentially on historical data) exceeds or equals 1, the applicable model will be based on the normal function. If the demand rate ($\overline{D}_{RP}$) is less than 1, the applicable model will be based on the Poisson function. Sparing for parts is based upon the formula:

$$\overline{D}_{RP} + t_p \widehat{\sigma_p}$$

where t_p is a risk factor and σ_p is the standard deviation of the part type. The t_p factor (risk factor) takes into consideration many elements, such as item cost, requisition sizes and demand for items. In addition, an effectiveness goal concept based on satisfied and unsatisfied load list requisitions is used to adjust the t_p factor for costs of overstocking or understocking stock levels. Also, the concept of criticality can be applied through the t_p factor. Judgement and budget constraints could work through the criticality concept to add or take away from the t_p factor that would ultimately affect stock levels. The same procedure is used when applying the Poisson model, except that a table lookup procedure could be used. The Navy uses the model for submarines and tenders.

According to OPNAV 4441.12A (title 40) and the allowance parts list (APL) (title 15) the basic resupply procedures are dependent upon the following classification of items:

1. demand based items -- those used aboard ship at least once during a 90 day period, has a .90 probability of filling total demand for these items over the entire operating period
2. insurance items -- those which have a demand of .25 or greater usage in 1 year but less than a demand base item will be selected only if essential to the support of equipment considered vital to the ship's mission
3. long life item -- those having a demand .25 or less in one year
4. technical override items -- those used to support a newly deployed equipment
5. military essentiality code (MEC) items -- currently there are two classifications for these items - critical and non-critical with most items being classified as critical (over 90%)
6. best replacement factor -- incorporated in the current Navy procedure, it is the basis for the calculations of the above items and is defined as: A weighted average which takes into consideration recent demand data, older demand data and the initial technical estimate of usage.

The OPNAV 4441.12A and the APL procedure are incorporated into the FLSIP (fleet logistics support improvement program) and are used for provisioning purposes. The procedure is depicted in title number 61 and is used for all Navy provisioning (other than that for submarines and tenders).

Refering to Table I, Navy model titles 9 (FMSO) and 61 (FLSIP) it will be noted that provisioning effectiveness and evaluation of cost, weight and cube are not considered in the current procedure. The provisioning effectiveness and cost constraints are approached indirectly through the risk factor (t_p) and gross and net effectiveness (for definitions of gross and net effectiveness see the Glossary). Without an effective methodology for determining the depth and range of parts as they relate to equipment/system,stockage of parts will be a unresolved problem. In other words, as depicted in the FMSO and FILSIP models,stockage is not based on a model which simulates the equipment/system but rather utilizes a per unit or part demand base.

Title 61 is a procedure used for computations of FLSIP COSALS. This procedure is rooted in OPNAV 4441.12A (title 40) and the APL (title 15). The Poisson function is used for depth computations for items to be provisioned.

Title number 15 is not a model. It merely describes the procedures used by the Navy for stocking shipboard parts. It is a reference for the provisioning and supply procedures and requirements for the Navy.

Title 10 is a proposal for stocking at the tender level. The purpose was to develop tables for provisioning technicians that would be easy to use. The tables were designed to allow for purchase of low cost items by provisioning technicians that are limited to $100.00.

Title 14 is a proposed procedure for sparing long life parts. This procedure would allow for long life items (those that have a demand rate that is less than insurance items) to be spared for a hull or tender. The current Navy model makes no provision for sparing items with low demand rates. The proposed method of title 14 would allow for the sparing of such items within certain cost constraints.

TABLE 1

CRITERIA FOR MODELS

Model	Title Number	Provisioning Effectiveness	Minimization: Cost	Minimization: Weight	Minimization: Cube	Navy Procedures And Essentiality Codes	Provisioning Level: Equipment	Provisioning Level: Tender	Provisioning Level: Depot	Provisioning Level: Hull
Navy (Poisson and Normal)										
Current	9 FMSO		X			X	X	X	X	X
	40 FLSIP					X	X	X	X	X
	61 FLSIP					X	X	X	X	X
	15 FLSIP					X				
Proposed	10					X		X		
	14						X	X	X	
Normal	13	X					X			
	30	X	X							
	32		X	X	X					X
	60	X					X	*	*	X
Negative Binomial	36,37,38		X	X	X	X	*	*	*	X
Compound Poisson	8						X			
Monte Carlo - Poisson	31	X	X				X			
Poisson	20	X	X				X			
	26	X	X				X			
	18						X			
	7	X	X			*	X			
	11	X	X	X	X	X	X	X	X	*

*Adaptable to this Criteria

The shortcomings of the Navy models (FMSO and FLSIP) are:

1. The provisioning effectiveness concept is not in either model. Indirectly the gross and net effectiveness concept contribute to a kind of provisioning effectiveness. The Navy's models are parts oriented (probabilities for depth only are assigned) rather than for equipment/system. If a model (stocastic) were used for provisioning on an equipment/system basis that incorporated the interaction of both range and depth for provisioning a probabilistic measure call provisioning effectiveness would be obtained.

The reliance upon historical data, as is being pursued currently by the Navy is adequate provided that the units do not change appreciably in failure characteristics and demand is relatively constant over time. However, for electronic equipments and new equipments where the demand history for items could and likely would be inadequate for provisioning the overall equipment/system approach is feasible.

2. The t_p factor in the FMSO model provides for cost evaluation through penalty factors for overstocking and understocking. However, the estimate for such penalty factors are subjective and the approach moves towards an emphasis on budget constraints. The model is geared to a cost effectiveness model rather than a mission effectiveness model.

3. The current models (FMSO and FLSIP) have no overall evaluation standard. Unless provisioning is measured in terms of mission effectiveness or a similar mode, the current approach will be open to question. The problem synthasizes to one of: Will cost effectiveness take priority over mission effectiveness or will cost effectiveness be a subset of mission effectiveness?

4. The military essentiality code (MEC) for FLSIP has two classifications (critical and non-critical). It appears that most items are classified as critical (over 90%). With this approach a viable procedure does not exist for provisioning for the range of items.

5. In effect FLSIP employs a Poisson function for determining part depth where the following equation is used:

$$\text{ALLOWANCE ITEM} = \text{MEAN (ITEM)} + 1.28 \cdot \text{MEAN (ITEM)}$$

For a COSAL this procedure for calculating depth parts is oversimplified.

Normal Models

There is a kind of evolution in the development of the normal model starting with title number 13 through 30, 32, and 60. The original concept was developed in title number 13. The approach was based on the central limit theorem with an assigned provisioning probability goal. Title number 30 expanded the concept of title number 13 to include the equipment/system availability. The author of title number 30 amplified and clarified approaches that were incorporated in title 13. Title 32 indicated a methodology not fully developed according to the author, for stocking a hull with constraints of cost, weight and cube.

The author of title 60 tested the model of title 13 and 32 above using a computer. Basically what was found was that the results were eratic. Certain distributions were skewed with the result that stocking was mostly too high. If the number of components (or processess per system as they are called) increased and if the operating time increased, then there was an improvement in results.

A weakness in the approach that seemed to be ignored was the basic central limit theorem concept, that is; the density function of a sum of independent random variables approach the normal density function regardless of the type of density function each of the variables had. The word random refers to the samples that would make up the resultant normal denisty function. These samples must be selected uniformly from the various distributions to generate a resultant normal distribution. Invariably, this is not the case. Each part that fails represents a part from a density function. There are as many density functions as part types (assuming that the process that produces these parts are in a state of statistical control) and the frequency of failure for part types are different. As a result, adherence to the central limit thereom is not achieved. In addition, the theorem upon which this approach is based states that the independent random variables must be sufficiently large (whatever large means) and that approximate normality will result. In the examples of title number 60, for small systems where the sample numbers were small, the weakness of the approach was borne out, the prediction for spare parts was poor.

The authors of the approach ignore the practical aspects of the technique in that the random concept seems difficult to handle, especially for small systems where the results are unreliable. What would be needed would be either a weighting technique to overcome the random problems or using a procedure that relys upon the distribution of sample means. Regardless, at this point in time, the following problems with the concept are evident:

1. it is unreliable for small equipments
2. a procedure must be developed to cope with the concept of randomness
3. the approach requires that the process generating the parts be statistically stable
4. the methodologies in the various write ups (title numbers 13, 30, 32, 60) would have to be merged to meet the requirements of the task
5. the approach would, for practical purposes, have to be computerized
6. a test procedure would have to be employed in order to determine whether the assumptions of normality is violated and if so, what procedure should subsequently be followed.

