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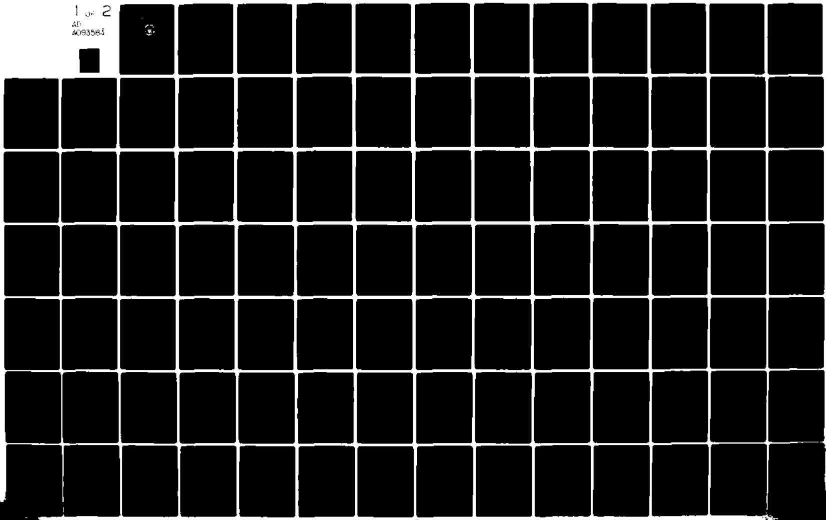

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

AN EVALUATION OF THE EFFECT OF SPARES ALLOWANCE POLICY UPON SHIP AVAILABILITY AND RELIABILITY

by

John Edward Leather

September 1980

Thesis Advisor: F. Russell Richards

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO. AD-A093584

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
An Evaluation of the Effect of Spares Allowance Policy Upon Ship Availability and Reliability

5. TYPE OF REPORT & PERIOD COVERED
Master's Thesis; September 1980

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
John Edward Leather

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Postgraduate School
Monterey, CA 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Postgraduate School
Monterey, CA 93940

12. REPORT DATE
September 1980

13. NUMBER OF PAGES
115

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)
Naval Postgraduate School
Monterey, California 93940

15. SECURITY CLASS. (of this report)
Unclassified

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)

Cosal
Provisioning
Tiger
Reliability
Availability

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

U.S. ships are provided onboard spare parts for equipment the ship's force is capable of repairing while at sea. The range and depth of spares provided has a pronounced effect on the availability of both ship and weapon systems. The spares suite for a particular ship is the Coordinated Shipboard Allowance List produced by the Ship's Parts Control Center. A mathematical model is used to produce this list, aiming to achieve stocking goals set by the Navy. This thesis examines the relationship between these

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(Page 1) S/N 0102-014-6601

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An Evaluation of the Effect of Spares Allowance Policy Upon Ship Availability and Reliability

by

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1980

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ABSTRACT

U.S. ships are provided onboard spare parts for equipment the ship's force is capable of repairing while at sea. The range and depth of spares provided has a pronounced effect on the availability of both ship and weapon systems. The spares suite for a particular ship is the Coordinated Shipboard Allowance List produced by the Ship's Parts Control Center. A mathematical model is used to produce this list, aiming to achieve stocking goals set by the Navy. This thesis examines the relationship between these goals and the model in use. A simulation model developed by the Naval Sea Systems Command has been modified so that it is compatible with the Naval Postgraduate School computer system, and this simulation model is used to evaluate the provisioning models. This simulation model is capable of being used for a variety of other projects at the Naval Postgraduate School.

TABLE OF CONTENTS

I. INTRODUCTION

The capability of a modern warship to be combat ready and maintain this readiness over a deployment period depends on logistics support. While this support includes such necessities as food, fuel, medical supplies etc., a crucial element in maintaining the sophisticated shipboard systems is the availability of repair parts. More important, of course, is the necessity of having a skilled technician capable of diagnosing any problems and effecting the required repairs. This thesis will focus entirely upon the 'part' side of this two-way problem, knowing full well that the desired technical expertise is not always available on all ships.

To provide for the capability of repairing equipment while away from port or support ships, each ship is provided a quantity of spares designed to enable it to be self sufficient for a period of 90 days. Budget and storage constraints prohibit stockpiling spares to cover all possible requirements, therefore a choice must be made as to the method to allocate the range and depth of spares to be provided.

Chapter II discusses the way the Navy is currently making this allocation. The method has been successful for a number of years, but less so recently due to changes in provisioning model parameters. These changes were dictated by the 'high cost' of the allowance list generated by previous parameters.

Chapters III, IV, and V describe the use of a reliability block diagram simulation program to evaluate the effect of changing the spares suite upon the reliability/availability of a shipboard system over a 90 day period with no external spares replenishment. To obtain an upper bound on the spares effectiveness, the 90 day period was simulated with all repairs being instantaneous; thereby placing the entire burden of making the system available on the spares suite and not upon the speed of the repair. From this technique a measure of effectiveness of each given spares suite can be derived.

As an example, a particular reliability block diagram is analyzed in chapter VI using the simulation technique. The nature/configuration of this block diagram has a large effect on the figure of merit results. For example, three different items connected in series would be less reliable than the same three connected in parallel where only two are required to be functioning at once and the third was in cold standby. It is for this type of reason that a provisioning process based on parts counting rather than reliability may provide satisfactory results for one system and unsatisfactory results for another when both systems possibly consist of the same piece parts or perform the same function.

The simulation (called TIGER) is a general reliability simulation model and is capable of many other uses besides the one chosen for this thesis. With the help of the appendices, the program listing, and the TIGER manual (Ref. 1) further use of this program on the Naval Postgraduate School (NPS) computer system or any other FORTRAN IV compatible system with random number generation capability should be feasible.

II. THE COORDINATED SHIPBOARD ALLOWANCE LIST (COSAL)

A. NAVY POLICY FOR PROVIDING SUPPLY SUPPORT OF THE OPERATING FORCES

The amount of logistic support required to support the desired levels of fleet readiness are delineated in Ref. 2. Of concern here are the sections on Shipboard Stock Levels and Criteria for Shipboard Allowances.

All non-Fleet Ballistic Missile (FBM) self-sustaining ships have a stockage objective of 90 days, which is equated to the endurance for the ship. This objective is applicable to repair parts, spares, and equipment related consumables.

The specific criterion for developing a COSAL from a list of those items capable of being repaired by shipboard personnel is the subject of the next section of this thesis.

The measures of effectiveness for COSAL performance as stated in Ref. 2, are to 'fill from onboard stocks 65% (gross effectiveness) of all demands and to provide an overall availability for items allowed to be carried of 85% (net effectiveness)'. It is essential to note that no mention is made of such terms as reliability, availability, or readiness in the context of the supported ship as a measure of COSAL effectiveness.

Net effectiveness is often called 'system' effectivenss, in that it is the effectiveness of the entire logistics system in replenishing shipboard spares once they are used and reordered. As this is not specifically related to the COSAL provisioning document, but is a function of such diverse items as order and shipping times, specific examination of this measure will not be attempted. Rather, certain stated assumptions will be made regarding the percentage of spares onboard when it is necessary to do so.

The objective of 65% gross effectiveness is the central issue which this thesis will focus upon. As will be shown in the next section, the COSAL mathematical model in no way can be substantiated as a '65% gross effectiveness model'. More important is the question of '65% gross effectiveness' as a measure of effectiveness for shipboard support. One could conceive of ways to fill 75% of the requisitions received in 90 days from shipboard stock and never be able to get underway. Alternatively, a low fill rate could result in a highly successful deployment. The key, obviously, is to stock those items which are important to the ships mission, and not to stock simply to maximize stock turn.

B. CURRENT COSAL MATHEMATICAL MODELS

Several mathematical models are currently being used to generate COSALs. The Fleet Logistic Support Improvement Program (FLSIP) model is used for surface ships and Fast Attack Submarines (SSN) and is the most extensively used technique. The TRIDENT model is used on Fleet Ballistic

Missile Submarines (FBM) and is similar to the Maintenance Criticality Oriented (MCO) COSAL being implemented on the FFG-7 Lo-Mix class of ships.

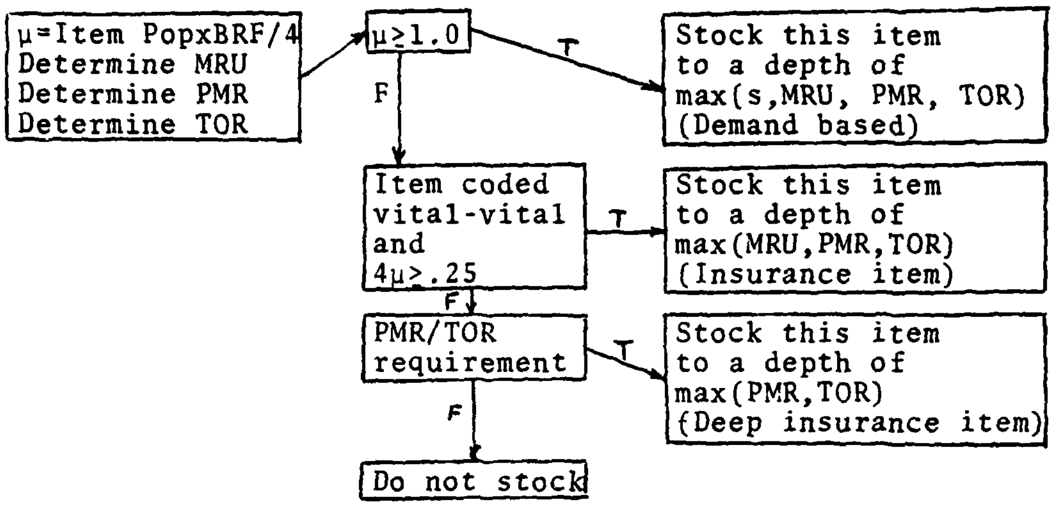
1. FLSIP Model

The FLSIP model has been in use for many years and has proven to be a rapid, workable, and understandable method of generating the large quantity of COSALS that must be run (approximately 50 per month). This model simply processes a list of all repair parts applicable to the particular ship and capable of being replaced by the ship's force. Each part is individually totaled for its' entire installed shipwide population and then is multiplied by its' Best Replacement Factor (BRF) (explained in chapter IV). The resultant value is called the 'mean', and this mean is used with the essentiality of the parent equipment to determine the final allowance quantity. A FLSIP logic diagram is shown in figure 1.

The attempt to incorporate essentiality into this model has been negated by the migration of over 90 percent of the parts on file into the 'vital' category. Technical Overides (TORS) have been frozen by the Chief of Naval Operations (CNO) as a cost reduction measure.

The currently used model is called a .25 FLSIP model since the insurance cut point is .25 (one expected demand in four years). As over 90 percent of the items stocked on-board a ship are stocked at a depth of one, this cut point is critical to the ability of the model to provide sufficient

FLSIP COSAL LOGIC



Definitions:

Item Pop - Consolidated population of the item throughout the ship's systems

BRF - Best replacement factor

s - minimum stocking depth such that Pr (Actual 90-day demand $\geq$ s) $\approx$ .90 (Assuming Poisson distribution)

MRU - Minimum replacement 'unit' quantity, if any

PMR - Required preventative maintenance quantity for planned maintenance

TOR - Technical override quantity, if any; determined by engineers/designers during equipment provisioning review

Vital-Vital code - Item vital to its parent component, and its component vital to a primary mission

Figure 1

support. This cut point was changed from a previous value of .15 due to various budgetary pressures.

Aside from the arbitrary nature of the value chosen as the cut point the main problems which continue to exist are the effectiveness criteria established in Ref. 2 and the fact that the FLSIP model (Figure 1) has no mathematical relationship to these criteria. If the FLSIP is to be continued in use, and indications are that it will (Ref. 3), meaningful effectiveness criteria must be established and a means developed to justify the use of the FLSIP model to meet these criteria.

2. TRIDENT Model

The TRIDENT model incorporates military essentiality codes (MEC) assigned to the parent equipment into the stockage allowance decision. The more essential the equipment, the better it will be supported. The following equation is used to calculate the allowance quantity:

$$\text{Allowance quantity} = \mu + (Z x \mu)$$

Where μ is the mean of the assumed Poisson distribution of repair part requirements in 90 days).

The multiplier Z is a function of essentiality and to a lesser degree the unit price of the part. As in the FLSIP model each candidate part is processed individually and is not subject to budget constraints (although the levels may be adjusted through the manipulation of the various factors which comprise Z).

This model is currently in use; takes essentiality of equipment into account; and provides excellent support. But as could be expected, the resulting COSAL provides generous allocation of spare parts and its cost would be hard to justify outside of the FBM arena.

3. Maintenance Criticality Oriented (MCO) Model

The MCO model is an allowance list to be implemented on an increment of the new FFG-7 Lo-Mix class of ships. The mathematical technique is very similar to the TRIDENT model, the main difference being that essentiality is carried all of the way to the part level. The documentation required to achieve this is extensive and costly and must be maintained throughout the life of the ship. The documentation required to backfit the MCO model to older classes of ships does not exist.

III. THE NAVAL SEA SYSTEMS COMMAND TIGER SIMULATION PROGRAM

A. INTRODUCTION

TIGER is the generic name for a family of computer simulation programs which can be used to evaluate a complex system in order to estimate various reliability, readiness, and availability measures. This program was developed by the Naval Sea Systems Command (NAVSEA) reliability branch. The reliability block diagram of the system/component under study is the foundation from which a TIGER simulation run is constructed. This block diagram may be for a large system (ship) with each block representing a component of the system; or it may be for a single component with each block representing a lowest replacement unit part; or the block diagram may be any type of combination of both. As an input for each block the Mean Time Between Failures (MTBF) and Mean Time to Repair (MTTR) must also be known.

The unique feature about TIGER is the flexibility incorporated into the program. Scenarios with block diagram configurations which change during the time period being simulated are evaluated through a series of different timeline 'phases' in the input. A phase is a specific reliability configuration for the ship being studied. The simulation will accept up to six different phases, and they may be sequenced in any order and be of any interval of time. The phases may be strung together until the simulation capacity of 95 total phases is reached. MTBF, MTTR, and spares multiplier factors may be entered to perform sensitivity analyses on the system under study.

TIGER uses Monte Carlo random number methods to evaluate the input block diagram. The random numbers are generated through the use of the NPS LLRANDOM routine (Ref.4).

The TIGER simulation is a discrete event step simulation. Exponential failure and repair times are generated using the MTBF and MTTR input data. As equipments fail spares are used; repairs effected (if allowed in the phase); standby equipment turned on/off if required; and different block diagrams initiated as the different phases are encountered during the timeline. Statistics are collected as a result of each event and change of configuration.

The TIGER output includes estimates of reliability, readiness, availability, and critical components which caused the most severe degredation of reliability and availability. The user may change the random number seed and replicate a timeline as many as 1000 times in a single TIGER run. TIGER will calculate and provide a lower confidence limit for the point estimate of reliability.

The inherent limitations to the use of this type of simulation include both the problem of providing accurate input data (MTBF, MTTR) and the exponential failure/repair rate assumption used in the program. Under many scenarios and for many types of equipment this exponential assumption is valid but certainly many types of equipment exhibit wearout and not all repair times are exponentially distributed.

In addition to the output mentioned above, spares usage may also be displayed as well as several standard and optional outputs of the progress of the simulation. The detail can vary from every event being shown to a much simpler management summary.

Two subroutines of TIGER were omitted in this thesis research but may be useful in different types of analysis. One of these, the GAMMA option, assumes that the system being evaluated has a gamma failure distribution and calculates the two parameters (shape and scale) for the gamma distribution which would exhibit the same mean and variance of mission failure times as the system being modeled. The DEMO option of TIGER provides the capability of generating a sequential probability test ratio plan for the system as prescribed in MIL-STD-781. Detailed information about TIGER including GAMMA; DEMO; and a TIGER/MANNING personnel requirements type program is found in Ref. 1.

B. PRESENT NAVSEA TIGER UTILIZATION

The TIGER program is being used by NAVSEA to evaluate Reliability, Maintainability, Availability (RMA) performance characteristics of new ship classes (Ref. 5). This analysis is performed only on the major mission-essential systems: Navigation, Auxiliary, Electrical, Ship Control, Propulsion, Exterior Communications, and Combat. Only these systems and equipment which impact the operational readiness of the ship and the ship's ability to perform its assigned primary combatant mission are included in the analysis.

All surface ships constructed since 1970 have reliability block diagrams available (in computer readable form). This eliminates the major undertaking of having to construct the reliability block diagrams prior to using TIGER. The necessary MTBF and MTTR data for existing equipment is found in the Reliability/Maintainability/Availability Design Data Bank (Ref. 6), which is a compilation of data from both engineering design and fleet feedback. Engineering estimates must be used for the many new systems found on a new class of ship, where no feedback data yet exists.

Along with the various reliability block diagram configurations (steaming, in-port, ASW, etc.) and MTBF/MTTR data, the operating rules for the equipment must also be provided. These rules include allowable downtime, spares, mission timelines, and maintenance policy.

A sample RMA timeline (Ref. 5) is shown in figure 2. Timelines are tailored to the class of ship and its designed usage in a period of combat.

Allowable downtime is the time that the system or equipment can be down for maintenance without causing a mission abort. During simulated combat periods this time is usually zero for most mission essential systems.

DAY	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
PHASE	A				A				B	A	A		A			B	A			B	A				B
ENGAGEMENT CODE									7							6/8				1					4
MISSION	TRANSIT				CONVOY ESCORT						TRANSIT		CARRIER TASK FORCE												

DAY	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
PHASE	A				B	A	A							B				A			C				
ENGAGEMENT CODE					3									2/5											
MISSION	CARRIER TASK FORCE				TRANSIT		AMPHIBIOUS OPERATIONS											TRANSIT			IN PORT				

DAY	51	52	53	54	55	56	57	58	59	60
PHASE	C									
ENGAGEMENT CODE										
MISSION	IN PORT									

CODE	PHASE
A	WARTIME CRUISING
B	ENGAGEMENT
C	IN PORT

CODE	ENGAGEMENT TYPE	DURATION (HOURS)
1	SUW	0.5
2	SUW	0.5
3	AAW	0.25
4	AAW	0.25
5	AAW	0.5
6	AAW	1
7	ASW	2
8	ASW	3

Figure 2

Maintenance policy limits certain equipment to being capable of repair only during certain phases. For example, repair of the main engine would not be permitted while hunting a submarine, but would be permitted while in-port.

Spares are assumed to be available as needed for initial TIGER analysis. Supportability tradeoff studies are conducted separately to evaluate the effect of different spares efficiency percentages and off-ship logistic delay times.

The results of the TIGER simulation are compared with design specifications to see if any inherent (non-spares related) reliability problems exist. Critical equipments are then identified and closely monitored during the final phases of design and construction.

C. PROPOSED TIGER UTILIZATION FOR COSAL PREPARATION

Reference 7 describes a methodology of using the TIGER program to evaluate a COSAL with respect to reliability. The inputs to the TIGER program would be the same as those in the last section with the exception of the spares input and the indenture level of the reliability block diagram. The diagram must not stop at the equipment level, but be carried out to the repair part level. MTBF/MTTR data must also be provided at the repair part level.

As may be readily apparent, the block design for just the essentail equipment of an entire ship would be very cumbersome and unworkable. This type of TIGER analysis must be done on a system or equipment basis. The spares input would be that generated by the COSAL model under evaluation, usually FLSIP.

A deployment timeline is simulated and the resulting reliability/availability figures are compared to the design goals. If the goals are not achieved the 'bad apples' list of repair parts indicates the particular parts which caused the most degredation. Additional quantities of these parts are added to the spares suite and the process is repeated until the goal is attained. This method may also be used in reverse, removing spares and observing the resulting changes to reliability/availability.

