AN ANALYSIS OF THE ENDURANCE OF MOBILE SATELLITE COMMAND AND CONTROL SYSTEMS

THESIS

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Steven O. Brown

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Abstract

This study investigated the endurance of a single deployed generic mobile space (GMS) command and control (C^2) system. Specifically, factors which affect overall system performance were examined. The analysis began with the development of a simulation model for a GMS C^2 system. Optimal settings of factor levels were determined by using the model to find peak system endurance and availability. Factors set were field support vehicle (FSV) access, numbers of maintenance personnel, and numbers of spare components available. After optimum values were chosen for these factors, an experimental design was conducted to determine factor effects between maintenance manpower and the component failure and repair rates. It was determined that access to the FSV increases system endurance by 6.1 percent. Increasing maintenance manpower does not significantly affect system availability. Eight components, most in the communications subsystems, were identified for increased spares levels which could increase system endurance by an additional 2.8 percent. Of all factors and combination of factors considered in the experimental design, only the rate of component failures significantly affected system performance.

AN ANALYSIS OF THE ENDURANCE OF MOBILE SATELLITE COMMAND AND CONTROL SYSTEMS

I. Introduction

1.1 Background

The military has been devising potential applications for artificial satellites since their inception. One important application is early warning of ballistic missile launchings. Early warning satellites "detect and track ballistic missile launches around the world"(3:23). Satellites have replaced much of the early warning radar system. "The [early warning] radars provided about 15 minutes [of warning]. The use of early warning satellites has extended this warning time to some 30 minutes"(10:33). "The satellites detect launches, analyze the data and relay it to ground control stations" (3:23). The ground control stations then relay all processed information to the North American Defense Command (NORAD). The stations primarily responsible for delivering this launch information are fixed ground stations that are inherently vulnerable to attack.

Mobile ground stations were developed in the late 1970s to increase the survivability of the receiving portion of the early warning satellite network. A generic mobile space (GMS) command and control (C^2) system is a road mobile, highly survivable ground processing and data distribution system designed to receive satellite transmissions. A GMS convoy is made up of several operational and support vehicles capable of completing an extended deployment. Each convoy typically contains the following vehicles:

1. Satellite Command Vehicle (SCV) - Provides satellite C^2.

2. Satellite Mission Vehicle (SMV) - Processes and routes satellite mission data to end users.

3. Personnel Vehicle (PV) - Houses personnel during deployment.

4. Supply Vehicle (SV) - Houses spares and maintenance supplies (9).

During an actual deployment, a Field Support Vehicle (FSV) is also deployed. This vehicle contains additional spares and maintenance equipment and is accessible by any convoy deploying from the same base.

The GMS operates out of two separate bases with one being designated as the main operating base (MOB). Typically, five convoys operate from each base. While not deployed, at least one of the systems is operating at all times to provide backup to the base's primary satellite C^2 system. Each base deploys one of the convoys every two months as an exercise. An exercise is a fixed length deployment with MOB support available during the deployment. Since MOB support is available, the FSV does not deploy during an exercise. During an actual deployment, all convoys deploy at a random azimuth somewhere between 25 and 250 miles from their home base. The purpose of each of the deploying convoys is to remain operational and provide satellite for C^2 as long as possible (9).

Maintenance personnel, spares, and maintenance equipment accompany each deployed convoy in order to extend the amount of time the SCV and SMV can remain operational. If no spares are available when a failure occurs, the FSV can be called upon to provide additional supplies. If the failure is not field-repairable, the convoy must either receive assistance from the operating base or return to base. Due to location uncertainties, inter-convoy cannibalization will not be considered in this thesis project (9).

1.2 Objectives

The purpose of this study was to analyze the performance of a single deployed GMS. Performance was analyzed by examining system endurance and availability. The cost and logistics of operating the system precludes using it to collect a significant amounts of data from field experiments. Therefore, a simulation model was developed to analyze the effect of varying one or more factors over multiple deployments. The primary objective of this study was to produce a discrete-event simulation model of an entire GMS deployment. The requesting agency for this study, the Logistics Studies and Analysis Division (LG4) of the Air Force Operational Test and Evaluation Center (AFOTEC), has requested the model be coded using the Simulation Language for Alternative Modeling (SLAM II). The model has been designed to allow different types of system configurations as well as a wide range of sensitivity analysis. A second objective was to use the sensitivity analysis capabilities of the model to choose optimum values of maintenance personnel, determine where spare part deficiencies exist, and analyze the effect of having FSV support. Since these optimum values are extremely sensitive to the failure and repair rates, the final objective was to conduct an experimental design to vary these rates and evaluate the robustness of the chosen parameters.

1.3 Sub-objectives

The following list breaks down the main objective into a group of achievable goals that were accomplished to solve the specific problem:

- Identify the level of detail to be included in the model;
- Identify the deployment policies and procedures of a GMS convoy;
- Identify all variables that affect the deployment and should be included in the model;
- Identify the outputs needed from the model;

- Gather data on variables and parameters to be included in the model;
- Build the SLAM II simulation code;
- Verify and validate the model;
- Document the model.
- Perform sensitivity analysis on key factors;
- Run an experimental design to determine the factor effects of maintenance manpower, failure rates, and repair rates.

1.4 Methodology

The requesting agency for this study provided some information pertaining to the level of detail of the model and other essential information concerning mobile ground systems. Detailed information was also be obtained from individuals who have previously worked on the Defense Support Program (DSP) satellite network.

The simulation model was developed using the Air Force Institute of Technology's computer resources. The verification of the model was performed by manually following entities through each stage of the simulation model. All entity attributes and simulation variables were calculated and verified as the entity proceeded through the network. Probability distributions used in the model were also checked to ensure that failures and repairs were occurring within specified limits. Validation of the model was accomplished by comparing the output of the model to existing satellite C^2 system deployment results. Documentation on how to use the model has been compiled for future reference.

II. Literature Review

2.1 Introduction

The following paragraphs review literature pertinent to this research. Specifically, this review covers the topics of reliability, maintainability, availability, and simulation. These four topics pertain to endurance and will be the primary subjects used in developing the simulation model for this thesis.