Negative Binomial Model

Title numbers 36, 37 and 38 concern the POLARIS logistics model. It is a cost oriented model for a hull. Actually, it is called a loss minimization model. Included in the model are penalty factors for overstocking and understocking as well as scaling or weighting factors similar to the t factor for the Navy's FMSO model (title number 9). The procedure is based upon demand data and is oriented to mission times of 2 to 3 months. Utilizing a coefficient of variation (in this case ratio of the sample mean to the sample variance) for part types the negative binomial distributions approximates the Poisson for values less than or equal to .75, the exponential for values equal to 1 and the normal and gamma for values greater than 1. The coefficient of variation in effect is a hazard rate which in essence allows for approximating the Weibull distribution. The model can be applied to new parts that belong to a certain class, without any demand history of these new parts and it can be applied to cases for low demand items.

A minimization procedure for cube, for example, requires a demand rate, the associated standard deviations and the associated holding and shortage cost ratios. The procedure requires having the allowance list of components in a priority sequence of nondecreasing essentiality (defined in a subsequent paragraph) in order to calculate a minimum cube. The process is an iterative one for approximating the total cube required. Adjustments would have to be made in assigned weighting factors for shortage and holding costs to derive a total cube that meets specified requirements. The entire allowance list would be determined by iteration through individual minimization of loss function (overstocking and understockage). A computerized approach would be required for this model beacuse of the volume of components involved.

A military essentiality code for items had been developed. A rating procedure was proposed ordering parts in importance to system mission. This was done in terms of probability values for 27 categories of items.

The model is cost oriented with built-in overstocking and understocking penalties. It is a component oriented model based upon the negative binomial distribution just as the FMSO model is based upon the Poisson and normal distributions.

The shortcomings that apply to this model are:

1. Much subjective judgement can be injected into the model when determining penalty cost values for overstocking and understocking. The analysis of cost losses from overstocking and understocking can vary substantially, dependent upon the interpretation of contributing factors to such lossess.

2. A question arises concerning how cost minimization relates to mission success. Indirectly, if cost minimization worked properly more funds would be available for provisioning. However, there is no provision in the model, except indirectly for measures of mission success.

3. Currently, items are precluded from being provisioned, especially when demand for them is low. The fact that certain items are not provisioned on one mission does not mean that they should not be provisioned on subsequent missions. No solution for this condition exists in the model. The claim is made that low demands could be provisioned but no perceivable procedure is described.

4. The scale values (weighting factors), like the t_p value for the FMSO model, serve as a dumping ground for unresolved factors. It serves much like a cranking device to increase or decrease spares in an endeavor to match demand. How well the procedure works has yet to be resolved.

5. The series concept for provisioning especially in relation to electronic equipments is not considered for range and depth of spare parts. For example, assume demands for parts are independent and the sparing procedure calls for the provisioning of parts for a three month mission with a probability of .90. If, for illustrative purposes, there were eight part types that were vital to the mission then the probability of not having sufficient vital spares would be $(.90)^8$

or .43. With an increase in the number of vital parts, it can be seen that mission success deteriorates rapidly without an adequate range and depth of spare parts.

6. The model is a cost oriented model and demand oriented model designed for provisioning a hull. It is not mission oriented and not well suited to meet the criteria of provisioning electronic equipments.

Poisson Model

Title number 8 was cited to illustrate the use of a compound Poisson function for spare provisioning. The concept of spare shelf life deterioration as well as bunch effects (where a part in an equipment fails, other parts are replaced, as well as the failed part, for maintenance and other purposes) has a bearing upon the spare distribution functions. A mode of representation would be a two parameter Poisson function (called a compound Poisson function) in lieu of the single parameter Poisson function.

Title number 31 illustrates the adaptability of the Black and Proschan model for system design. A Monte Carlo procedure is used to simulate random equipment failures. The equipment is simulated by a computer program based upon a series parallel configuration. As operating time increases, failures are simulated through the random generator to determine if the equipment/system would fail. Down times are cumulated as operating times increase in order to calculate the system availability. The equipment/system simulation in the series parallel configuration has the fault tree analysis characteristics (various modes of system failure such as one, two and three components). It is conceivable that the fault tree analytic approach could be a substitute for the Monte Carlo procedure. However, by the procedure described, the equipment/system can be analized for design (or redesign) purposes or for provisioning purposes.

Title number 20 is a spare part procedure for new equipments. It is a hand solution model. Given the components costs, the number of like components, operating time and the failure rate for the components, assuming an exponential process and the adequacy of spares as having a Poisson distribution, a model is developed. The model was designed for equipments with a small number of components and sparing is based only on critical items. A provisioning goal is set and based upon a series configuration of parts and exponential process, spares are added until a provisioning goal has been met. In conjunction with these computations, a cumulative cost value is derived.

Title number 26 is an expanded version of 20 above that was written by the same author. A more detailed account is given in this paper concerning the proposed methodology. It was emphasized that the procedure does not rely upon an exponential process, in other words; it can be designed for a normal, negative-binomial or Weibull processes.

Title number 18 is concerned with the Poisson model on a per part basis. A computer program has been written to generate output at various confidence levels (i.e., .80, .90, .95). Based upon a multitude of computer runs, charts have been drawn to determine the number of required spares dependent on the confidence level desired. The procedure does not consider provisioning effectiveness.

Title number 7 is a modified Black and Proschan opt[illegible] spare provisioning model for equipments/system. The claim is made that after exhaustive evaluation of the state of the art; the model (Black and Proschan) is the most capable of providing the support and trade off orientation required in the world of provisioning.

The methodology was computerized with some slight changes in the model. The computer program was first written in FORTRAN IV for the Honeywell 2200 for 900 line items. Subsequently, the model was programmed to run on the UNIVAC U-494 and it was capable of handling 7,000 line items. Then, the Naval Applied Science Laboraties at Brooklyn, New York, estimated that it would be possible to handle 30,000 line items on the CDC-6600 with running time over 3 hours.

The paper identified equipment for which usage data was collected over a 1½ to two year period for various equipments. [illegible] two tables, a comparison was made between the conventional Navy procedures and the Black and Prochan model for provisioning results. The comparison was very favorable for the Black and Proschan model.

Title number 11 is a modified Black and Proschan model for equipment(s)/system(s), tender(s) and depot(s). It is an expansion of the Black and Proschan model beyond the equipment/system level. It is a computerized system in the FORTRAN IV language and written for the 7090 computer. It handles up to 2500 line items and can easily be adjusted to handle 8,000 or more. The model was designed to provide a provisioning procedure for the AN/SPS-40 radar at the equipment (ship) tender and depot levels. Over 12,000 part application and over 2,000 distinctive parts were involved. The input was the FSN or part number, cube, weight, cost, number of applications, replacement rates and resupply procedures.

The program has the capability to set provisioning goals at prescribed levels for equipments/systems, tender(s) and depot(s), and cumulative cost, weight, and cube and a normalized provisioning reliability function. There are options in the computer program which allow for checks and verificati..s of computerized results. The provisioning probability calculations for the stock list of this model in contrast to the standard stock list for the APL was extremely favorable.

The shortcomings that apply to all of the Poisson models are:

1. The models must be adjusted to accomodate a multi-mission provisioning procedure. The Black and Proschan model is an initial type provisioning model. To accomodate for follow-on provisioning in certain cases, a modification in procedures may be required. This would be true especially when the complete range of on site parts was not provisionined during intial provisioning using this model.
2. The models are restricted to part replacements being distributed as a Poisson function. The models could be more general, certain failures for parts could be normal, compound Poisson, negative binomial or Weibull. Accomodations for such functions do not

exist in the models.

3. System availability calculations are not in any of the models.

Section VI

Rank of Applicable Models

Based upon the Scope of Effort for the task (Section III) and Description and Evaluation of Applicable Models (Section V), it is evident that there are shortcomings in all models that were found.

The reviewed models were designed for specific purposes. Some were designed for sparing a hull, others were designed to be simple to understand and apply, others were designed for table lookup or to be hand calculated, others were designed for sparing at the equipment/system level and others were designed to comply with budget constraints.

The purpose of the effort of this task was to find sparing models for electronic equipment(s). This would tend to restrict the problem to the area of low demand rate items. Low demand rate items, as far as provisioning is concerned, usually are depicted in terms of a Poisson function. Other functions, such as the compound Poisson, normal and negative binomial may apply. The above functions were found in selected models but the model designs did not completely meet the scope of the task for models as described in Section III.