While this methodology is feasible and would certainly provide better support than an unaugmented FLSIP COSAL, it has several drawbacks. One is the lack of reliability block diagrams down to the repair part level. Although new equipment procurement contracts may specify that this documentation must be provided, the task of assembling it for just one ship's essential equipment would be awesome.

Another problem is the lack of MTBF/MTTR data for each part. Reference 8 may be used to estimate the required parameters, but again this is a large undertaking. As was mentioned earlier in this thesis, current provisioning processes use a BRF vice MTBF to determine logistic support. A further clarification of the differences between these two and a proposed solution will follow in a later section.

A final problem results from the fact that repeated computer runs on a vast network of reliability block diagrams are required to produce a single COSAL. The computer system at the Ships Parts Control Center (SPCC) is saturated and could not begin to process the large quantity of simulation runs necessary to use this proposed method on all COSALs. In addition, a significant number of manhours would be required to review each run and decide which parts to augment and in what quantity. Though this process would undoubtedly produce a COSAL superior to the FSLIP model, practicality prevents its adaption at the present time.

IV. BEST REPLACEMENT FACTOR (BRF)

A. BRF - WHAT IS IT?

The BRF is the projected annual replacement rate for one installed unit of a repair part. Only one BRF exists for each part even if it is used in numerous applications throughout a given ship or the fleet or ashore. The BRF is found by dividing the annual reported usage in the fleet by the total installed population. This yields annual failures per installation. Before any calculations are made the input data are adjusted for inaccuracies caused by bad reporters and inactive ships in overhaul. The BRF is calculated annually for each item in the SPCC files. To prevent rapid fluctuations from occurring the previous value on file is updated with the new value by the use of exponential smoothing.

To illustrate this process suppose that 105 ships in the fleet were each recorded as having two of part 'A' installed. Five ships were in overhaul for this particular year so their data is not used for BRF update. The remaining 100 ships reported a total of 400 failures for item 'A'. Since there are 200 of 'A' installed and 400 were used, the unsmoothed BRF is 400/200 = 2.0. If the BRF currently on file is 2.4 and exponential smoothing with smoothing constant .25 is used, the updated BRF would be 2.4x.75 + 2.0x.25 =2.3.

This BRF would be put on file for use in all COSALS which contain part 'A'.

B. MEAN TIME BETWEEN FAILURE (MTBF)

MTBF is the expected value of the operating time between failures of an item. It is estimated by dividing the total time in service by the number of failures:

MTBF = total time in service/number of failures

Sometimes the expression Mean Time to Failure (MTTF) is used for the expected value. Another related measure is the failure (hazard) rate which is the conditional probability that an item surviving to age t will fail in the interval (t, t+dt). A constant failure rate is equivalent to having a failure distribution which is exponential; and for an exponential distribution the failure rate is the reciprocal of MTBF.

C. DIFFERENCES BETWEEN MTBF AND BRF

A MTBF provides an expected value of the length of time an item will operate until failure. It is based on operating time; and failures are not possible while the equipment is not in use or turned on. A BRF is the average number of times an item will fail in an average year in an average installation. Since these differences and similarities are crucial to the analysis in section VI of this thesis, the following example taken from Ref. 9 provides an insight into the MTBF/BRF relationship.

A piece of equipment (lamp) has four repair parts (bulb, socket/switch, cord, plug). It is operated for 1000 hours per year. An arbitrary MTBF and corresponding Failure Rate (expressed in failures per year) are shown below:

ITEM	MTBF	FAILURE RATE
Light Bulb	750 HRS	1.333
Socket/Switch	10,000 HRS	0.100
Electric Cord	15,000 HRS	0.066
Plug	10,000 HRS	0.100
TOTAL		1.599

As shown, the lamp is expected to fail 1.599 times per year. This would be a BRF for the lamp if the maintenance policy were to replace the whole lamp no matter what the cause of the failure. The following table shows how maintenance philosophy can have a pronounced effect on the five BRFs. The 'Replace Failed Part' column represents the way repairs are usually accomplished at the shipboard level. Only catastrophic failure would lead to the attempted replacement of the entire item, usually unsuccessful because the entire assembly would not likely be stocked due to the low BRF.

		MAINTENANCE PHILOSOPHY		
ITEM	FAILURE RATE PER YEAR	REPLACE FAILED PART	REPLACE LAMP	REPLACE FAILED BULB, OTHERWISE REPLACE LAMP
LAMP	1.599	BRF=0.	BRF=1.599	BRF= .266
BULB	1.333	BRF=1.333	BRF=0	BRF=1.333
CORD	0.066	BRF=0.066	BRF=0	BRF=0
S/SWITCH	0.100	BRF=0.100	BRF=0	BRF=0
PLUG	0.100	BRF=0.100	BRF=0	BRF=0

D. BRF AS AN INPUT TO TIGER

When MTBF is used as an input to TIGER, various timelines are used to provide scenarios in which the equipment configurations and usage rates are required. When equipment is on, it fails exponentially with the given MTBF, unless the duty cycle is less than 100 percent, in which case the MTBF is divided by the duty cycle. The BRF has incorporated the various reasons the timeline approach must be used with the MTBF; equipment being turned off and on; duty cycles for equipment with cycles of less than one; and the various configuration dependent usage rates for an average installation in an average year.

Consider, for example, an equipment with a duty cycle of one-half (operating 50 percent of the time) exhibiting five failures in a ten year period. The MTBF is calculated as before; total time in-service/failures = (10x.5)/5 = 1 year. Since the duty cycle is one-half, we would expect to see a failure every other year, or .5 per year. The BRF calculation yields the same result; 5 failures/10 years = .5 failures/year.

To use a BRF in TIGER requires that the entire block diagram, in a typical configuration, be used and equipment/parts be allowed to fail at an annual rate (BRF) which takes the numerous operating scenarios into account. While the results from this type of analysis would be very difficult to defend as providing entirely accurate reliability/

availability measures; they should be suitable for deriving a 'figure of merit' evaluation for the support provided by different COSAL models.

V. TIGER USED TO EVALUATE THE EFFECT OF SPARES ALLOWANCE POLICY UPON RELIABILITY AND AVAILABILITY

A. INTRODUCTION

The current utilization of gross effectiveness as a measure of COSAL effectiveness has been studied in previous sections. An alternative measure will now be proposed. The TIGER program calculates reliability, availability, and readiness figures for each simulation run. The definitions for these three measures, as found in Ref. 1, are summarized below.

B. RELIABILITY (REL)

For a given timeline the reliability (REL), as estimated by TIGER, is the probability that the ship will successfully complete the entire timeline. For example, if the timeline previously shown in figure 2 were used, REL would be the probability of the ship completing all of the different missions assigned during the 60 day period, in the sequence shown.

Reliability is calculated by TIGER as follows:

$$\text{REL (EST)} = 1 - \frac{\text{Number of mission failures (aborts)}}{\text{Total number of simulated missions}}$$

Note that this calculation incorporates logistics support considerations.

C. AVAILABILITY (AVA)

TIGER calculates two AVA parameters: Instantaneous and average. Instantaneous availability is the probability that the system will be 'up' at a specific point in time. Average availability is the probability that the system will be up at a random point in time. Because of the way TIGER is used, average availability is the relevant measure.

Average AVA is estimated as the ratio of total system 'uptime' to the total time simulated. These times are totaled for the entire number of missions simulated (up to 1000). The calculation is made as follows:

$$\text{AVA (EST)} = \frac{\text{Summation of uptime for all missions simulated}}{\text{Summation of total mission calendar time for all missions simulated}}$$

$$= \frac{\text{Uptime}}{\text{Calendar time}}$$

D. READINESS (RED)

RED, like AVA can be measured as instantaneous or average readiness. It is a measure of the probability that there is neither a mission abort nor a system down. The forthcoming methodology for the use of TIGER results in RED equaling AVA, so RED will not be considered any further as an alternative measure of effectiveness.

E. RELIABILITY VS AVAILABILITY AS A MEASURE OF EFFECTIVENESS

A very common measure of effectiveness in use by the Navy today is 'Operational Availability' (Ao). Ao is defined as the probability that an equipment is ready when you need it. MIL-HDBK-217C (Ref. 8) dictates that it be calculated by:

$$Ao = \frac{MTBF}{MTBF + MTTR}$$

An alternative form of this equation results from breaking the MTTR up into the repair time (MTTR) plus the Mean Supply Response Time (MSRT); the time necessary to provide the required repair part(s). This yields:

$$Ao = \frac{MTBF}{MTBF + MTTR + MSRT}$$

There are problems with the use of this formula for estimating system operational availability (Ref. 10). From a mathematical point of view the formula yields the correct result for the limiting value of operational availability when one considers a single component that transitions between up and down states as an alternating renewal process. If one is interested in the operational availability after a fixed period of time for a system whose components have limited spares support, the formula does not yield correct results. In fact, the formula makes little sense. A simulation like TIGER is precisely what is needed to estimate Ao for a complex system with limited spares support.

Since AVA implicitly considers component reliability, maintenance, spare parts support, system configuration and operational scenario, it is used in this thesis to evaluate COSAL models.

F. ALLOWANCE POLICY EFFECT

1. Reliability Block Diagram of System

The effect of a parts-counting type allowance policy upon reliability/availability is dependent on the configuration of the system being supported. Parts counting is a method of allocating spares in proportion to the number of each specific repair part in the equipment. In an environment of limited budgets and storage space, a more 'critical' spare (in terms of reliability/availability) may be sacrificed to provide unwarranted depth for another spare. Figure 3 shows a simple reliability block diagram with two

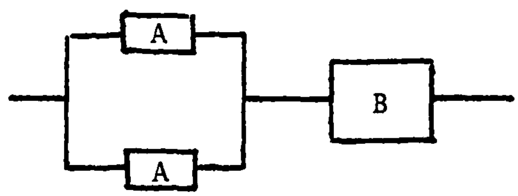


Figure 3

of part A in parallel with each other and then in series with part B. Both A and B have a BRF of 1. If A cost the same as B, and only one spare could be provided, provisioning by parts counting would provide one spare of type A, since there are twice as many A as B. However, the availability of this system would be much greater (all other things considered the same) if the one spare purchased were of type B, due to the parallel redundancy.

2. Proposed Allowance Policy Input

There are two methods of entering the quantity of spares for each part type into the TIGER simulation. One is to input that quantity as part of the input data. For small systems this may be the most efficient method. For larger systems or for those systems requiring a complicated mathematical model, a subroutine has been added to TIGER to calculate the COSAL.

For the FLSIP COSAL, the cut point is input with the other system data and the spares subroutine is used to generate the COSAL for the system. The MTBF is derived from the BRF in the following manner:

MTBF=(1/BRF)x8766 (yr/fail)x(hr/year) = hr/fail

This MTBF is used as the exponential failure rate input for the simulation, and converted back to BRF when necessary to determine COSAL support.

3. Figure of Merit Results

Several simplifying assumptions are made by using TIGER to obtain the output availability measure. The most important are exponential failures; BRF converted to MTBF; zero repair times; a full allowance of spares onboard at the beginning of the mission; and the use of a 'typical' reliability block diagram configuration for the duration of a single mission. Because of these assumptions, the availability figure provided by TIGER should not be considered as the true value for system availability. However, this figure should be useful as a 'Figure of Merit' for comparisons with the figure derived for the same system using a different methodology or level of logistics support. When used in this context, the figure should provide an accurate assessment of the relative effectiveness of two spares allowance policies.

VI. EXAMPLE OF TIGER ANALYSIS

A. EQUIPMENT CONFIGURATION AND FAILURE RATES

1. Block Diagram and Operating Rules

As an example of the use of TIGER proposed in this thesis a hypothetical video display unit will be analyzed. The unit consists of a power section; signal processing section; and video display section. The required reliability block diagram is shown in figure 4.

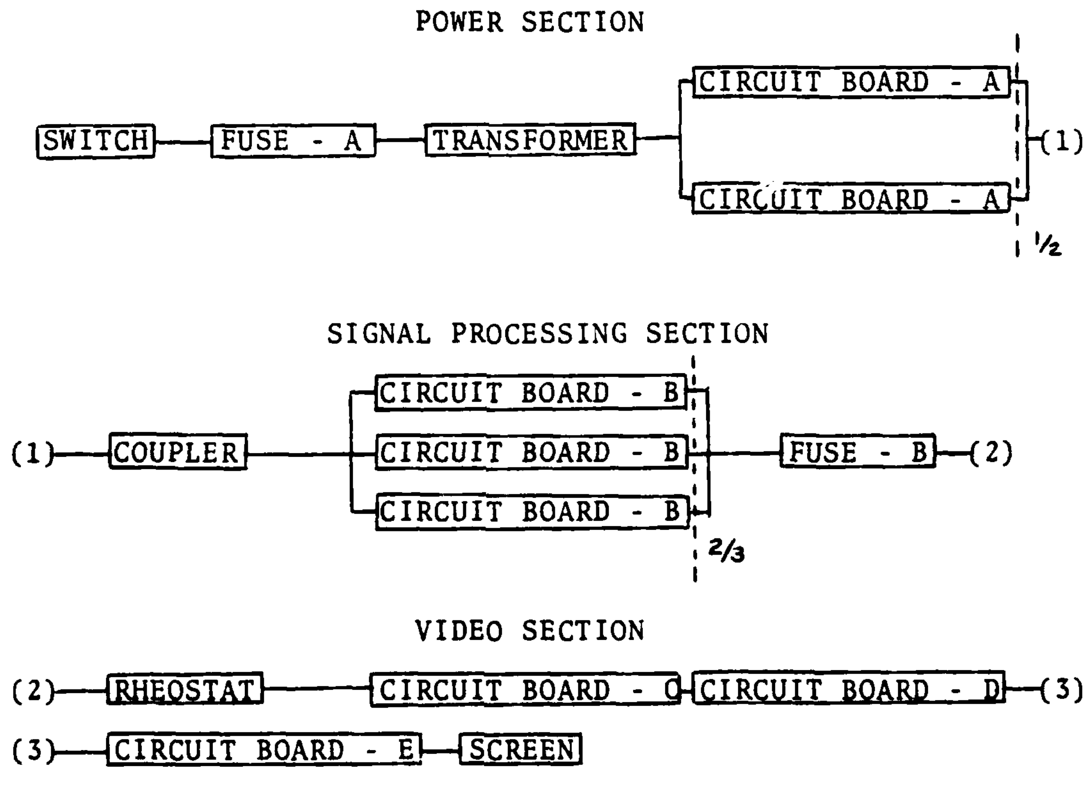


Figure 4

The three sections are connected in series to form the entire unit. Only one of circuit board A is required to be 'up' in the power section, and two of circuit board B in the signal processing section. The failure of two of either circuit board A or B or the failure of any other single part will cause system failure.

2. Failure Rates

The following is a list of the BRF for each part and corresponding MTBF:

ITEM	BRF	MTBF
Switch	.09	97400
Fuse - A	2.50	3506
Transformer	.17	51565
Circuit Board - A	2.10	4174
Coupler	.23	38113
Circuit Board - B	2.50	3506
Fuse - B	3.60	2435
Rheostat	.12	73050
Circuit Board - C	1.20	7305
Circuit Board - D	2.20	3985
Circuit Board - E	1.70	5156
Video Screen	.20	43830

B. LOGISTIC SUPPORT (COSAL) MODELS USED

The COSAL models evaluated were the standard .25 FLSIP and a modified FLSIP as proposed by the CNO Shipboard Parts Allowance Policy Study (Ref. 3). This modification consists of changing the FLSIP cut point to .1 (one demand in ten years) and providing an allowance quantity of two (vice one) for those items with a BRF between 2.0 and 4.0.

C. RESULTS OF ANALYSIS

1. Results of TIGER Simulation

The following tables provide a summary of the relevant output from the two TIGER simulation runs for 90 day missions. The actual computer output is self explanatory and a sample is included as a separate section of this thesis. The percent unavailability column indicates the percent of unavailability caused by each item.

.25 FLSIP (Availability = .7229)

ITEM	SPARES STOCKED	SPARES USED	FAIL/ MISSION	PERCENT UNAVA
Switch	0	.00	.025	3.35
Fuse - A	1	.50	.637	14.54
Transformer	0	.00	.042	6.42
Cir Bd - A	2	.96	1.05	6.77
Coupler	0	.00	.064	9.35
Cir Bd - B	4	1.84	1.897	.81
Fuse - B	1	.57	.793	24.01
Rheostat	0	.00	.030	3.74
Cir Bd - C	1	.27	.318	3.64
Cir Bd - D	1	.43	.541	11.99
Cir Bd - E	1	.34	.416	7.07
V. Screen	0	.00	.052	8.29
			5.865	99.98

.1 MOD FLSIP (Availability = .9064)

ITEM	SPARES STOCKED	SPARES USED	FAIL/ MISSION	PERCENT UNAVA
Switch	0	.00	.017	8.53
Fuse - A	2	.59	.607	5.41
Transformer	1	.05	.054	.75
Cir Bd - A	2	.92	1.015	24.70
Coupler	1	.06	.067	1.23
Cir Bd - B	4	1.84	1.897	2.58
Fuse - B	2	.79	.844	18.19
Rheostat	1	.04	.044	.00
Cir Bd - C	1	.27	.310	13.43
Cir Bd - D	2	.53	.553	5.42
Cir Bd - E	1	.35	.414	18.99
V. Screen	1	.04	.046	.74
			5.868	99.97

2. Interpretation of Results

As would be expected, the .1 Mod FLSIP provided a greater depth and range of spares than the .25 FLSIP. The addition of seven more spares resulted in an increase in AVA from .7229 to .9064, a significant increase. For the .25 FLSIP run, the item accounting for highest percentage of availability is fuse - B, with 24.01 percent. Since FLSIP provides a 90 percent confidence level of protection for those items with a BRF $\geq$4.0 ($\geq$ 1/qtr), the BRF of 3.60 places the fuse just below this cut and therefore it is allocated only one spare. For the .1 Mod FLSIP run fuse - B no longer is the largest contributor to unavailability. Circuit board - A is the largest, accounting for 24.70 percent of the unavailability. If further incremental improvements were to be made to the .1 Mod FLSIP COSAL, the first additional spare should be circuit board - A followed by circuit board - B, fuse - B, and so on down the list of unavailability percentages.

The difference in AVA for the two COSALS is the most important statistic. If availability in the range of .9 were required for the system, the .1 Mod FLSIP should be used. If however, the system were not that essential, the .7 availability provided by FLSIP should be used to enable scarce spares funding resources to be used on more essential systems.

VII. SUMMARY AND CONCLUSIONS

This thesis focused on one basic problem; that of providing logistics support for Naval units afloat. Current guidelines and measures of effectiveness were presented along with several of the methodologies by which the policies are being carried out.

The NAVSEA TIGER reliability block diagram simulation program was introduced as a currently used method of evaluating ship reliability and also as a proposed method of generating allowance documents. A key input to any reliability calculation is the MTBF. The use by the Navy of a BRF vice MTBF was reviewed and a solution proposed to enable BRF to be used as an input to the TIGER simulation.

A technique for using TIGER to evaluate the effect of various spares allowance policies upon system availability was introduced, followed by an example of such an analysis.

The Navy is interested in providing logistics support so as to maximize the operational availability of its ships within given resource constraints. Mathematical models designed to allocate spares while maximizing system availability require extensive amounts of data (much of which is either not available or retrievable by computer). They are computationally infeasible to implement on a Navy-wide basis. Thus, it appears that the Navy will continue to use simpler parts-counting models such as those described in this thesis. No claim of optimality with respect to 'system availability' can be made with such simple models that make no attempt to consider the system as anything other than a collection of parts.

The models that are being used are regulated by controlling the values of certain parameters such as FLSIP cut points or essentiality codes. Since there is no way to analytically relate these models to system effectiveness, a tool such as the TIGER simulator is needed to evaluate the future impact on system availability of a given provisioning or support policy. The assumptions required to perform this type of evaluation have been discussed throughout this thesis.

