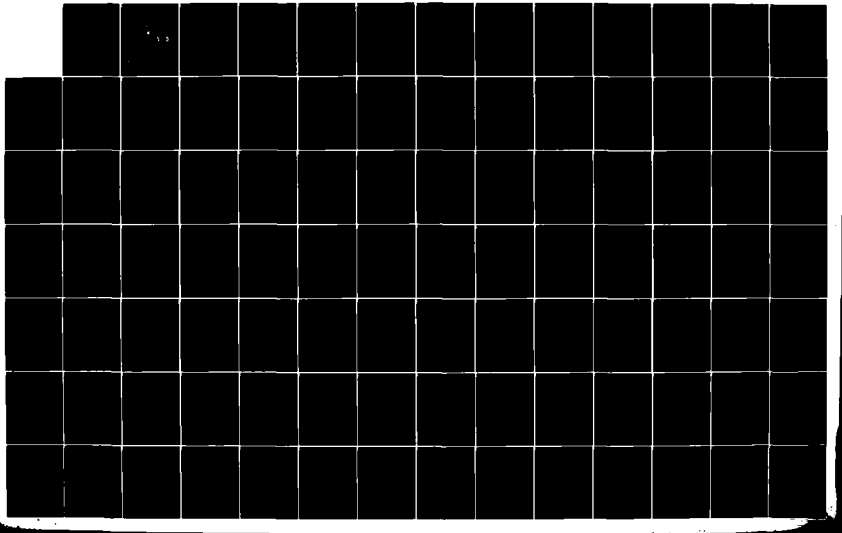
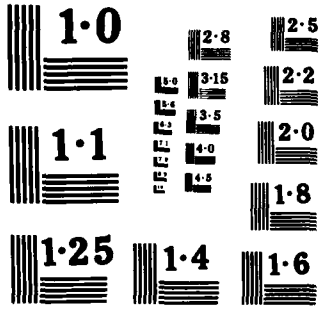
AD-A156 849 APPLICATION OF METEOR TO THE EVALUATION OF MULTI-ECHELON INVENTORY MODELS(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA D B WADSWORTH MAR 85 1/2

UNCLASSIFIED F/G 9/2 NL




1·0
1·1
1·25
1·4
1·6
1·8
2·0
2·2
2·5
2·8
3·15
3·5
4·0
4·5

AD-A156 849

(2)

NAVAL POSTGRADUATE SCHOOL

Monterey, California

DTIC
ELECTE
JUL 15 1985
S D
G

THESIS

APPLICATION OF METEOR TO THE EVALUATION OF MULTI-ECHELON INVENTORY MODELS

by

David Barry Wadsworth

March 1985

Thesis Advisor: F. Russell Richards

Approved for public release; distribution unlimited.

DTIC FILE COPY

85 06 24 006

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Application of METEOR to the Evaluation of Multi-Echelon Inventory Models		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis March, 1985
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) David Barry Wadsworth		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, CA 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, CA 93943		12. REPORT DATE March, 1985
		13. NUMBER OF PAGES 143
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Inventory Models, Simulation, Multi-Echelon, METEOR

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Navy supply system forms a complex multi-indenture, multi-echelon system designed to provide support to operating units both afloat and ashore. The current inventory models used by the Navy do not consider explicitly the multi-echelon nature of the system, possibly resulting in misallocations of material and sub-optimal uses of funds. A simulation program, call Multi-Echelon Technique for Evaluating Readiness (METEOR), was developed in an earlier

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. thesis to provide a means of evaluating the effects of the inventory models in existence at that time. This thesis enhances METEOR to model the Navy supply system in its current multi-echelon structure. Additionally, a heuristic, "see-through" model was developed that attempts to improve supply system performance by making shipboard demands visible to both intermediate and wholesale echelons. A preliminary comparison between this model and existing procedures was conducted and showed that the "see-through" model significantly improved effectiveness.

Approved for public release; distribution unlimited.

Application of METEOR to the Evaluation of Multi-Echelon Inventory Models

by

David Barry Wadsworth
Lieutenant Commander, Supply Corps, United States Navy
B.S., University of California, 1971

Accession For
NTIS GRA&I [X]
DTIC TAB [ ]
Unannounced [ ]
Justification
By
Distribution/
Availability Codes
Dist | Avail and/or Special
A/1

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March, 1985

Author: _____
David Barry Wadsworth

Approved by: _____
F. Russell Richards, Thesis Advisor

_____
Alan W. McMasters, Second Reader

_____
Alan R. Washburn, Chairman,
Department of Operations Research

_____
Kneale T. Marshall
Dean of Information and Policy Science

ABSTRACT

The Navy supply system forms a complex multi-indenture, multi-echelon system designed to provide support to operating units both afloat and ashore. The current inventory models used by the Navy do not consider explicitly the multi-echelon nature of the system, possibly resulting in misallocations of material and sub-optimal uses of funds. A simulation computer program, call Multi-Echelon Technique for Evaluating Readiness (METEOR), was developed in an earlier thesis to provide a means of evaluating the effects of the inventory models in existence at that time. This thesis enhances METEOR to model the Navy supply system in its current multi-echelon structure. Additionally, a heuristic, "see-through" model was developed that attempts to improve supply system performance by making shipboard demands visible to both intermediate and wholesale echelons. A preliminary comparison between this model and existing procedures was conducted and showed that the "see-through" model significantly improved effectiveness.

Additional keywords: Monte Carlo method; Navy; weapon systems.

TABLE OF CONTENTS

I. INTRODUCTION 9

II. THE NAVY SUPPLY SYSTEM 12

A. OVERVIEW 12

B. CONSUMER INVENTORY 14

C. INTERMEDIATE LEVEL 15

D. WHOLESALE LEVEL 16

E. OBSERVATIONS 16

III. CURRENT INVENTORY MODELS 18

A. CONSUMER LEVEL 18

B. INTERMEDIATE LEVEL 20

C. WHOLESALE LEVEL 26

D. OBSERVATIONS 30

E. SUMMARY 30

IV. MULTI-ECHELON INVENTORY MODELS 31

A. THE METRIC MODELS 31

B. THE MOD-METRIC MODELS 31

C. THE AVAILABILITY CENTERED INVENTORY MODEL (ACIM) 32

D. THE SEE-THROUGH MODEL 33

E. OBSERVATIONS 33

F. SUMMARY 34

V. MULTI-ECHELON TECHNIQUE FOR EVALUATING OPERATIONAL READINESS 35

A. MODEL DESCRIPTION 36

B. ENHANCEMENTS TO METEOR 38
C. MODEL ASSUMPTIONS 44
D. SAMPLE DATA SET 45
VI. VALIDATION OF METEOR 48
VII. METEOR AS AN EVALUATION TOOL 54
A. HYPOTHESIS 54
B. MEASURES OF EFFECTIVENESS 55
C. EXPERIMENTAL DESIGN 56
D. RESULTS AND ANALYSIS 58
E. CONCLUSIONS 64
VIII. SUMMARY AND RECOMMENDATIONS 65
APPENDIX A DATA CARD IMAGE FORMATS 68
APPENDIX B SAMPLE DATA SET 112
APPENDIX C VARIABLES IN METEOR 123
APPENDIX D BLOCK DIAGRAM OF METEOR 133
APPENDIX E SUADPS LEVELS ALGORITHM 138
APPENDIX F EXPERIMENTAL RESULTS 140
LIST OF REFERENCES 141
INITIAL DISTRIBUTION LIST 142

LIST OF TABLES

I. QUARTERLY REQUISITION FREQUENCY TO COG. 46

II. SPCC MATERIAL BREAKDOWN 46

III. SIMULATION RUNTIME IN CPU SECONDS ON THE NPS IBM 3033 . . 58

IV. RIMSTOP POLICIES 59

V. SEE-THROUGH MODEL 61

VI. LEAD TIME VARIANCE 63

VII. DATA ELEMENTS EXTRACTED FROM CARES DATA BASE 113

VIII. ORDER AND SHIPPING TIMES 116

IX. METEOR DATA SET 117

X. METEOR VARIABLE LISTING 123

XI. MULTE BLOCK DIAGRAM 133

XII. SIMULATION RRESULTS 140

LIST OF FIGURES

2.1 The Navy Supply System. 13

5.1 RIMSTOP Requisition Paths 40

6.1 Detailed Supply Transaction Listing 49

6.2 METEOR Data Summary 51

7.1 Measures of Effectiveness as a Function of Number of Iterations. 57

I. INTRODUCTION

The Naval Supply Systems Command (NAVSUP) is tasked by the Department of Defense (DOD) to provide the resource capabilities and readiness to meet material support needs of the active and reserve operating forces of the Navy. Specific readiness measures, as well as economic constraints, have been established by DOD. Additionally, DOD has mandated the basic procedures and models to be used to obtain the requisite levels of readiness.

The DOD approved inventory models are similar to those used in industry. These models generally use cost as the measure of effectiveness since reduction of inventory costs leads to maximization of profits. While profits are the raison d'etre for commercial enterprises, clearly the objectives of the DOD should deal instead with maximization of readiness subject to economic constraints. This difference in goals has been recognized recently and the DOD policies have been changed to emphasize improving readiness.

Over the years the Navy has developed a complex structure both afloat and ashore to provide supply support to the operating forces. This structure begins at the storerooms and repair parts bins aboard the individual ship and extends to the Mobile Logistic Support Force (MLSF) ships, the overseas Naval Supply Depots (NSD's), the Continental United States Naval Supply Centers (NSC's), and finally the Inventory Control Points (ICP's). These activities fall into supply echelons, and each echelon operates under a specific inventory model. Each of these

models has been approved by DOD and is designed to optimize the inventories held at each of these echelons.

However, the combination of the existing supply structure and the different inventory objectives is clearly beyond analytical modeling. As a consequence, a change of inventory policy at one echelon may improve readiness at that echelon, it is unclear what the effect on the total system may be.

This complex interaction between echelons has been recognized, and a simulation of the supply system has been undertaken at the Naval Postgraduate School; it is called METEOR [Ref. 1]. METEOR provides a multi-indenture, equipment oriented simulation of an integrated , multi-echelon Navy-oriented supply system. In this microcosm, various inventory models may be tested at any echelon and the effect on the entire supply system may be observed.

In this thesis, METEOR will be used as a tool for evaluating various inventory models, strategies, and policies. METEOR will be shown to model realistically the multi-echelon structure found in the current Navy supply system, enabling the model to be used as a valid test-bed for evaluation of the many factors effecting readiness measures of effectiveness. A sample data set emulating many of the conditions found in the supply system is provided for use in these analysis.

Chapters II, III, and IV provide background about the Navy supply system and about the inventory models that are currently used and those that are proposed for use in this multi-echelon system. Specific performance criteria for the echelons of the supply system and measures of effectiveness for the inventory models are also discussed. Chapter

V describes the design and assumptions used to construct METEOR. Chapter VI discusses the validation of the METEOR model.

Chapter VII demonstrates how METEOR may be used as a tool for the evaluation of stockage models, inventory policies, the effects of lead time variations, and other aspects of a multi-echelon inventory system. Chapter VIII summarizes the thesis and presents recommendations for future uses of METEOR in the research of complex multi-echelon inventory systems.

and the remaining parameters were defined above. The values of ρ are bounded as follows:

if $\rho \geq 0.50$, then set $\rho = 0.50$;

if $\rho \leq 0.01$, then set $\rho = 0.01$;

if $0.01 \leq \rho < 0.05$ then set $t = 2.41 - 1.62*\rho$;

if $0.05 \leq \rho < 0.14$ then set $t = 1.953 - 6.48*\rho$;

if $0.14 \leq \rho < 0.50$ then set $t = 1.59*\rho**2 - 3.893*\rho + 1.5527$;

where t = abscissa of a standard normal distribution with right tail area equal to ρ .

5. Compute the safety level, SL;

$$SL = 0.7217*t*MAD*\sqrt{LT}\ ,$$

where MAD = mean absolute deviation of quarterly demand;

and LT = lead time forecast in quarters.

6. Compute the mean lead time demand, LTD;

LTD = (AQD/3)*LT.

7. Compute the Reorder Point, RP;

RP = SL + LTD.

8. Compute the Requisition Objective, RO;

RO = RP + OL.

The RP and RO are used to manage the stock point retail inventory by providing a reorder point and an order quantity, RO-RP. ALthough these values are based on a continuous review inventory model, stock levels are reviewed about every two weeks. The order quantity is computed to be the difference between current assets and the RO.

category expressed in number of months of stock. The ICP develops these categories from analysis of the behavior of the stock point's inventory. Each of these categories is assigned an operating level factor which varies between one and twelve months. Assignment is made such that the highest VAD items have the smallest operating level factors. The stock point uses this information to compute the levels for each carried item. The procedure is described below:

1. Compute the VAD,

   VAD = 4*AQD*C

   where AQD = average quarterly demand

   and C = unit cost,

   and determine the VAD category.

2. Compute the Operating level, OL;

   OL = (AQD/3)*QMC

   where QMC = order quantity in months (based on the VAD).

3. Compute the Annual Requisition Frequency, F;

   F = CF + F1 + F2 + F3

   where CF = current quarter observed frequency;

   F1 = 1st past quarter observed frequency;

   F2 = 2nd past quarter observed frequency;

   F3 = 3rd past quarter observed frequency.

4. Compute the stockout risk, ρ,

   $\rho = \lambda*(C*OL)/F$

   where λ = shortage and holding cost parameter furnished by ICP;

Ω = 1/(average requisition size) = AF/(4*AQD)

E = item essentiality

AQD = average quarterly demand

K = response time input parameter (varies by COG)

AF = annual requisition frequency

Q = item order quantity

S = item safety level

C = unit price

b = current status of the item: b = 1, item is carried

b = 0, item is not carried

The decision variable, X, is set to one to determine the value of $L(1,\underline{\lambda})$ if the item is stocked, and set to zero to determine the value of $L(0,\underline{\lambda})$ if the item is not stocked. Then the values of of the two expressions are compared.

If $L(0,\underline{\lambda}) > L(1,\underline{\lambda})$, then the item should not be stocked;

If $L(0,\underline{\lambda}) < L(1,\underline{\lambda})$, then the item should be stocked;

and if $L(0,\underline{\lambda}) = 1(1,\underline{\lambda})$, the item should continue in its current status.

The range selection may also be influenced by manual intervention by the ICP IM and stock point personnel.

There are two major stages to the VOSL computations. The first consists of demand smoothing and forecasting, and the second consists of the actual levels computations procedures. The demand smoothing and forecasting procedures are discussed in [Ref. 3]. For the actual levels computation, the ICP provides lower bounds for ten categories of Values of Annual Demand (VAD) and the related order quantities for each

Mathematically, the ERM problem was originally stated as follows:

Determine the range of material which minimizes the essentiality weighted expected number of months delay subject to:

1) limits on Stock Fund investments,

2) workload considerations, and

3) cost of maintaining the range of stock.

This problem was initially solved using a LaGrange Multiplier approach. Today, the model is implemented in the form shown below. The values of the parameters are calculated by FMSO using the ERM Parameter Development Program, which is run several times during the year for each stock point. The stock point then uses those parameter values to determine the range of material to be carried.

The ERM model requires that the value of $L(X,\underline{\lambda})$ be determined where

$$L(X,\underline{\lambda}) = \Omega*X*E*K*AQD - \lambda1*X - \lambda2*(X*(AQD/Q + (1-b)) - \lambda3*X*C(S + Q/2) - \lambda4*(1-b)*X - \lambda5*(1-X)*b.$$

The elements of $L(X,\underline{\lambda})$ are

$\underline{\lambda}$ = LaGrangian multiplier vector ($\lambda1$, $\lambda2$, $\lambda3$, $\lambda4$, $\lambda5$)

$\lambda1$ = lower bound on number of requisitions per quarter for an item to be added to stock.

$\lambda2$ = lower bound on number of requisitions per quarter to justify order processing costs.

$\lambda3$ = lower bound on number of requisitions per quarter to increase marginal inventory cost by one dollar.

$\lambda4$ = lower bound on number of requisitions per quarter for an item to be added to stock range.

$\lambda5$ = lower bound on number of requisitions per quarter for an item to be deleted from stock range.

points then manage their retail inventories within the parameters provided by the ICPs. The objectives of these models are to provide 70% POE effectiveness and obtain an ACWT of 125 hours for IPG I and II maintenance related immediate use requirements. These models apply only to consumable material; repairable material inventory management is the responsibility of the ICP.

Each stock point maintains a Master Stock Item Record (MSIR) file containing demand data on all carried items, and a Demand Master File (DMF) recording demand data for all not carried items. The demand data is processed through several filtering and smoothing routines to minimize stock level churn (the number of items added to and deleted from stock). The ICP reviews the demand data and annually provides specific parameters for the ERM and VOSL computations to the stock point. Demand information is maintained by each stock point for a period of two years. ERM and VOSL programs are run quarterly by the stock points.

The ERM was developed by Fleet Material Support Office (FMSO) in an attempt to evaluate the performance contribution of each item in terms of five parameters:

1. incremental investment in range
2. the incremental workload
3. number of replenishments processed
4. the number of adds to inventory
5. the number of deletions from inventory.

In using the normal approximation, the depth, X, is selected from

$$X = BRF*POP/4 + 1.28* \sqrt{(BRF*POP/4)}.$$

The stocking policy for insurance depends on the essentiality of the item as follows:

For "P" items: If $4.0 > BRF*POP/4 \geq 2.0$ then stock 2 minimum replacement units.

If $2.0 > BRF*POP/4 \geq 0.1$ then stock 1 minimum replacement unit.

For "S" items stock 1 minimum replacement unit.

A minimum replacement unit is defined as the smallest quantity of an item required to repair an equipment. Generally, the minimum replacement unit is one; however, in certain applications more than one may be required. An example is a thrust bearing which requires eight identical bearing elements. Therefore, the minimum replacement unit is eight.

B. INTERMEDIATE LEVEL

There are two primary models used to compute requirements for retail inventories located at the Navy stock points. These models are the Economic Range Model (ERM) and the Variable Operating and Safety Level (VOSL) model. The ERM computes the range of items to carry at a given stock point subject to effectiveness and cost considerations. The VOSL model computes the depth requirements for each item in the carried range of inventory subject to effectiveness and financial constraints. Because the Navy ICPs, including FMSO for DLA material, have overall responsibility for budgetary and inventory management, the ICPs determine the control parameters used in the two models. The stock

maintenance data reporting system, and technical replacement factors (TRF), obtained from engineering reliability estimates. These two elements are combined into a weighted average which is a function of the operating population and its service ages. The BRF represents the expected annual number of replacements per installed unit of an item. BRF data is updated quarterly using exponential smoothing.

Range selection begins by identifying the components installed on-board the particular ship, followed by enumerating the piece parts required for each of these components. The BRF for an individual piece part is then extracted from the WSF. Each part is identified as to its mission essentiality. Parts essential to the ship's primary mission are coded "P"; all other parts are coded "S". The shipboard population (POP) of each part is also computed. An item is considered demand based if one or more failures are expected in a 90 day period. Items expected to have fewer than one failure are not stocked unless they are "insurance" items; i.e. their failure would seriously degrade the end user's mission should a spare repair part not be available. A "P" coded item is considered an insurance item if one or more failures is expected within a 10 year period, and a "S" is considered an insurance item if one or more will fail in a 4 year period.

The stocking depth for demand based items is computed either by using a Poisson distribution for values of $4.0 \leq BRF*POP/4 \leq 40.0$ or using a normal distribution for values of $BRF*POP/4 > 40.0$.

For the Poisson case, let m = BRF*POP/4 and then select the smallest X such that

$$\sum_{k=1}^{X} (\exp(-m) * m^{**}k/k! \geq 0.9$$

III. CURRENT INVENTORY MODELS

In the material below, we describe the inventory models currently in use at the specified echelons of supply. Each model has a specific objective function and method of implementation that has been approved by DOD. Most models have two phases of computation; range selection and depth computation.

A. CONSUMER LEVEL

The MOD-FLSIP model is the primary model used to determine consumer stock levels for most afloat activities. Each activity has a uniquely tailored allowance list, called the Coordinated Shipboard Allowance List (COSAL), that provides a consolidated list of those repair parts to be stocked and the specified depth for each part. The COSAL is created during the construction of the ship and is updated with monthly change information. The COSAL is recreated approximately every 5 years during major overhaul of the ship. The MOD-FLSIP model is designed to provide 90% protection for demand based items for a period of 90 days without resupply.

Demand information used by the MOD-FLSIP model is derived from the Navy's historical usage data and from contractor's reliability studies. This data is maintained in the Weapons System File (WSF) at SPCC. A key element of the usage data is each item's Best Replacement Factor (BRF). This is a convex linear combination of the experienced demand replacement factor (EDRF), obtained from shipboard casualty reports and

tender or repair ship. After implementation, the TARSLL is reconfigured only every two to five years. It depends totally on observed demand to account for changes in lower echelon configurations.