2.2 Discussion

2.2.1 Reliability. Reliability is the probability that an item will perform its specified function for a given period of time. Four variables commonly used in reliability are "system availability, first failure time, mean time between failure (MTBF), and mean time to repair (MTTR)" (8:551). Mean time between failures is defined as "the total functioning life of a population of an item during a specific measurement interval, divided by the total number of failures within the population during that interval" (7:2.1). The mean times are often determined by taking the inverse of the failure rate. Since reliability is a probability, there will be a confidence interval associated with the mean of each reliability variable. Confidence intervals can be calculated from experimental or simulated data (11:3). Failures can occur for individual components or for an entire system made up of several components. System failures are generally a key factor in the study of reliability. Given the individual component reliabilities, methods are available for calculating overall system reliability (8:551). Models typically used to calculate system reliabilities are series, parallel (or redundant), and combinations of the previous two. In a series model, all components are arranged in such a way that one path leads through all components. A failure in any component results in failure of the entire system. Parallel models have multiple paths, each leading through separate components. In contrast, all components of a parallel or redundant model must fail to cause system failure. Clearly, a redundant design results in a better overall reliability. Mixed models have combinations of series and parallel components. The calculations involved in determining system reliability for these models are usually much more involved than the previous two (7:2.4-2.7). Often portions of a model made up several components may be reduced to a single block with an associated block reliability. These reduced models, referred to as functional models, are extremely useful in modeling actual systems (7:2.8-2.9).

2.2.2 Maintainability. Maintainability is a term that is often confused with the act of maintaining, or maintenance. "Maintainability is a design consideration, whereas maintenance is the consequence of design" (7:3.1). Maintenance requires upkeep and repair of a system that was designed with a particular maintainability. The amount of maintenance, both preventive and corrective, required to keep a system operational is a direct result of the maintainability designed into the system (7:3.1-3.2). "Maintainability, M(t), is the probability that a repair is accomplished in at most, t, time, that is, t is the M-th percentage point of the time to repair distribution" (11:166). The time to repair is a random variable that may belong to any one of a number of distributions with a common being exponential. For an exponential distribution, maintainability can be calculated by:

$$M(t) = 1 - e^{\mu t} \tag{1}$$

where

μ = repair rate

t = time to repair taken from (11:168)

This equation produces a unitless maintainability figure for a given system (11:167-171).

"It is apparent, from the definition of maintainability, that the ability and need to perform maintenance actions is the underlying consideration when assessing maintainability" (7:3.2). Factors which should be considered when designing maintainability into a system are: accessibility, visibility, testability, complexity, and interchangeability. Visibility could be considered a subset of accessibility. Components must be accessible to be repaired or replaced within a reasonable time. As seen from equation (1), maintainability decreases exponentially as time to repair increases. Systems can be accessible and still not be very testable. Often components are grouped or tied together making testing of individual components difficult, thereby increasing the time to repair. Increasing complexity also tends to decrease maintainability. Therefore, designing a highly maintainable system requires extreme attention to the human factors involved in maintenance (7:3.2-3.4).

2.2.3 Availability. "Availability is the parameter that translates system reliability and maintainability characteristics into an index of effectiveness" (7:4.1). "For a repairable system, the availability, A, is the ratio of the actual operating time to the scheduled [operating time], excluding preventive maintenance or scheduled servicing" (11:166).

> Operational Availability (A_o) is a commonly used measure of effectiveness for systems operating under steady state conditions. A_o indicates the fraction of time a system is ready to perform its mission. (13:29)

Since availability is heavily dependent on reliability, it also is a time-related random variable. Figure 1 shows a breakdown of equipment operation times relevant to the calculation of availability. The equipment operating times shown in Figure 1 give rise to the mathematical definition of availability.

$$Availability = \frac{Up\ Time}{Total\ Time} = \frac{Up\ Time}{Up\ Time + Down\ Time} \tag{2}$$

taken from (7:4.2)

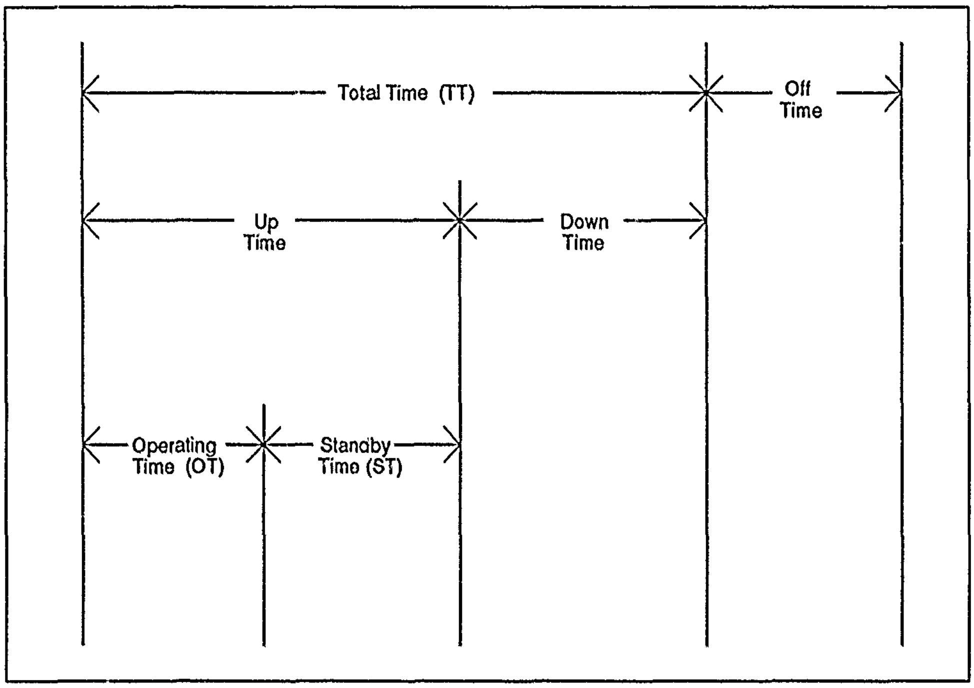

Figure 1. Breakdown of Total Equipment Time

taken from (7:4.1)

Inherent availability, A_i, is another commonly used form of availability. Unlike operational availability, inherent availability is calculated only from means and is not a random variable. The mathematical definition for inherent availability is:

$$A_i = \frac{MTBF}{MTBF + MTTR} \tag{3}$$

where

$MTBF$ = mean time between failures

$MTTR$ = mean time to repair　　taken from (7:4.3)

As shown in Figure 1, operational availability covers all time that the equipment is deployed. Thus, operational availability is usually considered a more useful measure of system capability than inherent availability (7:4.2-4.4). "This relationship is intended to provide a realistic measure of equipment availability when the equipment is deployed and functioning ..." (13:30).

> Assessing the confidence level for the [operational] availability is more complicated than it is for the reliability or the maintainability. Because an extra probability distribution is involved, and another set of data, closed formulas for confidence assessment are not obtainable, even in the simplest case when both events are exponential. Therefore, it is necessary to employ Monte Carlo simulation. (11:166-167)

According to Schroeder, "Complex availability conditions exist when two or more forms of simple availability exist in the system under consideration" (14:745). "The simulation approach [to modelling complex availability] often provides more information about the system's operating performance than can be obtained from analytic means" (14:746).