The selected models have been ranked based on the criteria of factors described in Section III (Area of Task). Provisioning effectiveness was considered the primary factor in ranking models in that a mission could be seriously affected due to the lack of parts. The use of a model which employs the provisioning effectiveness concept affords a measure whereby a missions success can be gauged for equipment(s)/system(s). Cost (as well as weight and cube) of parts was considered secondary in importance. A model with a cost (weight or cube) limiting feature that lacks provisioning effectiveness lacks dependability. Regardless of the model that is employed for provisioning, it is necessary to comply with the Navy's supply procedures. In effect, unless these procedures constitute a major problem for a provisioning model, they would not be considered significant. Provisioning for tender(s) or depot(s) is considered secondary to equipment(s) provisioning. If a model has this capability in addition to equipment(s)/system(s) provisioning capability, all else being equivalent, the model would be considered a superior model. Table I (Criteria for Models) depicts the criteria as applied to the models that were considered applicable for consideration. The ranking of the models are as follows:

1. Title number 11 (Poisson-Computerized)
2. Title number 7 (Poisson-Computerized)
3. Title number 31 (Poisson-Computerized)
4. Title numbers 20, 26 (Poisson-hand calculation)
5. Title numbers 36, 37, 38 (negative binomial-POLARIS model)
6. Title number 9 (FMSO model)
7. Title numbers 40, 15, 61 (FLSIP model)
8. Title number 60 (normal model-needs further development)
9. Title numbers 13, 30 (normal model-hand calculation)
10. Title number 13 (normal-hand calculation).

Title number 11 comes closest to meeting the requirement for the scope of effort for a model. It provides for provisioning effectiveness, calculations for cost, weight, cube,provisioning at three levels of supply and accomodates the Navy's supply procedures. However, it does not encompass multi-missions. Based on the provisioning goal assigned certain parts may not be provisioned on the first mission, especially for highly reliable equipments. On subsequent missions a procedure has to be set up to cope with this situation.

Title number 7 is similar to number 11, in that it needs to be multi-mission oriented. A major difference is that it is limited to the equipment level. There were no indications of calculations for weight or cube but apparently that would not be a problem. However, the provisions for the Navy's supply procedures may require a certain amount of computer program adjustments.

Title number 31 is a procedure to improve system design for the purpose of enhancing reliability. The purposes is to detect reliability weakness in an equipment/system. The procedure employs the Black and Proschan model with the Monte Carlo feature for simulating failures. It is a computerized model, requiring a simulation of a system (in terms of fault tree analysis, where a system is laid out in series and parallel configuration) for analysis. However, the range of the model is limited to small system. Although the model was designed as a tool for enhancing the reliability of an equipment, it is adaptable as a provisioning tool.

Title number 20 and 26 are hand models that are suited for small equipments.

The POLARIS model is prefered over the current Navy's procedure in that it is more flexible. The provisioning procedure for parts for the POLARIS model are refined through the use of the coefficient of variation and the military essentiality ratings. The POLARIS model is budget oriented and provisioning is geared in that direction rather than upon mission success. The procedures for POLARIS and FMSO are not that much different conceptually, except that FMSO relys upon the normal and Poisson functions for provisioning whereas the POLARIS model relys upon the negative binomial function.

The FMSO model through the use of weighting factors (assigned through the t value) give this model a depth of provisioning capabiltiy not possessed by the procedures of FLSIP COSALS (based upon OPNAV 4441.12A and the APL). Under the net effectiveness procedure for a COSAL for both models a kind of mission effectiveness is achieved (the net effectiveness is the demand satisfied divided by the demand received of requisitions for load list items).

Title number 60 has shortcomings which are listed under normal Model in Section V. These shortcomings apply to the underlying concept for all title numbers in this group (13, 30, and 60). This, in addition to the difficulty in administering and interpreting results is cause for not recommending the methodology.

Section VII

Conclusions and Recommendations

No model was found that would be general enough to meet the complete requirements for provisioning for electronic equipments/systems. Models that have favorable features have been found but no comprehensive model was found. The most applicable models that are available are those described under Poisson models. To meet the needs of a general and more complete model, the following modifications should be incorporated:

1. Provide for provisioning based upon the multi-mission concept. The sparing procedure for this concept should take into consideration long life items and those items that are not spared on previous missions. The multi-mission concept is not incorporated in the Black and Proschan model, under certain conditions, provisioning could be seriously affected, if the model was used for restocking.
2. Provide for a Monte Carlo procedure to circumvent the initial provisioning restriction of the Black and Proschan model. Component failures could be simulated for an exponential, normal or other type of combination of processes for spare parts provisioning.
3. Using the coefficient of variation (the ratio of the mean to the variance) for a test for unit provisioning. This would expand the capability of the model so that parts could be provisioned based upon the Poisson, normal or other distributions.
4. In order to provide for a bunched effect where the replacement of one unit leads to the inspection of other units and possible replacement, a compound Poisson distribution for parts replacement should be used.
   A procedure for estimating parts that are subject to such replacement should be set up and identified so that the information can be incorporated in the model.

5. A procedure should be incorporated to allow for the provisioning of long life items. This could be accomodated through the multi-mission procedure described above.

6. Provide for inputing to the model the necessary data to calculate availability and operational readiness.

7. The Poisson models have cost, weight and cube cumulative features. These values are cumulated as parts are added to the provisioning list. Occasions may arise where the minimization of cost, weight and cube would be required. This could be accomplished by the following calculations where the calculation for provisioning purposes is

$$MAX \left(\frac{\Delta PROB_i}{\Delta COST_i} \right)$$

where $\Delta PROB_i$ = incremented probability associated with the i-th spared item

$\Delta COST_i$ = cost of i-th item

$MAX\left(\frac{\Delta PROB_i}{\Delta COST_i}\right)$ = maximum provisioning probability for the cost increment

If minimization of weight and cube are desired $WEIGHT_i$ and $CUBE_i$ would be substituted in the denominator.

If the minimization of a combination of the three factors were desired, the following formula could be used

$$MAX \left(\frac{\Delta PROB_i}{WT_1 \cdot \Delta COST_i + WT_2 \cdot \Delta WEIGHT_i + WT_3 \cdot \Delta CUBE_i} \right)$$

where WT_1, WT_2, and WT_3 are assigned weighting factors for cost, weight and cube respectively and where

$\Delta COST_i$ = proportion of the total allowable cost of the i-th item

$\Delta WEIGHT_i$ = proportion of the total allowable weight of the i-th item

$\Delta CUBE_i$ = proportion of the total allowable cube of the i-th item

$\Delta PROB_i$ = incremental probability associated with the i-th item

8. Provide for a simple and effective hand or table lookup solution. Those model. (title 20 and 26) that were found and listed under the Poisson model would have to be made comprehensive and effective.

This task deals with the selection of the appropriate type of models to be used for provisioning of electronic equipment(s)/system(s). A review of the literature has lead to the above recommendations to be incorporated in a proposed model. If this task is to be pursued further, the outline of the proposed model above will have to be developed into a detailed procedure and thereafter tested and implemented. Using the computerized model depicted in title 11 which comes closest to approximating the scope of this task and the modifications recommended above, a comprehensive and versatile tool for provisioning electronic equipments/system would be available.

Section VIII

Literature Evaluation
(Form A)

TITLE	(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
1) A Queuing Approach To Logistics Systems * — Noel M. Mirasul	Queuing System	✓				✓			Peripheral Application
2) [illegible] In [illegible] Systems and the Theory of Reliability * — Warren Hirsch, M. Meisner	Dynamic Model					✓			Peripheral to Task
3) Detection of Failure Rate Increases * — G. Lorden and I. Eisenburg						✓			Peripheral to Task
4) Predicting Spare Part Needs * — S. S. Aipie	Cost Minimization Procedure for Machine Parts	✓				✓			
5) An Application of Logistic Support Models * — H. C. Okraski	Philosophical							✓	
6) Spare Parts For Machines: Which Ones And How Many * — Robert C. Chamberland	Optimization Procedure For Cost Control	✓				✓	✓		

* NOT APPLICABLE + APPLICABLE
O RELATED

FORM A

TITLE		(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
7) OPTIMUM SPARES [illegible] FOR ELECTRONIC EQUIPMENTS/SYSTEMS — R. POWELL AND R. LUTZ	+	BLACK AND PROSCHAN POISSON PROVISIONING MODEL (MODIFIED)					✓			APPLICABLE
8) INITIAL PROVISIONING WITH SPARE DETERIORATION — PAUL J. SCHWEITZER	+	COMPOUND POISSON PROVISIONING PROCEDURE					✓			CUMBERSOM METHODOLOGY BUT APPLICABLE
9) FMSO LOAD LIST MODEL	+	BASED ON NORMAL AND POISSON FUNCTION FOR PROVISIONING					✓			
10) FBM LOAD LIST PREDICTION MODEL (FOR TENDER)	+	BASED ON NORMAL AND POISSON FUNCTIONS AS WELL AS TABLES FOR COST CONTROL					✓			
11) STOCK PROVISIONING PROCEDURE FOR THE AN/SPS-40 RADAR — ARTHUR RUPP	+	PROVISIONING BASED ON POISSON FUNCTION FOR EXPONENTIAL PROCESS STOCKING FOR EQUIPMENTS SUB-DEPOTS AND DEPOTS					✓			
12) NEW INVENTORY ANALYSIS TECHNIQUE — JAMES EDGAR	*						✓		✓	STRESSES A MODIFIED AVAILABILITY MODEL