Each echelon depends on the recorded demand history to maintain effectiveness. With the exception of the TIR material, specific information on individual transactions is not provided to higher echelons, only the aggregate reorder information from the lower echelon is passed. This demand information is smoothed by each echelon and it requires significant, long term changes at the consumer level before any changes on stockage policies are seen at higher echelons. This not only reduces those costs incurred by adding or deleting material from stock, but also reduces responsiveness of the supply system to changes.

Other factors, such as the change in ship locations, the introduction of a new ship type, or changes in maintenance procedures may also effect demand patterns. The lack of current information on lower echelon equipment configuration can result in significant misallocations of material. It is possible through manual effort by IM and stock point personnel to overcome these deficiencies. However, nothing inherent in the inventory models causes information, other than historical demand information to flow between the echelons.

should be 125 hours for material required for immediate use to correct an equipment failure that prevents completion of the customer's primary mission.

D. WHOLESALE LEVEL

The wholesale level of stock is material that has predominantly Naval applications. It is managed intensively by an item manager (IM) at the Ships Part Control Center (SPCC) or the Aviation Supply Office. This material is physically located at the shore activity closest to the ultimate user. All transactions for this material are reported to the IM via TIRs on a daily basis. The IM uses the Uniform Inventory Control Point model to determine stockage levels, orders the replenishment material, and allocates it to the stocking activities. The IM also controls the induction of repairable material into repair facilities, and directs shipment of the repaired items to the various stocking activities.

E. OBSERVATIONS

The models used to make stockage decisions for the three echelons are not integrated in any fashion. Each echelon has different objectives and fails to take into account explicitly the number of units at the lower echelons. All demands from lower echelons are lumped together into an aggregate demand value. The only attempt at considering the composition of the lower echelon occurs in the construction of the Tender and Repair Ship Load List (TARSLL). During initial inventory development, this model uses the anticipated shipboard equipment configuration for the ships to be assigned to the specific

values. Generally, gross effectiveness is required to exceed 65% and net effectiveness is to exceed 85% [Ref. 2].

C. INTERMEDIATE LEVEL

The intermediate level provides the first echelon of resupply to the operating forces. This echelon of resupply is subdivided into two categories of material: the material carried aboard MLSF, aircraft carriers, and tenders and repair ships; and the retail material stocked at the supply centers and depots. Each of these categories has inventory levels set by separate models. The Fleet Issue Load List (FILL) model is used to specify stockage levels for material carried on MLSF ships. Similarly, tenders and repair ships are stocked to levels specified in individually tailored Tender and Repair Ship Load Lists (TARSLL). Intermediate inventories carried by depots and supply centers are determined by the Economic Range Model (ERM) in conjunction with the Variable Operating and Safety Level (VOSL) model.

Material required for stock replenishment at the depots and supply centers is either pulled from the wholesale level (for Navy managed material), pulled from the Defense Logistics Agency (DLA) or General Services Administration wholesale stock, or purchased from the manufacturer. Certain Navy-owned material stocked at this level is reported via Transaction Item Report (TIR) to the item manager.

DOD has specified that Point of Entry (POE) and net effectiveness as well as Average Customer Wait Time (ACWT) are to be used as the measures of effectiveness for the intermediate level of inventory. OPNAV has specified that the POE effectiveness should be 70% and the ACWT goal

B. CONSUMER INVENTORY

This level of inventory, sometimes referred to as organic support, is designed to provide the primary support for self-deployable units. These units include most ships not employing the Shipboard Uniform Automated Data Processing System (SUADPS) and with no resupply mission, and certain small shore activities, such as communications stations, hospitals, and other activities not under the Navy Ready Supply or Shop Store concept. All activities, both afloat and ashore, are provided with a basic allowance list of material to support the extended operation of that activity.

Various models are used to determine the stockage levels for spare parts. These models include the Modified Fleet Logistic Support Improvement Program (MOD-FLSIP), the Mission Criticality Oriented Model (MCO), and the Availabilty Centered Inventory Model (ACIM). These models will be discussed in greater detail in Chapter III and IV.

Material held onboard ships is replenished by ordering material from higher echelons; i.e. the material is "pulled" from the higher levels. Requisitions for non-stocked material are submitted to the next echelon or, in limited cases, are submitted directly to the manufacturer.

The measures of effectiveness at the consumer level mandated by DOD are gross and net effectiveness. Gross effectiveness is defined as the percentage of total demands for both stocked and non-stocked items satisfied from stock on hand. Net effectiveness is the percentage of total demands for stocked material satisfied from stock on hand. Typically, the Fleet Commanders specify the requisite effectiveness

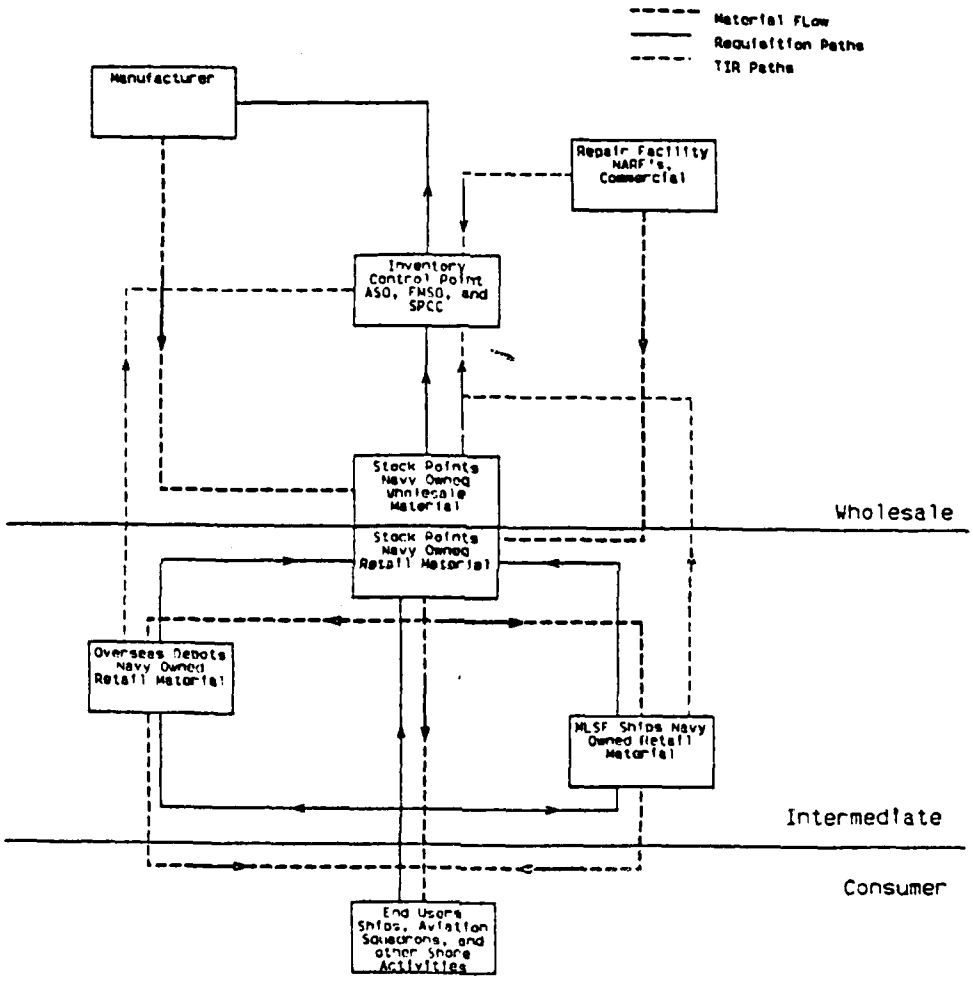


Figure 2.1 The Navy Supply System

II. THE NAVY SUPPLY SYSTEM

A. OVERVIEW

The Naval Supply System is established to provide material support for the active and reserve operating forces of the Navy. To carry out this mission, several levels of inventory have been established in support of the operating units. These levels of inventory form the echelons in this multi-echelon system. The following discussions will concentrate on the Navy managed material in the supply system.

The material carried onboard ships and by aviation squadrons forms the consumer level of inventory and is considered as organic support. The material carried onboard the Mobile Logistics Support Force ships, at the overseas supply depots and the CONUS supply centers forms the intermediate or retail level of inventory and the first echelon of resupply. The intermediate level inventory is subdivided in that the material held by the MLSF ships is managed under a different set of policies and models than the material held as retail stock by the CONUS supply centers. The third echelon of resupply consists of wholesale material held at CONUS supply centers and managed by the ICP's. Figure 2.1 provides a schematic representation of the Navy supply system. The specific policies and inventory models used at each of these echelons is discussed below.

C. WHOLESALE LEVEL

Wholesale material is directly managed by the ICP IM, but is not physically stocked at the Inventory Control Points (ICP). The activity holding wholesale stock makes daily transaction reports on all wholesale material. The IM manages the system wide inventory via AUTODIN and other remote means. Wholesale stock is categorized as either consumable or repairable, and each category of stock has a different model for levels computation. The objective of these inventory models is specified by DODINST 4140.39, [Ref. 4]:

> to minimize the total variable order and holding costs subject to a constraint on time-weighted, essentiality weighted requisitions short.

Both the repairable and the consumable models are rather straightforward modifications of the continuous review inventory models described in Hadley and Whitin [Ref. 5].

The Chief of Naval Operations has set a goal of 85% System Material Availability (SMA) for the wholesale system. However, neither of the wholesale models attempts to optimize this value, and predictions for expected SMA can be made only by simulations.

Both models are subject to many constraints and external overrides which modify their computed levels. Therefore, the actual inventory levels used by the supply system do not optimize any of the objective functions. Each model computes an order quantity and a reorder point for determining how much and when to order. Additionally, the repairable model computes an economic repair quantity and repair level. Levels are recomputed from this data using the equations described below. Both models use the demand information reported to the ICP via

the TIR system. This data is exponentially smoothed, and demand forecasts and mean absolute deviation are computed quarterly.

1. Consumable Model

Let Q denote the economic order quantity and R, the reorder point. Q is computed using the formula;

$$Q = \sqrt{8*D*A/I*C},$$

where D = average quarterly demand;

A = procurement setup costs;

I = inventory holding costs in dollars per dollar-years;

and C = item cost.

Then Q is constrained to:

$$Q^{*} = \text{Min} \begin{cases} 12*D \\ \text{Max} \begin{cases} D \\ 1 \\ Q. \end{cases} \end{cases}$$

Solving for the reorder point, R, is begun computed by computing the procuremen problem variable, Z;

$$Z = D*LT,$$

where LT = average procurement lead time.

Next, the probability of being out of stock during procurement lead time, called Risk, is computed:

$$\text{Risk} = (D*I*C)/(D*I*C + \lambda*W*E),$$

where λ = imputed cost for one requisition backordered for one year;

W = average quarterly requisition frequency;

and E = item essentiality.

Finally, the reorder point is computed by solving the following equation:

$$1 - F(R) = \text{Risk},$$

where $F(R)$ = assumed cumulative distribution function associated with the probability distribution for lead time demand.

For items experiencing less than one demand per year, the Poisson distribution with parameter Z is used for lead time demand. Items incurring annual demands between one and twenty units per year use the negative binomial distribution with parameters p = 1 - Variance / Z, and r = Z / p. Items having annual demand greater than twenty units per year use the normal distribution with mean Z. The variance is obtained from the forecasted Mean Absolute Deviation (MAD) data for lead time demand for each item.

2. Repairable Model

The repairable model computes four values; an economic order or procurement quantity, Q1, an economic repair quantity Q2, a procurement reorder point, R1, and a repair reorder point, R2.

First the procurement problem variable, Z, is computed:

$$Z = D*LT - REGEN*LT + REGEN*TAT$$

where D = average quarterly demand;

LT = forecasted procurement lead time in quarters;

REGEN = forecasted quarterly regeneration rate in units per quarter;

and TAT = forecasted repair turn around time in quarters.

Next the Wearout Rate, WR, and the average unit acquisition cost, C*, are computed. The WR represents the percentage of units that will

require replacement due to attrition and being beyond economical repair. C* is the wearout rate weighted average of the procurement cost and the repair cost,

$$WR = 1 - REGEN/D,$$

and $$C^* = (1 - WR)*C1 + WR*C2;$$

where C1 = unit repair cost;

and C2 = unit procurement cost.

The economic order quantity, Q1, is computed using:

$$Q1 = \sqrt{8*A*ADMD/I*C2}$$

where ADMD = attrition demand which is computed by D - REGEN;

A = procurement setup costs;

I = inventory holding cost in dollars per dollar-years;

As a first step in determining the procurement reorder point, the variable procurement stockout risk, ρ, is computed,

$$\rho = (I*(C^*)*D)/(I*(C^*)*D + \lambda*F*E)$$

where λ = imputed shortage cost of a backordered requisition;

F = average quarterly requisition frequency;

and E = item essentiality.

Then R1 is computed as shown in the consumable model above using ρ.

The economic repair quantity, Q2, is computed from:

$$Q2 = \sqrt{8*A2*\min(D,REGEN)/(I2*C1)}$$

where A2 = repair order and setup cost;

I2 = repair inventory holding cost in dollars per dollars-year;

Finally the basic repair level is computed from:

$$R2 = D*TAT + \max(0,R1 - Z).$$

D. OBSERVATIONS

A shortcoming of the current inventory system is that the models compute inventory levels based on historical data and they cannot react to short term changes in demand. In fact, due to the smoothing of the data at both the retail and wholesale levels, demand changes must either be extraordinarily large or be sustained for several quarters before the inventory levels will catch-up. The inertia built into the intermediate and wholesale echelons can result in poor support for the consumer level, and may place the major responsibility for adequate support on the consumer.

An additional shortcoming of the current inventory system results from the design of the individual inventory models. Each model attempts to compute only the inventory for a single echelon, and the combination of these models in the actual system results in a sub-optimal solution for overall system effectiveness.

E. SUMMARY

In this chapter, the current inventory models have been discussed. The current models fail to adequately fit the multi-echelon structure extant, and have been modified so much that they fail to provide optimal solutions to even a single echelon. In the next chapter, several proposed multi-echelon inventory models will be presented and their appropriateness for the Navy will be discussed.

IV. MULTI-ECHELON INVENTORY MODELS

In an attempt to model more accurately the actual multi-echelon inventory system that exists, several new inventory models have been proposed. These models have been developed primarily as tools to determine inventory levels at various supply echelons for complex hardware systems. The following sections briefly describe three of these models.

A. THE METRIC MODELS

The Multi-Echelon Technique for Recoverable Item Control (METRIC) model was originally developed by Sherbrooke [Ref. 6] as a tool for managing Air Force inventories. The model provides a methodology for computing optimal stock levels in a two echelon system consisting of a depot and several bases. Each activity may carry a stock of spares, and also may have a repair capability for that item. Demand is assumed to be distributed as a compound Poisson process. METRIC attempts to effectively allocate spares to the bases and depot in order to minimize the expected time-weighted backorders summed over all bases, subject to budgetary constraints.

B. THE MOD-METRIC MODELS

MOD-METRIC model is an extension of METRIC which takes into account the multi-indenture nature of repairable assemblies. Many of the repairable items contain subassemblies which are also repairable. In this case, repair of the failed assembly is usually accomplished by the

removal and replacement of its failed subassembly. The failed subassembly is either repaired by the base or the depot depending on the complexity of the repair. Two categories of material result. Line replaceable units (LRU)s may be repaired on-site, and shop replaceable units (SRU)s must be repaired at the base or depot repair facility.

Muckstadt's MOD-METRIC model [Ref. 6] takes this multi-indenture relationship into account, and minimizes the expected number of time-weighted backorders for LRU's at the bases subject to budgetary constraints. The MOD-METRIC model provides stocking policies for LRU's and SRU's at the bases and the depot.

C. THE AVAILABILITY CENTERED INVENTORY MODEL (ACIM)

Clark [Ref. 7] has proposed a multi-indentured, multi-echelon inventory model that claims to maximize equipment operational availability for a given total investment in spares. In that model, called ACIM, operational availability, Ao, is defined as:

$$Ao = MTBF/(MTBF + MTTR + MSRT),$$

where MTBF = mean time between failure;

MTTR = mean time to repair;

and MSRT = mean supply response time.

Ao is defined to be the probability that the equipment will be in an operational condition when it is called upon.

Clark claims that maximiziation of Ao is equivalent to minimization of MSRT and consequently focuses on MSRT in the ACIM optimization. Richards [Ref. 8] shows, however, that the two objectives do not necessarily lead to the same allocations. ACIM solves a system of six

interrelated equations recursively for each part in the equipment in determining the optimal stock level at each echelon subject to a budget constraint on the total system inventory cost.

D. THE SEE-THROUGH MODEL

The See-Through Model was developed at the Naval Postgraduate School in conjunction with the improvements made to METEOR. The See-Through model is a heuristic approach to improve effectiveness of the existing supply system by decreasing MSRT. This is accomplished by anticipating stock replenishment requirements at the retail and wholesale echelons. As a demand for an item occurs aboard ship, the demand information is passed on to the nearest retail stock point and to the ICP. The stock point and ICP decrement their inventory position in anticipation of the stock replenishment request from the ship. This allows the earlier procurement of stock at the retail and wholesale echelons, and reduces MSRT by reducing the number of backorders and referrals.

E. OBSERVATIONS

The METRIC family of models is inappropriate for the existing Navy supply system because of the models' failure to recognize more than two echelons. Additionally, the computations required to solve the complex multi-indenture system extant in a single ship severely tax the computing power available to the Navy. The unique operational environment found in the Navy also violates the assumptions of these models. The requirement to support 90 days of unreplenished operations cannot be modeled by the METRIC models.

ACIM has been used to compute shipboard allowances for specific equipments such as the Fleet Satellite Communications system and the PHALANX close-in weapon system on selected ships. These equipments have been placed on virtually all ships. However, ACIM requires a detailed logistics analysis of each equipment that includes MTBF and MTTR data for each part of the equipment, as well as response time information for each echelon. Because of the level of detail required, complete analyses have only been conducted on a small number of equipment.

F. SUMMARY

In this chapter, several multi-echelon models have been presented and discussed in terms of how well they actually model the exisiting Navy supply system. Unfortunately, most fail to either take into account the unique operating environment of the Navy, or require excessive effort to develop and process the data necessary to compute the inventory requirements of the complex systems in place today.

V. MULTI-ECHELON TECHNIQUE FOR EVALUATING OPERATIONAL READINESS

The complexities and interrelationships existing in the present Navy Supply System have prevented the determination of the system wide allocation of stock to maximize a measure of weapon system performance such as operational availability. Furthermore, system-wide optimization in respect to other measures of performance such as supply response time or gross/net effectiveness has also not been successful. All existing analytical models solve, at best, for only two of the echelons; and at that, fail to completely describe the entire system. Results from changes to the existing system are not completely predictable, and comparisons of competing proposed models cannot be conducted uniformly. These problems have lead to the development of a tool which can be used to evaluate and compare multi-echelon models in the Naval Supply System. This model is called Multi-Echelon Technique for Evaluating Operational Readiness (METEOR). METEOR is designed to provide a uniform test-bed for evaluating policies, models and procedures affecting any aspect of the supply system.

METEOR is a multi-indenture weapon system computer simulation of the multi-echelon aspects of the Naval Supply System. A variety of mission scenarios, ship configurations and inventory policies may be evaluated. METEOR simulates a supply system consisting of one ICP, an east and west coast supply center, an east and west coast repair facility, and an overseas supply depot. Two MLSF ships are simulated; one supports deployed combatants on the west coast and the other supports deployed

combatants on the east coast. Up to 30 combatant ships may be simulated, with up to 15 assigned to each coast. Each ship may be located in CONUS, or deployed with or without MLSF support. Each ship may have a different equipment configuration, and repair parts loads. Each of the other activities may have unique stock level.

METEOR divides time into periods called "phases". Up to six unique phase types of arbitrary lengths may be selected. Generally, one phase type is selected with a length of 2,190 hours, or one quarter. Ships may move from one location to another at the end of a phase, which creates a changing demand pattern at each of the supply activities resulting in a more realisitic simulation.

A complete set of measures of effectiveness, including gross and net effectiveness at each echelon, average inventory cost at each echelon, overall availability, and equipment availability and MSRT, is provided to aid in comparisons of different policies and models.

A. MODEL DESCRIPTION

METEOR was developed by Bunker [Ref. 1] and is a Monte Carlo, discrete event simulation. The simulation code for METEOR is written in the FORTRAN IV programming language. METEOR has two major routines: TIGER, which processes the equipment configuration and failure/repair functions; and MULTE which models the supply system and returns the specific supply response time for failed equipments.

TIGER was written by the Naval Sea Systems Command (NAVSEA) Readiness Branch in 1979 [Refs. 9 and 10] to evaluate, by simulation, a complex system in order to estimate various readiness measures. TIGER

allows virtually an unlimited variety of equipment configurations to be modeled; from complete systems representation to detailed piece part interrelations. TIGER allows complex equipment configurations to be built up from the lowest indenture level, called equipments. Equipments may be combined to form groups, which may, in turn, be combined into sub-systems. Sub-systems may be combined in series or parallel into the system to be evaluated. Each equipment is assigned a MTBF and MTTR, and is assumed to fail independently with an exponential rate. Repair times are also independent and exponential. Depending on the specific configuration, this failure may cause the entire system to fail, or may result in a backup equipment to begin operating.