2.2.4 Simulation. Models are simplifications of complex systems. They are usually developed to provide a description of or make inferences about the complex system being modelled. Simulation model can perform both functions, and are ideally suited for performing experiments without incurring the cost of building or operating the actual system (12:4-7).

> These experiments, or simulations, permit inferences to be drawn about systems
>
> - Without building them, if they are only proposed systems;
> - Without disturbing them, if they are operating systems that are costly or unsafe to experiment with;
> - Without destroying them, if the object of an experiment is to determine their limits of stress. (12:6)

"To create a [simulation] of a system, the modeler must be able to visualize operations of the system he is studying and convert them into a computer code that behaves in certain key ways like the system he is studying" (6:327). "A simulation experiment involves observing the dynamic behavior of a model by moving from state to state in accordance with well defined operating rules" (12:6). The moves from state to state can be one of two types.

> Simulation is often categorized as being discrete event or continuous. Discrete event practitioners view the world as a set of events separated by periods of time of varying sizes, definite or indefinite. Continuous simulationists view the world as a set of events (though they may not call them events) separated by time steps of constant sizes for a given process, although step size may vary to control error. (5:167)

According to Pritsker, there are ten stages involved in developing a simulation model.

1.	Problem Formulation	The definition of the problem to be studied including a statement of the problem solving objective.
2.	Model Building	The abstraction of the system into mathematical-logical relationships in accordance with the problem formulation.
3.	Data Acquisition	The identification, specification, and collection of data.
4.	Model Translation	The preparation of the model for computer processing.
5.	Verification	The process of establishing that the computer program executes as intended.
6.	Validation	The process of establishing that a desired accuracy exists between the simulation model and the real system.
7.	Strategic and Tactical Planning	The process of establishing the experimental conditions for using the model.
8.	Experimentation	The execution of the simulation model to obtain output values.
9.	Analysis of Results	The process of analyzing the simulation outputs to draw inferences and make recommendations for problem resolution.
10.	Implementation and Documentation	The process of implementing decisions resulting from the simulation and documenting the

model and its use.

(12:10-11)

Balci agrees that there are ten steps involved in developing a simulation model and implementing each of the steps is critical in creating a successful model (1:62-70). Verification and validation are often the most difficult of the ten steps to complete. Verification involves manually calculating and comparing results (12:12-13). Validation involves "evaluating reasonableness using all constant values in the simulation model or assessing the sensitivity of outputs to parametric variation of data inputs" (12:13).

> Ordinary techniques leading to a conclusive statement about the verification and validation of a model are not easily applied. Numerous verification and validation techniques are used, some of which are quite ingenious, but, it is impossible to conclude that a large, complex model is completely verified or completely validated. (2:33)

The ten stages are not always performed in the specific order listed. Often a model may require designing and redesigning before a final product can be reached (12:14).

Simulation is widely used as a problem solving tool. "The implementation of recommendations to improve system performance is an integral part of the simulation methodology" (12:14).

2.3 Summary

Reliability is the probability that an item will function properly for a given period of time (11:3). Maintainability is a design feature built into a system that determines the amount of maintenance required upon system failure (7:3.1-3.3). Reliability and maintainability combine to form availability, which is an index of effectiveness for a system. A useful measure of effectiveness is operational availability, which takes into account the entire time a system is deployed (7:4.1-4.5). Complex availability models are often analyzed using simulation modeling techniques (14:744-750). Simulation modeling is one mean available for making inferences about complex systems. Pritsker gives ten steps for building a successful simulation model (12:10-11). Careful attention to each of the ten steps when building a simulation model is critical to achieving the desired results.

III. System Description

The model presented in this thesis is designed to emulate the deployment of a single GMS convoy. The definition of a deployment for the purpose of this analysis is a complete cycle that begins when the convoy departs from the base and ends when it has returned and is ready to deploy again. A functional diagram depicting the major events during a deployment is shown in Figure 2. At any time during the deployment, the system must be either in an operational or non-operational state. When the system is operational, it is either traveling or performing a function associated with the mission. The middle portion of the diagram in Figure 2 represents the GMS convoy at all times it is operational. When the system is not operational, it is in a state of repair. The remaining portions of Figure 2 represent the GMS convoy in various states of repair.model uses during travel, in the field, or at the MOB.

A single FSV deploys with the five convoys from base B. All convoys have access to this FSV. Base A does not provide FSV access for any of its five convoys.

The convoy is assumed to be participating in an actual deployment during a wartime scenario and not on a routine exercise. During an exercise, MOB support is provided to the convoy in the field, as required, to ensure that the predetermined exercise length is achieved. However, during an actual deployment, the status of the MOB and it's personnel is assumed to be unknown and therefore is not considered. The system must be prepared to remain deployed and provide satellite C^2 for as long as possible.

3.1 GMS Deployment Cycle

As shown in Figure 2, the deployment cycle begins as the convoy departs the base for the next operating site. The convoy travels a random distance between 25 and 250 miles from the MOB to begin operations. If a failure of a transportation subsystem occurs during relocation, troubleshooting is performed to assess whether