* NOT APPLICABLE   + APPLICABLE
O RELATED

FORM A

TITLE		(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
13) TECHNIQUE FOR DETERMINING THE NUMBER OF SPARES WITH A PRECHOSEN [illegible] LEVEL N.E. LYNCH AND R.S. MORRIS	+	BASED ON CENTRAL LIMIT THEOREM (NORMAL MODEL)					✓			SPARING POLICY FOR DEPOT MORE THAN EQUIPMENT
14) A METHODOLOGY FOR ESTIMATING EXPECTED USAGE OF REPAIR PARTS WITH APPLICATION TO PARTS WITH NO HISTORY S.E. HABER AND R. SITGREAVES	+	REPAIR PARTS ARE POISSON DISTRIBUTED. ALIKE PART TYPES POOLED FOR DEMAND ESTIMATES					✓			ESTIMATING DEMAND FOR ITEMS THAT HAVE A HISTORY OF ZERO DEMAND FOR LONG TIMES
15) THE ALLOWANCE PARTS LIST	+								✓	STANDARDS FOR THE ALLOWANCE PARTS LIST
16) A MODEL FOR PROCUREMENT, ALLOCATION AND REDISTRIBUTION FOR LOW DEMAND ITEMS G. HADLEY AND TIM WHITIN	*	DYNAMIC PROGRAMMING INCORPORATING THE POISSON FUNCTION	✓	✓			✓			
17) OPTIMUM SPARES PROVISIONING ALLEN D. BRAGG	O	POISSON FUNCTION FOR PROVISIONING					✓			STATES THE CONCEPTS INVOLVED IN THE BLACK AND PROSCHAN POISSON MODEL
18) RELIABILITY APPROACH TO THE SPARE PARTS PROBLEM G.H. EBEL AND A.J. LANG	O	POISSON FUNCTION FOR PARTS PROVISIONING WITH CONFIDENCE INTERVALS					✓			

* NOT APPLICABLE + APPLICABLE
O RELATED

FORM A

TITLE	(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
19) SYSTEM AVAILABILITY PREDICTIONS — H. E. LYNCH	*							✓	DISCUSSION OF CONCEPTS CONCERNING AVAILABILITY
20) ON OPTIMAL REDUNDANCY — GUY BLACK AND FRANK PROSCHAN	+ POISSON FUNCTION FOR PROVISIONING WITH SERIES CONFIGURATION FOR EQUIPMENT					✓			
21) OPTIMAL POSITIONING OF INVENTORY STOCK IN A MULTI-ECHELON SYSTEM — G. BROWN, L. SILVERMAN, L. PEARLMAN	* DYNAMIC PROGRAMMING MODEL					✓		✓	INVOLVED WITH PROBLEMS OF REORDERING HOLDING, COSTS
22) PROJECT ABLE (ACQUISITION BASED ON CONSIDERATION OF LOGISTICS EFFECTS) IRVING KATZ	*	✓						✓	
23) NAVY LOGISTICS INFORMATION SHARING (NAVLIST)	*							✓	DISCUSSION OF LOGISTICS ORGINAZATION AND DECISION MAKING
24) ALLOCATION OF SPARES AND REPAIR RESOURCES TO A MULTI-COMPONENT SYSTEM — W.S. DEMMY	* DYNAMIC PROGRAMMING LAGRANGE MULTIPLIERS FOR COST MINIMIZATION	✓				✓			

* NOT APPLICABLE   + APPLICABLE
O RELATED

FORM A

TITLE	(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
25) RELIABILITY AND MAINTAINABILITY — MILITARY, THE LOGISTICS CHALLANGE * — GEORGE E. FOUCH								✓	
26) SPARE PARTS KITS AT MINIMUM COST + — GUY BLACK AND FRANK PROSCHAN	POISSON PROVISIONING FOR PART TYPES WITH EQUIPMENT REPRESENTED BY A SERIES CONFIGURATION					✓			
27) STOC[illegible] ALLOCATION OF SPARE COMPONENTS * — B. P. LIENTZ		✓				✓			
28) AN EASY ALLOTMENT METHOD ACHIEVING MAXIMUM RELIABILITY O — MASAFUME SASAKI	REDUNDANT-STANDBY MODEL APPLICABLE FOR EQUIPMENT DESIGN					✓			RELATED BUT NOT APPLICABLE
29) DYNAMIC PROGRAMMING AND THE RELIABILITY OF MULTICOMPONENT DEVICES *	DYNAMIC PROGRAMMING APPROACH APPLICABLE TO EQUIPMENT DESIGN					✓			
30) SPARES AND SYSTEM AVAILABILITY + — J. VANDEN BOSCH	NORMAL PROBABILITY MODEL				✓	✓			

* NOT APPLICABLE + APPLICABLE FORM A
O RELATED

TITLE		(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
31) A MONTE CARLO APPROACH TO SPARE PROVISIONING R. S. SEBENY	+	MONTE CARLO TECHNIQUE FOR ESTIMATING FAILURES FROM EXPONENTIAL PROCESS. FAULT TREE EQUIPMENT MODEL WITH [illegible]				✓	✓			
32) AN OPTIMAL ALLOWANCE LIST MODEL MINA H. GOURARY	+	BASED ON NORMAL FUNCTION, OPTIMIZATION PROCEDURE FOR COST MINIMIZATION					✓			
33) RESOURCE ALLOCATION IN A SEQUENTIAL FLOW PROCESS WITH AN APPLICATION TO THE NAVAL RESUPPLY SYSTEM L. D. [illegible]	*	DYNAMIC MODEL. CONCERNED WITH SHIPPING, HOLDING AND REORDERING TIMES	✓	✓			✓	✓		
34) OPTIMAL SPARES FOR STOCHASTICALLY FAILING EQUIPMENTS S. S. SUTTON, R. LLOYD	*	DYNAMIC MODEL	✓	✓			✓	✓		
35) AN APPLICATION OF NETWORK ANALYSIS TO THE DETERMINATION OF MINIMAL COST AIRCRAFT PIPELINE FACTORS C. H. FALKNER	*	NETWORK ANALYSIS WITH COST OPTIMIZATION FACTOR	✓					✓		
36) POLARIS LOGISTICS STUDY NO. 1 M. DENICOFF, J. FENNELL S. HABER, W. MARLOW F. SEGEL, H. SOLOMON	+	PROVISIONING [illegible] BASED ON THE NEGATIVE BINOMIAL DISTRIBUTION							✓	

* NOT APPLICABLE + APPLICABLE
O RELATED

FORM A

	TITLE	(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
37	POLARIS LOGISTICS STUDY #2 POLARIS ALLOWANCE INPUT DATA DENICOFF, FENNELL, HARLOW, SOLOMON +	PROVISIONING PROCEDURE BASED ON THE NEGATIVE BINOMIAL FUNCTION							✓	STANDARDS AND REQUIREMENTS FOR INPUT DATA
38	POLARIS LOGISTICS STUDY # 3 A POLARIS LOGISTICS MODEL DENICOFF, FENNELL, HARNER, SOLOMON +	PROVISIONING PROCEDURE BASED ON THE NEGATIVE BINOMIAL FUNCTION					✓			
39	OPNAV 4423.4 PROVISIONING OF END ITEMS OF MATERIALS *	PROCEDURES FOR PROVIDING END ITEM BY CONTRACTORS							✓	
40	OPNAV INSTRUCTIONS 4441.12A SUPPLY SUPPORT OF THE OPERATING FORCES +						✓	✓		
41	STATISTICAL CALCULATIONS FOR THE LOGISTICS OF ENGINE REMOVALS (SCALER) METHOD JAMES R. MATTHESEN, PH.D. *						✓			
42	THE UTILITY OF RELIABILITY PREDICTION FOR LOGISTICS FORECASTING JAMES H. BRADY *	PHILOSOPHICAL							✓	

* NOT APPLICABLE
o RELATED
\+ APPLICABLE

FORM A

TITLE	(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
3) AN OBJECTIVE BAYES APPROACH FOR INVENTORY CONTROL * G.J. FEENEY AND C.C. SHERBROOKE	DYNAMIC MODEL	✓							
4) PROCUREMENT AND MANAGEMENT OF SPARES O — H.S. CAMBELL (1966)	GENERAL DISCRIPTION OF SEVERAL MODELS							✓	GENERAL DESCRIPTION OF VARIOUS TYPES OF MODELS
5) TECHNIQUES IN OPTIMIZING SPARE-PARTS PROVISIONING (1967) O R.H. HYNES AND L.R. DOYON	SUMMARY OF SEVERAL INVENTORY TYPE MODELS					✓			SUMMARY OF SEVERAL TECHNIQUES — NOT FEASIBLE
6) A METHOD OF ACHIEVING EQUIPMENT RELIABILITY, MAINTAINABILITY AND LOGISTICS SUPPORT O R.R. BARKALOW	DEMAND TYPE MODEL					✓			PROVISIONING IS BASED ON PART FAILURES OPERATING TIME AND CALCULATION OF CONFIDENCE INT.
7) A STOCHASTIC MODEL OF A REPAIRABLE ITEM INVENTORY SYSTEM * — F.R. RICHARDS (1972)		✓				✓			MODELING OF A REPAIRABLE ITEM SYSTEM FOR INVENTORY MANAGEMENT
8) REPLACEMENT WHEN CONSTANT FAILURE RATE PRECEEDS WEAROUT O LARRY HUNTER AND FRANK PROSCHAN	DYNAMIC MODEL					✓			HAND SOLUTION METHOD. CAN BE CONSIDERED IN A MORE GENERAL APPROACH