The process of the discrete event simulation begins with a failure time being assigned for each equipment, and the time of the failure is then placed in an event queue. The first failure time in the queue is examined and a time to repair that equipment is established depending on the MTTR and the supply response time. The time when the repair is completed is then placed in the event queue. When this time becomes the current time, the equipment is returned to operating status and a new failure time is generated. Statistics on the equipment up-time and downtime are accumulated.

Documentation for TIGER in its stand-alone form may be found in the TIGER Manuals [Refs. 9 and 10]. METEOR allows TIGER to be run either separately or as an integrated part of the multi-echelon system.

MULTE was developed to provide supply response times to TIGER based on the multi-echelon supply system used by the Navy. The supply system simulation must react to provide a time for the arrival of the

replacement equipment. On-hand stocks for that equipment are checked at applicable support activities throughout the supply network and the replacement unit is issued to the end user by the first activity having the part. The appropriate supply response time is passed to TIGER. Simultaneously, the supply network conducts its internal bookkeeping to insure that all activities are properly stocked. Requisitions for stock replenishment material are passed to the higher echelons, and due-in times for these requisitions are established. Repair action is initiated for repairable material, with the repair time and shipping times being used to determine due-in time.

The remainder of this chapter discusses the enhancements made to Bunker's version of METEOR by this author, the assumptions associated with the enhanced model, and the description of the data set used in evaluating the enhanced model. The results of the simulations conducted with the data set are presented in Chapter VII.

B. ENHANCEMENTS TO METEOR

Various enhancements/options have been made to METEOR to increase the usefulness and to improve the accuracy of the model. Most of these enhancements are user selectable to allow evaluation of the specific option's effect. Details on option selections and data card image formats are presented in Appendix A.

1. Inclusion of Intermediate Level Stock

Originally, METEOR only allowed wholesale stock to be carried by the stock points. An option has been added to allow the selection of "RIMSTOP" policies, [Ref. 11], in which both retail and wholesale stock

will be carried at the stock points. The requisition paths have been modified under this model to check the retail stock first, and then check wholesale stock. A requisition is referred to another stock point only if it can not be filled by both retail and wholesale stock at the original stockpoint. Figure 5.1 shows the new requisition paths. The RIMSTOP option is selected by setting IWRIM on virtual data card type two to one, and including the system wholesale stock levels under the ICP heading on data card images 28 through 31.

2. See-Through Model

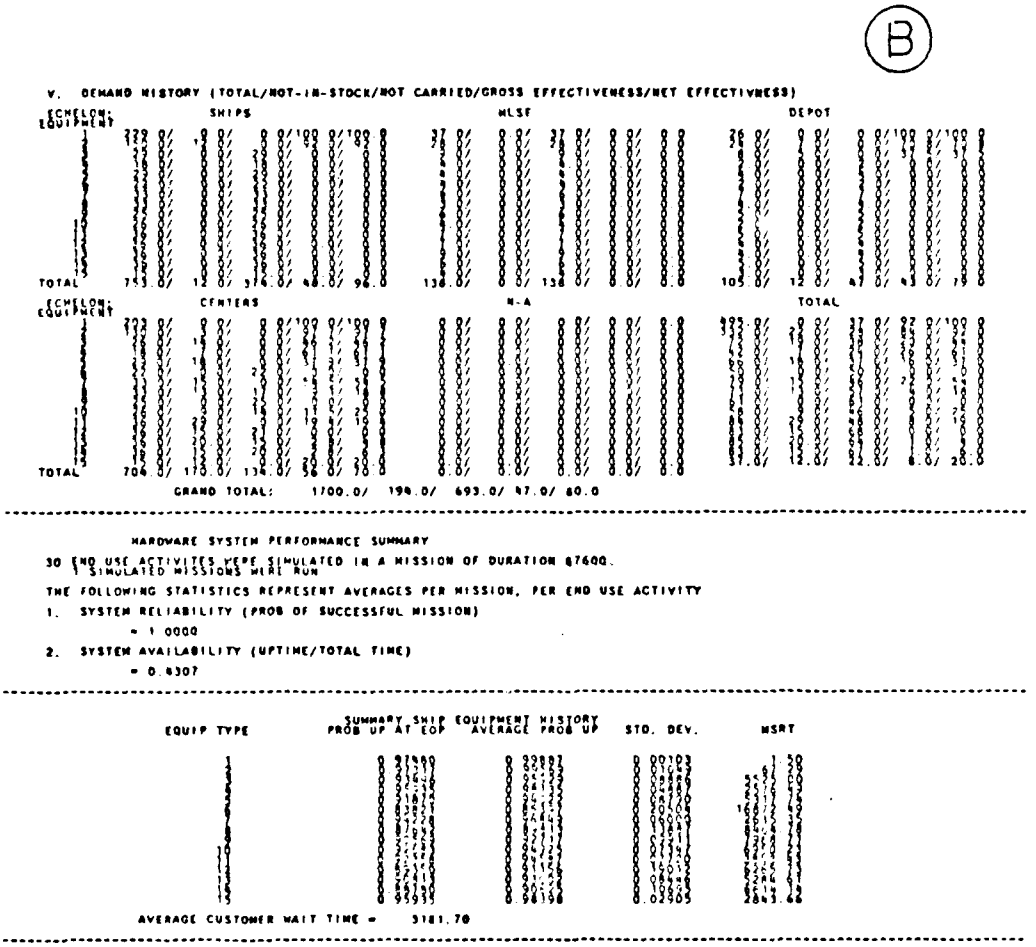
METEOR has also been modified to provide the option of running the heuristic see-through model described earlier. This model decrements the Inventory Position (IP) at the nearest stock point whenever a part fails aboard any of the ships. Additionally, the IP of the Inventory Control Point (ICP) is decremented if the failed part is a consumable. This allows the higher echelons to "see" demands as they occur allowing earlier procurement of stock, thus reducing the probability of a stockout when the requisition actually arrives. This option is selected by setting INMOD to one on data card image type two.

3. Initialization of Stock Levels

This modification causes the on-hand stock levels for all activities to be distributed uniformly between zero and the High Limit set on data card image types 28 through 31. This random assignment of stock levels reduces the simulation start-up effect, and causes the simulation to approach stationarity sooner. If the resulting on-hand quantity is less than or equal to the reorder point, an order for the item is established. The procurement lead time for this order is

Many other internal verifications were also conducted between the sections of the data summary display. These confirmed that the internal records keeping process was valid.

This validation does not imply that the model exactly duplicates the real world, but rather indicates that METEOR may be used as a test-bed, and that the tendencies of the responses are consistent from one run to another. Multiple missions (replications) are recommended when using METEOR to compare various models since significant variation may occur from one run to another.



V. DEMAND HISTORY (TOTAL/NOT-IN-STOCK/NOT CARRIED/GROSS EFFECTIVENESS/NET EFFECTIVENESS)

ECHELON: EQUIPMENT	SHIPS					MLSF					DEPOT				
1	229	0/	0	0/	0	0/100	0/100	0	37	0/	0	0/	37	0/	0	0/	0	0	26	0/	0	0/	0	0/100	0/100	0
2	25	0/	1	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
3	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
4	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
5	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
6	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
7	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
8	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
9	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
10	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
11	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
12	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
13	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
14	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
15	25	0/	0	0/	0	0/	0/	0	5	0/	0	0/	5	0/	0	0/	0	0	4	0/	0	0/	0	0/	0/	0
TOTAL	753	0/	12	0/	376	0/	48.0/	96.0	136	0/	0	0/	136	0/	0	0/	0.0		105	0/	12	0/	47	0/	43	0/	79	0

ECHELON: EQUIPMENT	CENTERS					N.A					TOTAL				
1	229	0/	0	0/	0	0/100	0/100	0	0	0/	0	0/	0	0/	0	0	493	0/	0	0/	37	0/	92	0/100	0/100	0
2	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	2	0/	5	0/	13	0/	0/	0
3	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
4	25	0/	2	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	2	0/	5	0/	13	0/	0/	0
5	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
6	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
7	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
8	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
9	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
10	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
11	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
12	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
13	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
14	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
15	25	0/	1	0/	0	0/	0/	0	0	0/	0	0/	0	0/	0	0	54	0/	1	0/	5	0/	13	0/	0/	0
TOTAL	704	0/	170	0/	134	0/	56	0/	70	0	0.0/		0.0/		0.0/		0.0		57.0/		12.0/		22.0/		6.0/		20.0	

GRAND TOTAL: 1700.0/ 198.0/ 693.0/ 87.0/ 80.0

HARDWARE SYSTEM PERFORMANCE SUMMARY

30 END USE ACTIVITIES WERE SIMULATED IN A MISSION OF DURATION 87600.
1 SIMULATED MISSIONS WERE RUN

THE FOLLOWING STATISTICS REPRESENT AVERAGES PER MISSION, PER END USE ACTIVITY

1. SYSTEM RELIABILITY (PROB OF SUCCESSFUL MISSION)
   = 1.0000
2. SYSTEM AVAILABILITY (UPTIME/TOTAL TIME)
   = 0.6307

SUMMARY SHIP EQUIPMENT HISTORY

EQUIP TYPE	PROB UP AT EOP	AVERAGE PROB UP	STD. DEV.	MSRT
1	0.21500	0.22887	0.00103	1.50
2	0.21500	0.22887	0.00103	1.50
3	0.53647	0.54133	0.00488	55.91
4	0.21500	0.22887	0.00103	1.50
5	0.21500	0.22887	0.00103	1.50
6	0.21874	0.24122	0.00720	63.17
7	0.83951	0.82119	0.00604	150.13
8	0.21500	0.22887	0.00103	1.50
9	0.21500	0.22887	0.00103	1.50
10	0.21500	0.22887	0.00103	1.50
11	0.21500	0.22887	0.00103	1.50
12	0.21500	0.22887	0.00103	1.50
13	0.21500	0.22887	0.00103	1.50
14	0.21500	0.22887	0.00103	1.50
15	0.95939	0.98198	0.03505	2843.62

AVERAGE CUSTOMER WAIT TIME = 3181.70

Figure 6.2 (Continued) METEOR Data Summary

```
SIMULATION COMPLETE-OPTIMUM NUMBER MISSIONS WERE RUN
                                    30 SHIP MODEL W-11.17.01 0302D01-1
     TOTAL NR OF MISSIONS IS:    1
                    DATA SUMMARY:  MULTI-ECHELON SUPPLY SYSTEM
                    SHIP MOVEMENT IN EFFECT
                    LEVELS COMPUTATION ENABLED
     1 SIMULATED MISSIONS WERE BEING RUN.  THE FOLLOWING
SUMMARY STATISTICS ARE BASED ON AVERAGE NUMBERS PER MISSION.
```

I. PROCUREMENTS

ECHELON SUMMARY

SHIPPED FROM WHR TO:	SHIPS	MLSF	DEPOT	SUPPLY CENTERS	W-A
NR PROCUREMENTS	137.8	8.8	48.8	388.8	8.8
NR ITEMS PROCURED					

EQUIPMENT SUMMARY

EQUIPMENT NR	1	2	3	4	5	6	7	8	9	10	11
NR PROCUREMENTS	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
NR ITEMS PROCURED	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8

(A)

II. REPAIRS REPAIR FACTOR: 1.50

ECHELON SUMMARY

SHIPPED TO REPAIR FACILITY TO:	SHIPS	MLSF	DEPOT	SUPPLY CENTERS	W-A
NR INDUCTIONS	138.8	8.8	8.8	8.8	8.8
NR ITEMS INDUCTED					

EQUIPMENT SUMMARY

EQUIPMENT NR	1	2	3	4	5	6	7	8	9	10	11
NR INDUCTIONS	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
NR ITEMS INDUCTED	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8

NR ITEMS RETURNED BY SHIPS TO REPAIR FACILITIES: 143.0

NR. REPAIRABLE CARCASSES LOST DUE TO ATTRITION: 16.0

III. MOVEMENTS (NR. SHIPMENTS)

DESTINATION ACTIVITY

(DESTINATIONS 1-6 REFER TO SHIP LOCATIONS)

	1	2	3	4	5	6	7	8	9	10	11	12
MLSF-W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
DEPOT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
CENTERS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
REPAIR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
W-A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
NSN	0.0	0.0	15.0	48.0	15.0	12.0	0.0	0.0	0.0	31.0	59.0	0.0

TOTAL NR OF ISSUES FROM SHIP STOCK: 367.0

IV. INVENTORY COSTS

MAXIMUM INVENTORY INVESTMENT

EQUIPMENT \ ECHELON:	SHIPS	MLSF	DEPOT	CENTERS	REPAIR	W-A
1	1913.80	0.00	799.10	6659.37	0.00	0.00
2	101.00	0.00	32.00	522.00	0.00	0.00
3	0.00	0.00	20.00	3744.00	0.00	0.00
4	0.00	0.00	0.00	6370.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	261.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	3565.00	0.00	0.00
10	0.00	0.00	0.00	2920.00	0.00	0.00
11	0.00	0.00	0.00	350.00	0.00	0.00
12	0.00	0.00	0.00	1400.00	0.00	0.00
13	0.00	0.00	0.00	3000.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00
TOTALS:	2014.80	0.00	851.14	127686.25	0.00	0.00

TOTAL INVESTMENT: 130530.19

AVERAGE ON-HAND INVENTORY DOLLAR VALUE

EQUIPMENT \ ECHELON:	SHIPS	MLSF	DEPOT	CE TERS	REPAIR	W-A
1	1193.11	0.00	507.53	9245.05	0.00	0.00
2	0.06	0.00	0.26	0.00	0.00	0.00
3	0.00	0.00	0.00	2087.52	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	2.06	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00
TOTALS:	1219.17	0.00	557.85	13917.62	1216.10	0.00

TOTAL INVESTMENT: 16912.75

Figure 6.2 METEOR Data Summary

the issue results in the wholesale system going into a buy position, since the wholesale reorder point is 27. The wholesale system orders up to the high limit of 76 resulting in a purchase of 49 items. These items are distributed to the stock points (activities 33 through 35) based on their inventory positions. The items are shipped from the manufacturer (activity 39), and the stock point's and ICP's inventory positions are incremented to reflect the due-in material.

C. A failure occurs on ship 4 at time 38060. The replacement is issued from shipboard stock, and a stock requisition is issued from the West Coast stock point (activity 35). Note that the due-in material shipped at time 37896 has arrived, and the on-hand inventory of activity 34 reflects the receipt of this material.

Using this detailed printout of supply transactions, several runs have been made using all available combinations of options and each transaction path has been completely traced. Response paths are as designed, and supply response times are in agreement with expected values.

Figure 6.2 shows the end-of-run summary statistics. These values can be validated using information provided by the detailed transaction listing and various internal checks. Equipment types one through ten refer to consumable material, and equipment types eleven through fifteen refer to repairable material. The following discussion is keyed to the letters on Figure 6.2:

A. Section I of the data summary presents the total number of procurements from the manufacturer. The values in the equipment summary section for equipment type 2 are in agreement with the number of transactions found in the detailed transaction listing.

B. Section V of the data summary shows the number of demands, not-in-stock, and not carried statistics for all echelons of the supply system. The values agree with those found in analysis of the detailed transaction listing.

```
     FAILURE OF EQUIPMENT TYPE  2 ON SHIP 12 AT TIME: 35901,
     RESULTED IN THE FOLLOWING SUPPLY ACTIONS:
END USE REQUIREMENT FILLED BY SSN 12.     SUPPLY RESPONSE TIME IS:       2.
NO ORDERS FOR STOCK RESULTED FROM THIS ISSUE.

ACT    31    32    33    34    35    36    37    38
O/H     0     0     0     7    23     0     0    17
I/P     0     0     0     7    23     0     0    30
```

```
     FAILURE OF EQUIPMENT TYPE  2 ON SHIP  4 AT TIME: 36042,
     RESULTED IN THE FOLLOWING SUPPLY ACTIONS:
END USE REQUIREMENT FILLED BY SSN  4.     SUPPLY RESPONSE TIME IS:       2.
ORDERS FOR STOCK WERE GENERATED AS FOLLOWS:
     REQUISITIONER(SSN)      DUE-IN AT TIME      ISSUED FROM(SSN)        QTY
             4                    36562                 35                1

ACT    31    32    33    34    35    36    37    38
O/H     0     0     0     7    22     0     0    17
I/P     0     0     0     7    22     0     0    29
```

```
     FAILURE OF EQUIPMENT TYPE  2 ON SHIP  5 AT TIME: 36491,
     RESULTED IN THE FOLLOWING SUPPLY ACTIONS:
END USE REQUIREMENT FILLED BY SSN  5.     SUPPLY RESPONSE TIME IS:       2.
ORDERS FOR STOCK WERE GENERATED AS FOLLOWS:
     REQUISITIONER(SSN)      DUE-IN AT TIME      ISSUED FROM(SSN)        QTY
             5                    37010                 35                1

ACT    31    32    33    34    35    36    37    38
O/H     0     0     0     7    21     0     0    17
I/P     0     0     0     7    21     0     0    28
```

```
     FAILURE OF EQUIPMENT TYPE  2 ON SHIP 29 AT TIME: 36918,
     RESULTED IN THE FOLLOWING SUPPLY ACTIONS:
END USE REQUIREMENT FILLED BY SSN 29.     SUPPLY RESPONSE TIME IS:       2.
ORDERS FOR STOCK WERE GENERATED AS FOLLOWS:
     REQUISITIONER(SSN)      DUE-IN AT TIME      ISSUED FROM(SSN)        QTY
            29                    37653                 38                1
            32                    49684                 32                2
            34                    37806                 34                7
            35                    50958                 39                3

ACT    31    32    33    34    35    36    37    38
O/H     0     0     0     6    33     0     0    17
I/P     0     0     8    34    34     0     0    76
```

```
     FAILURE OF EQUIPMENT TYPE  2 ON SHIP 21 AT TIME: 37198,
     RESULTED IN THE FOLLOWING SUPPLY ACTIONS:
END USE REQUIREMENT FILLED BY SSN 21.     SUPPLY RESPONSE TIME IS:       2.
ORDERS FOR STOCK WERE GENERATED AS FOLLOWS:
     REQUISITIONER(SSN)      DUE-IN AT TIME      ISSUED FROM(SSN)        QTY
            21                    37813                 34                1

ACT    31    32    33    34    35    36    37    38
O/H     0     0     0     7    33     0     0    17
I/P     0     0     8    33    34     0     0    75
```

```
     FAILURE OF EQUIPMENT TYPE  2 ON SHIP  4 AT TIME: 38060,
     RESULTED IN THE FOLLOWING SUPPLY ACTIONS:
END USE REQUIREMENT FILLED BY SSN  4.     SUPPLY RESPONSE TIME IS:       2.
ORDERS FOR STOCK WERE GENERATED AS FOLLOWS:
     REQUISITIONER(SSN)      DUE-IN AT TIME      ISSUED FROM(SSN)        QTY
             4                    38580                 35                1

ACT    31    32    33    34    35    36    37    38
O/H     0     0     0     7    33     0     0    17
I/P     0     0     8    33    33     0     0    74
```

Figure 6.1 Detailed Supply Transaction Listing

VI. VALIDATION OF METEOR

As with any complex simulation, the validation of the model is not only extremely important, but also extremely difficult. Data are not available to allow direct comparison of the output data from METEOR and actual data. Therefore, any validation of the model must be done internally, by tracing events through the model to insure that they are processed as expected and applying tests of "reasonableness".

METEOR has the capability to display all supply transactions. This capability may be exploited to conduct the required validation. A sample of the supply transaction ledger is shown in Figure 6.1. This ledger shows all transactions in chronological order for a single equipment. The following steps detail the methodology used in verifying the options selected for this run. This run displayed all transactions for equipment type 2, which is a consumable item. The system uses the existing inventory policies. The following validation steps are keyed to the letters shown on Figure 6.1:

A. At time 36042, an equipment failed on ship 4, which is assigned to the west coast and is not deployed. The requirement was filled from on hand stock, requiring 2 hours. Ship 4 has a high limit of 1 item and a reorder point of 0, and as a result of the issue, ship 4 orders one item from the closest supply activity, NSC West Coast (35). The stock replenishment item is due to arrive at ship 4 at hour 36562. At the end of this transaction, activity 35 has 22 items on-hand, and an inventory position of 22. The overall wholesale system (38) inventory position (I/P) is 29.

B. At time 36918, an equipment failed on ship 29, which receives supply support from activity 34. The requirement is filled from onboard assets, and a stock reorder is placed with activity 34. The stock reorder item is due in to ship 29 at time 37653. Activity 34's on-hand (O/H) count is decremented by the issue, and

Wholesale levels were computed using the CARESJR microcomputer program developed by FMSO based on the descriptions in reference 12. Parameters used to compute wholesale levels were obtained for each 4 digit COG. Consumable items were selected from 1H COG material and repairables from 7H COG material. Retail level for stock points were computed using the ERM/VOSL models given in reference 3. The VAD values on page 34 of reference 3 were used for the models. Stock levels for the MLSF ships were computed using initial provisioning procedures [Ref. 12]. Shipboard levels were computed using the MOD-FLSIP model, with all parts coded as "P".