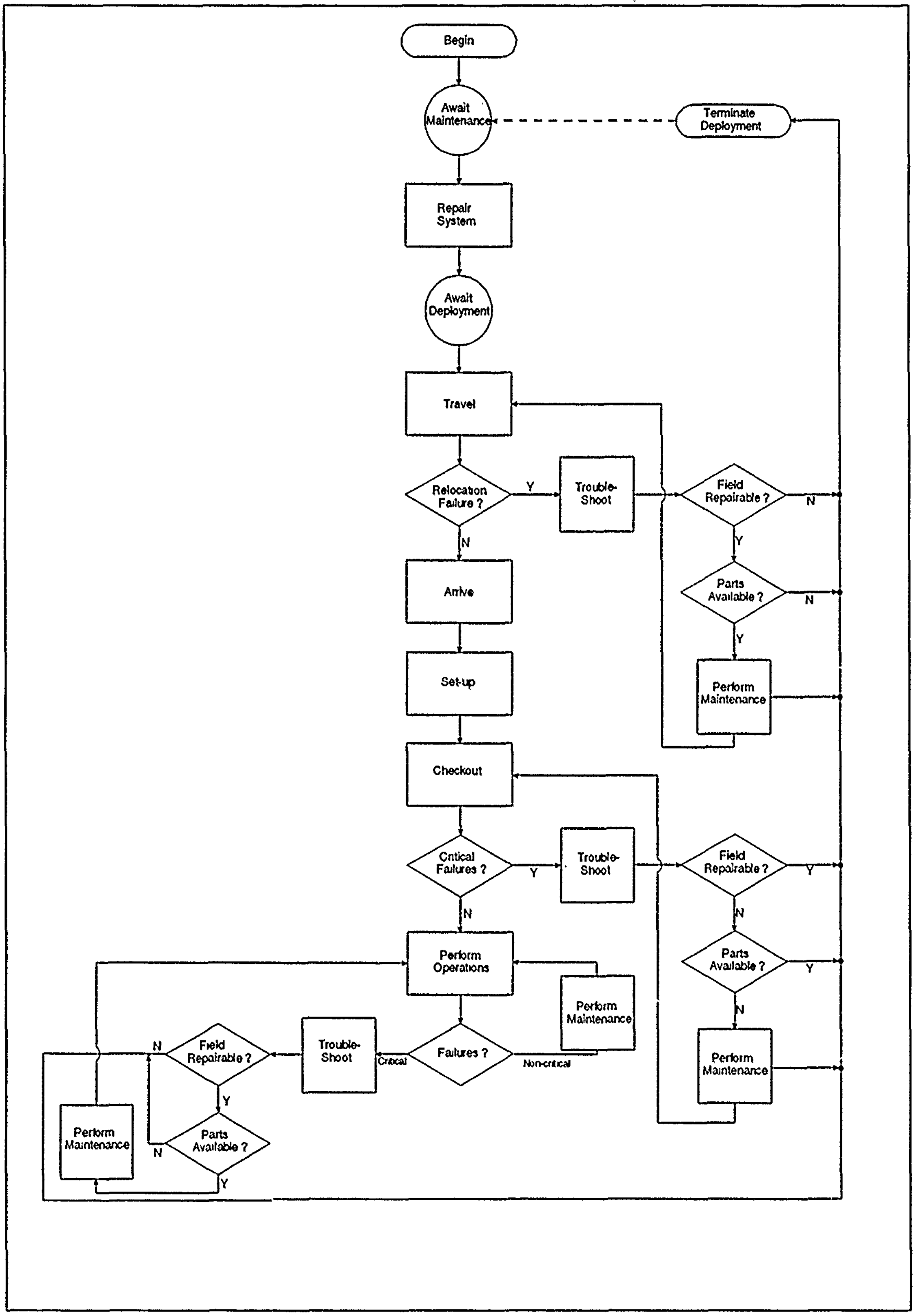

Figure 2. GMS Deployment Flow

the failure is field-repairable. There are three conditions under which a failure can terminate the deployment. First, a failure which is only repairable at MOB forces an abort. Second, since MOB support cannot be relied upon, any failure which would require MOB support also forces an abort. Last, any failure for which there is no spare or redundant unit available terminates the deployment. Any other failure is considered field repairable and travel resumes after maintenance personnel make the appropriate repairs. Upon arrival at the designated location, equipment set-up and check-out is performed. Since damage can occur to any piece of equipment during travel, failures may have occurred which could prevent the system from operating. Again, if failures are detected, troubleshooting is performed and either the deployment is terminated or a repair is made. This cycle is repeated until equipment check-out is passed. After check-out, the system begins operations and performs its mission. When a failure occurs, the "criticality" of the failure determines whether the system remains operational. Non-critical failures are those which do not interrupt operations. These failures are repaired, if possible, without interrupting operations; the repairs are subject to interruption due to higher priority critical failures. Critical failures render the system inoperable and initiate the same troubleshoot/repair procedure described above until a subsequent failure forces an abort. Once an abort-causing failure is detected, the GMS convoy is forced to return to the MOB. The MOB repairs all existing failures and restocks used spares. The GMS convoy is then ready to be redeployed and enters the await deployment phase of the cycle.

3.2 MOB Maintenance Network

The flow of repair entities through the MOB maintenance network is depicted in Figure 3. There are four distinct repair specialties associated with the MOB: power generation units (PGU), communications/electronic systems (CE), environmental control units (ECU), and vehicle (VEH) repair. When a convoy returns from a deployment, the failures are separated by class and sent to the appropriate repair