* NOT APPLICABLE + APPLICABLE
O RELATED

FORM A

TITLE		(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
49/ SPARE PARTS SUPPORT FOR PRE-PRODUCTION MODELS by JOSEPH D. PATTON, JR	*	COST OPTIMIZATION PROCEDURE / POISSON FUNCTION	✓				✓			
50/ PARTS ORIENTED RELIABILITY PROGRAMS AND PROBLEMS — C. S. BARTHOLOMEW	*	COST CONTROL PROCEDURE	✓				✓			
51/ AN INVENTORY MODEL FOR REPAIR PARTS — MARTIN J. BECKMAN	*		✓							
52/ RELIABILITY OF A SYSTEM IN WHICH SPARE PARTS DETERIORATE IN STORAGE — GEORGE WEISS	O	MARKOV PROCESS					✓			PERIPHERALLY RELATED TO TASK
53/ SPARES FOR WEAPONS SYSTEMS — LOUIS P. STANNARD	*	PHILOSOPHICAL OVERVIEW FOR SPARING WEAPONS SYSTEMS							✓	
54/ A QUEUING APPROACH TO LOGISTICS SYSTEMS — NOEL H. MIRASOL	*		✓				✓			

* NOT APPLICABLE + APPLICABLE FORM A
O RELATED

TITLE	(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
55) IMPACT OF ADVANCED LOGISTICS CONCEPT ON AN ISRC-20 FAMILY EQUIPMENTS * — G. A. COHEN (1974)	QUESTIONABLE MODEL - NOT SUITED FOR THIS TASK					✓			PROPOSAL FOR RELIABILITY MODEL AND DEPOT PROVISIONING
56) THE DESIGN OF MILITARY SUPPLY TABLES FOR SPARE PARTS (1958) O — M.A. GEISLER AND R.W. KARR	OBTAINING OR ESTIMATING THE PROPER DISTRIBUTIONS REQUIRED IN THE MODEL COULD BE PROBLEM					✓			METHODOLOGY USABLE OR TO BE CONSIDERED FOR TABLE LOOKUP FOR SPARING
57) THE (S-1,S) INVENTORY POLICY UNDER COMPOUND POISSON DEMAND A THEORY OF RECOVERABLE ITEM STOCKAGE * J.G. FEENEY AND C.C. SHERBROOKE	COMPOUND POISSON FUNCTION FOR DEMAND					✓			INVENTORY MANAGEMENT FOR REPAIRABLE ITEMS
58) THE INITIAL PROVISIONING DECISION FOR INSURANCE TYPE ITEMS * — R.W. BURTON AND S. C. JAQUETTE	BAYESIAN APPROACH WITHIN BUDGET CONSTRAINTS					✓	I		PERIPHERIAL APPLICATION TO TASK
59) PLANNING BY RESOURCE ALLOCATION METHODS * — J. L. TAYLOR AND J. E. WALSCH	DYNAMIC PROGRAMMING MODEL	✓				✓	✓		
60) AN EVALUATION OF A TECHNIQUE TO DETERMINE ITS APPLICABILITY + — RONALD D. OGLESBY	NORMAL MODEL				✓	✓			

* NOT APPLICABLE + APPLICABLE FORM A
O RELATED

TITLE	FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
1) LOGIC CHART COMPUTATION OF FLCIP COSALS + — FLEET MATERIAL SUPPORT OFFICE MECHANICSBURG, PA	PROCEDURE FOR CALCULATING AND DETERMINING COMPONENTS TO BE PROVISIONED							✓	
2) INVENTORY CONTROL WITH PROBABILISTIC DEMAND AND PERIODIC WITHDRAWALS * — W. H. HAUSMAN AND L. J. THOMAS	DYNAMIC MODEL	✓				✓			NOT IN AREA OF TASK
3) MAINTENANCE POLICIES WHEN FAILURE DISTRIBUTION OF EQUIPMENT IS ONLY PARTIALLY KNOWN * — R. [illegible] AND A. [illegible]	DYNAMIC PROGRAMMING WITH OPTIMUM CHECKING SCHEDULE			✓		✓			OUTSIDE REQUIREMENTS OF TASK
4) CALCULATING THE RELIABILITY OF [illegible] SYSTEMS WHILE TAKING INTO ACCOUNT THE WORKING SHIFTS OF MAINTAINANCE PERSONNEL * — D. G. [illegible]	QUEUING THEORY WITH OPTIMIZATION OF MAINTAINANCE TIME AND PERSONNEL			✓		✓			NOT APPLICABLE TO TASK
5) RELIABILITY - CENTERED MAINTAINANCE * — MAJOR GENERAL E. H. JOHANSEN	PHILISOPHICAL IN NATURE WITH EMPHASIS ON COST CONTROL							✓	NOT APPLICABLE TO TASK
6) AN INVENTORY MODEL FOR REPAIR PARTS - APPROXIMATIONS IN THE CASE OF VARIABLE DELIVERY TIME * — M. J. BECKMANN	DYNAMIC MODEL WHICH IS COST ORIENTED	✓				✓			NOT APPLICABLE TO TASK

* NOT APPLICABLE + APPLICABLE
O RELATED

FORM A

TITLE	(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINMENT	AVAILABILITY	STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
67) A UNIFIED MODEL FOR DEMAND PREDICTION IN THE CONTEXT OF PROVISIONING AND PROCUREMENT * S.E. HABER AND R. SITGREAVES	CONCERNED WITH INVENTORY CONTROL OF LOW USAGE ITEMS AND INVENTORY PROCEDURES	✓				✓			IMPROVEMENT OF DEMAND PREDICTION — NOT APPLICABLE TO TASIC.
68) A REPLACEMENT POLICY FOR COMPONENTS OF A PURE SERIES SYSTEM UTILIZING ONE COMPONENT AS AN INDICATOR OF REPLACEMENT TIME * M. G. O'DELL	REPLACEMENT OF COMPONENTS DEPENDENT ON KEY CLOCKED COMPONENTS.					✓			REPLACEMENT PROCEDURE FOR SUB SYSTEMS COMPONENTS — NOT APPLICABLE
69) ON CHOOSING A FAMILY OF PROBABILITY DISTRIBUTIONS FOR LEAD TIME DEMAND O F. R. RICHARDS AND M.V. RUSSELL	GAMMA FUNCTION AS A BETTER PROVISIONING MODEL THAN NORMAL					✓			INTUITIVE AND THEORETICAL ARGUMENTS SUGGESTED — NOT FEASIBLE
70) INITIAL PROVISIONING OF A STANDBY SYSTEM WITH DETERIORATING AND REPAIRABLE [illegible] * D. J. JAQUETTE	STOCKING PROCEDURE FOR KEEPING SYSTEM UP PROVIDED LESS THAN N COMPONENTS OF SYSTEM FAIL					✓			NOT APPLICABLE
71) A REVIEW OF MILITARY ESSENTIALITY CODING AND SHIPBOARD ALLOWANCE COMPUTATIONS O J. A. MATALAGAUE	COMMENTARY ON MEC AND FILSIP AND THEIR SHORTCOMINGS							✓	PERIPHERAL ARTICLE CONCERNING TASIC PERIPHERAL
72) BEST REPLACEMENT FACTOR O — F. C. STRAUCH	DESCRIPTION OF PROCEDURES FOR DERIVING THE BRF							✓	PERIPHERAL ARTICLE CONCERNING TASIC PERIPHERAL

* NOT APPLICABLE + APPLICABLE FORM A

O RELATED

VIII-13

TITLE	(MODEL) FORECASTING	INVENTORY CONTROL	DISTRIBUTION	MAINTAINABILITY	AVAILABILITY		STOCHASTIC	DETERMINISTIC	EMPIRICAL	COMMENTS
73) DEMAND FORECASTING * WITH PROGRAM. FACTORS — MARTIN COHEN	MATHEMATICAL PROCEDURE							✓	✓	DIFFERENT APPROACH TO DEMAND FORCASTING — NOT APPLICABLE
74) A COMPARATIVE STUDY * OF DEMAND FORCASTING TECHNIQUES FOR MILITARY HELICOPTER SPARES (SUB-SYSTEMS) — ROBERT E. MARKLAND	Polynomial exponential smoothing model						✓			USING HISTORICAL DEMAND TO PROJECT FUTURE DEMAND PROCEDURE NOT ADEQUATE FOR LOW DEMAND ITEMS

NUMEROUS OTHER ARTICLES WERE REVIEWED HOWEVER, THE TITLES SUGGESTED THAT THE CONTENTS WERE NOT APPLICABLE OR PERIPHERIALLY APPLICABLE TO THE TASK ASSIGNMENT

* NOT APPLICABLE
o RELATED
\+ APPLICABLE

FORM A

Literature Evaluation

Form B

Only title numbers applicable to the task Assignment are listed on this form.