The order and shipping time data were collected from the FMSO Requisition Response Time Management Information System. The values used represent the median value for order and shipping times for all Issue Priority Groups. Medians were used due to the observed severe skewing of the data toward longer order and shipping times.

last two digits of the four digit material cognizance symbol (COG). The breakdown of items in the data sample according to requisition frequency and consumable/repairable classification was taken to be proportional to the requisition frequency breakdown of the SPCC data base. Tables I and II show the breakdown of the four digit cogs at SPCC and the number of selected items, respectively.

TABLE I

QUARTERLY REQUISITION FREQUENCY TO COG

Requisition Frequency	Last Two Digits of COG
RF<= 1	ØØ
1<=RF<3	03
3<=RF<5	02
RF<= 5	01

TABLE II

SPCC MATERIAL BREAKDOWN

	ØØ	03	01/02	Total
SPCC Data	75,467 79%	14,024 13%	8,090 8%	107,571 100%
Consumable Data Set	8	1	1	10
Repairable Data Set	4	1	0	5

Note: The ratio of Consumable (1H) material to Repairable (7H) is: 72,961/34,610 or approximately 2/1.

computation and ship movement modules. METEOR allows a maximum of 40 phases, resulting in a simulation run of ten years.

4. Stochastic Variables

METEOR makes use of the gamma family of distributions for repair turn-around-times and procurement lead times. ALFA1 and ALFA2 on data card image type 25 control the gamma shape parameters for these variables. The individual Mean Procurement Lead Time (MPLT) and Mean Repair Turn-around-Time (MRT) parameters on data card image type 26 and 27 control the spread values for each equipment type. TIGER assumes exponential times between failures and exponential times to repair equipment at the shipboard level.

D. SAMPLE DATA SET

A sample data set and the source information used to construct it is provided in Appendix B. This data set is used in Chapter VI as a test bed to analyze the effects of simulation duration, effects of varying the procurement and repair turn-around-time shape parameters, and the effects of RIMSTOP and the see-through model on the supply system. A simulated fleet of thirty ships, fifteen assigned to each coast, was constructed with each ship having an identical equipment consisting of fifteen parts in series. These parts would have approximately the same demand distribution as found in the general population of Navy owned material. The stock levels for each activity are computed using the appropriate current inventory models.

The raw data were extracted from the FMSO Computation and Research Evaluation System (CARES) data base by random selection based on the

C. MODEL ASSUMPTIONS

Like most simulations, there are several major assumptions made by METEOR that affect the accuracy of the simulation. Some of these assumptions are immutable, while others can easily be changed to accommodate differing situations to be modeled.

1. Ship Configuration

METEOR depends on TIGER for much of the equipment related modeling conducted in the simulation. One assumption in TIGER is that during a phase, an equipment is called upon to operate for the entire phase. Each equipment may be assigned a variable duty cycle. However, TIGER accomplishes this by multiplying the MTBF for that equipment by the reciprocal of the duty cycle. Additionally, ships may not be added or removed from phase to phase. The total number of ships must remain constant throughout the simulation.

2. Constant Order and Shipping Times

The order and shipping time represents the administrative, and physical shipping delays experienced in moving material from one location to another. These are assumed to be constants and are added to procurement or repair time based on the source and destination of the material. These times are unaffected by the priority of the requirement, or any expediting procedures that might actually be used.

3. Phase Length

TIGER allows up to 6 different phase types, each with possible differing lengths. METEOR should be run with only one phase type, and the length should be 2,190 hours. This equates to a 90 day quarter. This length is required for the proper operation of the levels

card image type two. If REPFAC is left blank or set to zero, it is assigned the default value of 2.0.

6. Ship Movement at End of Phase

Ships may initially be assigned to one of three geographic regions: at a supply center in the continental United States (CONUS), deployed overseas with mobile logistics support, and deployed overseas without mobile logistics support. The ship movement module will maintain the same numbers of ships assigned to designated regions from phase to phase; however, the actual ships will change. This simulates the deployment cycles occurring in the actual fleet, and creates a changing demand pattern at each supply activity, resulting in a more realistic simulation. This option may be selected by setting IWPHA to one on data card image two, and selecting the ship's initial location as variable IRCC on data card image type 20.

7. End of Phase Levels Computations

As discussed in Chapter III, shipboard allowances are changed on the basis of actual demands incurred; if there are sufficient demands recorded, the allowance may be increased. Optionally, the experienced demand at each ship will be reviewed for each item, and a new set of levels will be computed if appropriate. The levels model used is similar to that used by the Shipboard Uniform Automated Data Processing System (SUADPS) model and is described in Appendix E. The SUADPS model was selected because its algorithm is designed for machine computation. Non-mechanized ships use a table look-up method to compute new levels. This option may be selected by setting IWLVL to one on date card image type two.

display includes the probability of each equipment type being operational at the end of a phase, the average ratio of uptime to total time for each equipment type, the standard deviation for the ratio, and the mean supply response time for that equipment type. Finally, the demand weighted mean supply response time for the entire weapon system is displayed. These equipment statistics may be selected by setting the appropriate value to IOPTP2 on data card image type one.

An extensive listing of all supply transactions may be selected which includes details on each supply transaction including supply response time, issuing activity, stock reorders, and repair facility inductions for repairable items. The on-hand and inventory position of each activity from the MLSF ships to the ICP are also shown. Alternately, a detailed display of only those transactions concerning a selected equipment type may be produced. Selecting either of these displays can result in voluminous outputs. These options may be selected by setting IOPTP1 on data card type one and IWSEL on data card image type two to the appropriate values.

5. Repairables Processing

The repairables processing module in MULTE has been rewritten to provide distribution of repaired items to the stock points based on the stock point's IP. Additionally, a maximum repair capacity value, called REPFAC, has been introduced to account for the limited capacity at the repair facility. REPFAC is multiplied by the equipment type's economic repair quantity to obtain the maximum repair capacity for the repair facility. The maximum capacity parameter is input as REPFAC on data

distributed as a gamma random variable with the shape parameter equal to ALFA2 input on data card image type 25 and the spread parameter equal to the Mean Procurement Lead Time (MPLT) value for the item input on data card image type 26. This lead time is scaled by the ratio of the on-hand quantity to the reorder point so that items with lower on-hand quantities will receive stock sooner, again reducing the startup effect. The adjusted spread parameter, PLT, is calculated as follows:

$$PLT = (OH/RO)*MPLT$$

where OH = on-hand stock level;

RO = reorder point;

and MPLT = mean procurement lead time for the item.

By initializing the on-hand quantities and the procurement lead times for the due-in quantities in this manner, the simulation approaches steady state much more rapidly, allowing shorter, less expensive computer runs. This modification is not user selectable.

4. New Measures of Effectiveness

Several new measures of effectiveness have been added to METEOR and are presented in both the simulation data summary and the detailed supply transaction listings. Point of entry or gross effectiveness and net effectiveness percentages are displayed for all equipments and each echelon. An optional set of equipment performance statistics is available which presents a display of the probability of each equipment on each ship being in an operational status at the end of a phase, and a display of the ratio of uptime to total time for that equipment for the entire simulation. Another option presents a display of summary statistics for each equipment type for the entire simulation. The

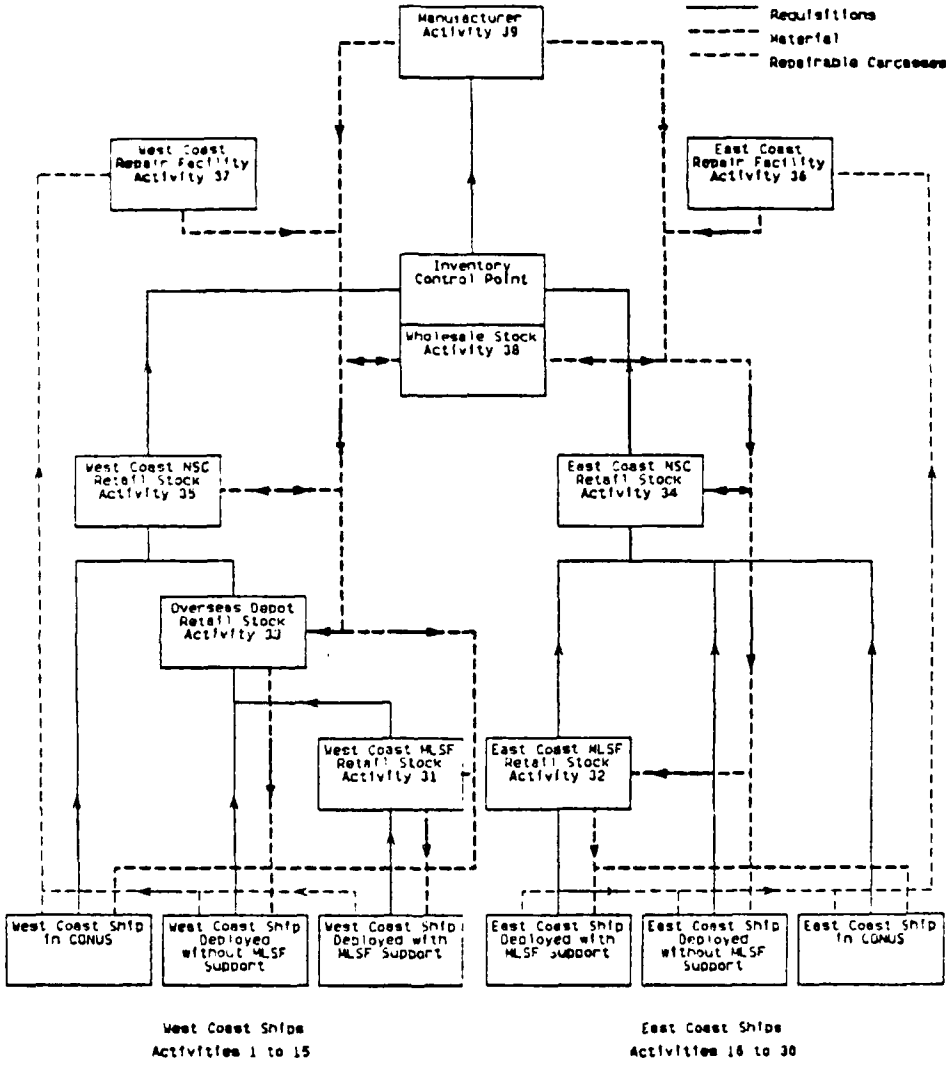


Figure 5.1 RIMSTOP Requisition Paths

VII. METEOR AS AN EVALUATION TOOL

This chapter reports on a set of experiments designed to demonstrate the use of METEOR for the evaluation of a multi-echelon inventory system. The sample evaluations reported here investigate modifications to the existing system and explore the effect of reducing lead time variability. Standard analysis of variance techniques were applied to the output of METEOR to test various hypotheses. The data set used in these experiments is described in Appendix B.

A. HYPOTHESIS

The following hypotheses are investigated:

1. RIMSTOP Policies

It is hypothesized that the RIMSTOP policies, i.e. implementing separate retail and wholesale stock levels as described earlier, has no effect on the supply system's measures of effectiveness.

2. See-through Model

It is hypothesized that implementing a see-through inventory model providing all echelons with demand information as it occurs, has no effect on the supply system's measures of effectiveness.

3. Lead Time Variance

It is hypothesized that a reduction in lead time variance will cause an improvement in the supply system's measures of effectiveness. Since lead time is assumed to be gamma distributed, and the variance of a gamma distribution is $\alpha/\beta^{**}2$, the reduction in variance is modeled

by increasing the shape parameter, α. The mean is kept constant by adjusting the spread parameter accordingly.

B. MEASURES OF EFFECTIVENESS

The hypotheses described above were tested using the following measures of effectiveness:

1. Shipboard gross and net effectiveness (in percent),
2. Overall system gross and net effectiveness (in percent),
3. Average Inventory cost (in dollars),
4. System availability (in percent),
5. Demand weighted mean supply response time (in hours).

These data elements were extracted from the Data Summary section of the METEOR output. Shipboard effectiveness indicates how well the ship's organic supply system performs, directly reducing supply response time and increasing equipment availability. Overall effectiveness provides a measure of how well the supply system avoids the long delays waiting for material to arrive from the manufacturer. Average inventory cost provides an observation of the holding costs involved in achieving a given level of effectiveness/availability and serves as a surrogate for the inventory investment. System availability, defined as up-time divided by total time, and demand-weighted mean supply response time both provide direct measures of how well the supply system supports the operating units. All of these measures of effectiveness are used to evaluate performance of the supply system at one echelon or another.

C. EXPERIMENTAL DESIGN

The experimental design used to test the hypotheses stated above consists of a factorial design with two factors to test for RIMSTOP and See-through effects and any interactions, and a one-way analysis of the lead time variance factor. It was previously determined that the duration of each simulation run should be for a period several years to allow long term effects due to long procurement lead times to appear. Therefore, all data were collected from simulations running for 10 years (87,600 hours).

Each simulation was run with ten missions (iterations) to smooth the observed measures of effectiveness. Figure 7.1 shows smoothed values of the measures of effectiveness as a function of the number of iterations. It is clear that the observed data values have stabilized with ten iterations to approximately the same levels found by iterating fifty times. Consequently, ten iterations were used in all experimental trials.

Table III shows the computer time required to simulate all factors at their high level for various numbers of iterations.

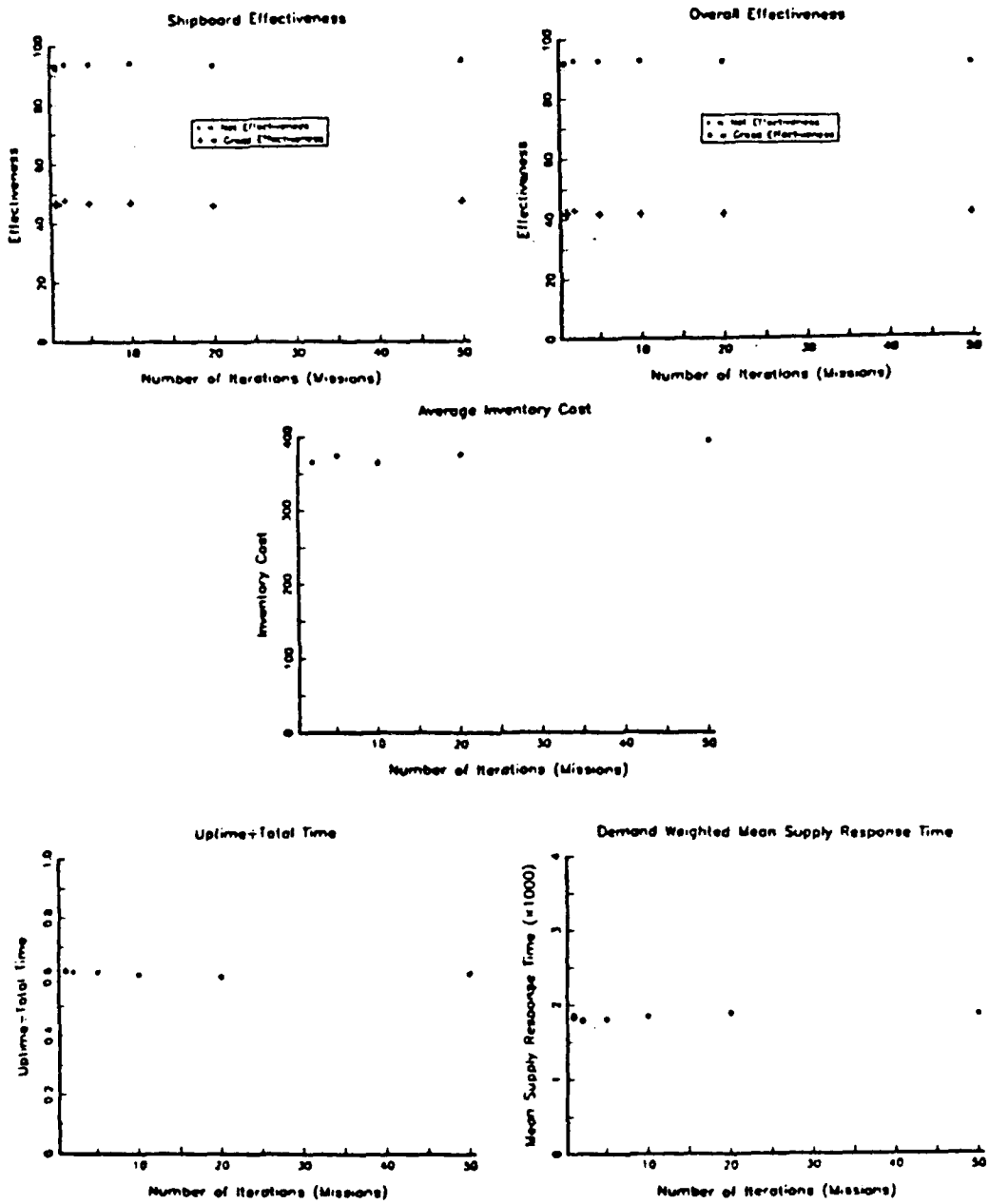


FIGURE 7.1 Measures of Effectiveness as a Function of Number of Iterations

TABLE III

SIMULATION RUN TIME IN CPU SECONDS ON THE NPS IBM 3033

Language: FORTRAN VS System: MVS

Iterations	CPU Seconds
1	7.98
2	15.54
5	35.82
10	63.01
20	141.86
50	351.82

Notes: Forty phases,each of duration 2,190 hours,were run.
Gamma shape parameter set to 10.
RIMSTOP selected.
See-through selected.
Compile time is not included.

Although not shown in Table III, the duration of the simulation affects the computer time linearly. A simulation of duration 40 phases will run ten times longer that one of duration four. Additionally, the more high demand items simulated the longer will be the simulation runs due to the increased numbers of failures, and the higher number of transactions generated.

D. RESULTS AND ANALYSIS

1. General Results

Appendix F contains a table of the raw data collected from the simulation runs. Data analysis was conducted using an APL analysis of variance routine written by Richards [Ref. 14]. The results of the ANOVA program are summarized below for each hypothesis. MOEs that are significant at a .05 or smaller level of significance are indicated in

bold print and an asterick (*) immediately preceding the measure of effectiveness.

2. RIMSTOP Policies

The following results were obtained by comparing simulation runs with either the RIMSTOP policies in effect (under the Enabled heading in Table IV), or with the older non-RIMSTOP policies in effect (under the Disabled heading in Table IV).

TABLE IV

RIMSTOP POLICIES

Measure of Effectiveness	F-Statistic (df)	Sig. Level	Disabled Mean	Disabled S.D.	Enabled Mean	Enabled S.D.
Shipboard Gross Effectiveness (%)	0.00 (1,5)	1.0000	47.5	0.58	47.5	0.58
Shipboard Net Effectiveness (%)	0.00 (1,5)	1.0000	94.8	0.50	94.8	0.96
*Overall Gross Effectiveness (%)	140.80 (1,5)	0.0000	47.5	1.91	41.0	1.83
*Overall Net Effectiveness (%)	585.00 (1,5)	0.0000	81.3	3.20	91.0	2.94
*Average Inventory Cost ($)	5.92 (1,5)	0.0453	83250	69206	210325	202581
*System Availability (%)	33.44 (1,5)	0.0007	46.6	0.50	56.3	0.80
*Average Customer Wait Time (hours)	102.70 (1,5)	0.0000	3034	486.8	2341	558.4

The lack of significant change in shipboard effectiveness is expected since the RIMSTOP policies do not affect the range or depth of shipboard material.

The significant effects observed in overall effectiveness result from the major changes to intermediate and wholesale inventory levels caused by implementing RIMSTOP. The decrease in gross effectiveness under RIMSTOP results from the change in stocking policy at the intermediate stock points. The ERM/VOSL model causes a much smaller range of material to be carried by the stock points than was previously carried as wholesale stock. This causes stock point gross effectiveness to decrease dramatically. However, the wholesale stock levels are still carried and requisitions are now filled at the wholesale level which were previously filled by retail assets. The increase in overall net effectiveness results from the added depth at the retail level.

The gains in overall net effectiveness do not come without cost. The average inventory cost increases dramatically due to the added layer of retail material carried at the stock points.

The increase in system availability and decrease in average customer wait time is due to the added protection provided by the retail stock level. The system is much less likely to be out of stock for high demand items due to the additional depth carried at the retail stock points.

3. See-through Model

The following results were obtained by analyzing simulation runs with the see-through model in effect (under the Enabled heading in Table V) and not in effect (under the Disabled heading in Table V).