The following are recommendations for additional work in the topic of this thesis or for additional uses of the TIGER simulation:

1. Use as an evaluation tool for various provisioning models.

2. Use to evaluate maintenance policies and their effect on required manning levels.

3. Use as a system design tool.

4. Use on new equipment being introduced into the fleet to establish a FLSIP cut point. Code equipment with this cut point instead of the vital/non-vital codes currently in use, and use this cut point when preparing the COSAL.

5. Evaluate the effect of the assumptions made in this thesis and other problems such as the gradual degredation of equipment (not simply up or down) and the effect of the annual revisions to the BRFs.

APPENDIX A

ACRONYMS

Ao	Operational Availability
AVA	Availability
BRF	Best Replacement Factor
COSAL	Coordinated Shipboard Allowance List
CNO	Chief of Naval Operations
EST	Estimate
FBM	Fleet Ballistic Missile
FFG	Guided Missile Frigate
FLSIP	Fleet Logistics Support Improvement Program
MCO	Maintenance Criticality Oriented
MEC	Military Essentiality Code
MRU	Minimum Replacement Unit
MTBF	Mean Time Between Failure
MTTF	Mean Time to Failure
MTTR	Mean Time to Repair
NAVSEA	Naval Sea Systems Command
NPS	Naval Postgraduate School
PMR	Preventative Maintenance Requirement
RED	Readiness
REL	Reliability
RMA	Reliability/Maintainability/Availability

SPCC	Ships Parts Control Center
SSN	Fast Attack Submarine (Nuclear)
TIGER	Simulation Program Name
TOR	Technical Overide

APPENDIX B

TIGER PROGRAM VARIABLES LIST

The following is a list of the variables used in the TIGER program and their respective usage/definition. All variables which were used in this thesis are included along with some from other optional parts of the TIGER program. Numbers at the right indicate the data card on which the variable is input into the program.

A	Subroutine DEMO producer risk	21A
ACMMH	Average corrective manhours per mission	
ADT	Administrative delay time	
AENDT1	Downtime in remainder of phase due to abort	
AENDT2	Downtime in remainder of mission due to abort (up to current phase)	
AFM	Average failures per mission	
ALDONE	Sum of three DONE(I); if zero, skips spare printout	
APPL	Bad apple unreliability and unavailability printout	21
AVA	Average availability or availability	
AVAINS	Instant availability	
AVA1	Average availability	
AVAL	Average availability	
AVGCST	Avergae cost per hour of repairman	7M
B	Subroutine DEMO consumer risk	21A

BAPRIN	Bad Apple printout indicator, when equals -1, print	
BILL	Temporary variable used to integerize the number of spares	
BLNK	Four character alphabetic blank	
COUNTB(I)	Number of failures for equipment I	
DAY(IX)	Occupation symbol	15A,M
DELT	Time Difference	
DEMO	Probability ratio test plan for system	21
DMNO	Same as DEMO	
DNT1	Total system downtime in phase	
DNT2	Total system downtime in mission	
DONE(I)	Average number of spares used from ship, tender, depot(I=1,3)	
DUM(J)	Dummy variable to read F1	
DUMMY	Skill types	
ENDPHA	End of phase time	
EQUIP(I)	Person type numbers of people who could be operating this type of equipment	15G
ETIME	Event time	
EX(I,J)	Administrative delay time (U,W)	
F(I,J)	Same as F1	
FCOUNT	Real value of JCOUNT	
F1	Alphabetic equipment description	8
GMMA	Alphabetic request for GAMMA subroutine	21
HAD	DEMO X-axis accept intercept	21A
HRD	DEMO X-axis reject intercept	21A
I	Various indices; equipment type number	8

IABC	Index	
IAUP	Instant availability (up for entire simulation)	
IAUP1(I)	Instant availability (up at beginning of sequence	
IAUP2(I)	Instant availability (cumulative up at beginning of sequence	
IB(I)	Group number and equipment and groups which make up the group	18
IBLANK	14 alphabetic blank spaces	
IBM	Equipment type number	
IBNUM(I,J)	Number of configuration matrix cards in phase	
ICHLD	Child in reliability tree	
ICRI	Subsystems exceeding mission allowable downtime (TAD2)	
ID	Alphabetic system name	16,17
IDIFF	Total equipment failures (all types)	
IDUM	Same as IUT	
IEQ	Absolute value of IEQU(J)	
IEQU(I)	Equipment type array	
IFF	Number of failures	
IFFEOP	Same as ISW	
IFLAG	Repair option in each phase	6
IFR	Number of repairs	
IGRP	Equipment group	
II	Spare location (ship, tender, depot)	
III	II-1	
IIUSED(I,J)	Spares used per equipment type from each location	

IK	Phase indicator	
IK2	Phase indicator	
IK3	Phase indicator	
ILB	Counter for NEQ	
ILL	Phase subscript for VDC(IU,ILL)	
IND	Equipment type	
INDEX	Index; equipment number	
INEWA	Index used to rank equipment by number of failures	
INMI(I)	Number of missions run	
INOABT(I)	Number of aborts in the sequence	
INREJ	Not used	
INUM	Maximum number of mission repetitions (50)	
IOR	Number of equipment operating rules	
IPTR	Parent/Child index	
IPRNT	Parent reliability tree	
IRULE	Equipment operating rule card	19
ISEED	Random number seed	2
ISO	+=string; -=standby	
ISPARE(I,J)	Quantity of spares at ship, tender, depot	15
ISS	System/subsystem identification number	16,17
ISSA(I)	Phase allowable downtime	
ISTB(I)	Equipment operating rules	19
ISUM	Summation	
ISW	Subsystem status (1=up, -1=down)	
ISSC	Subsystems exceeding allowable downtime	

ISYS(K)	System in phase K	
ITEMP	System status indicator	
ITEMP2	Subsystem status indicator	
ITIME	Number of sets	21A
ITER	Number of simulations per set	21A
ITOTAL	Integer value of total	
IU	Variable duty cycle (IUI(I))	
IUI(I)	Variable duty cycle indicator	8
IUNLIM	Alphabetic 'unlimited spares'	
IUT	Same as IDUM	
IUSED(I,K)	Spares used from ship, tender, depot	
IV	Variable duty cycle indicator (IUI=IV)	9
IVALUE(I)	Temporary variable for IB or ISTB	
IX	NUM+1	
IXX	Equipment type	
IXXT	Phase type	
J	Various indices; equipment type	
JA	Index for IB	
JB	Index for IB	
JBB	Phase sequence number	
JBB1	JBB-1	
JC	Current timeline	
JCC	Number of timelines	1
JCOUNT	Number of failed equipments	
JIND	Equipment type	
JNUM	Integer of XNUM	

K	Various indices	
KAA	Mission number being simulated	
KAB	Mission number being simulated	
KD	Trucation line accept	
KEQ	Equipment number	
KEQU(I)	Number of failures for equipment type I	
KID	Dummy variable	
KID1	Equipment group	
KID2	Equipment group	
KK	Same as LL; index of equipment number	
KKK	Phase in mission	
KKK2	Same as KKK	
KOPT	Printout option switch	5
KS(I)	Output options for KOPT	5
KSS	Index	
KT	IB(, ,1), or number required up in group	
K1	Equipment type; trail shape parameter	
L	Same as LL	
LCL	Lower confidence limit	
LL	Phase type number	16,17
LLL	Duration of phase sequence	
LOAD(I)	Equipment numbers assigned to equipment type	12
MAXIB	Maximum number of configuration matrix cards (300)	
MAXNEQ	Maximum number of equipments (500)	
MAXNPH	Maximum number of phases (6)	

MAXRUN	Maximum number of mission (1000)	
MAXSEQ	Total number of phases	
MAXSS	Maximum number of subsystems (31)	
MAXSTD	Maximum number of equipment operating rule cards (49)	
MAXTYPE	Maximum number of equipment types (200)	
MDT	Estimator of MTTR	
MKBA	Bad Apple equipment vector	
MM	0	
MTBMF	Mean time between mission failures	
MUT	Instanteneous MTBF parameter	
M1	Trial scale parameter	
N	Counter; NSS+1	
NEQ	Equipment type counter	
NLINE(I)	Number of configuration cards in phase	
NL1	NLINE(LL)	
NN	Index	
NMAX	Maximum number of missions	2
NOPT	Optimal number of mission	2
NPH	Number of phases	2
NRO	Number required operating	18
NSS	Number of subsystems in phase	16
NTY	Last number of equipment types	
NTYPE	Equipment type	12
NT1	Equipment type number	
NUM	Mission number counter	

PERC	Percent unreliable	
PL	Reliability specification	2
R	Dummy variable used to find next event temporary variable used to calculate VDC; discrimination ratio	21A
RDT	Running down time	
RED	Readiness	
REDAD1(I)	Adjusted time for readiness calculation in phase	
REDAD2	Adjusted time for readiness calculation in mission	
RED1	Readiness	
RED2	Readiness	
REL	Reliability	
RELGA(JBB)	Reliability (RELPY) for phase sequence	
RELPY	Reliability up to and including phase just completed	
REPOL	Percent of repairs performed aboard ship	7
RN	Random number	
RN3	Random number	
RUNID	Alphabetic program identification line	1
SLD	Slope	21A
SPRS	Alphabetic request for SPARES output	21
SR	Intermediate value used to calculate ST	
SSTIME(I,J)	System/subsystem allowable sustained downtime	16,17
ST	Intermediate time	
STEPHAS	Accumulated phase time	
SUMX	Total simulation time	

SUMX2	Sum of SUMX squared (for variance calculation)
SX	Spares multiplier
T	Duration of phase
TABORT	Time of abort
TACMMH	Total average corrective maintenance manhours/mission
TAD1	Same as SSTIME
TAD2	Mission allowable downtime 7
TAFM	Total average failures per mission
TDEOP	Time down at end of phase
TDOWN	Time system went down
TIMA(I)	Cumulative phase time
TIME	Simulation clock time
TITLE(K,N)	Alphabetic subsytem title
TNMI	Real value of INMI(JBB)
TOTAL	Number of failed missions
TR	Temporary variable used to find maximum unavailability/reliability
TRR	Same as TR
TP	Same as TIME
TTEMP	Downtime
TTF	Time for failure
TTR	Time to repair
TT1	Phase length
TT2(JBB)	Cumulative time of phase lengths
TT3	Cumulative phase times

TYCOON(I)	Downtime for equipment	
TYCUM	Unavailability	
TYCUM2	Percent unavailability	
T1	SSTIME(, ,1)	
T3	Downtime	
T3SUM	Cumulative downtime	
U	Duty cycle utilization	8
UNAVA	Unavailability	
UNREL	Unreliability	
UP1	Time system up in phase	
UP2(JBB)	Cumulative system uptime	
UP3	Cumulative system uptime	
UP4	Cumulative system uptime	
V	Administrative delay time (tender to ship)	8
VAR	MTBMF variance	
VDC(I)	Duty cycle utilization during each phase	9
VMTTR(I,J)	Variable mean time to repair	10
W	Administrative delay time (depot to ship)	8
X	Various; XMTBF; event indicator (+ fail; - repair)	
XAV	Instant availability	
XAVI	Instant availability	
XCUM	Successful missions in last 50	
XDWN	Number of mission failures (XNUM-XTCUM)	
XIAUPP	Real of IAUP	

XIAUPI	Real of IAUPI	
XID	Alphabetic ID	
XIFF	Real of IFF	
XIRR	Real of IRR	
XK	Standard deviation for lower confidence limit 2	2
XKAA	Real of KAA	
XLCLA	Lower confidence limit of 90 percent	
XM	XMTBF Multiplier	7
XMDT	System man down time	
XMTBA	Mean time between mission failures	
XMTBF	Mean time between failures	8
XMTTR	Mean time to repair	8
XMUT	System mean up time	
XM1	Same as XT	
XNO	Number of non aborts	
XNUM	Real of NUM (total missions run)	
XPCAP	Reliability	
XPLCL	Lower confidence limit	
XT	XMTBF multiplier	7
XTABT(I)	Time of abort mission I	
XTCUM	Cumulative successful missions	
XXT(I)	Phase type (I odd); Duration (I even)	3
XXX	XMTBF or VMTTR	
X2	X squared	
Y	Same as XMTTR	
YD	Truncation line accept	21A

APPENDIX C

SPARES SUBROUTINE VARIABLE LIST

CUT	FLSIP cut point
DUM	Dummy variable
EX90DD	Expected 90 day demand
ITMPOP(I)	Number of equipment type I in reliability block diagram
K	Counter
KFACT	K factorial
PRBSUM	Poisson probability summation
SPR1-14	Various user defined input variables

APPENDIX D

MODIFICATIONS TO TIGER PROGRAM INPUT

To use the GAMMA and DEMO options, the end of the main section of the program must be changed to the following:

```
1210 IF (GMMA.EQ.BLNK) GO TO 1230
1220 CALL GAMMA
1230 CONTINUE
     IF (DMNO.EQ.BLNK) GO TO 1240
     CALL DEMO
1240 STOP
     END
```

Subroutine GAMMA, function GAMF, subroutine DEMO, function CHISQ, subroutine TGEN, and subroutine CKTP must be added to the program deck (note: none of these have been utilized or verified for use on the NPS computer).

The following changes were made to the original input deck:

Card 2 - INREJ replaced by ISEED; the random number generator seed.

Card 14 - If spares subroutine is desired, enter 999. for SX. Fourteen variables (SPR1,SPR2,...,SPR14) may then be read into the spares subroutine in F4.0 format starting in column 25.

These changes are incorporated into the input requirements shown on the following pages. They should be used when preparing the TIGER data input deck.

All integer fields must be right justified

Columns	Format	Variable Name	Description
(1) Timeline Iteration Card			
1-4	I4	JCC	No. of timeline variations to be run for the data deck. If JCC exceeds 1, only phase type and duration card(s) must be added in the back of the data deck, followed by a blank card.
5-80	19A4	RUNID	Alphanumeric run identifier.
(2) Statistical Parameter Card			
1-4	I4	NMAX	Maximum number of missions to be run (should be in multiples of 50 and 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 calulating lower control limit.
17-20	I4	ISEED	Random number seed.
21-24	I4	NPH	No. of phase types--not to exceed 6.

NOTE: - If a predefined fixed number of missions is to be run, set PL =1.0, and NOPT and NMAX to the desired number of missions.

	Columns	Format	Variable Name	Description
(3)	Phase Type and Duration Card(s)			
	1-2	F2.0	XXT(1)	Phase type number for first simulation sequence.
	3-10	F8.0	XXT(2)	Duration of first sequence.
	11-12	F2.0	XXT(3)	Phase type number for second simulation sequence (if any).
	13-20	F8.0	XXT(4)	Duration of second sequence.
	21-22	F2.0	XXT(5)	Phase type number for third simulation sequence (if any).
	23-30	F8.0	XXT(6)	Duration of third sequence.
	31-32	F2.0	XXT(7)	Phase type number for fourth sequence (if any).
	33-40	F8.0	XXT(8)	Duration of fourth sequence.
	41-42	F2.0	XXT(9)	Phase type no. for fifth sequence (if any).
	43-50	F8.0	XXT(10)	Duration of fifth sequence.

Note: If more than 5 phase sequences are needed, continue on additional cards using the same fields. No more than 95 phase sequences are permitted.

(4) *****Blank Card********

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

If KOPT=5, select from the following output options as needed (otherwise leave the field(s) blank):

Columns	Format	Variable Name	Description
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: down time 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. (For 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 & subsystem status.
45-48	I4	KS(11)	= 1: TIGER/MANNING denugging printout.

Columns	Format	Variable Name	Description
Printout Option Card (Cont.)			
49-52	I4	KS(12)	= 1: Status of all groups
53-56	I4	KS(13)	= 1: Downtime message.
(6) Phase Repair Card			
1-4	I4	IFLAG(1)	Repair option for each phase type, up to 6: = 0 if on-board repair allowed in the phase. = 1 if no on-board repair allowed. = 2 if on-board repair allowed but failure inhibited.
5-8	I4	IFLAG(2)	
9-12	I4	IFLAG(3)	
13-16	I4	IFLAG(4)	
17-20	I4	IFLAG(5)	
21-24	I4	IFLAG(6)	
(7) Repair Policy Card			
1-4	F4.0	REPOL	Decimal fraction of repairs to be performed aboard ship, i.e. organizational level.
5-12	F8.2	TAD2	Mission allowable downtime
13-16	F4.0	XM	MTBF Multiplier. Default = 1.0
17-20	F4.0	XT	MTTR Multiplier. Default = 1.0

Columns	Format	Variable Name	Description
(8) Equipment Type Cards (one card for each equipment type)			
1-4	I4	I	Equipment type numbers - should be assigned sequentially starting at 1, not to exceed 200.
5-20	4A4	F1	Equipment type description/nomenclature.
21-28	F8.0	XMTBF	Mean time between failure (MTBF).
29-32	F4.0	XMTTR	Mean time to repair (MTTR). Precede by negative sign and include the variable MTTR card if variable MTTR option desired. Non-repairable is indicated by a value of 9999.
33-36	F4.0	U	Duty cycle/Utilization (non-zero decimal fraction).
37-40	F4.0	V	Administrative delay time from tender to ship.
41-44	F4.0	W	Administrative delay time from depot to ship.
45-48	I4	IUI	If a variable duty cycle (VDC) for this equipment type is desried, assign a sequential number (between 1 and 50) and include the VDC card following. Otherwise leave this field blank.

Columns	Format	Variable Name	Description
(9) Variable Duty Cycle (VDC) Card			(Optional - If IUI on previous type card is non-zero, place this card immediately behind the type card to which it refers. A maximum of 50 VDC cards per deck are allowed.)
1-4	I4	IV	VDC Identifier-sequential number, same as the value of IUI on the preceding equipment type card.
5-8	F4.0	VDC(1)	Duty cycle/utilization of the equipment type during each phase type 1-6. These values override the value of *U* on the preceding Equipment Type 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)	
(10) Variable Mean Time to Repair (MTTR) Card			(Optional - If XMTTR is negative on the Equipment Type Card place this card behind the VDC Card or, if there is no VDC Card, behind the Equipment Type Card.)
1-4	F4.0	VMTTR(1)	MTTR values of the equipment type during each phase type 1-6. Non-repairable is indicated by 9999.

	Columns	Format	Variable Name	Description
	Variable Mean Time to Repair (MTTR) Card (Cont.)			
	5-8	F4.0	VMTTR(2)	
	9-12	F4.0	VMTTR(3)	
	13-16	F4.0	VMTTR(4)	
	17-20	F4.0	VMTTR(5)	
	21-24	F4.0	VMTTR(6)	
(11)	*********Blank Card*********			(This indicates the end of the equipment type cards.)
(12)	Equipment Cards	(One for each equipment type - Place sequentially by type number)		
	1-4	I4	NTYPE	The type number associated with the equipment listed in the next field(s).
	5-8	I4	LOAD(1)	Equipment numbers of those equipment which belong to the designated equipment type - up to 19 equipment per card (if there are more than 19 equipment associated with a given type, use additional equipment cards and repeat the same type number). The largest equipment number allowed by the program is 500. The total number of equipment must not exceed 500. No gaps are allowed between equipment number 1 and the largest assigned equipment number.
	9-12	I4	LOAD(2)	
	13-16	I4	LOAD(3)	
	17-20	I4	LOAD(4)	
	21-24	I4	LOAD(5)	
	25-28	I4	LOAD(6)	
	29-32	I4	LOAD(7)	

Columns	Format	Variable Name	Description
Equipment Cards (Cont.)			
33-36	I4	LOAD(8)	
37-40	I4	LOAD(9)	
41-44	I4	LOAD(10)	
45-48	I4	LOAD(11)	
49-52	I4	LOAD(12)	
53-56	I4	LOAD(13)	
57-60	I4	LOAD(14)	
61-64	I4	LOAD(15)	
65-68	I4	LOAD(16)	
69-72	I4	LOAD(17)	
73-76	I4	LOAD(18)	
77-80	I4	LOAD(19)	

(13) ********Blank Card******** (This indicates end of equipment cards.)