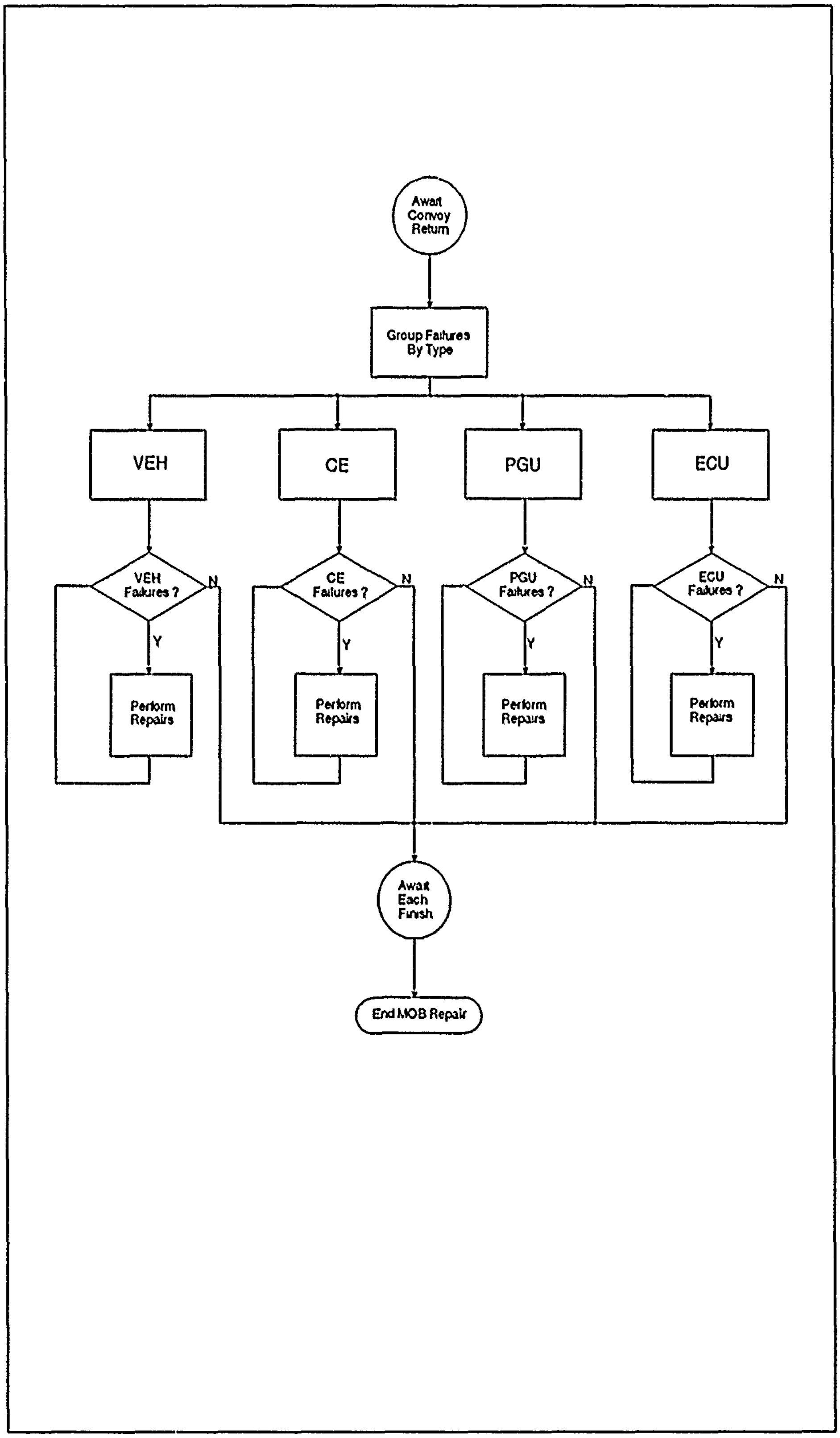

Figure 3. MOB Maintenance

area. Although maintenance resources are not shared between areas, the areas are assumed to be collocated and repairs can occur simultaneously. After all MOB maintenance is complete, the convoy is restocked and returned to operational status.

The number of maintenance resources allocated to each area depends on the number and length of repairs typically associated with a returning convoy. As mentioned in chapter 1, there are five convoys deploying from each base. Thus, there could be more than one convoy at the MOB awaiting repair at any particular time. Since this model only simulates the deployment of a single convoy, the number of MOB maintenance personnel that maximize system endurance are determined for one convoy. To determine the number required for five convoys, the expected number of convoys at the MOB at any particular time would have to be calculated. Once the expected number of convoys in service at any time is known, it could be used in conjunction with the optimum numbers for one convoy to determine the appropriate numbers.

3.3 Relocation Maintenance

The events carried out during relocation maintenance are fairly simple and are included in Figure 2. Only critical failures of relocation subsystems force the convoy to make repairs during relocation. All vehicles are assumed to stop when one vehicle experiences a critical failure. Troubleshooting is first performed to determine if the failure is field repairable and whether there is a spare or redundant unit available. If both conditions are present, the repair begins. Since critical relocation failures occur one at a time and all convoy personnel are available to assist, the number of maintenance personnel available is not a factor during relocation maintenance. Once the repair is complete, the convoy resumes travel.

3.4 Field Maintenance

Field maintenance events are handled in the same manner as relocation maintenance events and are also shown in Figure 2. The same procedure of troubleshooting and repairing the failures described above is performed for these events. However, all convoy personnel are assumed to be gainfully employed during operations, leaving only dedicated maintenance personnel to tend to repairs. Depending on when and what kind of failures occur, the number of maintenance personnel available can be a constraining factor on increasing system availability. Maintenance personnel are assumed to be trained to perform or assist in any repair occurring in the field, but, not all failures are field repairable. Failures which cannot be repaired in the field are designated "MOB only" repairs. Unlike relocation maintenance, several failures can be awaiting repair at one time during field maintenance. Non-critical failures are repaired as time and parts permit, subject to preemption by a critical failure. The maintenance cycle continues until a failure forces an abort back to the MOB. As stated above, this can be a repair which requires MOB assistance or a critical failure for which there is no spare or redundant unit.

The system can also be brought down by software aborts or satellite data drpoouts, which are considered failures. These failures are handled separately from the rest of the maintenance network. System operators repair these failures as they occur without assistance from maintenance personnel.

IV. Methodology

4.1 Model Construction

The model was coded to emulate the system described in the previous chapter. A top-level deployment network keeps track of the GMS convoy as it proceeds through the deployment and three sub-level networks are in place to model the three maintenance networks (MOB, relocation, and field). A detailed description of the model along with SLAM diagrams is given in Appendix A.

The database for the model was provided by AFOTEC/LG4. The data was originally gathered by the IBM Corporation for the Defense Support Program (DSP). Data is given for 535 line replaceable units (LRUs) contained in the SCV and SMV. The other vehicles are not considered mission critical and will not force an abort to the MOB. The term line replaceable unit is used loosely in this application to mean anything from a field-repairable circuit card to a large, non-repairable power generation unit. The basic structure of the model allows it to be used with any GMS systems by simply changing the database to reflect the LRUs contained in the system to be modeled.

The failure rates, repair rates, and number of spares given in the database are the driving factors for this model. The overall system endurance, E_A, is largely determined by the types of failures and number of spares available. As long as failures are repairable and spares are available, the system can operate indefinitely. The primary focus of this study is to analyze the sensitivity of endurance to other system parameters. Endurance is merely the length of time the system is able to remain operational. However, since extended downtime in the field can increase endurance, an endurance adjusted (E_A) for field downtime was used. Since adjusted endurance used alone gives no feel for the amount of time the system was down, it was used in conjunction with system availability to provide an overall performance measure of the system.

Three availabilities are calculated within the model; relocation availability (A_R), operational availability (A_O), and overall system availability (A_S). As shown in Equation 2, availability is up time divided by total time which gives the following equations:

$$A_R = \frac{Relocation\ Uptime}{Total\ Relocation\ Time} \tag{3}$$

$$A_O = \frac{Operations\ Uptime}{Total\ Operations\ Time} \tag{4}$$

$$A_S = \frac{Operations\ Uptime}{Total\ Deployment\ Cycle\ Time} \tag{5}$$

Failure and repair rates are the basis of these availabilities. Failures are given as a Poisson process while repair times are distributed lognormally. Data for failures is given in terms of failures per one million hours while the mean and standard deviation is given for repair times. Ten separate random number streams are dedicated to the different failure and repair processes in the model. These streams along with their associated process are shown in Table 1. Other statistics collected are mean

Table 1. SLAM Random Number Streams

Stream	Usage	Network
1	VEH repair times	MOB Maint
2	CE repair times	MOB Maint
3	PGU repair times	MOB Maint
4	ECU repair times	MOB Maint
5	Tractor repair times, tractor switchover times, tire replacement times	Rel Maint
6	Relocation maintenance repair times	Rel Maint
7	Data dropouts, software aborts, satellite acquisition	Field Maint
8	Field maintenance repair times	Field Maint
9	Relocation duration, LRU failure times	REL Subroutine
10	LRU failure times	OPS Subroutine

time between critical failures (MTBCF), maintenance manhours spent, and resource utilization.