TABLE V

SEE-THROUGH MODEL

Measure of Effectiveness	F-Statistic (df)	Sig. Level	Disabled Mean	Disabled S.D.	Enabled Mean	Enabled S.D.
Shipboard Gross Effectiveness (%)	1.67 (1,5)	0.2377	47.8	0.50	47.3	0.50
Shipboard Net Effectiveness (%)	0.83 (1,5)	0.3917	95.0	0.82	94.5	0.58
*Overall Gross Effectiveness (%)	30.00 (1,5)	0.0009	42.8	3.86	45.7	3.77
*Overall Net Effectiveness (%)	169.60 (1,5)	0.0000	83.5	5.80	88.8	5.50
*Average Inventory Cost ($)	20.19 (1,5)	0.0028	29425	6961	264150	140765
*System Availability (%)	39.05 (1,5)	0.0004	46.2	0.40	56.7	0.70
*Average Customer Wait Time (Hours)	170.70 (1,5)	0.0000	3135	386.5	2240	432.5

As was the case for the RIMSTOP policies, the lack of significant effect on shipboard gross and net effectiveness by the see-through model is expected since the see-through model does not change shipboard range or depth.

The improvements in overall effectiveness are a result of the anticipation of demands by the higher echelons resulting in the required material being available when demanded. This reduces the probability of stockout and backorders.

The see-through model causes a large increase in average inventory holding costs due to the earlier procurement of stock and the longer periods it must be held prior to issue.

The increase in system availability and reduction in average customer waiting time due to the see-through model was expected; demands are much more likely to be filled at the lower echelons rather than by direct shipment from the manufacturer. The see-through model clearly reduces the effect of long procurement lead times by buying the needed material sooner than the existing models.

Interaction effects between the RIMSTOP policies and the see-through model were also investigated. No significant interactions were observed except in average inventory cost. The interaction effect had a F Statistic value of 127.1 (1,4) and was significant at the 0.00003 level. This interaction is a result of the increased stock levels due to the RIMSTOP policy's retail stock level and the see-through model's earlier procurement feature. The combination of effects result in a greatly increased average inventory cost.

4. Lead Time Variance

A reduction in lead time variance is widely believed to lead to better effectiveness due to the reduced probability of stock outs during the procurement lead time. Lead time variance is the primary factor used in determining safety levels in most of the models discussed in Chapter III. It would be expected that a reduction in observed lead time variance from the level used to compute the safety level would result in higher effectiveness and smaller occurrence of stockouts. The effect of reducing the variability of procurement and repair lead times, while maintaining the mean value of the lead time constant is investigated below. The experiment compared simulation runs with high

procurement and repair lead time variance (under the Large heading on Table VI) and with low variance (under the Small heading on Table VI).

TABLE VI

LEAD TIME VARIANCE

Measure of Effectiveness	F-Statistic (df)	Sig. Level	Large Mean	Large S.D.	Small Mean	Small S.D.
Shipboard Net Effectiveness (%)	1.00 (1,6)	0.3559	95.0	0.82	94.5	0.58
Overall Gross Effectiveness (%)	1.71 (1,6)	0.2277	52.0	11.60	44.0	3.92
Overall Net Effectiveness (%)	0.00 (1,6)	0.9578	86.3	6.34	86.0	6.48
Average Inventory Cost ($)	0.00 (1,6)	0.9516	150550	177423	143025	158358
System Availability (%)	0.13 (1,6)	0.7338	52.5	0.90	50.4	0.80
Average Customer Wait Time (Hours)	0.96 (1,6)	0.3657	2738	663.2	8661	12092

For each measure of effectiveness, the effect of reducing the lead time variability by a factor of 10 was not signficant. In fact, the mean values of the measures of effectiveness decreased in the low variability case for most of the measures. The reason for this trend is somewhat counter-intuitive. With a shape parameter equal to one, the gamma distribution is exponential and is skewed to the right resulting in many observations with values less than the mean. With shape parameter equal to ten, the distribution shows little skewness and the observed values are found equally on either side of the mean with small variance. In the exponential case, the median is smaller than the mean

by a factor of 0.6931, emphasizing small lead times. Thus, by reducing the variability and keeping the means constant, we have, in effect, given up the opportunity to experience a large fraction of short lead times.

E. CONCLUSIONS

These experiments have shown that virtually all measures of effectiveness may be improved by the use of either the RIMSTOP policies or the See-through model or by using both. However, the improvements come at a significant cost. Higher inventory holding costs at the intermediate and wholesale echelons result from either of these models. Additionally, it is interesting to note that a simple heuristic approach to improving system availability can result in a large improvement over the long run. None of these improvements are realized in a short period of a year or less, but require several years to mature.

VIII. SUMMARY AND RECOMMENDATIONS

A brief description of a multi-indenture, multi-echelon simulation has been presented. It has been shown that METEOR may be used to evaluate inventory models, policies, and their underlying assumptions. While not providing predictive results, this simulation provides a rational means to evaluate policies and to rank their relative merit. METEOR does provide a needed evaluation capability.

In the simple experiments described in Chapter VII, METEOR provides useful insights into the interrelationships present in the complex, multi-echelon, multi-indenture system. The results indicate that by implementing either or both the RIMSTOP inventory policy and a simple, heuristic inventory policy, system availability and mean supply response time may be significantly improved. The experiment examining the effect of reducing lead time variability provided useful, counter-intuitive insight into the functioning of the multi-echelon system. It would be very difficult to determine analytically the effect of such a reduction in lead time variability, but such modification can be evaluated easily using a tool like METEOR. This is but a small sample of the types of analyses that could be performed using METEOR. Other investigations, such as the effects of order and shipping time variability, effects of changes in shipboard stocking policies on higher echelon effectiveness, and sensitivity analyses of the measures of effectiveness to changing demand patterns, are readily conducted using METEOR.

METEOR is relatively easy to implement, although it does require significant computer resources to operate. Once the input data have been prepared, results may be obtained with computer run times like those reported earlier in Table III. The complexity of the data set directly affects the computer run time.

Future researchers may use this simulation to test new inventory models to be used at the various echelons of the supply system, or to evaluate the effects of changes in current policies and procedures. METEOR provides a means to evaluate effects of system configuration on availability; evaluate essentiality weighting policies; reductions in lead times; effects on readiness of cuts in budgets; and other effects of resources on readiness. METEOR also provides a means to test the effects of changes in repairable processing. Additionally, data are available to evaluate the effects of improvements in shipping times. These areas of research are made significantly easier by using METEOR.

There are many areas still to be explored in METEOR. The interested student/analyst might consider some of the following recommendations and proposals:

1. Continue to validate and review the model and its representation of the Navy supply system. Policy changes and updated procedures that are being implemented in the field should be implemented in METEOR.

2. Expanded data sets that contain a variety of system configurations could be designed that allow investigations into system level interrelationships and the effect of complexity on effectiveness. A data set for a small equipment could be produced using actual data from the ICP's records. This would require establishing the reliability block diagram and retrieving the appropriate data elements from the Weapons System File and from Defense Logistics Agency records. This data set could provide a standard upon which to compare systems and to determine the biases in METEOR.

3. Evaluate existing multi-echelon models. Many claims have been made concerning proposed multi-echelon models such as METRIC and ACIM. METEOR provides a means of testing these claims and measuring the relative merits of these models.

4. Change METEOR to allow for the prioritization of shipment for critically required material. Material required to fill critical needs aboard ships receives special handling and expedited shipping by the supply system. METEOR could be changed to reflect these procedures.

5. Some of the existing deterministic parameters, such as order and shipping time, could be made random. This would improve the realism of the simulation and allow for studies to be made of the effects of variability.

6. Revision and possible elimination of TIGER routines not necessary for the operation of METEOR would eliminate program overhead and would speed up compile and run times. Additionally, replacement of existing event queues with improved data structures would appreciably improve simulation performance.

7. Additional sensitivity analysis of various aspects of METEOR would be useful. Determining how much effect changes in MTBF or MTTR would have on system performance is certainly possible. Further studies into the effect of distribution assumptions on procurement lead time and repair turn-around time would be useful.

Card Type 10. Phase Repair Card. This card is used to specify the repair option in effect during each phase type.

Column	Format	Variable Name	Description
1-4	I4	IFLAG(1)	Repair Option for each phase type (up to six).
5-8	I4	IFLAG(2)	= 0 if on-board repair allowed. = 1 if no on-board repair allowed.
9-12	I4	IFLAG(3)	= 2 if on-board repair allowed, but failure inhibited.
13-16	I4	IFLAG(4)	
17-20	I4	IFLAG(5)	
21-24	I4	IFLAG(6)	

Notes:
IFLAG = 1 will inhibit the ordering of repair parts even though an equipment has failed. This option is not recommended when running METEOR.

Sample Input Data:

```
  0   0   0   0   0   0
1234567890123456789012345678 90
```

This card image indicates that on-board repair is allowed in each of the six different phases.

Note:

Selection of KOPT = 5 and KS(1) = 1 is recommended when running METEOR.

Sample Input Data:

```
  5   1
1234567890
```

This card image selects printing of only TIGER input data, and is recommended for all METEOR runs.

Card Type 8. Printout Option Card. This card is used to select the TIGER output options.

Column	Format	Variable Name	Description
1-4	I4	KOPT	TIGER printout option switch. = 1 for management summary = 2 for engineering summary = 3 for complete details (used for debugging only) = 4 to suppress printout of input data = 5 to specify printout using KS( ) variables (see below) = 6 for TIGER/MANNING complete details (debugging only)

If KOPT = 5, select printing option from the following selections, otherwise leave fields blank.

5-8	I4	KS(1)	= 1 input data
9-12	I4	KS(2)	= 1 equipment down at time of mission failure
13-16	I4	KS(3)	= 1 downtime at end of phase
17-20	I4	KS(4)	= 1 abort messages
21-24	I4	KS(5)	= 1 all events
25-28	I4	KS(6)	= 1 ETIME matrix (debugging only)
29-32	I4	KS(7)	= 1 not used
33-36	I4	KS(8)	= 1 not used
37-40	I4	KS(9)	= 1 not used
41-44	I4	KS(10)	= 1 system and subsystem status
45-48	I4	KS(11)	= 1 TIGER/MANNING debugging
49-52	I4	KS(12)	= 1 status of all groups
53-56	I4	KS(13)	= 1 downtime message

Card Type 7. ***** Blank Card *****

Sample Input Data:

```
1.   2190.2.   2190.3.   2190.4.   2190.5.   2190.
12345678901234567890123456789012345678901234567890

6.   2190.
1234567890
```

These card images indicate that there are 6 distinct phases each having a duration of 2190 hours.

Card Type 6. Phase Type and Duration Card. Phases are the key to constructing scenarios in TIGER. Up to 6 different phase types may be specified, and they may be put together in a sequence of up to 95 phases which comprise the mission to be simulated. For example, normal steaming may be simulated in one phase, while combat operations are simulated in another. Equipment-related parameters may be varied on the input cards that follow to correspond to the type of operation modeled in any given phase. Note that requisitioning change at the end of each phase if IWPHA on card type 2 is set to 1.

Column	Format	Variable Name	Description
1-2	F2.0	XXT(1)	Phase type number for first simulation sequence.
3-10	F8.0	XXT(2)	Duration of first phase in hours.
11-12	F2.0	XXT(3)	Phase type number for second simulation sequence (if any).
13-20	F8.0	XXT(4)	Duration of second phase in hours.
on to			
41-42	F2.0	XXT(9)	Phase type number for fifth simulation sequence (if any).
43-50	F8.0	XXT(10)	Duration of fifth phase in hours.

Notes:

Continue this format on additional cards for up to 95 distinct phases.

Card Type 5. Statistical Parameter Card. This card is used to govern the number of missions (iterations) to be performed in the simulation. If METEOR is run, a predefined number of iterations should be run.

Column	Format	Variable Name	Description
1-4	I4	NMAX	Maximum number of missions to be run. As few as 1 may be run and NMAX must not exceed 1000.
5-8	I4	NOPT	Optimal number of missions (not to exceed NMAX).
9-12	F4.0	PL	Specification requirement for reliability.
13-16	F4.0	XK	Standard deviation to be used in calculating lower control limit.
17-20	I4	ISEED	Random number seed.
21-24	I4	NPH	Number of phase types, not to exceed 6.

Notes:

NMAX - To run a predefined number of missions, set PL = 1.0, and NOPT and NMAX to the desired number of missions. Complex configurations require significant computer time. NMAX = 1 should be used for long duration, complex systems.

XK - A value of 1.28 corresponds to a 90% lower confidence limit (assuming normality). Inconsequential when running METEOR.

Sample Input Data:

```
  1   1  1.1.285687   6
12345678901234567890123456789O
```

This card image indicates that 1 mission is to be run, and that the optimal number of missions is 1. The reliability goal is 1.0 and the standard deviation is 1.28 (not used by METEOR). The random number seed is 5687 and there are 6 different phase types in the simulation.

Card Type 4. Timeline Iteration Card. If TIGER is to be run on a stand alone basis, it is possible to run more than one mission scenario (timeline). If METEOR is used, only one mission scenario is permissible.

Column	Format	Variable Name	Description
1-4	I4	JCC	Number of timeline variations to be run from data deck. Set JCC = 1 when running METEOR.
5-80	19A4	RUNID	Alphanumeric run identifier.

Sample Input Data:

```
 1METEOR Sample Run Identifier Card
12345678901234567890132456789012345678 90
```

This card image indicates that there is only one timeline variation. JCC = 1 is mandatory for METEOR.

Card Type 3. Ship (Subsystem) Identification Numbers. This card is used to relate TIGER subsystem numbers to METEOR ship numbers. It must be omitted if IOPTM is set to 0 on card type 1.

Column	Format	Variable Name	Description
1-4	20I4	NUMSS(I)	Identify all ships to be simulated starting with the lowest number ship (i.e. 870 for West Coast, 885 for East Coast) and proceeding to the highest. If more than 20 ships are to be simulated, follow with card using the same format.

Sample Input Data:

```
 870 871 885 886
12345678901234567890
```

This card image indicates that there are 4 ships in this run, consistent with NRSHPS and NRWSC on card type 1. Ships 870 and 871 are located on the West Coast, and 885 and 886 are assigned to the East Coast.

REPFAC - This value is multiplied by the ERQ to generated the maximum repair capacity of the repair facility for the specific repairable.

IWPHA - The number of ships deployed will remain constant from phases to phase; however, the specific ships will change. The number of ships deployed is specified by the card type 20 input.

IWLVL - The SUADPS levels recomputation model is used at the end of each phase to increase or decrease levels as appropriate.

Sample Input Data:

```
   1  1.50   1    1    1  13
12345678901234567890123456789O
```

This card image would invoke the see-through model, and set the maximum repair capacity at the repair facilities to 1.5 times the ERQ for each repairable item. Ships will change location at the end of each phase, with the number deployed remaining the same as input on the card type 20 input. Ships consumable repair parts levels would be recomputed at the end of each phase, based on the experienced demand. RIMSTOP policies are in effect, and a detailed listing of supply actions for equipment type 13 is printed.

Card Type 2. METEOR Option Card 2. This card provides additional selection of METEOR options. It must be OMITTED if IOPTM on METEOR option card 1 is set to 0.

Column	Format	Variable Name	Description
1-4	I4	INMOD	Selects the see-through inventory policy model. = 0 to suppress = 1 to invoke
5-10	F6.2	REPFAC	Selects maximum number of carcasses that can be repaired at one time.
11-14	I4	IWPHA	Selects whether or not ships locations are changed at the end of a phase. = 0 to suppress = 1 to invoke
15-18	I4	IWLVL	Selects whether or not shipboard levels are recomputed to the end of a phase. = 0 to supress = 1 to invoke and print changes in level = 2 to invoke but suppress print of levels output
18-22	I4	IWRIM	Selects whether or not the RIMSTOP inventory model policies are in effect. = 0 Non-RIMSTOP model = 1 RIM-STOP model
23-26	I4	IWSEL	Selects equipment type for record of complete supply actions. Only valid if IOPTP1 on card type 1 set to 2.

Notes:

INMOD - The see-through model allows the ICP and appropriate stock point to register demands occurring at shipboard level, but not generating an off-ship demand.

36-39	I4	IOPTP2	METEOR print option switch for detailed equipment history. = 0 to suppress = 1 for detailed history = 2 for summary history

Notes:

IOPTM - If only TIGER is to be exercised, all other entries on this card may be left blank.

IOPTP1 - The record of all supply actions will be voluminous.

IRC - This field is ignored by the simulation. The ship location information is acquired from the card type 20 IRCC field.

SSADT - This input replaces TIGER allowable downtime parameters found on card types 4, 18 and 19.

Sample Input Data:

```
  1   3   2       4 450   2 8760.   2
12345678901234567890123456789012345678 90
```

This card image would cause METEOR to be run, and summary statistics would be provided by equipment type and supply echelon. Printing of each supply action is selected for the equipment type specified by IWSEL on card type 2. There are a total of 4 ships, containing 450 equipment, with 2 of the ships are assigned to the West Coast. Allowable ship downtime is 8760 hours (1 year) before the simulation will abort. A summary equipment history is printed at the end of the output.

Card Type 1. METEOR Option Card 1. The first METEOR option card will indicate whether the multi-echelon supply simulation is to be invoked on this run, or that TIGER is to be run in the stand alone mode. Depending on the option selected, some of the input cards that follow may not be required. Additionally, various input parameters and option settings will vary between the two simulations. These changes will be reflected in the notes that follow the card formats.

Column	Format	Variable Name	Description
1-4	I4	IOPTM	METEOR option switch = 0 to run TIGER only = 1 to run METEOR
5-8	I4	IOPTP	METEOR print option switch for supply performance summary statistics. = 1 by equipment type = 2 by supply echelon = 3 by equipment type and supply echelon
9-12	I4	IOPTP1	METEOR print option switch for detailed supply action report. = 0 to suppress = 1 for complete report = 2 for selected equipment (see IWSEL on card type 2)
13-16	I4	IRC	Requistioning Channels. = 1 CONUS operations = 2 deployed without MLSF = 3 deployed with MLSF
17-20	I4	NRSHPS	Total number of ships to be simulated.
21-24	I4	ITOTEQ	Total number of installed equipment to be simulated.
25-28	I4	NRWCS	Total number of ships assigned to the West Coast.
29-35	F7.0	SSADT	Ship's allowable downtime in hours.

APPENDIX A

METEOR INPUT REQUIREMENTS AND FORMATS

Most input requirements applicable to the TIGER portion of the METEOR simulation remain unchanged from the formats provided in the TIGER Manual. However, there are some variations in user options and file organization. To facilitate the use of METEOR, formats for the entire input file are provided below. Annotations are provided, where necessary, to reflect file structure when exercising TIGER on a stand alone basis. A complete sample data set is provided in Appendix B.

All data is entered in 80 column, card-image format. Data types are integer, real and alphanumeric. All integer data fields must be right justified.

Card Type 10. Repair Policy Card. This card is used to determine the repair policy in effect during the simulation, by specifying the percentage of repairs to be performed at the organizational level. Additionally, the user may specify a period of time that the system may be down during the mission before the mission is aborted. The MTBF and MTTR multipliers may changed from one simulation run to the next to conduct sensitivity analysis.

Column	Format	Variable Name	Description
1-4	F4.0	REPOL	Decimal fraction of repairs to be performed aboard ship.
5-12	F8.2	TAD2	Mission allowable downtime.
13-16	F4.0	XM	MTBF multiplier.
17-20	F4.0	XT	MTTR multiplier.

Notes:

REPOL - In METEOR, the repair process is handled explicitly by designating equipment as consumable or repairable. If using METEOR, set REPOL = 1.0.

TAD2 - If using METEOR, set TAD2 = 100000.

Sample Input Data:

```
 1.1000000.  1.  1.
12345678901234567890
```

This card image will result in all repairs being performed aboard ship, and will insure that the mission will not abort due to excessive downtime. The MTBF and MTTR are not modified from the Card Type 11 input values.

Card Type 11. Equipment Type Cards. All equipments in the simulation are given an equipment type number. If two or more equipments are essentially the same, (i.e. would have the same values for the parameters shown on this card, and would be treated as the same item by the supply system) they would be designated with the same equipment type. METEOR deals exclusively with equipment types in the provisioning and replenishment of inventories at the various echelons. One card is required for each equipment type.

Column	Format	Variable Name	Description
1-4	I4	I	Equipment type number. Should be sequentially starting with 1, not to exceed 200.
5-20	4A4	F1	Equipment type nomenclature.
21-28	F8.0	XMTBF	Mean time between failure.
29-32	F4.0	XMTTR	Mean time to repair. If variable MTTR option is desired, proceed this value with a negative sign, and include the variable MTTR card, card type 13. Nonrepairable equipment is indicated by the value 9999.
33-36	F4.0	U	Duty cycle/utilization (nonzero decimal fraction).
37-40	F4.0	V	Administrative delay from tender to ship.
41-44	F4.0	W	Administrative delay time from depot to ship.
45-48	I4	IUI	If variable duty cycle option is desired, assign a sequential number (from 1 to 200) and include the VDC, card type 12, after this card. Otherwise, leave this field blank.