(14) Blank Card or literal "UNLIMITED SPARES" starting in column 1. If Blank Card is used then the spares multiplier (SX) may be inserted in Col. 21-24. The format for SX is F4.0 and the default value is 1.0; Use 999. to call SPARES subroutine. Variables SPR1-SPR14 may be inserted in F4.0 format starting in Col. 25.

	Columns	Format	Variable Name	Description
(15)	Spares Cards	(Omit if unlimited spares specified above. One spares card for each equipment type-program assumes these cards are in sequential order starting with Type 1)		
	1-4	I4	ISPARE(1)	Number of organizational level spares (on-board) for the equipment type.
	5-8	I4	ISPARE(2)	Number of spares at the tender for the equipment type.
	9-12	I4	ISPARE(3)	Number of spares at the base (depot) for the equipment type.

NOTE: For each phase type, a set of the remaining cards (except the optional output and demo cards which appear once) must be placed consecutively in the data deck.

	Columns	Format	Variable Name	Description
(16)	System Card			
	1-4	A4	ID	Any alphanumeric, e.g., the literal "SYST"
	5-8	I4	LL	Phase type number (sequential) - Maximum value is 6.
	9-12	I4	NSS	Number of subsystems in the phase (varies only from 1 to 31)
	13-16	I4	ISS	System identification number (usually last group number on the configuration matrix cards).

Columns	Format	Variable Name	Description
System Card (Cont.)			
17-24	F8.0	SSTIME	System allowable sustained down time TAD1 (should not be less than subsystem TAD1 values). This value should be less than or equal to TAD2 (Repair Policy Card). To inhibit aborts use a value of 100000.
(17) Subsystem Cards	(One for each subsystem - up to 31.) At least one subsystem is required.		
1-4	A4	ID	Any alphanumeric, e.g., the literal "SS1", "SS2", ... "SS31".
5-8	I4	LL	Phase type number.
13-16	I4	ISS	Subsystem identification number. This is a group number for a group defined on a Configuration Matrix Card (see below). Each designated subsystem group must be a group that, upon its failure, causes the system to fail.
17-24	F8.0	SSTIME(2)	Subsystem allowable sustained down time (TAD1). This value should be less than or equal to SSTIME on the System Card. To inhibit aborts use a value of 100000.

	Columns	Format	Variable Name	Description
(18)	Configuration Matrix Cards			(One card for each group, up to 300 cards)
	1-4	I4	NRO	The number of members in the group defined on this card that are required to be operating and in an upstate.
	5-8	I4	IB(1)	The group 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 equipment and groups which make up the group defined on this card. The maximum number of members in a group is unlimited; however, if there are more than 7, a continuation card is required, which is of the same format. The number required and master group number must be identical on all continuation cards.
	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)	
(19)	Equipment Operating Rule Cards			(Optional - Usually this card is placed immediately behind the configuration matrix card which refers to the equipment and groups on this card.) These cards indicate the equipment operating rules for string or standby equipment. The string equipment operating rule causes shutdown of a designated series equipment upon failure of any of the other equipment or equipment groups on the card. The standby

Columns	Format	Variable Name	Description
Equipment Operating Rule Cards (Cont.)			
			equipment operating rule causes designated equipment to be energized upon failure of any of the other equipment or equipment groups on the card. The maximum number of equipment operating rules is 49. (One rule defined per card.)
1-4	I4	ISTB(1)	The designated equipment number. If it is a standby equipment, it must be preceded by a minus sign.
5-8	I4	ISTB(2)	The other equipment or equipment group numbers.
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	Place any non-zero integer in this field (to distinguish Equipment Operating Rule Cards from Configuration Matrix Cards).

	Columns	Format	Variable Name	Description
(20)	*******Blank Card*********			(This indicates end of phase configuration and operating rules.)
(21)	Optional Output Card			(Optional - Appears once in computer job deck)
	1-4	A4	SPRS	Place any alphanumeric, e.g., "SPR", in this field if a table of spares usage is desired.
	5-8	A4	APPL	Place any alphanumeric, e.g., "APL", in this field if a summary table of equipment that caused mission failures (unreliability) and system down times (unavailability) is desired.
	9-12	A4	GMMA	Place any alphanumeric, e.g., "GMA", in this field if the gamma distribution output is desired.
	13-16	A4	DEMO	Place any alphanumeric, e.g., "DEMO", in this field if a sequential probability ratio test plan for the system being analyzed is desried. If this option is exercised, an additional card, 21A, is required.
(22)	DEMO Information Card			(Optional - must be included if DEMO is specified on the Optional Output Card.)
	1-4	F4.0	A	Producer Risk.
	5-8	F4.0	B	Consumer Risk

Columns	Format	Variable Name	Description
DEMO Information Card (Cont.)			
9-12	F4.0	R	Discrimination Ratio.
The following are optional inputs:			
13-16	F4.0	HAD	X-Axis accept intercept (Delta).
17-20	F4.0	HRD	X-Axis reject intercept (Delta).
21-24	F4.0	YD	Trucation line accept (Delta).
25-28	F4.0	SLD	Slope (Delta).
29-32	I4	KD	Truncation line reject (Delta).
33-36	I4	ITIME	Number of sets (explained in Appendix C).
37-40	I4	ITER	Number of simulations per set.
41-44	I4	N	Random number initializer.

TIGER COMPUTER OUTPUT (SAMPLE)

EQUIP FAILURES AND CORRECTIVE MAINTENANCE(CM) SUMMARY

EQUIP. NO.	TYPE NO.	TOTAL EQUIP. FAILURES	AVG. NO. FAILURES PER MISSION	AVG. CM MANHOURS PER MISSION
1	1	25	0.025	0.0
2	2	637	0.637	0.0
3	3	42	0.042	0.0
4	4	525	0.525	0.0
5	4	525	0.525	0.0
6	5	64	0.064	0.0
7	6	636	0.636	0.0
8	6	582	0.582	0.0
9	6	679	0.679	0.0
10	7	793	0.793	0.0
11	8	30	0.030	0.0
12	9	318	0.318	0.0
13	10	541	0.541	0.0
14	11	416	0.416	0.0
15	12	52	0.052	0.0
		5865	5.865	0.0

AVERAGE NUMBER OF SPARES USED PER MISSION

SPARES TYPE	SHIP STOCK	USED	TENDER STOCK	USED	BASE STOCK	USED
2	1	0.50	0	0.0	0	0.0
4	2	0.96	0	0.0	0	0.0
6	4	1.84	0	0.0	0	0.0
7	1	0.57	0	0.0	0	0.0
9	1	0.27	0	0.0	0	0.0
10	1	0.43	0	0.0	0	0.0
11	1	0.34	0	0.0	0	0.0

CRITICAL EQUIPMENTS

UNAVAILABILITY AND PERCENT OF UNAVAILABILITY

NAME	NUM HRS	UNAVA	PERCENT	EQU TYPE	EQU NUM
FUSE - E	143678.1250	0.0665	24.01	7	10
FUSE - A	86987.9375	0.0403	14.54	2	2
CIRCUIT BD - D	71777.3125	0.0332	11.99	10	13
COUPLER	55935.1875	0.0259	9.35	5	6
VIDEO SCREEN	49632.4648	0.0230	8.29	12	15
CIRCUIT BD - E	42291.3203	0.0196	7.07	11	14
TRANSFORMER	38421.7227	0.0178	6.42	3	3
CIRCUIT BD - A	24414.9922	0.0113	4.08	4	5
RHEOSTAT	22381.4844	0.0104	3.74	8	11
CIRCUIT BD - C	21809.4063	0.0101	3.64	9	12
SWITCH	20024.2852	0.0093	3.35	1	1
CIRCUIT BD - A	16121.3125	0.0075	2.69	4	4
CIRCUIT BD - B	1794.4338	0.0008	0.30	6	8
CIRCUIT BD - B	1640.1653	0.0008	0.27	6	7
CIRCUIT BD - B	1433.9836	0.0007	0.24	6	9

CRITICAL EQUIPMENTS

UNRELIABILITY AND
PERCENT OF MISSION FAILURES

DESCRIPTION	NO. FAILURES	UNREL	PERCENT	EQUIP TYPE	EQUIP NO.
FUSE - B	162.0	0.1620	26.30	7	10
FUSE - A	102.0	0.1020	16.56	2	2
CIRCUIT BC - D	78.0	0.0780	12.66	10	13
CIRCUIT BD - E	49.0	0.0490	7.95	11	14
COUPLER	48.0	0.0480	7.79	5	6
VIDEO SCREEN	34.0	0.0340	5.52	12	15
TRANSFORMER	30.0	0.0300	4.87	3	3
CIRCUIT BD - A	25.0	0.0250	4.06	4	5
CIRCUIT BD - A	24.0	0.0240	3.90	4	4
CIRCUIT BD - C	22.0	0.0220	3.57	9	12
RHEOSTAT	20.0	0.0200	3.25	8	11
SWITCH	15.0	0.0150	2.44	1	1
CIRCUIT BD - B	3.0	0.0030	0.49	6	8
CIRCUIT BD - B	2.5	0.0025	0.41	6	7
CIRCUIT BD - B	1.5	0.0015	0.24	6	9

TOTAL NO. MISSIONS=1000
TOTAL NO. MISSION FAILURES= 616

```
ANOTHER SET OF 50MISSIONS WILL BE RUN TO OBTAIN REQUIRED STATISTICAL CONFIDENCE.
IN PHASE  1 SEQ  1    MISSION   952    ABORTED AT TIME 1418.5276  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   10 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   955    ABORTED AT TIME  686.8821  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    6 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   956    ABORTED AT TIME  358.1155  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    6 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   959    ABORTED AT TIME 1491.1406  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    2 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   960    ABORTED AT TIME  948.6260  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   13 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   961    ABORTED AT TIME 1098.0498  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    2 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   962    ABORTED AT TIME 1394.3967  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    2 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   963    ABORTED AT TIME   37.7034  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   11 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   966    ABORTED AT TIME 1703.9910  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   13 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   967    ABORTED AT TIME 1030.7476  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   11 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   968    ABORTED AT TIME  670.4741  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    1 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   969    ABORTED AT TIME  920.3120  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    2 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   970    ABORTED AT TIME 1631.4922  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    2 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   973    ABORTED AT TIME  762.5108  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   11 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   975    ABORTED AT TIME 1984.1504  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    5 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   976    ABORTED AT TIME 1109.6431  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    2 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   977    ABORTED AT TIME 1841.3823  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    5 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   978    ABORTED AT TIME  555.3267  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   10 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   979    ABORTED AT TIME  857.0833  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   10 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   980    ABORTED AT TIME 1542.3799  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   10 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   981    ABORTED AT TIME  903.8152  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   12 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   982    ABORTED AT TIME 2122.6633  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    2 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   983    ABORTED AT TIME 1103.4336  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   10 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   984    ABORTED AT TIME   73.3333  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   15 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   988    ABORTED AT TIME  945.9255  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   10 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   989    ABORTED AT TIME 1239.1401  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   10 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   990    ABORTED AT TIME 2102.9492  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   14 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   991    ABORTED AT TIME  476.9080  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   15 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   994    ABORTED AT TIME 1741.2859  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    2 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   995    ABORTED AT TIME 1524.3569  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   10 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   997    ABORTED AT TIME 1169.4402  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   10 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION   999    ABORTED AT TIME  870.4844  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT    2 DOWN IT WILL COME UP AT   -500000.0000
IN PHASE  1 SEQ  1    MISSION  1000    ABORTED AT TIME  415.2183  BECAUSE SYST  EXCEEDED MISSION ALLOWABLE DOWNTIME   0.0  HRS.
               EQUIPMENT   10 DOWN IT WILL COME UP AT   -500000.0000
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```
                                                   INSTANT AVAILABILITY          IS 1.0000
        RELIABILITY PHASE  1,   1, IS 0.3840       RELIABILITY UP TO PHASE     1 IS 0.3840
        READINESS                  IS 0.7229       READINESS                     IS 0.7229
        AVERAGE AVAILABILITY       IS 0.7229       AVERAGE AVAILABILITY          IS 0.7229
                                                   INSTANT AVAILABILITY          IS 0.3840

A GRAND TOTAL OF  1000 MISSIONS HAVE BEEN RUN.
THE RELIABILITY IS          0.3840
THE LOWER CONF LIMIT IS     0.3646
THE SPEC REQUIREMENT IS     1.0000
THE READINESS IS            0.7229
THE AVERAGE AVAILABILITY IS    0.7229
THE INSTANT AVAILABILITY IS    0.3840

THE MEAN TIME BETWEEN MISSION FAILURES IS                 2534.9
THE LCI,90, MTBMF IS                     1033.9
THE MTBMF VARIANCE IS                       1375166.0

THE SYSTEM MUT IS                 2535.0
THE SYSTEM MDT IS                  0.189
SIMULATION COMPLETE-OPTIMUM NUMBER MISSIONS WERE RUN
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TIGER IBM/360 FORTRAN IV COMPUTER PROGRAM

```
C          MAIN
C ++++++++ TIGER +++++++++++++++
C +++++ NAVSEC 6112 LUETJEN+MANDEL+VAIL+ALLEY+BROWN ++++++
C ============== FEB 1979 ===============
C
      COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ
     1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
     2,RELPY,REPOL,STPHAS,TP,T1,XCUM,TT3,UP3,IFFECP,T3,TIME,T3SUM
      COMMON/BETA/NRO(6,300),IB(6,300,8),NLINE(6)
      COMMON/EXTRA/ KS(20),ISW(31)
      COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
      COMMON/NPH/ NSS(6),IFLAG(6),TITLE(6,31),SSTIME(6,31,2),ISS(6,31)
      COMMON /SEQ/INOABT(100),INMI(100),IAUP1(100),TT2(100),UP2(100)
     1,IAUP2(100)
      COMMON /TYP/EX(2,200),ISPARE(3,200),IUSED(3,200),IIUSED(3,200)
      COMMON /MAX/MAXNEQ,MAXTYP,MAXIB,MAXSTD
      COMMON /GAMMAA/XMTBA,VAR,RELGA(100),TIMA(100),XXT(200),ITT,ISEED
      COMMON /TABORT/ XTABT(1000),RDT
      COMMON /TIGAP/ UP4,XNUM,BAPRIN,AVA,XPCAP,RUNID(19),TYCOON(500)
     +,COUNTB(500),XTCUM
      COMMON /DONE/DONE(3)
      DATA  BLNK/4H    /
C
      MAXRUN=1000
      MAXNPH=6
      MAXSTD=50
      MAXNEQ=500
      MAXTYP=200
      MAXIB=300
      MAXSS=31
      MAXSEQ=100
      CALL OVFLOW
      READ (5,10) JCC,(RUNID(I),I=1,19!
   10 FORMAT(I4,19A4)
      WRITE (6,220) JCC
      DO 1230 JC=1,JCC
   20 WRITE (6,30) (RUNID(I),I=1,19)
   30 FORMAT(1H1,30X,19A4//)
      WRITE (6,40)
      WRITE (6,50)
      WRITE (6,55)
   40 FORMAT(1X,50H ++++++++++++++++++++    TIGER   ++++++++++++++++++ )
   50 FORMAT(/1X,50H++ NAVSEC 6112 LUETJEN+MANDEL+VAIL+ALLEY+BROWN ++ )
   55 FORMAT(/1X,50H++NPS IBM/360 VERSION LT. J. LEATHER THESIS 9/80++)
      BAPRIN=0.0
      DO 70 I=1,MAXNEQ
   60 COUNTB(I)=0.0
      TYCOON(I)=0.0
```

```
      KEQU(I)=0                                                         MAIN0480
   70 ETIME(I)=100000.                                                  MAIN0490
      NUM=0                                                             MAIN0500
      IFF=0                                                             MAIN0510
      IFR=0                                                             MAIN0520
      UP4=0.0                                                           MAIN0530
      T3=0.0                                                            MAIN0540
      T3SUM=0.0                                                         MAIN0550
      SUMX=0.0                                                          MAIN0560
      SUMX2=0.0                                                         MAIN0570
      DO 80 I=1,100                                                     MAIN0580
   80 TIMA(I)=0.                                                        MAIN0590
      DO 90 I=1,3                                                       MAIN0600
      DO 90 J=1,MAXTYP                                                  MAIN0610
   90 IIUSED(I,J)=0                                                     MAIN0620
      DO 100 I=1,MAXSEQ                                                 MAIN0630
      TT2(I)=0.0                                                        MAIN0640
      UP2(I)=0.0                                                        MAIN0650
      IAUP1(I)=0                                                        MAIN0660
      IAUP2(I)=0                                                        MAIN0670
      REDAD1(I)=0.0                                                     MAIN0680
      INMI(I)=0                                                         MAIN0690
  100 INOABT(I)=0                                                       MAIN0700
      IAUP=0                                                            MAIN0710
      XTCUM=0                                                           MAIN0720
      IF (JC-1) 110,110,140                                             MAIN0730
  110 READ (5,120) NMAX,NOPT,PL,XK,ISEED,NPH                            MAIN0740
  120 FORMAT (2I4,2F4.0,2I4)                                            MAIN0750
  130 FORMAT (1X2I6,2XF4.2,2XF5.2,2XI6,2XI4)                            MAIN0760
  140 CONTINUE                                                          MAIN0770
  160 WRITE (6,170) ISEED                                               MAIN0780
  170 FORMAT (//1X15HRANDOM SEED IS ,I4)                                MAIN0790
      IF (NMAX-MAXRUN) 190,190,180                                      MAIN0800
  180 NMAX=1000                                                         MAIN0810
      NOPT=1000                                                         MAIN0820
  190 DO 200 I=1,NMAX                                                   MAIN0830
  200 XTABT(I)=100000.                                                  MAIN0840
      WRITE (6,130) NMAX,NOPT,PL,XK,ISEED,NPH                           MAIN0850
      IF (MAXNPH-NPH) 1240,210,210                                      MAIN0860
  210 INUM=50                                                           MAIN0870
  220 FORMAT (4I10)                                                     MAIN0880
  230 DO 250 I=1,191,10                                                 MAIN0890
      READ (5,240) XXT(I),(XXT(I+J),J=1,9)                              MAIN0900
      IF (XXT(I)) 260,260,250                                           MAIN0910
  240 FORMAT (5(F2.0,F8.0))                                             MAIN0920
  250 CONTINUE                                                          MAIN0930
  260 WRITE (6,270)                                                     MAIN0940
  270 FORMAT (1H1,10X40HPHASE SEQUENCE  TYPE  DURATION  CUM TIME)       MAIN0950
```