4.2 Factor Level Analysis

Three areas were considered for parameter level adjustment to maximize the endurance and availability of the system; number of maintenance personnel, access to the FSV, and number of spares.

4.2.1 FSV Access. The effect of having access to the FSV must be considered before analyzing numbers of maintenance personnel assigned to the MOB. The convoy always returns to the MOB with a critical failure, but it can also return with anywhere from zero to hundreds of non- critical failures. The percent reduction in these non-critical failures affects the number of maintenance personnel required at the MOB. In addition to influencing the required number of max personnel, access to the FSV can enhance the endurance and operational availability of the system.

Statistics were collected from one thousand simulated deployments; five hundred from base A (FSV access) and five hundred from base B (no FSV access). Total number of failures and total mean repair time for each base were used to determine if the average number of non-critical failures reduced with FSV access. A mean repair time weighted by the expected number of failures for each base was used to determine the effect of FSV access. The amount the FSV increased endurance and availability was investigated by comparing the average values of these parameters.

4.2.2 Maintenance Personnel. Since the number of personnel available is constantly fluctuating, more emphasis was placed on dividing the number of available personnel among the four MOB maintenance shops so as to provide the most effective service. To determine these percentages, the failures on the returning convoys were separated by type. Since repairs in the four areas are of a different nature, the repair times on the average are longer for some areas than others. Mean repair time weighted by the expected number of repairs was used to account for these different types and lengths of repairs. A different approach had to be used to determine the optimum number of maintenance personnel to use in the field. Obviously, as more maintenance personnel are taken on deployment the availability and endurance will increase while the number of non-critical failures returning will decrease. However, the rate of return decreases as number of personnel increases and at some point adding personnel no longer becomes beneficial. Since the adjusted endurance is not affected by number of field maintenance personnel available, only availability is plotted against number of field maintenance personnel to determine the appropriate cutoff point. Also, the utilization rate of the field maintenance resources, both maximum and mean, helped to determine the optimum number of field maintenance personnel.

4.2.3 Number of Spares. The numbers of spares available for each component are given in the database and are broken down into hot spares, cold spares, and FSV spares. These numbers are read into the model as fixed parameters, but, are still considered for sensitivity analysis because of their large impact on endurance and availability. The failures from the one thousand simulated deployments are listed in Appendix F. These failures are categorized by component and grouped into base A, base B, and combined. The number of failures and percentage of the total caused by each particular component are listed. The table also contains the number of FSV spares available for each of these components. This table gives a quick componentwise reference of the effect of having FSV spares available. Field-repairable failures which are causing a large percentage of the aborts can be identified and spares for that component increased.

4.3 Experimental Design

Although the number of maintenance personnel can be a constraining factor on availability, the influential factors behind the entire process are the failure and repair rates. These rates are usually the result of test data collected on the system and often a wide range of error associated with them. This error can be induced by something as simple as operator error when reading a gauge or by an insufficient number of samples being taken. An experimental design was set up to determine the effects of four factors: number of MOB maintenance personnel, number of field maintenance personnel, failures rates, and repair rates. The number of personnel was controlled by scaling the total number available. A typical number of MOB personnel employed for all shops is 15. Therefore, a high level of 20 and a low level of 10 were selected for the design. The breakdown of the combined number into separate shops takes place according to the optimal percentages shown in Table 7 and is summarized in Table 2. Since most repairs take two maintenance resources to complete, the minimum number allowed in any shop is two. The remaining two factors, failure and

Table 2. Breakdown of Maintenance Personnel by Shop

Repair Shop	High Level		Low Level	
Base	A	B	A	B
Vehicle	2	2	2	2
Comm/Elec	2	4	2	2
PGU	14	12	4	4
ECU	2	2	2	2

repair rates, were controlled by varying the mean of their respective distributions (exponential for failures and lognormal for repairs). The base rate was used as the low level with two times the base rate used as the high level. The factors along with their associated levels are shown in Table 3. The small number of factors involved allows a full factorial design to be implemented. The design, shown in Table 4, consists of 16 runs and considers all possible combinations between the four factors. The following table shows the factor settings for each run of the experimental design.

Table 3. Experimental Design Factors and Levels

Factor	Description	High Level	Low Level
A	MOB Manpower	20	10
B	Field Manpower	4	2
C	Failure Rate Scale	2	1
D	Repair Rate Scale	2	1

Table 4. 2^4 Full Factorial Design

	Factor			
Run	A	B	C	D
1	+	+	+	+
2	+	+	+	−
3	+	+	−	+
4	+	+	−	−
5	+	−	+	+
6	+	−	+	−
7	+	−	−	+
8	+	−	−	−
9	−	+	+	+
10	−	+	+	−
11	−	+	−	+
12	−	+	−	−
13	−	−	+	+
14	−	−	+	−
15	−	−	−	+
16	−	−	−	−

V. Results

5.1 FSV Availability

Table 5 depicts the cumulative failure results obtained from the deployment simulation runs. The table shows the results of 500 simulated deployment from base A and the same number from base B. The "number failed" column shows the total number of failures returning to each MOB shop over the 500 runs. Since 500 of the failures for each base are critical, the remaining 62 for base B and 188 for base A are non-critical failures. Therefore, access to the FSV did reduce the number of non-critical failures, as expected, by 126. However, the total mean repair time remained roughly unchanged (increasing by 30 manhours for base B). Since there

Table 5. Breakdown of Component Failures

Repair Shop	Base A			Base B		
	Number Failed	Mean Rpr Time	Repair Std Dev	Number Failed	Mean Rpr Time	Repair Std Dev
Vehicle	15	118.9	10.2	19	102.2	10.0
Comm/Elec	429	149.4	63.5	300	266.1	58.4
PGU	180	1079.0	161.1	171	1001.6	153.9
ECU	64	80.2	35.0	74	87.5	37.3
Total	688	1427.5	289.8	562	1457.4	259.6

are 126 additional failures with no FSV access, it would seem the mean repair time should increase. However, a closer examination of the types of failures, especially the critical failures, explains the lack of increase. A failure which is field-repairable has, in almost all cases, a considerably lower mean repair time than a non-field-repairable failure. Field-repairable failures can be as easy as changing a fuse or replacing a circuit card. However, when no spares exist, these simple failures force an abort to the MOB. The FSV is designed to carry additional field-replaceable spares to handle most of the minor repairs. Therefore, once access to the FSV is available, the types of failures which actually cause aborts are generally more serious, longer repair failures. As can be seen from Table 6, the capability to handle more of the field- repairable failures increases the mean adjusted endurance by more than 23 (6.25by .021 (2.35unavailable, it is unclear whether this justifies the existence of the FSV. However, in a wartime scenario an additional day of satellite C^2 per GMS convoy could be significant in a wartime scenario.