Notes:

XMTTR	- If an equipment type is given and XMTTR of 9999, it will not be ordered from the supply system in METEOR. This option is not recommended when running METEOR.
U	- Duty cycle values other that one cause the MTBF to increase by MTBF/U.
V,W	- Administrative delay time is not utilized in METEOR, and these fields should be left blank.

Sample Input Data:

```
   1NSN 1              3930.  4.  1.
12345678901234567890123456789012345678901234567890
```

This card image indicates that equipment type 1 is NSN 1 and has a MTBF of 3930. hours. The MTTR is 4. hours and the equipment is utilized 100% of the time. There are no delays or variable MTTR values.

Card Type 12. Variable Duty Cycle Card. A variable duty cycle may be utilized to vary the percentage of time that the equipment is operational during a phase type. If IUI on card type 11 is nonzero, place this card immediately behind the equipment type card to which it refers. A maximum of fifty VDC are allowed.

Column	Format	Variable Name	Description
1-4	I4	IV	VDC identifier-sequential number, same as appearing in the IUI field on the preceding equipment type card.
5-8	F4.0	VDC(1)	Duty cycle/utilization fraction of the equipment type during each phase type 1 to 6. These values override the value of U on the preceding card.
9-12	F4.0	VDC(2)	
13-16	F4.0	VDC(3)	
17-20	F4.0	VDC(4)	
21-24	F4.0	VDC(5)	
25-28	F4.0	VDC(6)	

Sample Input Data:

```
  1 .80 .95 .05 .80 1.0 0.0
12345678901234567890123456789O
```

This card image indicates that the equipment operates at 80% duty cycle during phase type 1, 95% during phase type 2, etc.

Card Type 13. Variable Mean Time to Repair Card. This card may be used to vary an equipment's mean time to repair between phase types. It is an optional card, and may only be used when XMTTR is negative on the equipment type card. This card is placed behind the equipment type card and any Variable Duty Cycle cards as appropriate.

Column	Format	Variable Name	Description
1-4	F4.0	VMTTR(1)	MTTR values of this equipment type during each phase type 1 to 6. Nonrepairable equipment are indicated by 9999, but should not so designated if METEOR is to be run.
9-12	F4.0	VMTTR(3)	
13-16	F4.0	VMTTR(4)	
17-20	F4.0	VMTTR(5)	
21-24	F4.0	VMTTR(6)	

Sample Input Data:

```
 3.5  4. 18. 0.5 1.0  .5
12345678901234567890123456789O
```

This card image indicates that this equipment will require 3.5 hours to repair during phase type 1, 4 hours in phase type 2, etc.

Card Type 14. ***** Blank Card *****.

Card Type 15. Equipment Cards. Equipment cards identify similar equipments to their equipment type. There may be no more than 500 equipments in total. Number each equipment in sequential order starting with number 1, beginning with the first equipment type. Continue in unbroken sequence through all equipment types.

Column	Format	Variable Name	Description
1-4	I4	NTYPE	The equipment type number associated with the equipment listed in the following fields.
5-8	I4	LOAD(1)	Equipment numbers of those equipments which belong to the equipment type specified in NTYPE. Up 19 equipments may be designated per card. If more than 19 are associated with a given equipment type, use additional equipment cards with the same type number in NTYPE.
9-12	I4	LOAD(2)	
13-16	I4	LOAD(3)	
17-20	I4	LOAD(4)	
21-24	I4	LOAD(5)	
On to			
73-76	I4	LOAD(19)	

Sample Input Data:

```
  1   1   2   3   4   5
12345678901234567890123456789O
```

This equipment card image indicates that equipment numbers 1 through 5 are of equipment type 1. These equipment numbers are used in the reliability block diagram to relate specific units with equipment parameters.

Card Type 16. ***** Blank Card *****.

Card Type 17. Spare Option Card. There are four options available to input spares into the simulation:

1. If METEOR is being exercised, spares will be input in the MULTE input section, and this card must be left blank. If TIGER is being used in its stand-alone mode, the following three options apply.

2. Use the literal "UNLIMITED SPARES" in columns 1-16 to simulate unlimited spares (90,000 spares are internally assigned to each equipment type).

3. If spares are to be input by the user, leave this card blank and enter spares data on the Type 18 cards that follow. If a spare part sensitivity analysis is desired, enter a spare parts multiplier (SX) in columns 21-23 of this card. The multiplier will increase or decrease (depending on the value assigned) the spare parts levels that are specified on the Type 18 cards. The last card must be blank.

4. Enter "999" in card column 21-24 to invoke the SPARES subprogram. This will determine levels based on the calculations of the

Sample Input Data:

```
UNLIMITED SPARES
12345678901234567890
```

This card image would cause TIGER to use unlimited spares. For METEOR, leave this card blank and omit any Type 18 cards.

Card Type 18. Spares Card. If METEOR is being exercised, this card must be omitted. For TIGER, these cards are only used if the allowances for spares are to be input directly (i.e. the previous card did not specify UNLIMITED SPARES or invoke the SPARES subprogram). One card must be input for each equipment type.

Column	Format	Variable Name	Description
1-4	I4	ISPARE(1)	Number of organizational level spares for this equipment type.
5-8	I4	ISPARE(2)	Number of spares held onboard the tender for this equipment type.
9-12	I4	ISPARE(3)	Number of spares held at the Depot for this equipment type.

Sample Input Data:

```
000100010004
12345678901234567890
```

This card image would indicate to TIGER that one spare of this equipment type is carried at the organizational level, 1 onboard the tender, and 4 at the depot level. This card must be omitted when running METEOR.

Card Type 19. System Card. Card types 19-24 govern the hardware system configuration. Since the configuration may change from one phase type to another, one complete set of these cards for each phase type must be placed sequentially in the data deck. Starting with the individual components, groups are formed from subsets of components which are connected in either series or parallel. Groups are nested and combined with other equipments to form new groups. This process continues for each ship being simulated, until the hardware system on each ship can be represented by a single group. This group is called a 'subsystem' by TIGER, and individual 'subsystems' (ships) are then combined in series to form the overall 'system'.

Column	Format	Variable Name	Description
1-4	A4	ID	Any alphanumeric (i.e. the literal "FLT") used to identify the overall system.
5-8	I4	LL	Phase type number (sequential) from 1-6.
9-12	I4	NSS	Number of subsystems (ships) in this phase.
13-16	I4	ISS	System identification number (usually the last group number on card type 21).
17-24	F8.0	SSTIME	System allowable sustained downtime (should not be less than the subsystem allowable downtime value from card type 20). Should be less than or equal to TAD2 on card type 10. To inhibit aborts, use 100000.

Notes:

NSS - In METEOR, the number of subsystems (ships) must remain constant for all phase types.

SSTIME - Because ships are configured in series in METEOR, system allowable downtime has little meaning. The system would be considered down anytime one or more of the individual ship's system was down. Therefore, SSTIME should be set to 100000.

Sample Input Data:

```
FLT     1     4 9991000000.
12345678901234567890123456789O
```

This card image indicates that the system, called "FLT" is used in phase 1 and consists of 4 ships (subsystems). 999 is the highest equipment number used and the 1000000 prevents mission aborts.

Card Type 20. Subsystem Card. There must be one subsystem card for each ship being simulated. At least one subsystem card is required.

Column	Format	Variable Name	Description
1-4	A4	ID	Any alphanumeric (e.g. "SHP1").
5-8	I4	LL	Phase type number.
13-16	I4	ISS	Subsystem identification number. This will be the group number from the card type 21's that follow.
17-24	F8.0	SSTIME(2)	Subsystem allowable sustained downtime. This value should be less than or equal to SSTIME on card type 19. To inhibit aborts, use 100000.
25-28	I4	IRCC	Initial requisitioning channel. Assigns the ship's initial location.

Notes:

ISS - In METEOR, the ISS must be assigned sequentially, running from 870 to 884 for West coast ships, and from 885 to 899 for East coast ships.

SSTIME - This downtime parameter will impact reliability and availability measures when METEOR is used. Set this value to 100000, and use SSADT on card type 1 if downtime measures are to be used.

Sample Input Data:

```
SHP1   1      8701000000.   1
12345678901234567890123456789O
```

This card image assigns 870 to ship 1 during phase type 1. The 1000000 prevents mission aborts. The ship is based in CONUS and submits off ship requisitions to the West Coast Supply Center.

Card Type 21. Configuration Matrix Cards. These cards define the reliability block diagram of the system under evaluation.

Column	Format	Variable Name	Description
1-4	I4	NRO	The number of members in this group that are required to be operating for the system to be operational.
5-8	I4	IB(1)	The number assigned to the group of members defined on this card. It may vary from 501 to 1000, in any order.
9-12	I4	IB(2)	The numbers of the equipments and groups which make up the group defined by this card. The maximum number of members in a group is unlimited; however, if there are more than 7, a continuation card is required. The continuation card has the same format, and has the identical master group number.
13-16	I4	IB(3)	
17-20	I4	IB(4)	
21-24	I4	IB(5)	
25-28	I4	IB(6)	
29-32	I4	IB(7)	
33-36	I4	IB(8)	

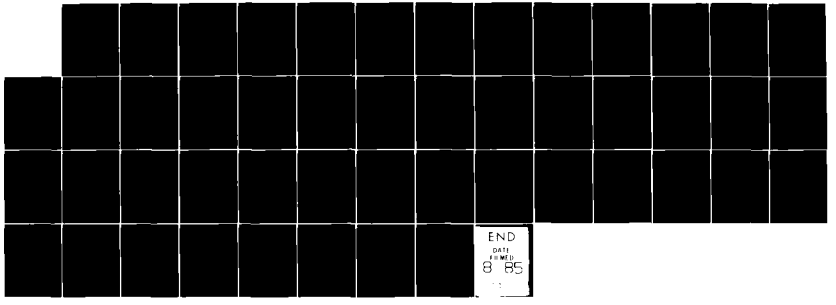
Sample Input Data:

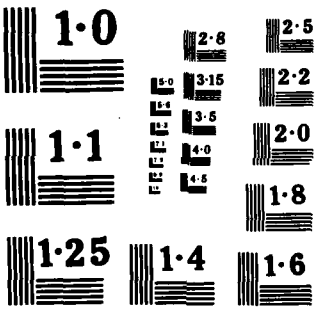
```
   2 501   1   2
12345678901234567890

   1 502   3   4
12345678901234567890
```

The 2 on the first card image indicates that group 501 requires both equipments be operating for this group to function (series). The 1 on the second card image indicates that at lease on of 3 or 4 must be operating for 502 to be functional (parallel).

AD-A156 849 APPLICATION OF METEOR TO THE EVALUATION OF MULTI-ECHELON INVENTORY MODELS(U) NAVAL POSTGRADUATE SCHOOL MONTEREY CA D B WADSWORTH MAR 85 2/2

UNCLASSIFIED F/G 9/2 NL




1·0
1·1
1·25
2·8
3·15
3·5
4·0
4·5
1·4
2·5
2·2
2·0
1·8
1·6

Card Type 22 Equipment Operating Rule Card. These cards indicate the equipment operating rules for string and standby equipment. The string equipment operating rules cause shutdown of a designated series equipment upon failure of any of the other equipment or equipment groups on the card. The standby operating rule causes designated equipment to be energized upon failure of any of the other equipment or equipment groups on the card. This is an optional card which is placed immediately behind the appropriate Card Type 21 which refers to the equipment and groups on this card. The maximum number of Card Type 22 is 49.

Column	Format	Variable Name	Description
1-4	I4	ISTB(1)	The designated equipment number. Standby equipment is designated by a leading minus sign.
5-8	I4	ISTB(2)	The other equipments or groups.
9-12	I4	ISTB(3)	
13-16	I4	ISTB(4)	
17-20	I4	ISTB(5)	
21-24	I4	ISTB(6)	
25-28	I4	ISTB(7)	
29-32	I4	ISTB(8)	
33-36	I4	ISTB(9)	
37-40	I4	ISTB(10)	
41-44	I4	IRULE	This field must have any non-zero integer to distinguish this card from Card Type 21.

Sample Input Data:

```
  -8   7 501                                                1
12345678901234567890123456789012345678901234567890
```

This card image indicates that equipment 8 is a standby for equipments 7 and 501. Equipment 8 is not operational and not subject to failure until either 7 or 501 fails.

Card Type 23. ***** Blank Card *****.

Card Type 24. Equipment/Subsystem Cross Reference Card. This card is required in METEOR to identify on which ship the equipment failure occurred. If IOPTM=0 on card type 1, omit this card, otherwise one set will be required for each phase type.

Column	Format	Variable Name	Description
1-4	I4	NSSEQ(1)	Order ship numbers from card type 20 from lowest to highest and assign each ship a sequential starting with 1. Assign that number to NSSEQ(i) if equipment number 'i' is installed on that ship. If more than 18 equipments are modeled, use as many card type 24's as necessary.
5-8	I4	NSSEQ(2)	
9-12	I4	NSSEQ(3)	
13-16	I4	NSSEQ(4)	
17-20	I4	NSSEQ(5)	
on to			
69-72	I4	NSSEQ(18)	

Sample Input Data:

```
   1   1   1   1   2
12345678901234567890
```

This card image indicates that equipments 1, 2, 3, and 4 are on ship 1 (870), and that equipment 5 is installed on ship 2 (the next sequential ship number).

Card Type 25. METEOR Parameter Card. This card, and those that follow, are only required if the METEOR simulation is in effect.

Column	Format	Variable Name	Description
1-5	I5	M1	Input option. = 1 If this option is selected then selected supply input data for 1 ship is required. All other ships will be configured with the same stocking objectives and reorder points. = 2 If this option is selected then supply input data must be entered separately for each ship.
6-15	F10.0	CRAR	Carcass return attrition rate. Enter decimal fraction of repairable carcasses that are lost due to attrition.
16-25	F10.0	MSDT	MLSF screening delay time in hours. Enter time required to process NIS requisitions through the MLSF screening and refer the requisition to the next echelon.
26-35	F10.0	SSRT	Shipboard issue time in hours.
36-45	F10.0	ALFA1	Gamma distribution shape parameter for repairable item turnaround time.
46-55	F10.0	ALFA2	Gamma distribution shape parameter for procurement lead time.

Sample Input Data:

```
    1      0.075       3.5         1.5         1.0         1.0
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

This card image causes all ships to be stocked identically. The carcass attrition rate is 7.5%. The MLSF screening delay is 3.5 hours

and an issue from onboard stock takes a ship 1.5 hours. The gamma distribution shape for turnaround time and procurement lead time is 1, indicating that an exponential distribution is being used.

Card type 26. Supply Information Card. The following 4 card types input supply related information for each equipment type. On set of cards is required for each equipment type when M1 = 1. When M1 = 2, the set will consist of only card types 26 and 27.

Column	Format	Variable Name	Description
1-10	I10	RPAIR	Repair Code. = 0 for Consumable items. = 1 for Repairable items, which cannot be repaired at the organizational level. Upon failure, this item will be shipped to the nearest repair facility.
11-20	F10.0	MPLT	Mean procurement lead time in hours for this item.
21-30	F10.0	ECOST	Unit cost for this item.

Sample Input Data:

```
         0      10052.       405.
12345678901234567890123456789 0
```

This card image indicates that the item is consumable and has a mean procurement lead time of 10052 hours. The unit cost is $405.00.

Card Type 27. Repairable Item Information Card. This card is placed immediately behind the applicable card type 26 whenever RPAIR = 1.

Column	Format	Variable Name	Description
1-10	F10.0	MRT	Mean repair turnaround time for this item.
11-20	I10	ERQ	Economic repair quantity for the repair facility. Items will be inducted for repair whenever the on-hand balance of carcasses equals or exceeds this value.

Sample Input Data:

```
    2190.         13
12345678901234567890
```

If RPAIR on the preceding Type 26 card is 1, then this card type must follow. This card image assigns a mean repair turn-around time of 2190 hours and an economic repair quantity of 13 to this item.

Card Type 28. High Limit Card. (Option 1). If M1 = 1, card types 28 and 29 are used to set activity high limits and reorder points. In this case all ships would be given identical high limits and reorder points. One card set is input for each type of equipment. If M1 = 2, these cards are omitted, and card types 30 and 31 would be used to input high limits and reorder points for each activity.

Column	Format	Variable Name	Description
1-5	I5	HILIM(1)	Shipboard high limit.
6-10	I5	HILIM(2)	W. Coast MLSF high limit.
11-15	I5	HILIM(3)	E. Coast MLSF high limit.
16-20	I5	HILIM(4)	WESTPAC Overseas depot high limit.
21-25	I5	HILIM(5)	E. Coast CONUS Supply Center high limit.
26-30	I5	HILIM(6)	W. Coast CONUS Supply Center high limit.
31-35	I5	HILIM(7)	E. Coast repair facility high limit. {used only to initially compute number of carcasses available}.
36-40	I5	HILIM(8)	W. Coast repair facility high limit.
41-45	I5	HILIM(9)	ICP high limit. {Usually the sum of the supply depot and centers high limits.}

Sample Input Data:

See card types 30 and 31.

Card Type 29. Reorder Point Card. (Option 1). This card uses exactly the same format as card type 28, except that the variable is now the activity's reorder point. This card is placed immediately behind card type 28.

Card type 30. High Limit Card. (Option 2). When M1 = 2, high limits and reorder points must be input for each activity being simulated.

Use a set of high limit cards (type 30) and reorder point cards (type 31) for each activity starting with the lowest numbered ship and proceeding to the highest. Enter the remainder of the activities in the following sequence: W. Coast MLSF, E. Coast MLSF, WESTPAC Overseas Depot, E. Coast Supply Center, W. Coast Supply Center, E. Repair Facility, W. Repair Facility, and ICP.

Column	Format	Variable Name	Description
1-5	I5	HILIM(1)	High limit for equipment type 1.
6-10	I5	HILIM(2)	High limit for equipment type 2.
11-15	I5	HILIM(3)	High limit for equipment type 3.
Continue on to			
76-80	I5	HILIM(16)	High limit for equipment type 16.

Note:
Enter high limits for each equipment type in the simulation. If the number of equipments exceeds 16, use as many card type 30's as necessary.

Card Type 31. Reorder Point Card. (Option 2). Reorder point cards follow immediately behind card type 30 for that activity. These cards have the same format as card type 30, except that the variable is the reorder point for each equipment.

Sample Input Data:

This data is for card types 28 and 29.

```
    8     2     2     6    28    28    13    13    62
12345678901234567890123456790123245678901234567890

    7     1     1     4    27    27     0     0    58
12345678901234567890123456790123456789012345678 90
```

These card images represent shipboard allowance data for all ships when M1 = 1. These cards indicate that all ships will have a high limit of 8 and a reorder point of 7. The other activities are indicated similarly.