```
      IK=1                                                              MAIN0960
      IK2=2*IK                                                          MAIN0970
      IK3=IK2-1                                                         MAIN0980
      IXXT=XXT(IK3)                                                     MAIN0990
      TIMA(1)=XXT(2)                                                    MAIN1000
      WRITE (6,280) IK,IXXT,XXT(IK2),TIMA(IK)                           MAIN1010
  280 FORMAT (19XI4,2XI4,2XF8.2,2XF8.2)                                 MAIN1020
      DO 300 IK=2,100                                                   MAIN1030
      IK2=2*IK                                                          MAIN1040
      IK3=IK2-1                                                         MAIN1050
      IF (XXT(IK2)) 290,310,290                                         MAIN1060
  290 TIMA(IK)=TIMA(IK-1)+XXT(IK2)                                      MAIN1070
      IXXT=XXT(IK3)                                                     MAIN1080
      WRITE (6,280) IK,IXXT,XXT(IK2),TIMA(IK)                           MAIN1090
  300 CONTINUE                                                          MAIN1100
  310 CONTINUE                                                          MAIN1110
      IF (JC-1) 320,320,330                                             MAIN1120
  320 CALL PACK                                                         MAIN1130
C                                                                       MAIN1140
  330 CONTINUE                                                          MAIN1150
      JBB=1                                                             MAIN1160
      RELPY=1.0                                                         MAIN1170
      RELP=1.                                                           MAIN1180
      UP3=0.0                                                           MAIN1190
      TT3=0.0                                                           MAIN1200
      REDAD2=0.0                                                        MAIN1210
      DO 340 I=1,MAXSS                                                  MAIN1220
  340 ISW(I)=1                                                          MAIN1230
      ICRI=0                                                            MAIN1240
      DNT2=0.0                                                          MAIN1250
  350 STPHAS=0                                                          MAIN1260
      T1=0.0                                                            MAIN1270
C                                                                       MAIN1280
C     RDT IS RUNNING DOWNTIME                                           MAIN1290
C                                                                       MAIN1300
      RDT=0.0                                                           MAIN1310
C                                                                       MAIN1320
C  KKK = 0  INDICATES FIRST PHASE IN MISSION.                           MAIN1330
C                                                                       MAIN1340
C                                                                       MAIN1350
C     START OF MISSION INDICATION                                       MAIN1360
C                                                                       MAIN1370
      IF (KS(8)) 380,380,360                                            MAIN1380
  360 KAB=NUM+1                                                         MAIN1390
      WRITE (6,370) KAB                                                 MAIN1400
  370 FORMAT(1X,16HSTART OF MISSION,I5,20H********************)         MAIN1410
  380 KKK=0                                                             MAIN1420
  390 I=1                                                               MAIN1430
```

```
  400 LL=XXT(I)                                                          MAIN1440
      IF (LL) 450,450,410                                                MAIN1450
  410 ENDPHA=STPHAS+XXT(I+1)                                             MAIN1460
      I=I+2                                                              MAIN1470
      CALL RUN                                                           MAIN1480
      IX=NUM+1                                                           MAIN1490
      IF (XTABT(IX)) 420,420,440                                         MAIN1500
  420 WRITE (6,430)                                                      MAIN1510
  430 FORMAT (1X44HTHE ABORT TIME IS ZERO,CHECK THE INPUT DATA.)         MAIN1520
      GO TO 1240                                                         MAIN1530
  440 STPHAS=ENDPHA                                                      MAIN1540
      N=NSS(LL)+1                                                        MAIN1550
      GO TO 400                                                          MAIN1560
C                                                                        MAIN1570
C STATISTICAL SUMMARY BEGINS HERE                                        MAIN1580
C                                                                        MAIN1590
  450 NUM=NUM+1                                                          MAIN1600
      IF (IFFEOP) 460,460,480                                            MAIN1610
  460 IFF=IFF+1                                                          MAIN1620
      IF (T3) 470,480,470                                                MAIN1630
  470 CONTINUE                                                           MAIN1640
      T3SUM=T3SUM+T3                                                     MAIN1650
      T3=0.0                                                             MAIN1660
  480 XTCUM=XTCUM+XCUM                                                   MAIN1670
      UP4=UP4+ENDPHA-DNT2                                                MAIN1680
C  JBB IS THE PHASE SEQUENCE NUMBER                                      MAIN1690
      IF (XTABT(NUM)-100000.) 500,490,500                                MAIN1700
  490 X=ENDPHA                                                           MAIN1710
      GO TO 510                                                          MAIN1720
  500 X=XTABT(NUM)                                                       MAIN1730
  510 X2=X**2                                                            MAIN1740
      SUMX=SUMX+X                                                        MAIN1750
      SUMX2=SUMX2+X2                                                     MAIN1760
      IF (ISW(N)) 530,530,520                                            MAIN1770
  520 IAUP=IAUP+1                                                        MAIN1780
  530 IF (NUM-INUM) 330,540,540                                          MAIN1790
  540 INUM=INUM+50                                                       MAIN1800
  550 WRITE (6,560) NUM                                                  MAIN1810
  560 FORMAT (/1X16HA GRAND TOTAL OF,I6,24H MISSIONS HAVE BEEN RUN.)     MAIN1820
  570 XNUM=NUM                                                           MAIN1830
  580 XPCAP=XTCUM/XNUM                                                   MAIN1840
  590 WRITE (6,600) XPCAP                                                MAIN1850
  600 FORMAT (1X24HTHE RELIABILITY IS      ,F8.4)                        MAIN1860
  610 XPLCL=XPCAP-XK*SQRT(XPCAP*(1.-XPCAP)/XNUM)                         MAIN1870
      IF (XPLCL) 620,630,630                                             MAIN1880
  620 XPLCL=0.0                                                          MAIN1890
  630 WRITE (6,640) XPLCL                                                MAIN1900
  640 FORMAT (1X24HTHE LOWER CONF LIMIT IS ,F8.4)                        MAIN1910
```