Table 6. Availability and Endurance by Base

Parameter	Base	Minimum	Mean	Maximum
Adjusted Endurance	A	13.05	367.7	960.77
Adjusted Endurance	B	5.36	391.0	960.54
System Availability	A	0.489	0.893	0.964
System Availability	B	0.267	0.914	0.965

5.2 Maintenance Personnel

Table 7 depicts the breakdown by percentage of MOB maintenance personnel into the four separate shops. These percentages were arrived at by dividing the total mean repair time for each shop by the total mean repair time for all repairs (given in Table 5). This division allows the same breakdown of MOB maintenance personnel at each shop as incoming failures. The numbers are given for each base since access to the FSV increased average repair times for two of the four shops and decreased repair times for the other two. Since in this case only integer numbers are used, rounding up or down will cause these percentages to change slightly.

Plots of availability against field maintenance personnel for each base are shown in Figure 4. The availabilities increase with personnel up to three for base A and four for base B. From the SLAM II resource statistics shown in Appendix F, the maximum utilization of this resource was three for base A and four for base B with average utilization being less than two for each case. Since the number utilized by

Table 7. Optimal Percentages of Maintenance Personnel by Shop

Repair Shop	Base A	Base B
Vehicle	0.083	0.070
Comm/Elec	0.104	0.183
PGU	0.756	0.687
ECU	0.057	0.06

each type is fairly small, the maximum number required (four) can be taken on deployment, thus effectively removing number of field maintenance personnel as a constraining factor on system availability. However, the amount of time the third and fourth person are employed is so small that deploying only two field maintenance personnel would seem to be the most cost-efficient choice.

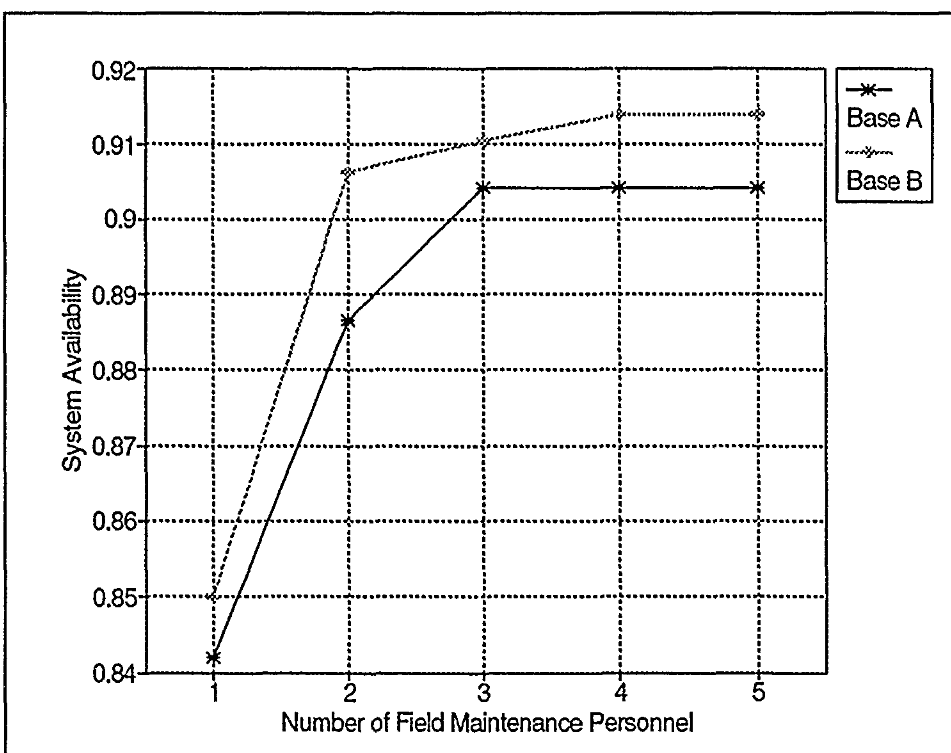

Figure 4. Manpower Effect on Availability

5.3 Number of Spares

Table 8 is extracted from the complete list of failures shown in Appendix F with only field-repairable failures which cause more than 10 aborts shown here. The number of failures is given for systems deploying from both bases along with the number of spares of that type carried in the FSV. It is interesting to note how the

Table 8. Components Causing More than Ten Aborts

Component	Subsystem	Base A	FSV Spares	Base B
20	Comm Equip	15	0	14
23	Comm Equip	19	0	12
24	Comm Equip	14	0	10
25	Comm Equip	37	0	25
30	Comm Equip	17	0	12
31	Comm Equip	13	0	22
35	Comm Equip	11	0	11
40	Comm Equip	8	0	13
384	JRSCT RF/IF	15	1	0
389	JRSCT RF/IF	20	1	0
400	JRSCT Baseband	43	1	3
408	JRSCT Baseband	24	1	0
495	JRSCT USC/28	16	1	0

last five components listed caused 118 of the 500 aborts for base A systems while causing only 3 of 500 for base B systems because of access to one FSV spare. The addition of these five FSV spares are largely responsible for the additional 23 hours of operation for base B systems. If a single FSV spare were added for each of the first eight components listed in Table 9, endurance would be increased an additional 10.9 hours. If storage space aboard the FSV is a constraint, there are several spares currently aboard for components which are causing very few aborts, if any, and could be replaced.

5.4 Experimental Design

The experimental design depicted in Table 4 using the factors given in Table 3 was conducted with the following results. Table 9 shows the results for each experimental design point based on 100 replications. Values are given for the mean adjusted endurance and the mean system availability for both bases. The factors set at their high level and the number of the run, shown in columns 1 and 2, were taken from Table 4. In all four cases, the numbers fluctuate around two distinct

Table 9. Experimental Design Results

Factor	Run No.	Base A		Base B	
		E_A	A_S	E_A	A_S
ABCD	1	236.42	0.8697	306.76	0.8848
ABC	2	236.96	0.8720	307.49	0.8872
ABD	3	350.10	0.9158	444.80	0.9204
AB	4	350.40	0.9168	445.32	0.9219
ACD	5	236.42	0.8697	306.76	0.8848
AC	6	236.96	0.8720	307.49	0.8872
AD	7	350.10	0.9158	444.80	0.9204
A	8	350.40	0.9168	445.32	0.9219
BCD	9	236.42	0.8697	306.76	0.8848
BC	10	236.96	0.8720	307.49	0.8872
BD	11	350.10	0.9158	444.80	0.9204
B	12	350.40	0.9168	445.32	0.9219
CD	13	236.42	0.8696	306.76	0.8848
C	14	236.96	0.8720	307.49	0.8872
D	15	350.10	0.9158	444.80	0.9204
	16	347.17	0.9163	445.32	0.9219

levels. Transition between the two levels appears to depend solely on the setting of factor C, the scaling factor for the failure rate. As factor C is set to its low level, base A endurance increases almost 115 hours while base B increases over 135 hours. Other factors and combinations of factors have little affect in comparison to factor C. According to Box and Jenkins, "the main effect of a given variable [...] is the average difference in the level of response as one moves form the low to the high level of that variable" (4:109).