Title No. 7

Subject: Optimum Spare Provisioning for Electronics Equipments/ Systems

Literature Source: Naval Engineering Journal, Feb. 1970 R. I. Powell and R. D. Lutz

Purpose: Alternative to the part probability method as used by Fleet Logistics Supply Improvement Program (FLSIP).

Model: Spare provisioning model of Black and Proschan (Poisson process)

Input: Failure rates, costs

Output: Equipment/System effectiveness vs. costs

Comments: Method is based upon the Poisson function assuming a series configuration to derive a probabilistic effectiveness for equipment(s)/systems.

FORM B

Title No. 8

<u>Subject:</u> Initial Provisioning with Spare Deterioration

<u>Literature Source:</u> Operations Research, Vol. 15, May 1967, Initial Provisioning with Spare Deterioration, Paul J. Schweitzer

<u>Purpose:</u> A study to determine the steps required to establish a spare parts provisioning procedure under the assumption that spare parts lifetimes deteriorate.

<u>Background:</u> Spare provisioning procedures usually assume that (1) spare parts do not fail on shelf, (2) spare parts have the same failure rates as parts in use. A study has indicated that even a small amount of spare deterioration results in serious degradation of system reliability.

<u>Model:</u> System of N identical parts with an initial supply of M parts. The N parts are assumed to fail independently each with a constant failure rate λ while the spare parts are assumed to fail independently with a constant failure rate μ. Compound Poisson function used to derive spare part depth.

<u>Input:</u> Failure rates, failure rates for spare equipments (weighted), probability provisioning goal for equipments, operating time

<u>Output:</u> Equipment spares for operating time (t).

<u>Comments:</u> A graphic method for determining spare requirements necessary for a mission of specified operating time with a preset probability provisioning level. Hand calculations are cumbersom requiring interpolation. Applicable to reliable equipments requiring a small number of spare parts in that the calculations are cumbersom.

Title No. 9

Subject: FMSO Load List Model

Literature Source: Load List Manual, Navy Fleet Material Support Office, Mechanicsburg, PA

Purpose: Provide load list quantities for the three levels of material support: Individual ship, mobile logistic support force and selected shore activities, and depots that serve to supply the other two levels

Background: A method simple enough to understand and apply was required.

Model: Load list is based upon rates derived from historical demand data, population and failure data and technical overrides. With the mean demand and variation in demand for specified time periods, load lists are calculated based upon the normal and poisson distributions. The criticality of a part is assigned a risk factor which is used for generating the load lists.

Input: Average demand (3 month), variation in demand, number of applications, risk control parameters

Output: Load lists for individual ships, mobile logistic support force and selected shore activities and depots

Comments: No overall protection level is obtainable under this procedure. Relation between cost and mission effectiveness is not obtainable. Sparing is on a per item or unit basis, dependent upon demand, demand variation and risk control (weighting) parameters.

FORM B

Title No. 10

Subject: FBM load list prediction model

Literature Source: ALRAND working memorandum 304-FBM load list prediction model, 20 May 1977

Purpose: Provide Tender load list quantities for use during the provisioning of SSBN hull for mechanical, electrical, electronic or ordnance equipments

Background: The TLL (Tender Load List) computation models for determining range and depth derives quantities which vary with original provisioning quantities and excesses/shortages result. Provisioning technicans need an equation or table to determine range and depth of items that will be easy to use and practical.

Model: The procedure is based on the QAD (quarterly average demand) where items have a demand history of two or more years. Where history is lacking the QAD is the product of the BRF (best replacement factor) and the population to be supported. The Poisson distribution is assumed to be descriptive where the forecasted QAD is one or less and the normal distribution is assumed where the QAD is greater than one.

Input: QAD's, BRF's, number of part applications per part, price, risk control parameter.

Output: Tender load lists with and without constraints on price and stocking levels per part type.

Comments: This procedure is a supplement to the tender load list computational model. This procedure has the option of imposing arbitrary constraints such as a maximum of $100.00 per unit/fifty unit types. The load list levels are dependent on the assigned risk control parameter which is an input of the model.

FORM B

Title No. 11

Subject: Stock list provisioning procedure with detailed AN/SPS-40 radar application

Literature Source: Technical report number 01862.01-1 stock list provisioning procedure with detailed AN/SPS-40 radar application
Arthur Rupp

Purpose: A logistic study to determine the procedure required to establish a spare parts provisioning list and to develop a computer program for performing the necessary calculations.

Background: During the performance of equipment evaluation by the electronics maintenance engineering center, it was found that a major source of difficulties resulted from inadequate logistic support. The logistic problem was found to be acute on the AN/SPS-40 radar system.

Model: The provisioning procedure is based on the Poisson probability function. It is assumed that equipment parts have a series configuration and that parts are added to the equipment in a standby status until a provisioning probability goal has been met. Provisioning probability goals can be set for equipments, sub-depots and depots (e.g. Provisioning levels could be set as follows: .90 for a 3 month stock period for equipments, .95 for 6 months for 6 equipments for sub-depots and .99 for one-year for 42 equipments for the depot).

Input: Part type, part name, cube, weight, price, number of applications, replacement rates, assigned provisioning probability goals (for equipment, sub-depot, depot) for specified calander times.

Output: Stock lists for equipment, sub-depot, and depot with the associated price, cube and weight.

Comments: With minor modifications the computer program can be adjusted to generate provisional probability goals with a cost minimization feature. With repair time data, the operational readiness of the equipment can be determined thru the computer run.

Title No. 13

Subject: Technique for Determining the Number of Spares with a Prechosen Probability Level

Literature Source: Tenth Annual Reliability and Mathematical Conference, Annals of the Assurance Sciences, Anaheim, California, 1971, N. E. Lynch and R. S. Norris

Model: The basis of the technique is that the density function of a sum of independent random variables approaches the normal density function regardless of the type of density function each of the variables had.

This assumes a sparing of unlike equipment for different operating time at sites such as a depot. Provisioning goal is set. No cost optimization procedure.

Comments: The method is cumbersom. It needs someone with a statistical background to interpret the results.

FORM B

Title No. 14

Subject: A Methodology for estimating expected usage of repair parts with application to parts with no usage history

Literature Source: Naval Research Logistics Quarterly, Vol. 17, Dec. 1970, S. E. Haber and R. Sitgreaves

Purpose: Develop a sparing procedure for part types that have no usage estimates

Background: Handling usage estimates with zero values over long periods of time

Model: Repair part demands are assumed to be Poisson distributed while their means are assumed to be Gamma distributed. Alike type of items are pooled for estimating usage rate for zero demand items.

Comments: The method is peripheral to the task assignment.

Title No. 15

Subject: The allowance parts list

Literature Source: Newsletter, December 1975, R. G. Hakemian

Purpose: Defining the procedures and philosophy involved in generating the allowance parts list

Background: Procedure used by Navy for generating shipboard parts list.

Model: Procedural model

Comments: Any sparing model for the Navy would have to consider the procedures and concepts as described in this write up. Procedures are required for the task assignment.

FORM B

Title No. 18

Subject: Reliability Approach to the Spare Parts Problem

Literature Source: George H. Ebel and Andrew Lang

Purpose: Develop a procedure whereby unskilled personnel, using charts and tables can select the number of spare parts required to support a given program.

Model: Poisson function for provisioning of parts

Input: Failure rates, applications per part type

Output: Spart part number per part type

Comments: A procedure using graphs has been developed for calculating spare part needs. Confidence limits have been calculated to determine whether certain part types may fall critically short.

Title No. 20

Subject: On optimal redundancy

Literature Source: Operations Research, Vol. 7, 1959, Guy Black and Frank Proschan

Purpose: Provide spare part kit for new equipment

Model: A complex system is to be placed in the field for a fixed period. During the period only the spares initially provided may be used to replace components that have failed. Independence of failures is assumed among the essential components considered. Given the cost of components, the number of like components of each type simultaneously operating, the length of operation scheduled for each component, the failure distributions of components, a general mathematical solution is obtained for the composition of the spare parts kit which maximizes assurance of continued operation during the period, subject to a fixed budget for spares. Explicit formulas are obtained in the case of exponential failure distributions, constructive procedures in the case of monotone likelihood ratio densities. Fortunately, the identical mathematical model is applicable in determining the optimal allocation of redundancy in designing system reliability under a weight or cost restraint.