```
      WRITE (6,650) PL                                                   MAIN1920
  650 FORMAT (1X24HTHE SPEC REQUIREMENT IS ,F8.4)                        MAIN1930
      WRITE (6,660) RED2                                                 MAIN1940
  660 FORMAT (1X17HTHE READINESS IS ,7XF8.4)                             MAIN1950
      AVA=UP4/TT3                                                        MAIN1960
      WRITE (6,670) AVA                                                  MAIN1970
  670 FORMAT (1X28HTHE AVERAGE AVAILABILITY IS ,F8.4)                    MAIN1980
      XIAUP=IAUP                                                         MAIN1990
      AVAINS=XIAUP/XNUM                                                  MAIN2000
      WRITE (6,680) AVAINS                                               MAIN2010
  680 FORMAT (1X28HTHE INSTANT AVAILABILITY IS ,F8.4)                    MAIN2020
      XDWN=XNUM-XTCUM                                                    MAIN2030
      IF (XDWN) 690,690,700                                              MAIN2040
  690 XMTBA=2.0*SUMX                                                     MAIN2050
      XLCLA=0.434*SUMX                                                   MAIN2060
      VAR=(0.5*SUMX)**2                                                  MAIN2070
      GO TO 710                                                          MAIN2080
  700 XMTBA=SUMX/XDWN                                                    MAIN2090
      VAR=(SUMX2/XNUM)-(SUMX/XNUM)**2                                    MAIN2100
      CORR=(SUMX*(1/XDWN-1/XNUM))**2                                     MAIN2110
      VAR=VAR+CORR                                                       MAIN2120
      XLCLA=XMTBA-(1.28*SQRT(VAR))                                       MAIN2130
  710 WRITE (6,720) XMTBA                                                MAIN2140
  720 FORMAT (/1X41HTHE MEAN TIME BETWEEN MISSION FAILURES IS,F20.1)     MAIN2150
      WRITE (6,730) XLCLA                                                MAIN2160
  730 FORMAT (1X21HTHE LCL,90, MTBMF IS ,F20.1)                          MAIN2170
      WRITE (6,740) VAR                                                  MAIN2180
  740 FORMAT (1X27HTHE MTBMF VARIANCE IS      ,F20.1)                    MAIN2190
      XIFF=IFF                                                           MAIN2200
      XIFR=IFR                                                           MAIN2210
      IF (IFF) 760,750,760                                               MAIN2220
  750 XMUT=2.0*UP4                                                       MAIN2230
      XMDT=0.0                                                           MAIN2240
      GO TO 790                                                          MAIN2250
  760 XMUT=UP4/XIFF                                                      MAIN2260
      IF (IFR) 780,770,780                                               MAIN2270
  770 XMDT=(TT3-UP4-T3SUM)/XIFF                                          MAIN2280
      GO TO 790                                                          MAIN2290
  780 XMDT=(TT3-UP4-T3SUM)/XIFR                                          MAIN2300
  790 WRITE (6,810) XMUT                                                 MAIN2310
  800 WRITE (6,820) XMDT                                                 MAIN2320
  810 FORMAT (/1X18HTHE SYSTEM MUT IS ,F20.1)                            MAIN2330
  820 FORMAT (1X18HTHE SYSTEM MDT IS ,F20.3)                             MAIN2340
  830 IF (XPCAP-PL) 840,840,920                                          MAIN2350
  840 IF (NOPT-NUM) 870,870,850                                          MAIN2360
  850 WRITE (6,860)                                                      MAIN2370
  860 FORMAT (1X14HANOTHER SET OF,3H 50,20HMISSIONS WILL BE RUN,43H TO OMAIN2380
     1BTAIN REQUIRED STATISTICAL CONFIDENCE.)                            MAIN2390
```

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      GO TO 330                                                         MAIN2400
  870 WRITE (6,880)                                                     MAIN2410
  880 FORMAT (1X52HSIMULATION COMPLETE-OPTIMUM NUMBER MISSIONS WERE RUN)MAIN2420
      IF(PL.EQ.1.) GO TO 910                                            MAIN2430
  890 WRITE (6,900)                                                     MAIN2440
  900 FORMAT (1X33HWEAPON SYSTEM FAILS REQUIREMENTS.)                   MAIN2450
  910 GO TO 1010                                                        MAIN2460
  920 IF (NMAX-NUM) 930,930,960                                         MAIN2470
  930 WRITE (6,940)                                                     MAIN2480
  940 FORMAT (1X52HSIM COMPLETE-PREDEFINED MAX NUMBER MISSIONS WERE RUN)MAIN2490
  950 IF (XPLCL-PL) 890,990,990                                         MAIN2500
  960 IF (XPLCL-PL) 850,970,970                                         MAIN2510
  970 WRITE (6,980)                                                     MAIN2520
  980 FORMAT (2X22HSIMULATION COMPLETE - )                              MAIN2530
      IF(PL.EQ.1.) GO TO 1010                                           MAIN2540
  990 WRITE (6,1000)                                                    MAIN2550
 1000 FORMAT (1X33HWEAPON SYSTEM MEETS REQUIREMENTS.)                   MAIN2560
 1010 CONTINUE                                                          MAIN2570
C*****READ CARD CONTAINING PRINTOUT OPTIONS                             MAIN2580
C*****SPRS=SPARES   GIVES PRINTOUT OF AVG. SPARES USED PER MISSION      MAIN2590
C*****BY EQUIPMENT TYPE                                                 MAIN2600
C*****APPL=APPLE   GIVES PRINTOUT OF CRITICAL EQUIPMENTS AND UNREL.     MAIN2610
C*****GMMA=GAMMA   GIVES PRINTOUT OF GAMMA FUNCTION WHICH REPRESENTS THEMAIN2620
C*****SYSTEM OR SUBSYSTEM CONFIGURATION AND VALUES AT TIME INTERVALS   MAIN2630
C*****SPECIFIED ON PHASE CARD                                           MAIN2640
      IF (JC-1) 1020,1020,1040                                          MAIN2650
C1020 READ (5,1030) SPRS,APPL,GMMA                                      MAIN2660
 1020 READ (5,1030) SPRS,APPL,GMMA,DMNO                                 MAIN2670
C1030 FORMAT (3A4)                                                      MAIN2680
 1030 FORMAT (4A4)                                                      MAIN2690
C1040 IF (SPRS) 1050,1190,1050                                          MAIN2700
 1040 IF (SPRS.EQ.BLNK) GO TO 1190                                      MAIN2710
C                                                                       MAIN2720
C     EQUIP FAILURE AND CORRECTIVE MAINTENANCE SUMMARY                  MAIN2730
C                                                                       MAIN2740
 1050 IDIFF=0                                                           MAIN2750
      TAFM=0.0                                                          MAIN2760
      TACMMH=0.0                                                        MAIN2770
      WRITE (6,1060)                                                    MAIN2780
 1060 FORMAT (1H1,4X53HEQUIP FAILURES AND CORRECTIVE MAINTENANCE(CM) SUMMAIN2790
     1MARY/8X71HEQUIP. NO.  TYPE NO.  TOTAL EQUIP.  AVG. NO. FAILURES  AMAIN2800
     2VG. CM MANHOURS/32X8HFAILURES,7X11HPER MISSION,5X11HPER MISSION/) MAIN2810
      DO 1090 I=1,NEQ                                                   MAIN2820
      IF(XMTTR(IEQU(I)).EQ.9999.) GO TO 1090                            MAIN2830
      IF (KEQU(I)) 1090,1090,1070                                       MAIN2840
 1070 AFM=KEQU(I)/XNUM                                                  MAIN2850
      IEQ=IABS(IEQU(I))                                                 MAIN2860
      ACMMH=AFM*ABS(XMTTR(IEQ))                                         MAIN2870
```

```
      WRITE(6,1080) I,IEQ,KEQU(I),AFM,ACMMH
 1080 FORMAT (10XI4,6XI4,6XI10,6XF10.3,6XF10.3)
      IDIFF=IDIFF+KEQU(I)
      TAFM=TAFM+AFM
      TACMMH=TACMMH+ACMMH
 1090 CONTINUE
      WRITE (6,1100) IDIFF,TAFM,TACMMH
 1100 FORMAT (31X10H----------,6X10H----------,6X10H----------/31XI10,6X
     1F10.3,6XF10.3)
 1110 CONTINUE
      WRITE (6,1120)
 1120 FORMAT (1H1,3X41HAVERAGE NUMBER OF SPARES USED PER MISSION)
      WRITE (6,1130)
 1130 FORMAT (/4X6HSPARES,7X4HSHIP,18X6HTENDER,16X4HBASE)
      WRITE (6,1140)
 1140 FORMAT (8X4HTYPE,4X3(5HSTOCK,3X4HUSED,10X))
      DO 1170 J=1,NTYPE
      ALDONE=0.0
      DO 1150 I=1,3
      DONE(I)=IIUSED(I,J)/XNUM
      ALDONE=ALDONE+DONE(I)
 1150 CONTINUE
      IF(ALDONE) 1155,1170,1155
 1155 WRITE(6,1160)J,(ISPARE(I,J),DONE(I),I=1,3)
 1160 FORMAT (8XI4,4X3(I5,F7.2,10X))
 1170 CONTINUE
 1180 CONTINUE
C1190 IF (APPL) 1200,1210,1200
 1190 IF (APPL.EQ.BLNK) GO TO 1210
 1200 BAPRIN=-1.0
      CALL APPLE
C
C     SEE APPENDIX TO THESIS ON PROCEDURE TO ADD GAMMA AND DEMO
C
 1210 CONTINUE
 1220 CONTINUE
 1230 CONTINUE
 1240 STOP
      END
```

```
      SUBROUTINE RUN
      COMMON /MAX/MAXNEQ,MAXTYP,MAXIB,MAXSTD
      COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ
     1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
     2,RELPY,REPOL,STPHAS,TP,T1,XCUM,TT3,UP3,IFFEOP,T3,TIME,T3SUM
      COMMON/BETA/NRO(6,300),IB(6,300,8),NLINE(6)
      COMMON/EXTRA/ KS(20),ISW(31)
      COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
      COMMON/NPH/ NSS(6),IFLAG(6),TITLE(6,31),SSTIME(6,31,2),ISS(6,31)
      COMMON /SEQ/INOABT(100),INMI(100),IAUP1(100),TT2(100),UP2(100)
     1,IAUP2(100)
      COMMON /TYP/EX(2,200),ISPARE(3,200),IUSED(3,200),IIUSED(3,200)
      COMMON /GAMNAA/XMTBA,VAR,RELGA(100),TIMA(100),XXT(200),ITT,ISEED
      COMMON /TABORT/ XTABT(1000),RDT
      COMMON /DELTA/KKK2
      COMMON /XXX/XXX
      COMMON/VDC/VDC(50,6),IUI(200),VMTTR(200,6),TAD2
      COMMON/STAN/ISTB(60,10,6)
      COMMON/RUNAP/ITEMP2,DELT,ISSA(31),ISSC
C
C   START OF PHASE LL
C
      TDEOP=0.0
      TP=STPHAS
      KAA=NUM+1
      XKAA=KAA
      NX=NSS(LL)
      N=NX+1
      ITEMP=0
      ITEMP2=0
      IF (KKK) 40,10,40
   10 DO 20 I=1,3
      DO 20 J=1,NTYPE
      IUSED(I,J)=0
   20 CONTINUE
      DO 30 I=1,NEQ
   30 ETIME(I)=100000.
   40 CONTINUE
C
C   KKK = 0  INDICATES FIRST PHASE IN MISSION.
C   IFLAG = 0  INDICATES REPAIR IS ALLOWED DURING PHASE.
C
C
C   DEFINE EVENT TIME VECTOR
C     I. IF REPAIR WAS PREVIOUSLY INHIBITED,GENERATE TTR.
C
   50 DO 120 ILB=1,NEQ
      KEQ=ILB
```

```
      IF(ETIME(KEQ)+100001.001)55,120,55
   55 IF(ETIME(KEQ)+99999.)60,60,120
   60 IF (IFLAG(LL)) 120,70,120
C     IF A NEGATIVE ETIME IS PASSED TO TTE A TTF IS GENERATED.  WE WANT
C     TO START REPAIR AT THE BEGINNING OF THE PHASE SO A POSITIVE ETIME
C     MUST BE PASSED.
   70 ETIME(KEQ)=STPHAS
      IABC=IABS(IEQU(KEQ))
      IF (XMTTR(IABC)) 80,80,100
   80 XXX=VMTTR(IABC,LL)
      IF (XXX-9999.) 120,90,120
   90 ETIME(KEQ)=-99999.
      GO TO 120
  100 XXX=XMTTR(IABC)
  110 CALL TTE
  120 CONTINUE
C
C   II. TAG ALL EQUIPMENTS PREVIOUSLY FAILED OR OPERATING,NOT STANDBY.
C
      DO 140 ILB=1,NEQ
      KEQ=ILB
      IEQU(KEQ)=IABS(IEQU(KEQ))
      IF (ETIME(KEQ)-100000.) 130,140,130
  130 IEQU(KEQ)=-IABS(IEQU(KEQ))
  140 CONTINUE
  150 CONTINUE
C
C   III. FOR EQUIPMENTS USED IN CURRENT PHASE CONFIGURATION
C            A. THAT WERE USED IN PRIOR PHASE
C               1. IF EQUIPMENT IS UP, LEAVE AS IS
C               2. IF EQUIPMENT IS DOWN AND REPAIR IS ALLOWED, LEAVE AS
C                  IS
C               3. IF EQUIPMENT IS DOWN AND REPAIR IS DISALLOWED, ADD
C                  CURRENT PHASE DURATION
C            B. THAT WERE NOT USED IN PRIOR PHASE
C               1. IF EQUIPMENT IS DOWN AND REPAIR IS ALLOWED, LEAVE AS
C                  IS
C               2. IF EQUIPMENT IS DOWN AND REPAIR IS DISALLOWED, ADD
C                  CURRENT PHASE DURATION
C               3. OTHERWISE, GENERATE TTF
C
      KKK2=KKK
      K=NLINE(LL)
      DO 250 I=1,K
      DO 250 J=2,8
      KEQ=IABS(IB(LL,I,J))
      IF (KEQ-MAXNEQ) 151,151,250
  151 IF(KEQ)250,250,155
```

```
  155 IF(ETIME(KEQ)+100001.001)160,250,160
  160 IEQU(KEQ)=IABS(IEQU(KEQ))
      IABC=IEQU(KEQ)
      IF (XMTTR(IABC)) 170,170,180
  170 IF (VMTTR(IABC,LL)-9999.) 180,190,180
  180 CONTINUE
      IF (IFLAG(LL)-1) 210,190,210
  190 IF (ETIME(KEQ)) 200,210,210
  200 ETIME(KEQ)=ETIME(KEQ)-(ENDPHA-STPHAS)
  210 IF (ETIME(KEQ)-100000.) 220,240,220
  220 IF (ABS(ETIME(KEQ))-STPHAS) 240,230,230
  230 IF (STPHAS) 250,240,250
  240 ETIME(KEQ)=-STPHAS
      IABC=IABS(IEQU(KEQ))
      XXX=XMTBF(IABC)
      CALL TTE
  250 CONTINUE
      KKK2=1
C
C    IV. FOR EQUIPMENTS NOT IN CURRENT PHASE CONFIGURATION
C            A. IF EQUIPMENT IS UP,PUT IN STANDBY.
C            B. IF EQUIPMENT IS DOWN
C                1. IF REPAIR IS ALLOWED,LEAVE AS IS.
C                2. IF REPAIR IS DISALLOWED,ADD DURATION OF CURRENT PHASE
      DO 330 ILB=1,NEQ
      KEQ=ILB
      IF(ETIME(KEQ)+100001.001)255,330,255
  255 IF(IEQU(KEQ))260,260,330
  260 IEQU(KEQ)=IABS(IEQU(KEQ))
      IABC=IEQU(KEQ)
      IF (XMTTR(IABC)) 270,270,280
  270 IF (VMTTR(IABC,LL)-9999.) 280,290,280
  280 CONTINUE
      IF (IFLAG(LL)-1) 310,290,310
  290 IF (ETIME(KEQ)) 300,320,320
  300 ETIME(KEQ)=ETIME(KEQ)-(ENDPHA-STPHAS)
      GO TO 330
C     EQUIPMENTS THAT WERE DOWN AT THE BEGINNING OF A PHASE IN WHICH
C     THEY WERE NOT USED, WERE NOT PUT IN STANDBY AFTER REPAIR.  INSTEAD
C     THEY WERE ALLOWED TO FAIL AGAIN IN THAT PHASE.
  310 IF(ETIME(KEQ)) 331,320,320
  320 ETIME(KEQ)=100000.
      IEQU(KEQ)=IABS(IEQU(KEQ))
      GO TO 330
  331 IEQU(KEQ)=-IABS(IEQU(KEQ))
  330 CONTINUE
C
C    V. SET STANDBY EQUIPMENTS ETIME TO 100000.
```

```
C
      CALL STATUS
      CALL STNDBY
C
C  CALCULATIONS FOR INSTANT AVA AT START OF PHASE.
      CALL STATUS
      IF (ISW(N)) 350,350,340
  340 IAUP1(JBB)=IAUP1(JBB)+1
  350 XIAUP1=IAUP1(JBB)
      XAVI=XIAUP1/XKAA
C
C DNTI IS TOTAL SYSTEM DOWNTIME IN PHASE.
      TIME=STPHAS
      DNTI=0.0
      DO 360 KSS=1,N
  360 SSTIME(LL,KSS,1)=0.0
C
C THE ACTUAL MISSION SIMULATION BEGINS HERE
C
  370 TP=TIME
      CALL STNDBY
  380 IF (KS(6)) 390,440,390
  390 WRITE (6,430) TP
      DO 410 J=1,NEQ
      IF (ETIME(J)-100000.) 400,410,400
  400 IEQ=IABS(IEQU(J))
      WRITE(6,420) J,IEQ,ETIME(J)
  410 CONTINUE
  420 FORMAT (1XI5,1XI5,5XF22.4)
  430 FORMAT (1XF12.4)
  440 CALL EVENT
      TIME=ABS(ETIME(KEQ))
      IF (KS(5)) 450,470,450
  450 WRITE (6,460) KEQ,ETIME(KEQ),KAA
  460 FORMAT (10X5HEQUIP,I5,F12.4,5X7HMISSION,I10)
  470 DELT=TIME-TP
      CALL STATUS
C
C SET TIME CLOCKS
C
  480 DO 510 KSS=1,NX
      IF (ISW(KSS)) 490,490,500
  490 SSTIME(LL,KSS,1)=SSTIME(LL,KSS,1)+DELT
      GO TO 510
  500 SSTIME(LL,KSS,1)=0.0
  510 CONTINUE
      IF (ISW(N)) 520,520,530
  520 SSTIME(LL,N,1)=SSTIME(LL,N,1)+DELT
```

```
      T3=T3+DELT
      IF (TIME-ENDPHA) 522,522,521
  521 T3=T3+ENDPHA-TP-DELT
  522 RDT=RDT+DELT
      GO TO 550
  530 T3=0.0
      RDT=0.0
      IF (SSTIME(LL,N,1)) 1140,550,540
  540 T1=SSTIME(LL,N,1)
      SSTIME(LL,N,1)=0.0
  550 CONTINUE
C
C  SYSTEM FAILURE AND REPAIR TALLY
C
      IF (SSTIME(LL,N,1)) 570,560,570
  560 IF (T1) 620,620,580
  570 IF (T1) 620,610,620
  580 IFF=IFF+1
  590 IFR=IFR+1
  600 T1=0.0
      GO TO 620
  610 T1=SSTIME(LL,N,1)
  620 CONTINUE
C
C CHECK IF ANY DOWN TIMES HAVE EXCEEDED CRITERIA
C
      IF(ICRI) 640,640,660
C
C     TAD2 - MISSION ALLOWABLE DOWNTIME
C
  640 ISSC=1
      ISSA(1)=N
      IF(RDT-TAD2)645,645,930
  645 ICRI=0
      IF(SSTIME(LL,N,1)-SSTIME(LL,N,2)) 650,650,960
  650 ICRI=0
      ISSC=0
      DO 655 KSS=1,NX
      IF(SSTIME(LL,KSS,1)-SSTIME(LL,KSS,2))655,655,652
  652 ISSC=ISSC+1
      ISSA(ISSC)=KSS
  655 CONTINUE
      IF(ISSC)660,660,962
  660 CONTINUE
C
C CHECK IF TIME GREATER THAN END OF PHASE
C
      IF (TIME-ENDPHA) 670,670,1140
```

```
C
C  IFLAG = 0  INDICATES REPAIR IS ALLOWED DURING PHASE.
C  REPOL IS THE PROBABILITY THAT A REPAIR IS PERFORMED.
C
  670 IF (ISW(N)) 680,680,730
  680 CALL APPLE
  730 IF (ETIME(KEQ)) 810,810,740
  740 IABC=IABS(IEQU(KEQ))
      IF (IFLAG(LL)-1) 750,760,750
  750 CALL RANDOM(ISEED,RN,1)
      IF (RN-REPOL) 770,770,800
  760 ETIME(KEQ)=-99999.
      GO TO 830
  770 IF (XMTTR(IABC)) 780,780,790
  780 XXX=VMTTR(IABC,LL)
      IF (XXX-9999.) 820,760,820
  790 XXX=XMTTR(IABC)
      GO TO 820
  800 ETIME(KEQ)=-100001.001
      GO TO 830
  810 IABC=IABS(IEQU(KEQ))
      XXX=XMTBF(IABC)
  820 IF(IEQU(KEQ))811,821,821
  811 IEQU(KEQ)=IABS(IEQU(KEQ))
      ETIME(KEQ)=100000.
      GO TO 830
  821 CALL TTE
  830 IF (ETIME(KEQ)) 840,1150,870
C
C EVENT WAS FAILURE
C
  840 KEQU(KEQ)=KEQU(KEQ)+1
      IF (ISW(N)) 850,850,370
  850 DNT1=DNT1+DELT
      IF (ICRI) 860,370,860
  860 REDAD1(JBB)=REDAD1(JBB)+DELT
      GO TO 370
C
C EVENT WAS REPAIR
C
  870 CONTINUE
      IF (ISW(N)) 880,880,370
  880 DNT1=DNT1+DELT
      IF (ICRI) 890,900,890
  890 REDAD1(JBB)=REDAD1(JBB)+DELT
  900 TDOWN=TIME-SSTIME(LL,N,1)
      TTEMP=SSTIME(LL,N,1)
      IF (KS(13)) 370,370,910
```

```
  910 WRITE (6,920) LL,TDOWN,TTEMP,KAA
  920 FORMAT (13H DURING PHASE,I6,20HSYSTEM WENT DOWN AT ,F14.4,13H DOWN
     1TIME IS ,F14.4,3X7HMISSION,I6)
      GO TO 370
C
C ABORT PROCEDURE
C
  930 ICRI=5
      TABORT=TIME-(RDT-TAD2)
      IF(TABORT-ENDPHA)940,645,645
  940 IF (XTABT(KAA)-100000.) 660,950,660
  950 ITEMP=1
      ITEMP2=1
      WRITE(6,1010)LL,JBB,KAA,TABORT,TITLE(LL,N),TAD2
      GO TO 1020
  960 ICRI=4
      GO TO 964
  962 ICRI=2
  964 TABORT=TIME-(SSTIME(LL,ISSA(1),1)-SSTIME(LL,ISSA(1),2))
  970 IF (TABORT-ENDPHA) 990,980,980
  980 IF(ICRI-2)650,985,650
  985 ICRI=0
      GOTO 660
  990 IF (XTABT(KAA)-100000.) 660,1000,660
 1000 ITEMP=1
      ITEMP2=1
      DO 1005 I=1,ISSC
 1005 WRITE(6,1009)LL,JBB,KAA,TABORT,TITLE(LL,ISSA(I))
     1,SSTIME(LL,ISSA(I),2)
 1009 FORMAT(1X9HIN PHASE ,I2,1X3HSEQ,I3,4X7HMISSION,I6,4X15HABORTED AT
     1TIME,F10.4,10H  BECAUSE ,A4,35H  EXCEEDED PHASE ALLOWABLE DOWNTIME
     2,2XF10.3,5H HRS.)
 1010 FORMAT (1X9HIN PHASE ,I2,1X3HSEQ,I3,4X7HMISSION,I6,4X15HABORTED AT
     1 TIME,F10.4,10H  BECAUSE ,A4,37H  EXCEEDED MISSION ALLOWABLE DOWNT
     2IME,2XF10.3,5H HRS.)
 1020 XTABT(KAA)=TABORT
      IF (TABORT) 1590,1590,1040
 1040 DO 1110 I=1,NEQ
      IF (ETIME(I)) 1050,1110,1110
 1050 IF (IEQU(I)) 1080,1110,1080
 1080 IF (KS(2)) 1090,1110,1090
 1090 WRITE (6,1100) I,ETIME(I)
 1100 FORMAT (17X9HEQUIPMENT,I5,24H DOWN IT WILL COME UP AT,F16.4)
 1110 CONTINUE
 1120 CALL APPLE
      ITEMP2=0
 1130 GO TO 660
C
```

```
C END OF PHASE  PROCEDURE
C   TDEOP  IS TIME DOWN AT END OF PHASE
C DNT2 IS TOTAL SYSTEM DOWNTIME IN MISSION.
C AENDT1 IS DOWNTIME IN REMAINDER OF PHASE DUE TO ABORT
C AENDT2 IS DOWNTIME IN MISSION DUE TO ABORT (UP TO CURRENT PHASE)
C REDAD1 IS ADJUSTMENT TIME FOR REDINESS CALCULATION IN PHASE
C REDAD2 IS ADJUSTMENT TIME FOR REDINESS CALCULATION IN MISSION
C
 1140 CONTINUE
      IFFEOP=ISW(N)
      IF (ISW(N)) 1160,1160,1270
 1150 CONTINUE
 1160 TDEOP=ENDPHA-TP
 1170 CONTINUE
      IF (KS(3)) 1210,1210,1180
 1180 IF (TDEOP) 1190,1210,1190
 1190 WRITE (6,1200) LL,TDEOP,KAA
 1200 FORMAT (1X27HSYSTEM DOWN AT END OF PHASE,I6,13H FOR DURATION,F10.4
     1,6X7HMISSION,I6)
 1210 CONTINUE
      DNT1=DNT1+TDEOP
      RDT=RDT+TDEOP-DELT
      DELT=TDEOP
      CALL APPLE
 1270 CONTINUE
      IF (ICRI) 1280,1290,1280
 1280 REDAD1(JBB)=REDAD1(JBB)+TDEOP
 1290 DNT2=DNT2+DNT1
 1300 IF (DNT2) 1310,1330,1310
 1310 IF(KS(6)) 1325,1330,1325
 1325 WRITE(6,1320) LL,KAA,DNT2
 1320 FORMAT (1X5HPHASE,I5,1X29HTOTAL SYS DOWNTIME IN MISSION,I5,1X3HWAS
     1,F12.4,4H HRS)
 1330 CONTINUE
C
C     COMPUTE RELIABILITY FOR EACH PHASE *******************************
C  JBB IS THE PHASE SEQUENCE NUMBER
C
      IF (ICRI) 1350,1350,1340
 1340 IF (ITEMP) 1360,1360,1350
 1350 XCUM=1-ITEMP
      INOABT(JBB)=INOABT(JBB)+1-ITEMP
      INMI(JBB)=INMI(JBB)+1
 1360 CONTINUE
      XNO=INOABT(JBB)
      TNMI=INMI(JBB)
      IF (TNMI) 1380,1380,1370
 1370 RELY=XNO/TNMI
```

```
      GO TO 1390                                                        RUN 3850
 1380 RELY=0.0                                                          RUN 3860
 1390 RELPY=RELPY*RELY                                                  RUN 3870
      TT1=ENDPHA-STPHAS                                                 RUN 3880
      TT2(JBB)=TT2(JBB)+TT1                                             RUN 3890
      UP1=TT1-DNT1                                                      RUN 3900
      UP2(JBB)=UP2(JBB)+UP1                                             RUN 3910
      IF (ISW(N)) 1410,1410,1400                                        RUN 3920
 1400 IAUP2(JBB)=IAUP2(JBB)+1                                           RUN 3930
 1410  XIAUPP=IAUP2(JBB)                                                RUN 3940
      XAV=XIAUPP/XKAA                                                   RUN 3950
      IF (KAA-INUM) 1570,1420,1570                                      RUN 3960
 1420 WRITE (6,1430) XAVI                                               RUN 3970
 1430 FORMAT (/47X20HINSTANT AVAILABILITY,5X2X4H IS ,F6.4)              RUN 3980
 1440 WRITE (6,1450) LL,JBB,RELY,LL,RELPY                               RUN 3990
 1450 FORMAT (9X17HRELIABILITY PHASE,I3,1H,,I3,5H, IS ,F6.4,3X25HRELIABIRUN 4000
     1LITY UP TO PHASE   ,I2,4H IS ,F6.4)                               RUN 4010
      RELGA(JBB)=RELPY                                                  RUN 4020
      AENDT1=0.0                                                        RUN 4030
      AENDT2=0.0                                                        RUN 4040
      DO 1520 I=1,KAA                                                   RUN 4050
 1460 IF (XTABT(I)-100000.) 1470,1520,1520                              RUN 4060
 1470 IF (XTABT(I)-TIMA(JBB)) 1480,1520,1520                            RUN 4070
 1480 AENDT2=AENDT2+TIMA(JBB)-XTABT(I)                                  RUN 4080
      JBB1=JBB-1                                                        RUN 4090
      IF (JBB1) 1500,1500,1490                                          RUN 4100
 1490 IF (TIMA(JBB1)-XTABT(I)) 1500,1500,1510                           RUN 4110
 1500 AENDT1=AENDT1+TIMA(JBB)-XTABT(I)                                  RUN 4120
      GO TO 1520                                                        RUN 4130
 1510 AENDT1=AENDT1+TIMA(JBB)-TIMA(JBB1)                                RUN 4140
 1520 CONTINUE                                                          RUN 4150
      TT3=TT3+TT2(JBB)                                                  RUN 4160
      UP3=UP3+UP2(JBB)                                                  RUN 4170
      REDAD2=REDAD2+REDAD1(JBB)                                         RUN 4180
      RED1=(UP2(JBB)-AENDT1+REDAD1(JBB))/TT2(JBB)                       RUN 4190
      RED2=(UP3-AENDT2+REDAD2)/TT3                                      RUN 4200
 1530 WRITE (6,1540) RED1,RED2                                          RUN 4210
 1540 FORMAT (9X16HREADINESS        ,9X4H IS ,F6.4,3X25HREADINESS       RUN 4220
     1          ,2X4H IS ,F6.4)                                         RUN 4230
      AVA1=UP2(JBB)/TT2(JBB)                                            RUN 4240
      AVA2=UP3/TT3                                                      RUN 4250
      WRITE (6,1550) AVA1,AVA2                                          RUN 4260
 1550 FORMAT (9X23HAVERAGE AVAILABILITY   ,2X4H IS ,F6.4,3X25HAVERAGE AVRUN 4270
     1AILABILITY      ,2X4H IS ,F6.4)                                   RUN 4280
      WRITE (6,1560) XAV                                                RUN 4290
 1560 FORMAT (47X20HINSTANT AVAILABILITY,5X2X4H IS ,F6.4)               RUN 4300
 1570 CONTINUE                                                          RUN 4310
 1580 KKK=1                                                             RUN 4320
```

```
      JBB=JBB+1
      T1=SSTIME(LL,N,1)
 1590 RETURN
      END
```

```fortran
      SUBROUTINE PACK
      COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ
     1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
     2,RELPY,REPOL,STPHAS,TP,T1,XCUM,TT3,UP3,IFFECP,T3,TIME,T3SUM
      COMMON/BETA/NRO(6,300),IB(6,300,8),NLINE(6)
      COMMON/EXTRA/ KS(20),ISW(31)
      COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
      COMMON/NPH/ NSS(6),IFLAG(6),TITLE(6,31),SSTIME(6,31,2),ISS(6,31)
      COMMON /TYP/EX(2,200),ISPARE(3,200),IUSED(3,200),IIUSED(3,200)
      COMMON /MAX/MAXNEQ,MAXTYP,MAXIB,MAXSTD
      COMMON/VDC/VDC(50,6),IUI(200),VMTTR(200,6),TAD2
      COMMON /PACKAP/ IBNUM( 6,500),ISYS( 6),F(200,4)
      COMMON/STAN/ISTB(60,10,6)
      COMMON /CSPARE/ SPR1,SPR2,SPR3,SPR4,SPR5,SPR6,SPR7,SPR8,SPR9
     1,SPR10,SPR11,SPR12,SPR13,SPR14,ITMPOP(200)
      DIMENSION LOAD(19)
      DIMENSION DUM(4)
      DIMENSION IVAL(10)
      DATA IBLANK/4H    /
C
C   KOPT OBTAINS ONE OF SUNDRY COMBINATIONS OF SWITCHES
C   KOPT=1 GIVES MANAGEMENT SUMMARY PRINTOUT
C   KOPT=2 GIVES ENGINEERING SUMMARY PRINTOUT
C   KOPT=3 GIVES COMPLETE DETAILS PRINTOUT
C   KOPT=4 INPUTS SUPPRESSED ON OUTPUT PRINTOUT
C   KOPT=5 DESIGN YOUR OWN OUTPUT PRINTOUT
C
      READ (5,10) KOPT,(KS(I),I=1,13)
      WRITE (6,20) KOPT,(KS(I),I=1,13)
   10 FORMAT (20I4)
   20 FORMAT (1H1,I10,5X19I4)
C
C   IFLAG = 0  INDICATES REPAIR IS ALLOWED DURING PHASE.
C
      READ (5,10) (IFLAG(I),I=1,NPH)
      WRITE (6,30) (IFLAG(I),I=1,NPH)
   30 FORMAT (10I4)
C
C   REPOL IS THE PROBABILITY THAT A REPAIR IS PERFORMED.
C
      READ(5,40) REPOL,TAD2,XM,XM1
   40 FORMAT(F4.0,F8.0,2F4.0)
   50 FORMAT(20F4.0)
      IF(XM) 35,35,55
   35 XM=1.0
   55 IF(XM1) 36,36,56
   36 XM1=1.
   56 WRITE(6,60) REPOL,TAD2,XM,XM1
```

AD-A093 584 NAVAL POSTGRADUATE SCHOOL MONTEREY CA F/G 15/5
AN EVALUATION OF THE EFFECT OF SPARES ALLOWANCE POLICY UPON SHI--ETC(U)
SEP 80 J E LEATHER
UNCLASSIFIED NL