```
25  26  27  28  29  30   1   2   3   4   5   6   7   8   9  10  11  12
13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30
 1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5   6
 7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24
25  26  27  28  29  30   1   2   3   4   5   6   7   8   9  10  11  12
13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30
 1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18
19  20  21  22  23  24  25  26  27  28  29  30   1   2   3   4   5   6
 7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24
25  26  27  28  29  30   1   2   3   4   5   6   7   8   9  10  11  12
13  14  15  16  17  18  19  20  21  22  23  24  25  26  27  28  29  30
 1      .075       3.5       1.5       1.0       1.0
       0  12198.3    21.26
 3     0    0  35  156  157    0    0  348
 2     0    0  26  114  115    0    0  255
       0   5694.0     3.38
 1     0    0   8   34   34    0    0   76
 0     0    0   3   12   12    0    0   27
       0  14388.3    60.00
 0     0    0   1    2    3    0    0    6
 0     0    0   0    1    2    0    0    3
       0  15702.3  2446.07
 0     0    0   0    2    2    0    0    4
 0     0    0   0    1    1    0    0    2
       0   8762.4 28501.37
 0     0    0   0    1    2    0    0    3
 0     0    0   0    1    1    0    0    2
       0  17191.5    48.69
 0     0    0   0    0    0    0    0    0
 0     0    0   0    0    0    0    0    0
       0   7183.2    40.40
 0     0    0   0    2    2    0    0    4
 0     0    0   0    0    1    0    0    1
       0  10950.0   292.66
 0     0    0   0    0    1    0    0    1
 0     0    0   0    0    0    0    0    0
       0   8322.0   888.00
 0     0    0   0    0    0    0    0    0
 0     0    0   0    0    0    0    0    0
       0   5891.1  4565.00
 0     0    0   0    0    1    0    0    1
 0     0    0   0    0    0    0    0    0
       1   5256.0  1980.00
 4771.3         3
 0     0    0   0    2    3    0    0    5
 0     0    0   0    2    2    0    0    4
       1  25557.3  5502.00
 4095.3         1
 0     0    0   0    0    1    0    0    1
 0     0    0   0    0    0    0    0    0
```

```
15 890  21  51  81 111 141 171 201
15 890 231 261 291 321 351 381 411
15 890 441
15 891  22  52  82 112 142 172 202
15 891 232 262 292 322 352 382 412
15 891 442
15 892  23  53  83 113 143 173 203
15 892 233 263 293 323 353 383 413
15 892 443
15 893  24  54  84 114 144 174 204
15 893 234 264 294 324 354 384 414
15 893 444
15 894  25  55  85 115 145 175 205
15 894 235 265 295 325 355 385 415
15 894 445
15 895  26  56  86 116 146 176 206
15 895 236 266 296 326 356 386 416
15 895 446
15 896  27  57  87 117 147 177 207
15 896 237 267 297 327 357 387 417
15 896 447
15 897  28  58  88 118 148 178 208
15 897 238 268 298 328 358 388 418
15 897 448
15 898  29  59  89 119 149 179 209
15 898 239 269 299 329 359 389 419
15 898 449
15 899  30  60  90 120 150 180 210
15 899 240 270 300 330 360 390 420
15 899 450
 1 997 870 871 872 873 874 875 876
 1 997 877 878 879 880 881 882 883
 1 997 884
 1 998 885 886 887 888 889 890 891
 1 998 892 893 894 894 896 897 898
 1 998 899
 1 999 997 998

 1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5  6
 7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
25 26 27 28 29 30  1  2  3  4  5  6  7  8  9 10 11 12
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
 1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5  6
 7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
25 26 27 28 29 30  1  2  3  4  5  6  7  8  9 10 11 12
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
 1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
19 20 21 22 23 24 25 26 27 28 29 30  1  2  3  4  5  6
 7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
```

```
15 873   4  34  64  94 124 154 184
15 873 214 244 274 304 334 364 394
15 873 424
15 874   5  35  65  95 125 155 185
15 874 215 245 275 305 335 365 395
15 874 425
15 875   6  36  66  96 126 156 186
15 875 216 246 276 306 336 366 396
15 875 426
15 876   7  37  67  97 127 157 187
15 876 217 247 277 307 337 367 397
15 876 427
15 877   8  38  68  98 128 158 188
15 877 218 248 278 308 338 368 398
15 877 428
15 878   9  39  69  99 129 159 189
15 878 219 249 279 309 339 369 399
15 878 429
15 879  10  40  70 100 130 160 190
15 879 220 250 280 310 340 370 400
15 879 430
15 880  11  41  71 101 131 161 191
15 880 221 251 281 311 341 371 401
15 880 431
15 881  12  42  72 102 132 162 192
15 881 222 252 282 312 342 372 402
15 881 432
15 882  13  43  73 103 133 163 193
15 882 223 253 283 313 343 373 403
15 882 433
15 883  14  44  74 104 134 164 194
15 883 224 254 284 314 344 374 404
15 883 434
15 884  15  45  75 105 135 165 195
15 884 225 255 285 315 345 375 405
15 884 435
15 885  16  46  76 106 136 166 196
15 885 226 256 286 316 346 376 406
15 885 436
15 886  17  47  77 107 137 167 197
15 886 227 257 287 317 347 377 407
15 886 437
15 887  18  48  78 108 138 168 198
15 887 228 258 288 318 348 378 408
15 887 438
15 888  19  49  79 109 139 169 199
15 888 229 259 289 319 349 379 409
15 888 439
15 889  20  50  80 110 140 170 200
15 889 230 260 290 320 350 380 410
15 889 440
```

```
  11 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319
  11 320 321 322 323 324 325 326 327 328 329 330
  12 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349
  12 350 351 352 353 354 355 356 357 358 359 360
  13 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379
  13 380 381 382 383 384 385 386 387 388 389 390
  14 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409
  14 410 411 412 413 414 415 416 417 418 419 420
  15 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439
  15 440 441 442 443 444 445 446 447 448 449 450

FLT    1  30 9991000000.
SHP1   1     8701000000.   1
SHP2   1     8711000000.   1
SHP3   1     8721000000.   1
SHP4   1     8731000000.   1
SHP5   1     8741000000.   1
SHP6   1     8751000000.   1
SHP7   1     8761000000.   1
SHP8   1     8771000000.   1
SHP9   1     8781000000.   1
SHPA   1     8791000000.   1
SHPB   1     8801000000.   2
SHPC   1     8811000000.   2
SHPD   1     8821000000.   3
SHPE   1     8831000000.   3
SHPF   1     8841000000.   3
SHPG   1     8851000000.   1
SHPH   1     8861000000.   1
SHPI   1     8871000000.   1
SHPJ   1     8881000000.   1
SHPK   1     8891000000.   1
SHPL   1     8901000000.   1
SHPM   1     8911000000.   1
SHPN   1     8921000000.   1
SHPO   1     8931000000.   1
SHPP   1     8941000000.   1
SHPQ   1     8951000000.   2
SHPR   1     8961000000.   2
SHPS   1     8971000000.   3
SHPT   1     8781000000.   3
SHPU   1     8991000000.   3
  15 870   1  31  61  91 121 151 181
  15 870 211 241 271 301 331 361 391
  15 870 421
  15 871   2  32  62  92 122 152 182
  15 871 212 242 272 302 332 362 392
  15 871 422
  15 872   3  33  63  93 123 153 183
  15 872 213 243 273 303 333 363 393
  15 872 423
```

TABLE IX

METEOR DATA SET

```
  1   3   0   3  30 450  15  8760.   2
  0   1.5   1   1   0   0
870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889
890 891 892 893 894 895 896 897 898 899
  130 SHIP MODEL W-11.17.01 1219001-1
 01  01  1.1.285687   1
1.   2190.1.   2190.1.   2190.1.   2190.1.   2190.

  5   1
  0
 1.1000000.  1.  1.
  1NSN  1          12198.312.2  1.
  2NSN  2          16102.916.1  1.
  3NSN  3          87600.048.0  1.
  4NSN  4          87600.048.0  1.
  5NSN  5          87600.048.0  1.
  6NSN  6          87600.048.0  1.
  7NSN  7          87600.048.0  1.
  8NSN  8          87600.048.0  1.
  9NSN  9          87600.048.0  1.
 10NSN 10          87600.048.0  1.
 11NSN 11          87600.048.0  1.
 12NSN 12          87600.048.0  1.
 13NSN 13          87600.048.0  1.
 14NSN 14          87600.048.0  1.
 15NSN 15          87600.048.0  1.

  1   1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19
  1  20  21  22  23  24  25  26  27  28  29  30
  2  31  32  33  34  35  36  37  38  39  40  41  42  43  44  45  46  47  48  49
  2  50  51  52  53  54  55  56  57  58  59  60
  3  61  62  63  64  65  66  67  68  69  70  71  72  73  74  75  76  77  78  79
  3  80  81  82  83  84  85  86  87  88  89  90
  4  91  92  93  94  95  96  97  98  99 100 101 102 103 104 105 106 107 108 109
  4 110 111 112 113 114 115 116 117 118 119 120
  5 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139
  5 140 141 142 143 144 145 146 147 148 149 150
  6 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169
  6 170 171 172 173 174 175 176 177 178 179 180
  7 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199
  7 200 201 202 203 204 205 206 207 208 209 210
  8 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229
  8 230 231 232 233 234 235 236 237 238 239 240
  9 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259
  9 260 261 262 263 264 265 266 267 268 269 270
 10 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289
 10 290 291 292 293 294 295 296 297 298 299 300
```

TABLE VIII

ORDER AND SHIPPING TIMES

The values for OST used in this data set were collected from the RRTMIS reports for the period 9/83 through 12/83. The values below were computed by weighting the median value for each IPG with the number of reported requisitions. The retrograde pipeline values are estimates since no data has been collected on this time.

Order and Shipping Times
(Days)

From	1 CONUS W	2 West w/MLSF	3 West wo/MLSF	4 CONUS E	5 East w/MLSF	6 East wo/MLSF	7 West MLSF	8 East MLSF	9 Depot	10 NSCE	11 NSCW
NSCW	46.3	60.2	60.2	57.3	80.5	80.5	60.2	80.5	40.9	26.0	----
NSCE	53.0	60.6	60.6	34.7	50.2	50.2	60.6	63.7	34.1	----	23.0
Depot	39.1	43.4	43.4	55.0	----	----	29.6	----	----	32.7	54.5

Shipping Time
(Days)

MFR RFACW RFACE	21.6	33.8	33.8	25.6	30.4	30.4	33.8	30.4	33.8	21.6	27.6
To RFAC	30	45	70	30	45	70					

MFR = Manufacturer
RFACW = West Coast Repair Facility
RFACE = East Coast Repair Facility

DEN	Description	Item 11	Item 12	Item 13	Item 14	Item 15
C003	Stores Acct.	2C	1F	1C	2F	3C
	Mark Code	3	0	0	0	0
D046	NIIN	010914361	010924300	010931436	010934861	010941256
B011A	Leadtime	2.40	11.67	4.23	4.56	2.40
B012F	Repair TAT	2.27	1.87	2.07	1.97	1.97
	Policy Recvr	0	0	0	0	0
B055	Repl. Cost	1980.00	5502.00	340.00	1450.57	1000.00
B074	Qtr Demand	0.50	0.00	0.00	0.00	0.24
B074A	Regen Rate	2.97	0.00	0.00	0.00	0.20
B019A	Variance	0.00	0.00	0.00	0.00	2.07
A023B	Reqn Freq.	0.50	0.00	0.00	0.00	0.24
	PPR	0	0	0	1	0
B058	Setup Cost	0.00	0.00	0.00	0.00	0.00
B019C	Repair PPV	2.93	0.00	0.00	0.00	0.98
B055A	Repair Cost	507.00	2475.70	153.00	715.02	500.00
B058A	Rep Setup Cost	0.00	0.00	0.00	0.00	0.00
B020	Reorder Limit	1	0	2	0	0
	MAD	0.68	0.00	0.00	0.00	0.42
	BRF(Note 1)	0.67	0.00	0.00	0.00	0.27
	MTBF(Note 2)	87600.00	87600.00	87600.00	87600.00	87600.00
	MTTR(Note 3)	48.00	48.00	48.00	48.00	48.00

DEN	Description	Item 6	Item 7	Item 8	Item 9	Item 10
C003	Stores Acct.	S4	2C	1C	3F	3C
	Mark Code	0	0	0	0	0
D046	NIIN	010926828	010931311	010931746	010934884	010939984
B011A	Leadtime	7.85	3.28	5.00	3.80	2.69
B012F	Repair TAT	0.00	0.00	0.00	0.00	0.00
	Policy Recvr	1	0	0	0	0
B055	Repl. Cost	48.69	40.40	292.66	888.00	4565.00
B074	Qtr. Demand	0.00	0.20	0.03	0.00	0.14
B074A	Regen Rate	0.00	0.00	0.00	0.00	0.00
B019A	Variance	0.00	0.68	0.19	0.02	0.40
A023B	Reqn Freq.	0.00	0.04	0.02	0.01	0.15
	PPR	1	1	0	1	0
B058	Setup Cost	0.00	0.00	0.00	0.00	0.00
B019C	Repair PPV	0.00	0.00	0.00	0.00	0.00
B055A	Repair Cost	0.00	0.00	0.00	0.00	0.00
B058A	Rep Setup Cost	0.00	0.00	0.00	0.00	0.00
B020	Reorder Limit	0	0	0	0	0
	MAD	0.00	0.00	0.00	0.00	0.00
	BRF(Note 1)	0.00	0.00	0.00	0.00	0.00
	MTBF(Note 2)	87600.00	87600.00	87600.00	87600.00	87600.00
	MTTR(Note 3)	48.00	48.00	48.00	48.00	48.00

TABLE VII

DATA ELEMENTS EXTRACTED FROM CARES DATA BASE

DEN	Description	Item 1	Item 2	Item 3	Item 4	Item 5
C003	Stores Acct.	N3	N3	N4	3F	1C
	Mark Code	4	2	0	0	0
D046	NIIN	010908884	010910143	010910464	010915463	010924097
B011A	Leadtime	5.57	2.60	6.57	7.17	3.96
B012F	Repair TAT	0.00	0.00	0.00	0.00	0.00
	Policy Recvr	3	2	2	0	1
B055	Repl. Cost	21.26	3.38	60.00	2446.07	28501.37
B074	Qtr. Demand	30.48	4.08	0.20	0.23	0.24
B074A	Regen Rate	0.00	0.00	0.00	0.00	0.00
B019A	Variance	1934.53	186.66	6.03	7.88	0.97
A023B	Reqn Freq.	2.11	1.52	0.01	0.23	0.01
	PPR	84	27	1	15	2
B058	Setup Cost	676.00	676.00	676.00	0.00	0.00
B019C	Repair PPV	0.00	0.00	0.00	0.00	0.00
B055A	Repair Cost	0.00	0.00	0.00	0.00	0.00
B058A	Rep Setup Cost	0.00	0.00	0.00	0.00	0.00
B020	Reorder Limit	0	0	0	0	0
	MAD	236.57	45.24	0.09	0.00	0.00
	BRF(Note 1)	4.064	0.544	0.027	0.031	0.032
	MTBF(Note 2)	2155.51	16102.9	87600.0	87600.0	87600.0
	MTTR(Note 3)	2.2	16.1	48.0	48.0	48.0

Note 1: BRF is computed from the total annual system demand divided by the population. BRF = (4.0*B074)/30.0

Note 2: MTBF is computed from the inverse of the BRF converted to hours. MTBF = 8760.0*(1/BRF)

Note 3: MTTR is computed as 0.001 times the MTBF, except when the MTBF equals 87,600 (ten years).

APPENDIX B

SAMPLE DATA SET

The following tables contain source data used to create the data set used for data analysis in Chapter VII. Tables VII and VIII present the data elements extracted from the CARES and RRTMIS data bases which were used to create the data set shown in Table IX. This data set was used for all runs in Chapter VII.

Card Type 42. Optional Output Card. These are special TIGER options that have not been discussed in this report. They are included here for information only; additional information may be found in the TIGER manual. This card must be blank for METEOR.

Column	Format	Variable Name	Description
1-4	A4	SPRS	Place any alphanumeric in this field if a table of spares usage is desired. NOTE: this table will not be printed if METEOR is being run.
5-8	A4	APRL	Place any alphanumeric in this field if a summary table of equipment that caused mission failure and system downtime is desired.
9-12	A4	GMMA	Place ant alphanumeric in this field if the gamma distribution output is desired.

Card Types 34 to 41. Order and Shipping Times. A total of eight order and shipping time cards will be input, each having the same format and representing the shipment time from one activity to all the other activities in the supply network. The format is identical to that used on card type 33. All times are in hours. Note that is clearly inappropriate for some activities to ship to others (e.g. MLSF to supply center); in these cases, no entry is required. The order and shipping time cards must be input in the following order:

Card 34. W. Coast MLSF

Card 35. W. Coast Overseas Depot

Card 36. W. Coast Supply Center

Card 37. W. Coast Repair Facility

Card 38. E. Coast MLSF

Card 39. ***** Blank Card *****

Card 40. E. Coast Supply Center

Card 41. E. Coast Repair Facility

Card Type 33. Order and Shipping Time: Manufacturer. This card is used to input the shipping time from the manufacturer to all other activities in the supply network. Note that these times are independent of procurement lead time.

Column	Format	Variable Name	Description
			From manufacturer to:
1-7	F7.0	OSTM(1)	W. Coast ship in CONUS.
8-12	F7.0	OSTM(2)	W. Coast deployed ship without MLSF support.
15-21	F7.0	OSTM(3)	W. Coast deployed ship with MLSF support.
22-28	F7.0	OSTM(4)	E. Coast ship in CONUS.
29-35	F7.0	OSTM(5)	E. Coast deployed ship without MLSF support.
36-42	F7.0	OSTM(6)	E. Coast deployed ship with MLSF support.
43-49	F7.0	OSTM(7)	W. Coast MLSF.
50-56	F7.0	OSTM(8)	E. Coast MLSF.
57-63	F7.0	OSTM(9)	WESTPAC overseas depot.
64-70	F7.0	OSTM(10)	E. Coast supply center.
71-77	F7.0	OSTM(11)	W. Coast supply center.

Sample Input Data:

```
  518.   811.   811.    14.   730.   730.   811.   730.   811.
12345678901234567890123456789012345678901234567890123456789012345678901234567890123456

518.   662.
78901234567890
```

This data format is used for card types 33 to 41.

Card Type 32. Order and Shipping Time: Ship to Repair Facility. The following cards input the shipping times in hours between the various activities. This card inputs the time required for a repairable carcass to move from a ship to the repair facility.

Column	Format	Variable Name	Description
1-7	F7.0	OSTSR(1)	Shipment time from a west coast based ship to the west coast repair facility.
8-14	F7.0	OSTSR(2)	Shipment time from a deployed west coast ship without MLSF support to the west coast repair facility.
15-21	F7.0	OSTSR(3)	Shipment time from a deployed west coast ship with MLSF support to the west coast repair facility.
22-28	F7.0	OSTSR(4)	Shipment time from an east coast based ship to the east coast repair facility.
29-35	F7.0	OSTSR(5)	Shipment time from a deployed east coast ship without MLSF support to the east coast repair facility.
36-42	F7.0	OSTSR(6)	Shipment time from a deployed east coast ship with MLSF support to the east coast repair facility.

Sample Input Data:

```
 1070.  1310.  1670.  1070.  1310.  1670.
12345678901234567890123456789012345678901234567890
```

This card image shows the retrograde pipeline shipping time for repairable material.

```
     1    9263.7    340.00
 4533.3         1
 0    0    0    0    0    1    0    0    1
 0    0    0    0    0    0    0    0    0
     1    9986.4   1450.57
 4314.3         1
 0    0    0    0    0    1    0    0    1
 0    0    0    0    0    0    0    0    0
     1    5256.0   1006.00
 4314.3         2
 0    0    0    0    1    2    0    0    3
 0    0    0    0    1    1    0    0    2
1070.  1310.  1670.  1070.  1310.  1670.
 518.   811.   811.   614.   730.   730.   811.   730.   811.   518.   662.
   0.     0.   731.     0.     0.     0.     0.     0.     0.     0.     0.
 957.  1041.  1041.  1321.     0.     0.   710.     0.     0.   785.  1308.
1110.  1444.  1444.  1232.  1932.  1932.  1444.  1932.   982.   624.     0.
 518.   811.   811.   614.   730.   730.   811.   730.   811.   518.   662.
   0.     0.     0.     0.     0.   571.     0.     0.     0.     0.     0.