Comments: Poisson provisioning with equipment represented by series configuration. Cost minimization also derived.

FORM B

Title No. 26

Subject: Spare part kits at minimum cost

Literature Source: Proceding - Fifth National Symposium on Reliability and Quality Control, 1959, Guy Black and Frank Proschan

Purpose: Provide spare part kit for new equipments

Model: Poisson function with equipment represented by series configuration

$$P(x) = \prod_{i=1}^{r} \left(\sum_{x=0}^{n} \frac{(\lambda t)^x e^{-\lambda_i t_i}}{x!} \right)$$

where: P = provisioning probability goal
r = part type size
n = depth of part type
x = part type
λ = failure rate of part type
t = time (operating)

Input: failure rates, part type, price and no. of operating hours, part type size, provisioning goals

Output: spare kit for specified operating time with a cost evaluation procedure

Title No. 30

Subject: Spares and Systems Availability

Literature Source: Proceedings, 1976 Annual Reliability and Maintainability Symposium, Wm. J. Vonden Bosch

Purpose: To predict the expected system availability, number of hours between restocking spares, number of spares necessary, expected time system will be down and minimize cost.

Model: Technique for determining the number of spares necessary for a system or groups of systems utilizing a prechosen probability level that sufficient spares would be available. The basis for this technique was that the density function of a sum of independent random variables approaches the normal density function, regardless of the type of density function each of the variables had.

Comments: The claim made is the methodology and application is simple. This is not true but the approach is interesting.

FORM B

Title No. 31

Subject: A Monte Carlo Approach to Spare Provisioning

Literature Source: R. J. Sebeny

Purpose: Simulated technique for stocking equipment(s)

Background: The program described in the paper illustrates a method of provisioning spares for a complex system on the basis of their impact on system availability and cost. Through the use of a Monte Carlo technique, a wide variety of system configurations and maintenance practices can be simulated and analyzed. Also, by employing a computer generated table describing system success as a function of assembly status, the input data required to use the program is greatly simplified. Input data is "user" oriented requiring only knowledge of system operation and maintenance practices thus permitting use of the program by personnel of varied disciplines.

Model: Simulation, monte carlo technique, probabilistic using Poisson function and fault tree type of model for the system.

Input: Failure Rates, repair rates

Output: System reliability and availability

Comments: It is necessary to develop a computer model for each equipment. The methodology in that sense is not general enough in that these computer models of the system may be extensive. The limits of a computerized model are restricted. This restricts the size of an equipmert to be handled.

FORM B

Title No. 32

Subject: An optimal allowance list model

Literature Source: Mina Haskino

Purpose: The problem we shall consider can be stated as follows: How does one properly stock a vessel with necessary commodities, subject to the limitations of available space? This entails a decision on the number of commodities to be carried, the quantity of each commodity to be stocked, and the relative weight (i.e., "military worth", etc) to given each commodity, all subject to the overriding considerations of space. In this paper we shall attempt to treat a somewhat idealized version of this problem by a method which might be extended to more complicated situations.

Model: Expected demand, normal distribution, lagrange multipliers for optimization, with weighting factors to consider the factor of essentiality

Input: Expected demand for mission, total allowable cost, weight or cube

Output: Part lists with constraints of cost, weight or cube

FORM B

Title Nos. 36-38

Subject:	POLARIS Logistics Studies 1, 2, 3 Study 1 -- Military Essentiality System (AD 603 385) Study 2 -- Allowance List Input (AD 294 633) Study 3 -- Logistics Model (AD 416 391)
Literature Source:	Defense Documentation Center, Defense Logistics Agency, Cameron Station, Alexandria, Virginia; by Marvin Denicoff, Joseph Fennell, W. H. Manlow and Henry Solomon
Model:	Sparing based upon demand rate (2-3 month basis). Using the negative binomial demand model and coefficient of variation. Sparing is on a part basis by means of table lookup. Scaling factor and essentiality factors have been developed and proposed for use.
Input:	Demand rate, variance, price, weight, cube, holding cost, shortage cost, scaling parameters, essentiality factors
Output:	Spare parts for part types, cost, weight, cube for hull
Comments:	Sparing is on a part basis

FORM B

Title No. 40

Subject: OPNAV Instruction 4441.12A, Change Transmittal #2

Literature Source: Department of the Navy, Office of the Chief of Naval Operations

Purpose: Supply support of the operating forces. To prescribe range and depth of material to be carried by individual ships.

Model: Heuristic model. Range and depth of provisioning based on definitions of (1) demand based items, (2) military essentiality, (3) low demand items and (4) net effectiveness concept.

FORM B

Title No. 60

Subject: An Evaluation of a Technique to Determine its Applicability (1973)

Literature Source: National Technical Information Service, U. S. Department of Commerce, Springfield, VA, Ronald D. Oglesby

Purpose: Calculate number of spares needed to meet a predetermined probability projection level with a minimum of system down time

Background: Evaluation of a technique based on the central limit theorem

Model: Normal model based on the central limit theorem

Input: Number of systems (or parts), time (operating), mean of different processes, associated variance third moment, and the desired probability level

Output: Probability level, number of spares per system(s)

FORM B

Title No. 61

Subject: Logic Chart Computation of FILSIP COSALS

Literature Source: Navy Fleet Material Support Office, Mechanicsburg, PA

Purpose: Describe procedure used for component provisioning of COSALS.

Model: A model based on demand or expected demand and the Poisson function for determining depth of items.

Input: Best replacement factor, demand(s), various restrictive criteria on demands

Output: Range and depth of provisioned items.

Literature Evaluation
Form C

TITLE	PROVISIONING MODEL	MODE OF CALCULATION: HAND	TABLES	COMPUTER	INPUTS: PART DATA	PRICE	CUBE	WEIGHT	APPLICATIONS PER PART	RATES: REPLACEMENT	DEMAND	FAILURE	REPAIR	PROVISION LEV.: EQUIPMENT	EQUIP'KITS	SUB-DEPOT	DEPOT	OUTPUTS: PART TYPE	SPARES PER PART TYPE	PRICE/SPARE	WEIGHT/SPARE	CUBE/SPARE	TOTAL: PRICE	WEIGHT	CUBE	COMMENTS
7) OPTIMUM SPARES PROVISIONING METHOD FOR ELECTRONICS EQUIPMENTS/SYSTEMS	MODIFIED BRACY AND [illegible] METHOD (POISSON METHOD)			✓	✓	✓			✓	✓		✓		✓				✓	✓	✓			✓			
8) INITIAL PROVISIONING WITH SPARE DETERMINATION	COMPOUND POISSON FUNCTION	✓	✓							✓		✓			✓			✓	✓							
9) FMCO LOAD LIST MODEL	PART PROVISIONING BASED UPON NORMAL AND POISSON DISTRIBUTIONS	✓	✓		✓	✓			✓	✓	✓			✓	✓	✓	✓	✓	✓							
10) FBM LOAD LIST MODEL (TENDER)	BASED ON FMSO MODEL	✓	✓		✓	✓			✓		✓					✓		✓	✓							
11) STOCK PROVISIONING PROCEDURE FOR AN/SPS-40 RADAR	SERIES CONFIGURATION FOR EQUIP. FOLLOWING SPARING PROCEDURE			✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
3) TECHNIQUE FOR DETERMINING THE NUMBER OF SPARES WITH A PRECHOSEN PROBABILITY	NORMAL MODEL	✓			✓	✓				✓		✓		✓				✓	✓	✓			✓			

F[illegible] C

TITLE	PROVISIONING MODEL	MODE OF CALCULATION: HAND	TABLES	COMPUTER	INPUTS: PART DATA	PRICE	CUBE	WEIGHT	[illegible]	REPLACEMENT	RATES: DEMAND	FAILURE	REPAIR	PROVISION LEV.: EQUIPMT	EQUIPMTS	SUB-DEPOT	DEPOT	OUTPUTS: PART TYPE	[illegible]	[illegible]	PRICE/SPARE	WEIGHT/SPARE	CUBE/SPARE	TOTAL: PRICE	WEIGHT	CUBE	COMMENTS
14) A METHODOLOGY FOR ESTIMATING EXPECTED USAGE OF REPAIR PARTS WITH APPLICATION TO PARTS WITH NO HISTORY	POISSON	✓			✓						✓			✓				✓	✓								
15) THE ALLOWANCE PART LIST	STANDARDS FOR PARTS LIST																										
18) PROBABILITY APPROACH TO THE SPARE PARTS PROBLEM	POISSON FUNCTION WITH CONFIDENCE INTERVALS		✓								✓	✓		✓													
23) ON OPTIMUM REDUNDANCY	SERIES CONFIG. FOR EQUIP. WITH POISSON SPARING PROCEDURE	✓	✓		✓	✓			✓	✓		✓						✓	✓	✓				✓			
26) SPARE PARTS KIT AT MINIMUM COST	SERIES CONFIG. FOR EQUIP. WITH POISSON SPARING PROCEDURE AND COSTING FACTOR	✓			✓	✓			✓	✓		✓		✓				✓	✓	✓				✓			
30) SPARES AND SYSTEM AVAILABILITY	NORMAL MODEL	✓							✓			✓		✓				✓	✓	✓				✓			