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```
   60 FORMAT(1X,4F10.2)                                              PACK0490
      GO TO (70,90,100,120,130),KOPT                                 PACK0500
C                                                                    PACK0510
C KS SWITCHES ARE ON WHEN SET=1                                      PACK0520
C                  OFF        =0                                     PACK0530
C                                                                    PACK0540
   70 KS(1)=1                                                        PACK0550
      KS(4)=0                                                        PACK0560
   80 KS(3)=0                                                        PACK0570
      KS(2)=0                                                        PACK0580
      KS(2)=1                                                        PACK0590
      KS(5)=0                                                        PACK0600
      KS(6)=0                                                        PACK0610
      KS(7)=0                                                        PACK0620
      KS(8)=0                                                        PACK0630
      KS(9)=0                                                        PACK0640
      KS(10)=0                                                       PACK0650
      GO TO 130                                                      PACK0660
   90 KS(1)=1                                                        PACK0670
      KS(6)=0                                                        PACK0680
      KS(10)=0                                                       PACK0690
      GO TO 110                                                      PACK0700
  100 KS(1)=1                                                        PACK0710
      KS(6)=1                                                        PACK0720
      KS(7)=1                                                        PACK0730
      KS(10)=1                                                       PACK0740
      KS(12)=1                                                       PACK0750
  110 KS(2)=1                                                        PACK0760
      KS(3)=1                                                        PACK0770
      KS(4)=1                                                        PACK0780
      KS(5)=1                                                        PACK0790
      KS(7)=0                                                        PACK0800
      KS(8)=1                                                        PACK0810
      KS(9)=1                                                        PACK0820
      GO TO 130                                                      PACK0830
  120 KS(1)=0                                                        PACK0840
      KS(4)=0                                                        PACK0850
      GO TO 80                                                       PACK0860
C                                                                    PACK0870
C FILL EQUIPMENT AND TYPE TABLES                                     PACK0880
C                                                                    PACK0890
  130 NEQ=0                                                          PACK0900
      DO 140 I=1,MAXNEQ                                              PACK0910
      ETIME(I)=100000.                                               PACK0920
      IEQU(I)=0                                                      PACK0930
  140 CONTINUE                                                       PACK0940
      DO 155 J=1,6                                                   PACK0950
      DO 150 I=1,MAXTYP                                              PACK0960
```

```
      XMTBF(I)=0.0                                                      PACK0970
      VMTTR(I,J)=0.0                                                    PACK0980
  150 XMTTR(I)=0.0                                                      PACK0990
  155 CONTINUE                                                          PACK1000
C                                                                       PACK1010
C READ TYPE CARDS                                                       PACK1020
C                                                                       PACK1030
  160 WRITE (6,170)                                                     PACK1040
  170 FORMAT (/11H TYPE  NAME,18X4HMTBF,5X4HMTTR,7X2HDC,8X4HADT1,4X4HADTPACK1050
     12)                                                                PACK1060
  180 READ (5,190) I,(DUM(J),J=1,4),X,Y,U,V,W,IDUM                      PACK1070
  190 FORMAT (I4,4A4,F8.0,4F4.0,I4)                                     PACK1080
      IF (I) 200,490,200                                                PACK1090
  200 IF (I-MAXTYP) 220,220,210                                         PACK1100
  210 WRITE (6,440)                                                     PACK1110
      GO TO 1000                                                        PACK1120
  220 DO 230 J=1,4                                                      PACK1130
  230 F(I,J)=DUM(J)                                                     PACK1140
      IUI(I)=IDUM                                                       PACK1150
      IF (IUI(I)) 240,250,240                                           PACK1160
  240 READ (5,450) IU,(VDC(IU,ILL),ILL=1,NPH)                           PACK1170
  250 IF (Y) 260,280,280                                                PACK1180
  260 READ (5,50) (VMTTR(I,J),J=1,NPH)                                  PACK1190
  270 IF (I) 280,490,280                                                PACK1200
  280 EX(1,I)=V                                                         PACK1210
      EX(2,I)=W                                                         PACK1220
      IF (KS(1)) 310,310,290                                            PACK1230
  290 WRITE (6,300) I,(F(I,J),J=1,4),X,Y,U,V,W                          PACK1240
  300 FORMAT (1XI4,2X4A4,2XF10.1,F10.2,F10.3,2(F8.1))                   PACK1250
  310 IF (IUI(I)) 380,380,320                                           PACK1260
  320 IF (KS(1)) 340,340,330                                            PACK1270
  330 WRITE (6,460) (VDC(IU,ILL),ILL=1,NPH)                             PACK1280
  340 DO 370 ILL=1,NPH                                                  PACK1290
      IF (VDC(IU,ILL)) 360,360,350                                      PACK1300
  350 VDC(IU,ILL)=(X/VDC(IU,ILL))*XM                                    PACK1310
      GO TO 370                                                         PACK1320
  360 VDC(IU,ILL)=(X/.0001)*XM                                          PACK1330
  370 CONTINUE                                                          PACK1340
  380 IF (KS(1)) 410,410,390                                            PACK1350
  390 IF (Y) 400,410,410                                                PACK1360
  400 WRITE (6,470) (VMTTR(I,J),J=1,NPH)                                PACK1370
  410 IF (XMTBF(I)) 420,430,420                                         PACK1380
  420 WRITE (6,480) I                                                   PACK1390
      GO TO 1000                                                        PACK1400
  430 IF(U) 435,435,433                                                 PACK1410
  433 XMTBF(I)=XM*(X/U)                                                 PACK1420
  435 XMTTR(I)=Y*XM1                                                    PACK1430
      GO TO 180                                                         PACK1440
```

```
  440 FORMAT (9X39HEQUIP TYPES HAVE EXCEEDED MAX ALLOWABLE)             PACK1450
  450 FORMAT (I4,19(F4.0))                                              PACK1460
  460 FORMAT (14X16HVARY DUTY CYCLE ,4F10.3)                            PACK1470
  470 FORMAT (14X16HVARIABLE MTTR    ,4F10.3)                           PACK1480
  480 FORMAT (1X4HTYPE,I5,1X13HDEFINED TWICE)                           PACK1490
C                                                                       PACK1500
C AFTER LAST TYPE CARD MUST BE A BLANK CARD, THEN FOLLOWS EQU CARDS.   PACK1510
C                                                                       PACK1520
  490 WRITE (6,500)                                                     PACK1530
  500 FORMAT (/1X15HTYPE  EQUIPMENT)                                    PACK1540
  510 READ (5,10) NTYPE,(LOAD(I),I=1,19)                                PACK1550
      IF (LOAD(1)) 520,650,520                                          PACK1560
  520 DO 620 I=1,19                                                     PACK1570
      IF (LOAD(I)) 530,620,530                                          PACK1580
  530 IBM=LOAD(I)                                                       PACK1590
      IF (IBM-500) 560,560,540                                          PACK1600
  540 WRITE (6,550)                                                     PACK1610
  550 FORMAT(55H EQUIPMENT NUMBER GREATER THAN 500 ********************)PACK1620
      GO TO 1000                                                        PACK1630
  560 IF (IBM-NEQ) 580,580,570                                          PACK1640
  570 NEQ=IBM                                                           PACK1650
  580 IF (IEQU(IBM)) 590,610,590                                        PACK1660
  590 WRITE (6,600) IBM                                                 PACK1670
      GO TO 1000                                                        PACK1680
  600 FORMAT (1X9HEQUIPMENT,I5,1X34HDEFINED TWICE ********************) PACK1690
  610 CONTINUE                                                          PACK1700
      IEQU(IBM)=NTYPE                                                   PACK1710
  620 CONTINUE                                                          PACK1720
      IF (KS(1)) 640,640,630                                            PACK1730
  630 WRITE (6,10) NTYPE,(LOAD(I),I=1,19)                               PACK1740
  640 NTY=NTYPE                                                         PACK1750
      GO TO 510                                                         PACK1760
C                                                                       PACK1770
C ALL EQUIPMENT & TYPE CARDS HAVE BEEN READ IN.                         PACK1780
C THE LAST CARD AT THIS POINT MUST BE A BLANK CARD.                     PACK1790
C                                                                       PACK1800
  650 WRITE (6,660)                                                     PACK1810
  660 FORMAT(/1X11HSPARES TYPE,6X4HSHIP,4X6HTENDER,6X4HBASE,12X6HFACTOR)PACK1820
      DO 670 I=1,3                                                      PACK1830
      NTYPE=NTY                                                         PACK1840
      DO 670 J=1,NTYPE                                                  PACK1850
  670 IUSED(I,J)=0                                                      PACK1860
      READ(5,675)IUNLIM,SX,SPR1,SPR2,SPR3,SPR4,SPR5,SPR6,SPR7,SPR8,SPR9 PACK1870
     1,SPR10,SPR11,SPR12,SPR13,SPR14                                    PACK1880
  675 FORMAT(A4,16X,15F4.0)                                             PACK1890
      IF(SX-999.) 681,676,681                                           PACK1900
  676 CALL SPARES                                                       PACK1910
      IF(KS(1)) 740,740,677                                             PACK1920
```

```
  677 DO 678 I=1,NTYPE                                                      PACK1930
  678 WRITE(6,750) I,(ISPARE(J,I),J=1,3),SX                                 PACK1940
      GO TO 740                                                             PACK1950
  681 IF(SX) 684,682,684                                                    PACK1960
  682 SX=1.0                                                                PACK1970
  684 IF(IUNLIM-IBLANK)690,720,690                                          PACK1980
  690 WRITE (6,700)                                                         PACK1990
  700 FORMAT (1X41HALL EQUIPMENT TYPES HAVE UNLIMITED SPARES)               PACK2000
      DO 710 I=1,NTYPE                                                      PACK2010
      DO 710 J=1,3                                                          PACK2020
  710 ISPARE(J,I)=90000                                                     PACK2030
      GO TO 760                                                             PACK2040
  720 DO 740 I=1,NTYPE                                                      PACK2050
      READ (5,10) (ISPARE(J,I),J=1,3)                                       PACK2060
      BILL=FLOAT(ISPARE(1,I))*SX                                            PACK2070
      IF(INT(BILL)-BILL) 727,725,727                                        PACK2080
  725 ISPARE(1,I)=BILL                                                      PACK2090
      GO TO 728                                                             PACK2100
  727 ISPARE(1,I)=INT(BILL)+1                                               PACK2110
  728 CONTINUE                                                              PACK2120
      IF (KS(1)) 740,740,730                                                PACK2130
  730 WRITE(6,750)I,(ISPARE(J,I),J=1,3),SX                                  PACK2140
  740 CONTINUE                                                              PACK2150
  750 FORMAT(5X,I4,2X,3I10,13X,F6.2)                                        PACK2160
C                                                                           PACK2170
  760 WRITE (6,770) NPH                                                     PACK2180
  770 FORMAT (1H1,3X28HTHE MISSION WILL BE RUN WITH,I4,7H PHASE ,27HTYPEPACK2190
     1S IN VARIABLE SEQUENCE.)                                              PACK2200
C                                                                           PACK2210
C PHASE CARDS APPEAR NEXT.                                                  PACK2220
C                                                                           PACK2230
      DO 777 I=1,6                                                          PACK2240
      DO 776 J=1,10                                                         PACK2250
      DO 775 K=1,60                                                         PACK2260
      ISTB(K,J,I)=0                                                         PACK2270
  775 CONTINUE                                                              PACK2280
  776 CONTINUE                                                              PACK2290
  777 CONTINUE                                                              PACK2300
      DO 990 K=1,NPH                                                        PACK2310
      READ (5,780) XID,LL,NSS(K),ISS(K,NSS(K)+1),SSTIME(K,NSS(K)+1,2)       PACK2320
      ISYS(K)=ISS(K,NSS(K)+1)                                               PACK2330
  780 FORMAT (A4,3I4,F8.0)                                                  PACK2340
      NX=NSS(K)                                                             PACK2350
      N=NX+1                                                                PACK2360
      IF (KS(1)) 820,820,790                                                PACK2370
  790 WRITE (6,810) XID,LL,NSS(K),ISS(K,N),SSTIME(K,N,2)                    PACK2380
  800 FORMAT (1XA4,3I4,F10.2)                                               PACK2390
  810 FORMAT (/1XA4,3I4,F10.2)                                              PACK2400
```

```
  820 TITLE(K,N)=XI)                                                    PACK2410
      DO 840 IK=1,NX                                                    PACK2420
      READ (5,780) TITLE(K,IK),KK,MM,ISS(K,IK),SSTIME(K,IK,2)           PACK2430
      IF (KS(1)) 840,840,830                                            PACK2440
  830 WRITE (6,800) TITLE(K,IK),LL,MM,ISS(K,IK),SSTIME(K,IK,2)          PACK2450
  840 CONTINUE                                                          PACK2460
C                                                                       PACK2470
C EQUIPMENT & GROUP CONFIGURATION MATRIX                                PACK2480
C                                                                       PACK2490
      DO 850 JA=1,MAXIB                                                 PACK2500
      DO 850 JB=1,8                                                     PACK2510
      IB(K,JA,JB)=0                                                     PACK2520
      NRO(K,JA)=0                                                       PACK2530
  850 CONTINUE                                                          PACK2540
      IOR=0                                                             PACK2550
      I=0                                                               PACK2560
  860 I=I+1                                                             PACK2570
      READ(5,10) (IVAL(J),J=1,10),IRULE                                 PACK2580
      IF(IVAL(1).EQ.0) GO TO  990                                       PACK2590
      IF(IRULE.NE.0)GOTO 930                                            PACK2600
C** GROUP CARD. CHECK IF MORE THAN ALLOWED.                              PACK2610
      IF(I.LE.MAXIB) GO TO 880                                          PACK2620
      WRITE(6,870) MAXIB                                                PACK2630
  870 FORMAT(1H1,10X,29H# OF GROUP CARDS GREATER THAN,I4)               PACK2640
      STOP                                                              PACK2650
  880 NRO(K,I)=IVAL(1)                                                  PACK2660
      DO 890 J=1,8                                                      PACK2670
      IB(K,I,J)=IVAL(J+1)                                               PACK2680
  890 CONTINUE                                                          PACK2690
      IBNUM(K,IB(K,I,1)-500)=I                                          PACK2700
      NLINE(K)=I                                                        PACK2710
  900 IF(KS(1)) 860,860,910                                             PACK2720
  910 WRITE(6,920) NRO(K,I),(IB(K,I,J),J=1,8)                           PACK2730
  920 FORMAT(1X,I3,8I4)                                                 PACK2740
      GO TO 860                                                         PACK2750
  930 CONTINUE                                                          PACK2760
      I=I-1                                                             PACK2770
      IOR=IOR+1                                                         PACK2780
C** OPERATE RULE CARD. CHECK IF MORE THAN ALLOWED.                       PACK2790
      IF(IOR.LE.MAXSTD) GO TO 950                                       PACK2800
      WRITE(6,940) MAXSTD                                               PACK2810
  940 FORMAT(1H1,10X,36H# OF OPERATE RULE CARDS GREATER THAN,I4)        PACK2820
      STOP                                                              PACK2830
  950 CONTINUE                                                          PACK2840
      DO 960 J=1,10                                                     PACK2850
      ISTB(IOR,J,K)=IVAL(J)                                             PACK2860
  960 CONTINUE                                                          PACK2870
      IF(KS(1)) 860,860,970                                             PACK2880
```

```
  970 WRITE(6,980) (ISTB(IOR,J,K),J=1,10)                                PACK2890
  980 FORMAT(30X,10I4)                                                   PACK2900
      GO TO 860                                                          PACK2910
  990 CONTINUE                                                           PACK2920
 1000 CONTINUE                                                           PACK2930
      RETURN                                                             PACK2940
      END                                                                PACK2950
```

```
      SUBROUTINE EVENT
      COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ
     1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
     2,RELPY,REPOL,STPHAS,TP,T1,XCUM,TT3,UP3,IFFEDP,T3,TIME,T3SUM
      COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
C
C DETERMINES SMALLEST VALUE IN ETIME VECTOR
C
      R=ABS(ETIME(1))
      KEQ=1
      DO 20 I=2,NEQ
      RR=ABS(ETIME(I))
      IF (R-RR) 20,20,10
   10 R=RR
      KEQ=I
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TTE
      COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ
     1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
     2,RELPY,REPOL,STPHAS,TP,T1,XCUM,TT3,UP3,IFFECP,T3,TIME,T3SUM
      COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
      COMMON/EXTRA/ KS(20),ISW(31)
      COMMON/NPH/ NSS(6),IFLAG(6),TITLE(6,31),SSTIME(6,31,2),ISS(6,31)
      COMMON /TYP/EX(2,200),ISPARE(3,200),IUSED(3,200),IIUSED(3,200)
      COMMON /DELTA/KKK2
      COMMON /XXX/XXX
      COMMON/VDC/VDC(50,6),IUI(200),VMTTR(200,6),TAD2
      COMMON /GAMMAA/XMTBA,VAR,RELGA(100),TIMA(100),XXT(200),ITT,ISEED
C
   10 K=KEQ
   20 J=IABS(IEQU(K))
      IF (ETIME(K)-100000.) 30,120,30
   30 IF (ETIME(K)) 120,120,40
C
C    CHECK IF ANY SPARES REMAIN
C
C
C       IF INFINITE REPAIR TIME, NO SPARE IS USED
C
   40 IF (ABS(XXX)-9999.) 41,120,41
   41 DO 60 I=1,2
      IF (ISPARE(I,J)-IUSED(I,J)) 60,60,50
   50 IUSED(I,J)=IUSED(I,J)+1
      IIUSED(I,J)=IIUSED(I,J)+1
      II=I
      GO TO 120
   60 CONTINUE
      IF (ISPARE(3,J)-IUSED(3,J)) 70,70,110
   70 IF (ETIME(K)-100000.) 80,120,80
   80 ETIME(K)=-500000.
      IF (KS(12)) 340,340,90
   90 WRITE (6,100) J
  100 FORMAT (1X15HEQUIPMENT TYPE ,I4,25H HAS CONSUMED ALL SPARES.)
      GO TO 340
  110 IUSED(3,J)=IUSED(3,J)+1
      IIUSED(3,J)=IIUSED(3,J)+1
      II=3
C
C    GENERATE TIME-TO-EVENT
C
  120 XXX=ABS(XXX)
C
C    KKK = 0  INDICATES FIRST PHASE IN MISSION.
C
```