1272.  1456.  1456.   833.  1206.  1206.  1456.  1529.   818.     0.   553.
 518.   811.   811.   614.   730.   730.   811.   730.   811.   518.   662.
```

APPENDIX C

VARIABLES USED IN METEOR

Table X provides a description of the variables used in the MULTE unit of METEOR, and those variables used in TIGER to interact with MULTE. Appendix B of reference 10 provides a similar listing for variables unique to TIGER.

TABLE X

METEOR VARIABLE LISTING

Variable Name	Type	Description
A	R	Random number array.
AADV(I,J)	R	Average inventory value per mission for equipment I at echelon J.
AAGTV	R	Total average inventory value.
AATDV(I)	R	Average inventory value at echelon I.
ACT	I	Activity number designator.
ADMD(I)	R	Average number of demands for equipment I.
ALFA1	R	Gamma distribution shape parameter for repair time.
ALFA2	R	Gamma distribution shape parameter for procurement leadtime.
ALH(I,J)	I	Allowance high limit for ship I and equipment J.
ALR(I,J)	I	Allowance reorder point for ship I and equipment J.
ASAVA	R	Average equipment availabilty per mission per ship.
ASREL	R	Average equipment reliability per mission per ship.

AVASS(I)	R	Average equipment availabilty per mission for ship I.
COAST	I	= 1 for West Coast, = 2 for East Coast.
CRAR	R	Carcass return attrition rate.
CTIME	R	Current simulation time.
DE(I)	R	Average equipment availability for equipment type I.
DELOH(I)	I	Change in on-hand quantity at echelon I during current call to MULTE.
DELTIM	R	Elapsed time since last call to MULTE.
DEQCUM(I)	R	Accumulated equipment availabilty for equipment type I.
DES(I)	R	Sum of squared equipment availability for equipment type I.
DESTN	I	Shipping destination of material.
DM	R	Demand value.
DMF(I,J,K)	I	Demand counter for ship I, equipment J, and phase K.
DNUM	I	Activity designator with minimum due-in time.
DTIME	R	Calculated due-in time for current requisition in process.
DTOT	I	Total number of due-in's established for stock requisition during current call to MULTE.
DUE	I	Initial shortage quantity at beginning of mission.
DUEA(I)	I	Activity designator for due-in requisition I.
DUEE(I)	I	Equipment type of due-in I.
DUEN	I	Total number of due-in's.
DUEQ(I)	I	Quantity of due-in I.
DUES	I	Quantity of due-in material that has arrived since last call to MULTE.
DUET(I)	R	Arrival time of due-in I.
ECH	I	Echelon: 1 = Ships, 2 = MLSF, 3 = Depot, 4 = NSC's, 5 = Repair Facilities, and 6 = Wholesale/ICP.

ECOST(I)	R	Cost of equipment type I.
ENUSE	I	End use activity designator.
EQTYP	I	Equipment type number.
ERQ(I)	I	Economic repair quantity for equipment type I.
FRQ	I	Frequency of demand.
FRQ12	I	Frequency of demand for last 12 months.
FRQ6	I	Frequency of demand for last 6 months.
HILIM(I,J)	I	Inventory High limit for at activity I for equipment type J.
I	I	Counter variable.
IA	I	Issuing activity.
IB	I	Counter variable.
IC	I	Counter variable.
IASRT	I	Serial number of activity issuing end use requirement.
ICTIME	I	Integer representation of current time.
IDUEJ(I,J)	I	Summary of current stock transactions, where I = 1 SSN of ordering activity, I = 2 Due-in time of order, I = 3 SSN of issuing activity, and I = 4 quantity issued. J is sequential number of stock transaction during this call to MULTE.
INMOD	I	Switch selecting See-through inventory policy.
IOPTM	I	Switch selecting MULTE processing.
IOPTP1	I	Switch selecting printing of detailed transaction information.
IOPTP2	I	Switch selecting printing of equipment statistics.
IOTIME	I	Integer time of equipment failure.
IP(I,J)	I	Inventory position of activity I for equipment type J.
IRC(I,J)	I	Requisitioning channel for ship I during phase J.

IRCS	I	Ship number.
IRFCST	I	Coast indicator.
IS	I	Ship indicator for attrition loss.
ISD	I	Random number generator seed.
ISHIP	I	Ship indentification number.
ISSUE	I	Issue quantity for this requisition.
ISWT	I	Switch variable.
ITEMA	I	Activity number.
ITEMP	I	Temporary variable.
ITEMQ	I	Quantity required.
ITMSM	I	Total number of missions run.
IU	I	Counter variable
IU1	I	Activity indicator.
IUT	I	Counter variable.
IWCNT	I	Number of phases completed.
IWITCN	I	Switch to insure both repair facilities are screened on referals.
IWLVL	I	Switch selecting levels computations at the end of a phase.
IWPHA	I	Switch selecting movement of ships at end of a phase.
IWPK	I	Current phase counter.
IWPRNT	I	Switch selecting print options.
IWRIM	I	Switch selecting RIMSTOP model.
IWRITE	I	Switch selecting print options.
IWSEL	I	Equipment type selection for detailed print out.
IXD(I,J)	I	Initial provisioning level for equipment I at echelon J.

IXG	I	Total inventory quantity.
IXT(I)	I	Total inventory counter for echelon I.
IX1	I	Random number seed.
IX2	I	Random number seed.
IX3	I	Random number seed.
IX4	I	Random number seed.
I1	I	Counter variable.
J	I	Counter variable.
JA	I	Activity indicator.
JEA	I	Echelon indicator.
JQT	I	Quantity indicator.
JS	I	Shipping activity indicator.
JSW	I	Switch selecting RIMSTOP issuing activity.
JSWR	I	Switch selecting EXREP procedure.
JSW70	I	Switch limiting number of passes in retail reorder.
JSW75	I	Switch limiting number of passes in wholesale reorder.
K	I	Counter variable.
KEQ	I	Failed component from TIGER.
KMI	I	K minus I.
KR	I	Counter variable.
L	I	Counter variable.
L1	I	Counter variable.
LEVEL(I)	I	Echelon of SSN I.
LL	I	Current phase type.
LSRT	I	Temporary SRT variable.
MAXD	I	Maximum due-in vector size (2000).

MAXF	I	Maximum months of supply (12).
MAXNEQ	I	Maximum number of equipment types (200).
MERQ	I	Maximum number of items that may be repaired during this call to *METEOR*.
MFLAG	I	Switch signaling start of new mission.
MINF	I	Minimum months of supply (1).
MPLT(I)	I	Mean procurement leadtime for equipment type I.
MRT(I)	I	Mean repair time for equipment type I.
MSD	I	MLSF screening delay for NIS/NC material.
MSDT	I	MLSF screening delay time.
MULTC	I	Number of calls to MULTE.
M1	I	Switch selecting type of repair parts input.
N	I	Temporary variable.
NEED(I)	I	Deficiency for repairable material at stock point I.
NEEDAC(I)	I	SSN of stock point.
NIST	I	Number of issued from ship's stock.
NMFE(I,K)	I	Number of equipments I procured from manufacturer. K = 1 counts number of procurements, and K = 2 counts number of items procured.
NMFL(J,K)	I	Number of equipments I procured from manufacturer for level J. K as above.
NMFR(I,J,K)	I	Number of items I procured from manufacturer for echelon J. K as above.
NMFT(K)	I	Total number of equipments procured. K as above.
NMS	I	Temporary ship number.
NMS1	I	Temporary ship number.
NNN(I,J,K)	I	Number of demands for item I at echelon J. K = 1 counts number of demands, K = 2 counts number of NIS, and K = 3 counts number of NC.

NNNE(I,K)	I	Number of demands for equipment I. K as above.
NNNL(J,K)	I	Number of demands at echelon J. K as above.
NNNT(K)	I	Total number of demands. K as above.
NRA	I	Counts total number of carcasses attrited.
NRF(I,J,K)	I	Number repairs for equipment I inducted for echelon J. K = 1 counts number of inductions, and K = 2 counts total number inducted.
NRFE(J,K)	I	Number of equipments inducted by repair facility for echelon J. K as above.
NRFL(I,K)	I	Number of equipments I inducted for repair facility. K as above.
NRFT(K)	I	Total number of equipment inducted by repair facility. K as above.
NRRT	I	Total number of items turned into repair facilities.
NRS	I	Temporary variable.
NRSHPS	I	Total number of ships in the simulation.
NRWCS	I	Number of ships assigned to the west coast.
NSHIP(I,J)	I	Number of shipments from I to J.
NSSEQ(I)	I	Component to equipment cross-reference.
NTY	I	Number of equipment types being simulated.
NUM	I	Mission number.
NUMSS(I)	I	Ship number of ship I.
NUM1	I	Corrected mission number (NUM+1).
OL	R	Operating level.
OLMF	R	Operating level multiplier (100).
ONHND(I,J)	I	Onhand quantity of equipment type J at activity I.
OQICP	I	System stock deficiency at ICP.
OQREQ(I)	I	Stock deficiency for stock point I.

ORACT(I)	I	Ordering activity for requisition I.
ORDER(I)	I	Order quantity for stock point I.
ORQDT(I)	I	Order quantity for requisition I.
OST(I,J,K)	I	Order and shipping time from coast I, echelon J to destination K.
OSTC	I	Temporary OST in RIMSTOP model.
OSTF	R	Order and Shipping Time value (1 or 3).
OSTL	I	Adjusted operating level.
OSTM(I)	I	Shipping time from manufacturer to destination I.
OSTSR(I)	I	Shipping time from location I to repair facility.
OTIME	R	Time of last call to MULTE.
PA(I)	R	Probability that equipment I is up at the end of a phase.
PHCNT(I)	R	Accumulated probability that equipment I is up at the end of a phase.
PLT	R	Procurement leadtime.
QDEST	R	Destination string for report header.
QDESTF	R	Destination string for report header.
QDESTT	R	Destination string for report header.
REORD(I,J)	I	Reorder point at activity I for equipment type J.
REPFAC	R	Value for maximum repair quantity (REPFAC*ERQ).
REQN	I	Number of requisitions currently in the system.
RESON(I)	I	Reason code, 1 = End use, 2 = Stock, for requisition I.
RORD	I	Quantity to be repaired.
RP	I	Issuing repair facility.
RPAIR(I)	I	Repair code, 0 = Consumable, 1 = Repairable, for equipment type I.
RTIME	R	Repair time.

SHIPR	I	Shipping activity address.
SHLOC	I	Current ship location.
SHPR	I	SSN of activity whose stock due-in has been diverted to fill an end use requirement.
SHPR1	I	Shipping activity designator.
SL	I	Safety level.
SLF	R	Safety level factor (1.0).
SRT	R	Supply response time for this call to MULTE.
SRT1	R	Temporary variable holding SRT.
SSN	I	Activity identification number: 1 - 15 = West Coast ships 15 - 30 = East Coast ships 31 = West Coast MLSF 32 = East Coast MLSF 33 = Western Supply Depot 34 = East Coast Supply Center 35 = West Coast Supply Center 36 = East Coast Repair Facility 37 = West Coast Repair Facility 38 = Wholesale Stock Point 39 = Manufacturer
SSRT	I	Shipboard supply response time.
SUMD(I,J)	R	Change in inventory value at echelon J, for equipment I.
SUMXD(I,J)	R	Current on-hand inventory level for equipment I at echelon J.
T	R	Due-in time plus OST.
TO	I	Echelon of requisitioning activity.
TOTAVA	R	Summation of shipboard availabilities.
TOTREL	R	Summation of shipboard reliabilities.
TPM	R	Time per mission.
U(I)	R	Array of random numbers.
U1(I)	R	Array of random numbers.

X	R	Mean supply response time.
XD(I,J)	R	Initial inventory investment for equipment I at echelon J.
XG	R	Initial inventory investment.
XL	R	Sum of failure rates.
XLM	R	Demand weighted mean supply response time.
XSRT	I	Supply response time adjustment variable.
XT(I)	R	Initial inventory investment at echelon I.

APPENDIX D

MULTE BLOCK DIAGRAM

The following table presents a low resolution block diagram of the MULTE module of METEOR. Description of the TIGER module is available in the TIGER Manuals [Ref. 9 and 10].

TABLE XI

MULTE BLOCK DIAGRAM

MULTE Initialization

Local variables, including SRT and MSD, are set to zero. If this is the first call to MULTE in this mission, subroutine MPACK is called to initialize stock levels, and other supply system variables. MULTC is incremented to count number of calls to MULTE.

Ship Location Determination

The ship in which the failure occurred is determined, and the coast which this ship is assigned is computed.

Demand Information Accumulated

If levels computation is enabled, demand information is accumulated for this failure. This demand information is used at the end of the phase by subroutine SETLVL to compute new shipboard levels.

Repair Facility Processing

If the failed equipment is not repairable, this module is skipped and control passes to shipboard stock review. Otherwise, it is determined if the retrograde carcass is lost or not. Each repair facility's due-in file is checked and the on-hand quantity is updated for any receipts. Then the repair facility on-hand quantity is checked to see if there are sufficient carcasses available to induct for repair. If there are sufficient carcasses, they are inducted and distributed to the stock points.

Shipboard Stock Review

The ship's due-in file is reviewed for any due-in items that may have arrived by the failure time. The on hand quantity is updated accordingly. Demand statistics are accumulated, and if the see-through model is selected, the appropriate stock point and ICP's inventory positions are adjusted. If there is sufficient material available, a supply response time is generated. If there is no material on-hand to fill the demand, a requisition is generated and passed to the next echelon. If the material is available, it is issued and the stock position is adjusted. If the ships inventory position is less than or equal to the reorder point, a stock replenishment requisition is issued.

Intermediate Level Stock Review

Depending on the requisitioning path for the ship, either the MLSF ship, overseas depot, or CONUS stockpoint will process the ship's requisition. The due-in file for the activity is checked and if there is sufficient material to fill the requisition, the material is shipped to the end user, and a supply response time is generated for end use requirements. If the first intermediate activity is a MLSF

ship or the overseas depot, and they cannot fill the ship's requisition, the requisition is referred to the appropriate CONUS stock point. If there are no further unfilled requisitions, MULTE returns to TIGER.

ICP Processing - RIMSTOP

If the RIMSTOP policies are in effect, unfilled requisitions are screened against wholesale stock, and if material is available, it is issued to the requesting ship. Otherwise, if the requisition is for stock replenishment, it is filled from the manufacturer. If the requisition is for end use, the stock point on the other coast is screened. Additionally, if the end use requirement is repairable, both repair facilities are screened for possible expeditious repair and direct shipment; otherwise, the requirement is passed to the manufacturer.

Next, each of the intermediate activities has it's stock levels reviewed, and if appropriate, requisitons are generated for stock replenishment. These requisition are filled from either wholesale stock or from the manufacturer.

Finally, the wholesale stock position is reviewed, and, if appropriate, requistions are submitted to the manufacturer. MULTE then passes control back to TIGER.

ICP Processing - Non-RIMSTOP

Requisitions are screened against the other coast's stock point for any ship or MLSF requistions outstanding. Any end use ship requisitions for repairable material not filled by a stock point are referred to the repair facilities to see if expeditious repair and shipment is possible.

Wholesale inventory position is reviewed, and if system inventory position is less than or equal to the

wholesale reorder point, requisitions are submitted to the manufacturer for direct shipment to the overseas depot and stock points.

Inventory Levels

Prior to returning to TIGER, on hand inventory levels at all echelons are updated to reflect receipts and issues.

The following subroutines are called from MULTE:

ESDUE:

This subroutine establishes due-in material in the due-in queue. This queue is maintained in due-in time sequence.

CHKDU:

This subroutine searches the due-in queue for requisitions for a specified equipment that have due-in times less than or equal to the current time. These requisitions are accumulated and the total number of due-in's that have arrived are passed back to MULTE. These requisitions are deleted from the due-in queue.

PRIOR:

This subroutine checks the activities due-in file for any stock requisitions that may arrive sooner than the end use item. If any are found, one is diverted for the end use requirement and the original end use item is sent to stock.

SWITCH:

When an end use requisition is backordered from a repair facility or the manufacturer, this subroutine will check all due-in's for stock at the depot and stock points for any material that will arrive earlier than the backordered requisition. If one is available it will be diverted to the end user, and the backordered requisition will be diverted to the intermediate activity to satisfy the stock requirement.

MPACK:

This subroutine is called at the beginning of each mission (iteration) and initializes stock levels, high limits and reorder points at all activities.

The following subroutines are called from TIGER:

MSTAT:

This subroutine computes and displays the end of run summary statistics.

SETLVL:

This subroutine computes shipboard levels based on experienced demand. It is called at the end of each phase wnen IWLVL is set to one.

APPENDIX E

SHIPBOARD LEVELS COMPUTATION

The following algorithm is used by the levels module in METEOR to compute the changes in shipboard stock levels at the end of a phase. Phase length is assumed to be 2,190 hours, or one quarter.

1. Compute frequency of demand for preceding 6 months, and if less than two demands have occurred, make no changes to allowance quantities.
2. Compute operating level, OL, as follows:

   $OL = OLMF * \sqrt{DMD/COST}$,

   where OLMF = Operating level multiplier specified by the Type Commander. METEOR uses the value 10.0;

   DMD = Average monthly demand;

   and COST = Unit cost for the item.
3. Constrain OL to minimize number of changes in levels,

   if OL < MINF*DMD then OL=MINF*DMD, or

   if OL > MAXF*DMD then OL=MAXF*DMD;

   where MINF = Minimum months of supply specified by the Type Commander. METEOR uses 1.0;

   and MAXF = Maximum months of supply specified by the Type Commander. METEOR use 12.0.
4. Compute Safety Level, SL, as follows

   SL = SLF*DMD

where SLF = Safety Level factor specified by the Type Commander. METEOR uses 1.0.

5. Compute Order and Shipping Time Demand, OSTL, as follows:

   OSTL = OSTF*DMD,

   where OSTF = Order and shipping time parameter specified by the Type Commander. METEOR uses 1.0 for non-deployed ships, and 3.0 for deployed ships.

6. Compute Reorder Point, RP, as follows;

   RP = SL + OSTL.

7. Compute High Limit, HL, as follows;

   HL = RP + OL.

Material will be ordered whenever the current inventory position is less than or equal to the reorder point. The order quantity will be the difference between inventory position and the high limit.

APPENDIX F

EXPERIMENTAL RESULTS

Table XII presents the results of the experiment described in Chapter VII.

TABLE XII

SIMULATION RESULTS

Observation	Shipboard Effectiveness Gross	Shipboard Effectiveness Net	Overall Effectiveness Gross	Overall Effectiveness Net	Average Inventory Cost	System Avail.	Supply Response Time
- - - -	48	96	51	87	48700.	.7671	2446.8
D - - -	48	95	47	79	23300.	.4435	3646.5
- G - -	47	97	50	87	47500.	.7245	2609.6
D G - -	47	95	45	78	23500.	.4085	3445.3
- - R -	49	97	39	89	51400.	.7667	3054.6
D - R -	48	96	39	88	35200.	.4933	2951.3
- G R -	48	96	37	87	55600.	.7377	3253.7
D G R -	48	94	40	89	35700.	.5034	2677.3
- - - S	48	97	52	89	60300.	.7738	2233.2
D - - S	47	94	49	84	138600.	.5180	2653.6
- G - S	47	97	50	87	47500.	.7245	2609.6
D G - S	48	95	49	84	147600.	.4943	2573.7
- - R S	48	98	39	91	65600.	.7756	3013.5
D - R S	47	95	43	94	405100.	.6457	1879.1
- G R S	48	97	38	88	56700.	.7332	3189.7
D G R S	47	94	42	93	365300.	.6094	1854.6

Notes: - = factor at low level
D = duration at 87,600 hours
G = gamma shape parameter set to 10
R = RIMSTOP policies in effect
S = See-through policies in effect
Effectiveness data reported in percent.
Cost data reported in dollars.
Availability data reported as probability.
Mean supply response time data in hours.

LIST OF REFERENCES

1. Bunker, T. A., METEOR: A Tool for Evaluating Multi-Echelon Inventory Models and Material Readiness, M.S. Thesis, Naval Postgraduate School, Monterey, Ca., March, 1983.

2. Naval Supply System Command, NAVSUP Publication 553, Inventory Management, 1984.

3. Fleet Material Support Office, Variable Operating and Safety Level (VOSL)/Economic Range Model (ERM) Training Manual, 1984.

4. Department of Defense Instruction 4140.39, Procurement Cycles and Safety Levels of Supply for Secondary Items, 17 July 1970.

5. Hadley, G. and Whitin, T.M., Analysis of Inventory Systems, pp. 159-217, Prentice-Hall, 1963.

6. Demmy, W.S. and Presutti, V.J., "Multi-Echelon Inventory THeory in the Air Force Logisitics Command", Multi-Level Production/Inventory Control Systems: Theory and Practice, pp. 279-299, North-Holland, 1981.

7. Clark, A. J., "Experiences with a Multi-Indentured, Multi-Echelon Inventory Model", Multi-Level Production/Inventory Control Systems: Theory and Practice, pp. 299-330, North-Holland, 1981.

8. Naval Postgraduate School Report - NPS55-83-026, Wholesale Provisioning Models: Model Development, by F. R. Richards and A. W. McMasters, September 1983.

9. Naval Ship Engineering Center, Report 6112B-036-78, Tiger Manual, February, 1979.

10. Naval Sea Systems Command, Report TE660-AA-MMD-010, Tiger Manual, January, 1980.

11. Office of the Assistant Secretary of Defense Installations and Logisitics, DoD Retail Inventory Management and Stockage Policy, RIMSTOP, Volume II, Part 1, March 1976.

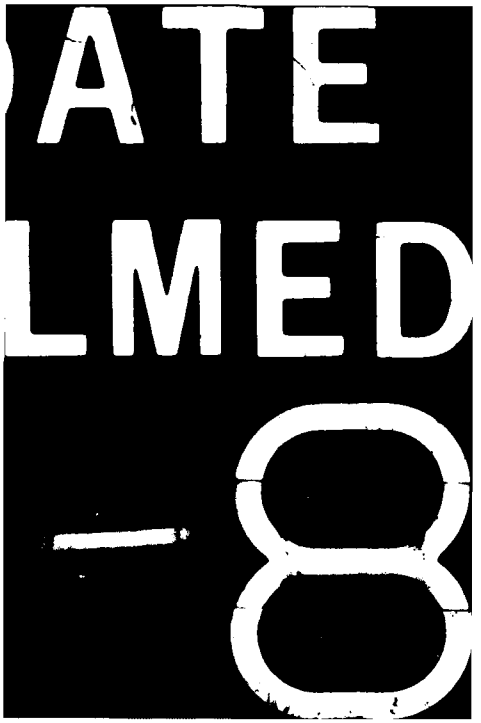
12. Engelman, J. and Merkel, W., Application D, Operation 56 - CARES (Computation and Research Evaluation System) III, Fleet Material Support Office, 30 October 1978.

13. Ships Parts Control Center Instruction 4400.30C, 6 February 1980.

14. Richards, F. R., ANOVA APL Program, 1985.

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2.	Defense Logistics Studies Information Exchange U. S. Army Logistics Management Center Fort Lee, Virginia 23801	1
3.	Library, Code 0142 Naval Postgraduate School Monterey, California 93943	2
4.	Commanding Officer Naval Supply Systems Command, Attn: SUP042 Washington, D.C. 20376	2
5.	Commanding Officer Navy Fleet Material Support Office, Attn: Code 93 Mechanicsburg, Pennsylvannia 17055	2
6.	Assoc. Professor F. R. Richards, Code 55Rh Naval Postgraduate School Monterey, California 93943	5
7.	Assoc. Professor A. W. McMasters, Code 55Mg Naval Postgraduate School Monterey, California 93943	3
8.	LCDR D. B. Wadsworth, SC, USN Navy Fleet Material Support Office, Code 93 Mechanicsburg, Pennsylvannia 17055	2


ATE
LMED
-8