VIII-36

FORM C

TITLE	PROVISIONING MODEL	MODE OF CALCULATION: HAND	TABLES	COMPUTER		INPUTS: PART DATA	PRICE	CUBE	WEIGHT	RATES: [illegible]	REPLACEMENT	DEMAND	FAILURE	REPAIR	PROVISION LEV: EQUIPMENT	EQUIPMENTS	SUB-DEPOT	DEPOT	OUTPUTS: PART TYPE	[illegible]	[illegible]	PRICE/SPARE	WEIGHT/SPARE	CUBE/SPARE	TOTAL: PRICE	WEIGHT	CUBE	COMMENTS
31) A MONTE CARLO APPROACH TO SPARE PROVISIONING	COMPUTER MODEL OF EQUIPMENT, SIMULATION OF FAILURES WITH RANDOM NUMBER GENERATOR			✓		✓	✓			✓	✓		✓			✓			✓	✓	✓				✓			
33) AN O[illegible]AL ALLOWANCE LIST	NORMAL MODEL	✓				✓	✓	✓		✓	✓		✓	✓					✓	✓	✓				✓			
36-38) POLARIS LOGISTICS STUDY #1, 2, 3	NEGATIVE BINOMIAL MODEL WITH WITH ESSENTIAL CODES AND WEIGHTING FACTORS	✓	✓	✓		✓	✓	✓	✓	✓		✓			✓	✓	✓	✓	✓	✓	✓				✓	✓	✓	
40) OPNAV INSTRUCTION 4441.12A	NORMAL AND POISSON DISTRIBUTION FOR ITEMS	✓				✓				✓		✓			✓	✓	✓	✓	✓	✓								
61) COMPUTATION OF F. S. [illegible] COSAL	POISSON DISTRIBUTION FOR ITEM DEPTH	✓				✓				✓		✓			✓	✓	✓	✓	✓	✓								
6[illegible]) AN EVALUATION OF A TECHNIQUE TO DETERMINE ITS APPLICABILITY	NORMAL MODEL			✓						✓	✓		✓			✓	✓	✓	✓	✓								

FORM C.

Section IX

Glossary

Allowance Parts List (APL)	-The technical portion of the COSAL. Identified by individual equipment. The parts which are candidates for ship's allowance,including initial range and depth as well as maintenance and supply instructions for each part.
Availability	-The probability than an equipment/system is operating satisfactorily in time when used under stated conditions where the total time considered includes operating time, active repair time, administrative time and logistics time.
Best Replacement Factor (BRF)	-A usage rate which represents the best estimate of annual usage of an item for each installation of that item. If the BRF is 1 or greater for a 90 day period it is considered a demand item if it is less than 1 but greater than .25 for a 90 day period it is considered as an insurance item provided it is critical for a ship's mission.
Coordinated Shipboard Allowance List (COSAL)	-Document which lists the equipment, components, repair parts, consumables, and operating space items required for an individual ship to perform its operational mission.
Critical Item	-An item considered vital for the success of a mission/or function of an equipment/system.
$\overline{D}_{RP}$	-Average demand rate per part.
Demand Base Items	-Those items used aboard ships at least once during a 90 day period, has a .90 probability of filling total demand for these items over the entire operating period.
Depth	-The quantity of items on a load list.

FLSIP	-Fleet Logistic Support Improvement Program. A procedure which incoporates the requirements of OPNAV 4441.12A and the APL for stocking a hull (see procedures in title 61).
Follow-on Provisioning	-Subsequent provisioning for an equipment/system.
Gross Effectiveness	-How well the load meets the demand for all items whether they are involved in the range of the load list or not. The gross effectiveness goal is set at 65%. Gross effectiveness is calculated as the demand satisfied by the demand received of requisitions for load list items plus other items.
Initial Provisioning	-The first-time provisioning for an equipment/ system.
Insurance Items	-Those items which a demand of .25 or greater usage in 1 year but less than a demand base item. It will be selected only if essential to the support of equipment considered vital to the ship's mission.
Long Life	-Those items having a demand .25 or less usage in 1 year. These items are not stocked aboard ship.
Military Essentiality Code (MEC)	-Currently there are two classifications under this class of items -- critical and non-critical with most items being classed as critical (over 90%)
Mission (Reliability)	-The probability of non-failure of the equipment/ system for the period of time to complete a mission.
Multi-mission	-Subsequent time periods (missions) within which an equipment/system would be operable.
Net Effectiveness	-How well the load meets the demand for items on the load itself. The net effectiveness goal is set at approximately 85%. Net effectiveness is calculated as the demand satisfied by the demand received of requisitions for load list items.

Normal Usage	-Peacetime operating stock level.
Operational Readiness	-The probability that an equipment/system is either operating satisfactorily or is ready to be placed in operation on demand under stated conditions. It would be represented by reliability times availability.
Provisioning	-A process for determining the range and depth of support items necessary to operate and maintain an end item of material for a specified period of time.
Provisioning Effectiveness	-The probability that sufficient spare items are available at a site in order to meet a prescribed probabilistic goal based on a stochastic model.
Provisioning Level	-A probabilistic value assigned for provisioning an equipment(s)/system(s).
Range	-The variety of items on a load list.
Reliability	-The probability that an equipment/system will perform satisfactorily for a given time when used under stated conditions.
Spares	-Items that are to be used as repairable items.
Technical Overrides	-Those items used to support newly deployed equipment and to support critical equipments.

Section X

Bibliography

The following abstracts were reviewed for source material which served as major source documents for literature evaluations.

Science and Technical Aerospace Reports -- 1974-79
Institute of Electronics and Electrical Engineers (IEEE) -- 1974-79
Logistics Spectrum -- 1974-79
Management Science -- 1974-79
Operations Research -- 1974-79
Proceedings of Reliability and Maintainability -- 1974-79
Applied Science and Technology Index -- 1974-79
Naval Research Logistics Quarterly Index -- 1974-79
Mathematical Reviews -- 1974-79
Dept. of Defense Bibliography of Logistics Studies -- 1977-79
Defense Document Center, Logistics Agency, Report on Spare Provisioning -- 1979

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3. Marlow (ed). Modern Trends in Logistics (1977). The MIT Press, Cambridge, Massachussetts
4. Ladson, L. S. (1970). Optimization Theory for Large Systems, MicMilan
5. Barlow, R. E. and F. Proschan (1975). Statistical Theory of Reliability and Life Testing: Probability Models (Holt, Rinehart and Wilson)
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Appendix A

Applicable Literature Source List

Listed are the literature sources (called titles in section VI) that were selected as being applicable and related to the task. They appear under a separate cover but the title numbers and literature sources are as follows:

Title No.	Literature Source	Author
7	Provisioning for Electronics Equipments/Systems	R. Powell and R. Lutz
8	Initial Provisioning with Spare Deterioration	Paul J. Schweitzer
9	FMSO Load List Model	
10	FBM Load List Prediction Model (for Tender)	
11	Stock Provisioning Procedure for the AN/SPS-40 Radar	Arthur Rupp
13	Technique for Determining the Number of Spares with a Prechosen Probability Level	N. E. Lynch and R. S. Morris
14	A Methodology for Estimating Expected Usage of Repair Parts with Application to Parts with no History	S. E. Haber and R. Sitgreaves
15	The Allowance Parts List	
18	Reliability Approach to the Spare Parts Problem	C. H. Ebel and A. J. Lang
20	On Optimal Redundancy	Guy Black and Frank Proschan
26	Spare Parts Kit at Minimum Cost	Guy Black and Frank Proschan
30	Spares and System Availability	J. Vanden Bosch

Title No.	Literature Source	Author
31	A Monte Carlo Approach to Spare Provisioning	R. S. Sebeny
32	An Optimal Allowance List Model	Mina Gooray
36-37-38	POLARIS Logistics, Studies 1, 2, 3	M. Denicoff, J. Fennell, S. Haber, W. Marlow, F. Segel, H. Solomen
40	OPNAV Instruction 4441.12A, Supply Support of the Operating Forces	
60	An Evaluation of a Technique to Determine its Applicability	R. D. Oglesby
61	Logic Chart Computation of FLSIP COSALS	

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