```
      IF (KKK2) 140,130,140                                      TTE 0490
  130 TP=0                                                       TTE 0500
      II=0                                                       TTE 0510
  140 IF (ETIME(K)-100000.) 160,150,160                          TTE 0520
  150 ETIME(K)=-TP                                               TTE 0530
      GO TO 170                                                  TTE 0540
  160 IF (ETIME(K)) 170,170,180                                  TTE 0550
  170 X=1.                                                       TTE 0560
      GO TO 190                                                  TTE 0570
  180 X=-1.                                                      TTE 0580
  190 CALL RANDOM(ISEED,RN,1)                                    TTE 0590
      IF (II-2) 200,210,210                                      TTE 0600
  200 ADT=0.                                                     TTE 0610
      GO TO 220                                                  TTE 0620
  210 III=II-1                                                   TTE 0630
      ADT=EX(III,J)                                              TTE 0640
  220 CONTINUE                                                   TTE 0650
      IF (ETIME(K)) 230,230,330                                  TTE 0660
  230 K1=IABS(IEQU(K))                                           TTE 0670
      IF (IUI(K1)) 330,330,240                                   TTE 0680
  240 IU=IUI(K1)                                                 TTE 0690
      ST=0.0                                                     TTE 0700
      SR=1.0                                                     TTE 0710
      RN3=RN                                                     TTE 0720
      DO 310 I=JBB,100                                           TTE 0730
      T=XXT(2*I)                                                 TTE 0740
      IF (T) 250,320,250                                         TTE 0750
  250 IF (ST) 300,260,300                                        TTE 0760
  260 T=TIMA(I)+ETIME(K)                                         TTE 0770
      IF (T) 270,310,300                                         TTE 0780
  270 T=0                                                        TTE 0790
      GO TO 310                                                  TTE 0800
  300 LLL=XXT(2*I-1)                                             TTE 0810
      XM=VDC(IU,LLL)                                             TTE 0820
      IF (XM) 280,320,280                                        TTE 0830
  280 R=EXP(-T/XM)                                               TTE 0840
      SR=SR*R                                                    TTE 0850
      IF (SR-RN) 320,320,290                                     TTE 0860
  290 ST=ST+T                                                    TTE 0870
      RN3=RN/SR                                                  TTE 0880
  310 CONTINUE                                                   TTE 0890
  320 ETIME(K)=ST-(XM*ALOG(RN3))+ABS(ETIME(K))+ADT               TTE 0900
      GO TO 340                                                  TTE 0910
  330 ETIME(K)=X*(-XXX*ALOG(RN)+ABS(ETIME(K))+ADT)               TTE 0920
  340 IF (IFLAG(LL)-1) 370,370,350                               TTE 0930
  350 IF (ETIME(K)+500000.) 360,370,360                          TTE 0940
  360 ETIME(K)=100000.                                           TTE 0950
  370 CONTINUE                                                   TTE 0960
```

```
      RETURN                                                          TTE 0970
      END                                                             TTE 0980
```

```
      SUBROUTINE EVENT                                                  EVNT0010
      COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ  EVNT0020
     1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2 EVNT0030
     2,RELPY,REPOL,STPHAS,TP,T1,XCUM,TT3,UP3,IFFEOP,T3,TIME,T3SUM       EVNT0040
      COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)   EVNT0050
C                                                                       EVNT0060
C DETERMINES SMALLEST VALUE IN ETIME VECTOR                             EVNT0070
C                                                                       EVNT0080
      R=ABS(ETIME(1))                                                   EVNT0090
      KEQ=1                                                             EVNT0100
      DO 20 I=2,NEQ                                                     EVNT0110
      RR=ABS(ETIME(I))                                                  EVNT0120
      IF (R-RR) 20,20,10                                                EVNT0130
   10 R=RR                                                              EVNT0140
      KEQ=I                                                             EVNT0150
   20 CONTINUE                                                          EVNT0160
      RETURN                                                            EVNT0170
      END                                                               EVNT0180
```

```
      SUBROUTINE STNDBY                                                 STND0010
      COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ  STND0020
     1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2 STND0030
     2,RELPY,REPOL,STPHAS,TP,T1,XCUM,TT3,UP3,IFFECP,T3,TIME,T3SUM       STND0040
      COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)   STND0050
      CCMMON /XXX/XXX                                                   STND0060
      COMMON/STAN/ISTB(60,10,6)                                         STND0070
      DO 170 I=1,50                                                     STND0080
      IF (ISTB(I,1,LL)) 10,180,10                                       STND0090
C INDEX=1 INDICATES ALL EQUIPMENTS IN STRING ARE UP.                    STND0100
   10 INDEX=1                                                           STND0110
      DC 50 J=2,10                                                      STND0120
      KK=ISTB(I,J,LL)                                                   STND0130
      IF (KK) 30,60,20                                                  STND0140
   20 IF (ETIME(KK)) 40,50,50                                           STND0150
C INDEX=0 INDICATES AT LEAST ONE OF THE EQUIPMENTS IN THE STRING IS DOWNSTND0160
   30 KK=IABS(KK)                                                       STND0170
      IF (ETIME(KK)) 40,40,50                                           STND0180
   40 INDEX=0                                                           STND0190
      GO TO 60                                                          STND0200
   50 CONTINUE                                                          STND0210
C   K IS THE EQUIPMENT NUMBER WHICH WILL BE PUT UP OR STANDBY.          STND0220
   60 K=IABS(ISTB(I,1,LL))                                              STND0230
C ISO PLUS OR MINUS INDICATES STRING OR STANDBY LOGIC.                  STND0240
      ISO=ISTB(I,1,LL)                                                  STND0250
C IF EQUIPMENT DOWN (ETIME MINUS) LEAVE ALONE.                          STND0260
   70 IF (ETIME(K)) 170,170,80                                          STND0270
   80 IF (ETIME(K)-100000.) 120,90,120                                  STND0280
   90 IF (INDEX) 170,110,100                                            STND0290
  100 IF (ISO) 170,170,150                                              STND0300
  110 IF (ISO) 150,170,170                                              STND0310
  120 IF (INDEX) 170,140,130                                            STND0320
  130 IF (ISO) 160,170,170                                              STND0330
  140 IF (ISO) 170,170,160                                              STND0340
C CALL TTE TO PUT ON EQUIPMENT THAT WAS OFF(STANDBY).                   STND0350
  150 IABC=IABS(IEQU(K))                                                STND0360
      XXX=XMTBF(IABC)                                                   STND0370
      KEQ=K                                                             STND0380
      CALL TTE                                                          STND0390
      GO TO 170                                                         STND0400
C TO PUT OFF(STANDBY) EQUIPMENT THAT WAS ON.                            STND0410
  160 ETIME(K)=100000.                                                  STND0420
  170 CONTINUE                                                          STND0430
  180 RETURN                                                            STND0440
      END                                                               STND0450
```

```
      SUBROUTINE STATUS
      COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ
     1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
     2,RELPY,REPOL,STPHAS,TP,T1,XCUM,TT3,UP3,IFFEOP,T3,TIME,T3SUM
      COMMON/BETA/NRO(6,300),IB(6,300,8),NLINE(6)
      COMMON/EXTRA/ KS(20),ISW(31)
      COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
      COMMON/NPH/ NSS(6),IFLAG(6),TITLE(6,31),SSTIME(6,31,2),ISS(6,31)
C
      KID=0
      NL1=NLINE(LL)
   10 DO 130 K=1,NL1
   12 KT=IB(LL,K,1)
   14 IF(KID-KT)16,18,16
   16 ISUM=0
C
C NRO IS NUMBER OF EQUIPMENTS REQUIRED UP
C
   18 IF(NRO(LL,K))130,130,20
   20 DO 60 J=2,8
   30 KK=IABS(IB(LL,K,J))
      IF (KK) 70,70,40
   40 IF (ETIME(KK)) 60,60,50
   50 ISUM=ISUM+1
   60 CONTINUE
   70 CONTINUE
      IF (ISUM-NRO(LL,K)) 80,90,90
   80 ETIME(KT)=-1.
      GO TO 100
   90 ETIME(KT)=1.
  100 IF(KS(12))125,125,110
  110 WRITE(6,120)KT,ETIME(KT)
  120 FCRMAT(1X3HKK=,I5,7H ETIME=,F10.5)
  125 KID=KT
  130 CONTINUE
      N=NSS(LL)+1
      DO 160 I=1,N
      J=ISS(LL,I)
      IF (ETIME(J)) 140,140,150
  140 ISW(I)=-1
      GO TO 160
  150 ISW(I)=1
  160 CONTINUE
      KZZ=0
      RETURN
      END
```

```
      SUBROUTINE APPLE
      DIMENSION IPRNT(50),ICHLD(50),MKBA(100)
      COMMON /ALPHA/DNT2,ENDPHA,ICRI, IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ
     1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
     2,RELPY,REPOL,STPHAS,TP,T1,XCUM,TT3,UP3,IFFEOP,T3,TIME,T3SUM
      COMMON/BETA/NRD(6,300),IB(6,300,8),NLINE(6)
      COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
      COMMON /TIGAP/ UP4,XNUM,BAPRIN,AVA,XPCAP,RUNID(19),TYCOON(500)
     +,COUNTB(500),XTCUM
      COMMON/RUNAP/ITEMP2,DELT,ISSA(31),ISSC
      COMMON/NPH/NSS(6),IFLAG(6),TITLE(6,31),SSTIME(6,31,2),ISS(6,31)
      COMMON /PACKAP/ IBNUM( 6,500),ISYS( 6),F(200,4)
C
      IF(BAPRIN)790,90,90
   90 JCOUNT=0
C**********   INITIALIZE
C            CLEAR STACK,NUM PRIORITY FAIL=0,SET PHASE,SET TREE PARENT TO
  100 IPTR=0
      L=LL
      IF(ITEMP2)240,105,107
  105 K=IBNUM(L,ISYS(L)-500)
      GOTO 108
  107 KSS=ISSA(ISSC)
      K=IBNUM(L,ISS(L,KSS)-500)
  108 KID1=IB(L,K,1)
  110 NN=2
C**********   LOOK AT CHILDREN OF PARENT
C               LOOK FROM (NN-1)TH CHILD,
  120 DO 210 N=NN,8
      IGRP=IB(L,K,N)
      IF(IGRP)240,212,140
  140 IF (ETIME(IGRP)) 150,150,210
  150 IF (IGRP-500) 170,170,160
C     *****   WE HAVE A FAILED PRIORITY EQUIPMENT
C        ***   HAVE WE SEEN THIS EQ. BEFORE
  170 IF (JCOUNT) 240,200,180
  180 DO 190 I=1,JCOUNT
      IF (MKBA(I)-IGRP) 190,210,190
  190 CONTINUE
  200 CONTINUE
C        ***   ADD TO LIST OF FAILED PRIORITY EQ.
      JCOUNT=JCOUNT+1
      MKBA(JCOUNT)=IGRP
  210 CONTINUE
  212 IF(K-1)220,220,214
  214 KID2=IB(L,K-1,1)
      IF(KID1-KID2)220,216,220
  216 K=K-1
```

```
      GOTO 108
  220 IF (IPTR) 240,260,230
C**********  GO BACK TO LAST PARENT
  230 K=IPRNT(IPTR)
      KID1=IB(L,K,1)
      NN=ICHLD(IPTR)
      IPTR=IPTR-1
      GOTO 120
C**********  LOOK AT CHILDREN OF FAILED CHILD
  160 IF (N-8) 165,167,240
C     *****   PUT PARENT INTO STACK AND MAKE CHILD NEXT PARENT
  165 IPTR=IPTR+1
      IPRNT(IPTR)=K
      ICHLD(IPTR)=N+1
  167 K=IBNUM(L,IGRP-500)
      GOTO 108
  240 WRITE (6,250)
  250 FORMAT (12H APPLE ERROR)
      GO TO 300
C**********  BOOKKEEPING
  260 IF(ITEMP2) 240,265,262
  262 ISSC=ISSC-1
      IF (ISSC) 240,265,100
  265 FCOUNT=FLOAT(JCOUNT)
      IF (ITEMP2) 270,270,280
C     *****  SUMMING DOWNTIME BY EQ
  270 DO 275 I=1,JCOUNT
  275 TYCOON(MKBA(I))=TYCOON(MKBA(I))+DELT/FCOUNT
      GOTO 300
C     *****  SUMMING ABORTS BY EQ.
  280 DO 290 I=1,JCOUNT
  290 COUNTB(MKBA(I))=COUNTB(MKBA(I))+1/FCOUNT
  300 CONTINUE
      RETURN
C
C BEGINNING OF FINAL PRINTOUT
C
  790 CONTINUE
      WRITE (6,800) (RUNID(I),I=1,19)
  800 FORMAT(1H1,3X,19A4//)
      WRITE (6,810)
  810 FORMAT(32X,19HCRITICAL EQUIPMENTS//32X,18HUNAVAILABILITY AND/   27
     1X25HPERCENT OF UNAVAILABILITY//)
      WRITE (6,820)
  820 FORMAT (24X4HNAME,17X7HNUM HRS,11X5HUNAVA,2X7HPERCENT,6X8HEQU TYPE
     1,5X7HEQU NUM/)
C
C     SKIPS BAD APPLE PRINTOUT WHEN AVA OR REL = 1.0
```

```
C                                                                       APPL0970
      IF (AVA-1.) 830,880,830                                           APPL0980
  830 TR=TYCOON(1)                                                      APPL0990
      INDEX=1                                                           APPL1000
      DO 850 I=2,NEQ                                                    APPL1010
      TRR=TYCOON(I)                                                     APPL1020
      IF (TR-TRR) 840,850,850                                           APPL1030
  840 TR=TRR                                                            APPL1040
      INDEX=I                                                           APPL1050
  850 CONTINUE                                                          APPL1060
      TYCUM=TYCOON(INDEX)/TT3                                           APPL1070
      TYCUM2=TYCOON(INDEX)/(TT3-UP4)*100.                               APPL1080
      IF (TYCOON(INDEX)) 860,880,860                                    APPL1090
  860 IXX=IABS(IEQU(INDEX))                                             APPL1100
      WRITE (6,870) (F(IXX,J),J=1,4),TYCOON(INDEX),TYCUM,TYCUM2,IXX     APPL1110
     1,INDEX                                                            APPL1120
  870 FORMAT (20X4A4,F20.4,4XF8.4,F8.2,8XI4,10XI4)                      APPL1130
      TYCOON(INDEX)=0.0                                                 APPL1140
      GO TO 830                                                         APPL1150
  880 WRITE (6,800) (RUNID(I),I=1,19)                                   APPL1160
      WRITE (6,910)                                                     APPL1170
  910 FORMAT(32X,19HCRITICAL EQUIPMENTS//32X,17HUNRELIABILITY AND/   27XAPPL1180
     127HPERCENT OF MISSION FAILURES//)                                 APPL1190
      WRITE (6,920)                                                     APPL1200
  920 FORMAT (12X11HDESCRIPTION,8X3HNO.,6X6HUNREL ,3X7HPERCENT,2X13HEQUIAPPL1210
     1P  EQUIP /28X8HFAILURES,22X10HTYPE   NO.)                         APPL1220
      IF (XPCAP-1.) 930,1090,930                                        APPL1230
C                                                                       APPL1240
C*****THROW OUT EQUIPMENTS WITH ZERO FAILURES                           APPL1250
C                                                                       APPL1260
  930 INEWA=0                                                           APPL1270
      DO 950 I=1,NEQ                                                    APPL1280
      IF (COUNTB(I)) 950,950,940                                        APPL1290
  940 INEWA=INEWA+1                                                     APPL1300
      MKBA(INEWA)=I                                                     APPL1310
  950 CONTINUE                                                          APPL1320
C                                                                       APPL1330
C*****RANK LIST BY NO. FAILURES                                         APPL1340
C                                                                       APPL1350
      TOTAL=XNUM-XTCUM                                                  APPL1360
  955 IF (INEWA-1) 1010,975,952                                         APPL1370
  952 INDEX=MKBA(1)                                                     APPL1380
      NN=1                                                              APPL1390
      TR=COUNTB(INDEX)                                                  APPL1400
      DO 970 I=2,INEWA                                                  APPL1410
      IF (TR-COUNTB(MKBA(I))) 960,970,970                               APPL1420
  960 INDEX=MKBA(I)                                                     APPL1430
      NN=I                                                              APPL1440
```

```
      TR=COUNTB(INDEX)
  970 CONTINUE
  977 UNREL=TR/XNUM
      PERC=TR/TOTAL*100.
      IND=IABS(IEQU(INDEX))
      WRITE(6,990) (F(IND,J),J=1,4),TR,UNREL,PERC,IND,INDEX
  990 FORMAT (9X4A4,3XF6.1,5XF6.4,3XF6.2,4XI4,3XI4)
      MKBA(NN)=MKBA(INEWA)
      INEWA=INEWA-1
      GOTO 955
  975 INDEX=MKBA(1)
      TR=COUNTB(INDEX)
      GOTO 977
 1010 JNUM=IFIX(XNUM)
      WRITE (6,1020) JNUM
 1020 FORMAT (//9X19HTOTAL NO. MISSIONS=,I4)
      ITOTAL=TOTAL
      WRITE (6,1030) ITOTAL
 1030 FORMAT (9X27HTOTAL NO. MISSION FAILURES=,I4)
 1090 RETURN
      END
```

```
      SUBROUTINE SPARES
C
C     FLSIP COSAL MODEL WITH INSURANCE CUT POINT READ IN WITH DATA
C
      COMMON /ALPHA/DNT2,ENDPHA,ICRI,IFF,IFR,INUM,IOPT,JBB,KEQ,KKK,KZZ
     1,KK1,KS1,LL,LLLAST,NEQ,NPH,NTYPE,NUM,REDAD2,REDAD1(100),RELP,RED2
     2,RELPY,REPOL,STPHAS,TP,T1,XCUM,TT3,UP3,IFFEOP,T3,TIME,T3SUM
      COMMON /N/IEQU(500),KEQU(500),ETIME(1000),XMTBF(200),XMTTR(200)
      COMMON /TYP/EX(2,200),ISPARE(3,200),IUSED(3,200),IIUSED(3,200)
      COMMON /CSPARE/ SPR1,SPR2,SPR3,SPR4,SPR5,SPR6,SPR7,SPR8,SPR9
     1,SPR10,SPR11,SPR12,SPR13,SPR14,ITMPOP(200)
      CUT=SPR1
      DO 10 I=1,NTYPE
      ITMPOP(I)=0
   10 CONTINUE
      DO 20 I=1,NEQ
      ITMPOP(IEQU(I))=ITMPOP(IEQU(I))+1
   20 CONTINUE
      DO 90 I=1,NTYPE
      EX90DD=((8766./XMTBF(I))/4.)*ITMPOP(I)
      IF(EX90DD-1.) 60,30,30
C
C     DEMAND BASED ITEM
C
   30 PRBSUM=EXP(-EX90DD)
      DUM=PRBSUM
      KFACT=1
      K=0
   40 K=K+1
      KFACT=KFACT*K
      PRBSUM=PRBSUM+DUM*(EX90DD**K)/KFACT
      IF(PRBSUM-.9) 40,50,50
   50 ISPARE(1,I)=K
      GO TO 90
   60 IF(4.*EX90DD-CUT) 80,80,70
C
C     INSURANCE ITEM
C
   70 ISPARE(1,I)=1
      GO TO 90
   80 ISPARE(1,I)=0
   90 CONTINUE
      DO 100 I=1,NTYPE
      DO 100 J=2,3
      ISPARE(J,I)=0
  100 CONTINUE
      RETURN
      END
```

LIST OF REFERENCES

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

2. Chief of Naval Operations Instruction 4441.12A, Supply Support of the Operating Forces, 9 August 1973.

3. Center for Naval Analysis Memorandum (CNA)80-0881, Third Advisory Committee Briefing on Shipboard Parts Allowance Policy Study, by Cdr. J. Bagby, 19 June 1980.

4. Learmonth, G. P. and Lewis, P. A. W., 'Naval Postgraduate School Random Number Generator Package', Naval Postgraduate School Report NPS55LW3061A, June 1973

5. Buckberg, M. L. and Vail, J. A., 'DDG-47 Reliability Engineering Analysis,' Naval Engineers Journal, v. 90, no. 3, p. 85-90, June 1978.

6. Naval Sea Systems Command Report 313-110-79, Reliability/Maintainability/Availability Design Data Bank, September 1979.

7. Judge, S. D. and Luetjen, P., 'Determination of Shipboard Repair Parts Level,' Naval Engineers Journal, v. 91, no. 2, p. 37-43, April 1979.

8. Department of Defense Military Standardization Handbook MIL-HDBK-217C, Reliability Prediction of Electronic Equipment, 9 April 1979.

9. Straub, D. R., 'Differences Between Failure Rates and Best Replacement Factors,' Navy Supply Corps Newsletter, v. 42, no. 5, p. 35-38, May 1979.

10. Esary, J. D. and Richards, F. R., Some Hostile Comments About the Definition of Operational Availability, paper presented at 44th Symposium of MORS, Vandenberg AFB California, 5 December 1979.

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