The factor effects for all factors including the mean are shown in Table 10. The effect of factor C is significant in all four cases and is the only significant factor of all tested. The effect of factor CD is slightly higher than the remaining effects, however, it is not significant enough to warrant using it for system improvements. The rate at which components fail is by far the most significant factor for this system.

Table 10. Factor Effects

Factor	Base A		Base B	
	E_A	A_S	E_A	A_S
Mean	293.27	0.8935	376.09	0.9036
A	0.40	0.0001	0	0
B	0.40	0.0001	0	0
C	-113.16	-0.0454	-137.94	-0.0352
D	-0.02	-0.0016	-0.63	-0.0020
AB	-0.19	0.0008	0.31	-0.0010
AC	-0.40	-0.0001	0	0
AD	-0.40	-0.0001	0	0
BC	-0.40	-0.0001	0	0
BD	-0.40	-0.0001	0	0
CD	-0.52	-0.0007	-0.11	-0.0005
ABC	0.40	0.0001	0	0
ABD	0.40	0.0001	0	0
ACD	0.40	0.0001	0	0
BCD	0.40	0.0001	0	0
ABCD	-0.40	-0.0001	0	0

VI. Conclusions and Recommendations

6.1 Conclusions

The primary purpose of this study was to analyze the performance of a single deployed GMS convoy to determine which system parameters most affected system endurance and availability. Objectives included developing a simulation of the GMS system, choosing optimum values for several parameters, and running an experimental design to determine if any factor effects were significant.

The GMS simulation model executes as intended and proved to be an effective tool in the analysis. The model is capable of a wide range of sensitivity analyses without requiring changes in the actual code. The database used for this analysis was originally compiled for the DSP system before it became operational and is unclassified. Therefore, the results from this analysis do not apply specifically to any current system. Current data for DSP and other GMS systems, however, are classified, and using that data with this model would provide more meaningful results.

Several parameters were explored in chapters 4 and 5, starting with FSV support. The FSV does increase the system endurance by approximately 6 percent while increasing system availability by 2.4 percent. Having FSV support also appears to reduce the number of non-critical failures on each convoy returning to the MOB. However, the failures generally have lengthier repair times since the "quick fixes" are being repaired in the field which means MOB turnaround time is not significantly reduced. The overall effect of FSV support is that it only serves to benefit the GMS system and should be provided at both MOBs if the resources and costs permit.

As can be seen from the failed component results in Appendix F, the majority of field aborts are caused by a fairly small number of components. Replacements for five of the abort-causing components for base A are carried aboard the FSV and these components caused virtually no aborts for base B systems. Eight components, listed in Table 50, not carried aboard the FSV cause a large number of aborts for both systems. Adding a single spare for these components on the FSV could significantly reduce the number of aborts caused by field-repairable failures. The system availability would have to be considered maximized if all aborts were caused by "MOB only" repairs.

It is important to employ sufficient maintenance personnel to "keep up" with failing components. However, the number required to maintain this state seems to be fairly small. As shown in the results of the experimental design, the effect of increasing the number of field maintenance personnel from two to four was negligible; as was increasing the number of MOB maintenance personnel from ten to twenty. Realistically, these numbers may not be able to be reduced. Repairing GMS convoys is only a portion of MOB maintenance personnel's duties. However, increasing MOB or field maintenance personnel is not an effective means of increasing system availability.

Another factor which proved to be negligible is the rate of repair. Doubling the rate of repair had very little effect on overall system performance. This indicates that providing personnel training or repair equipment beyond established levels is also not an effective way to increase system performance. This is not meant to imply that these factors are unimportant. However, it does imply that established repair rates appear to be adequate for maximizing system performance.

The one factor examined which does have a significant impact on system performance is the rate of component failures. Failures rates are related to reliability and is a parameter which is designed into the component or system. Once a system is delivered and operational, the failure rates are typically inherent to the system. However, for acquisition of future systems, it is apparent that money spent during development improving system/component reliabilities is far better spent than trying to improve the repair process.

6.2 Recommendations

The development and coding of the GMS model consumed most of the time allotted for this thesis. There is still room for refinement and improvement of the model, but, the framework of the model is sound and the majority of the work done. Continuation of this thesis at its current point would allow the focus to be placed upon the model results and different analysis techniques which could be employed. Several techniques could be used to provide additional insight.

A run of 100 replications for this model can take one hour, or more, depending on the amount of CPU time the process is allocated. When numerous runs are required, obtaining the results can involve several days. Variance reduction, such as the control variate technique, could be applied to reduce the amount of runtime required.

Although working with classified data can place limits on the thesis process, future theses in this area may consider using current data for an operational GMS system.

Appendix A. *Model Description*

The GMS simulation model is a discrete event, disjoint network model. Four SLAM networks and several Fortran subroutines are used to model the GMS system. The top-level or deployment network models the GMS convoy as it moves through each phase of deployment. Its arrival at different points in the network controls the subroutines and the three sub-level networks: MOB maintenance, relocation maintenance, and field maintenance. The three maintenance networks model the flow of failures as they are analyzed and repaired. They are controlled in the simulation by making pseudo-resources available and unavailable for failure repair. These pseudo-resources control the timing of the failures occurrences.

A.1 SLAM II Description

The deployment network, shown in Figure 5, begins by creating a single entity to represent the GMS convoy. This entity flows through the network for the duration of a deployment. The first node reached initializes user input variables for simulation control flags and options. For the initial deployment, the convoy skips the MOB maintenance portion of the network and proceeds to the travel portion. The convoy begins travel at the REL node by triggering the relocation events. These events call subroutines that determine relocation duration and generate, classify, and file failures that occur during relocation. The final action taken by the relocation subroutines is to close the await relocation gate, AWTREL, to allow any relocation maintenance to occur. Upon completion of the REL subroutines have completed, the REL resources are made available allowing the relocation maintenance network to make the necessary repairs. Once this maintenance, if any, is complete, the relocation maintenance resources are made unavailable and the relocation gate opened. At this point, the relocation phase of the deployment is complete. If a failure has

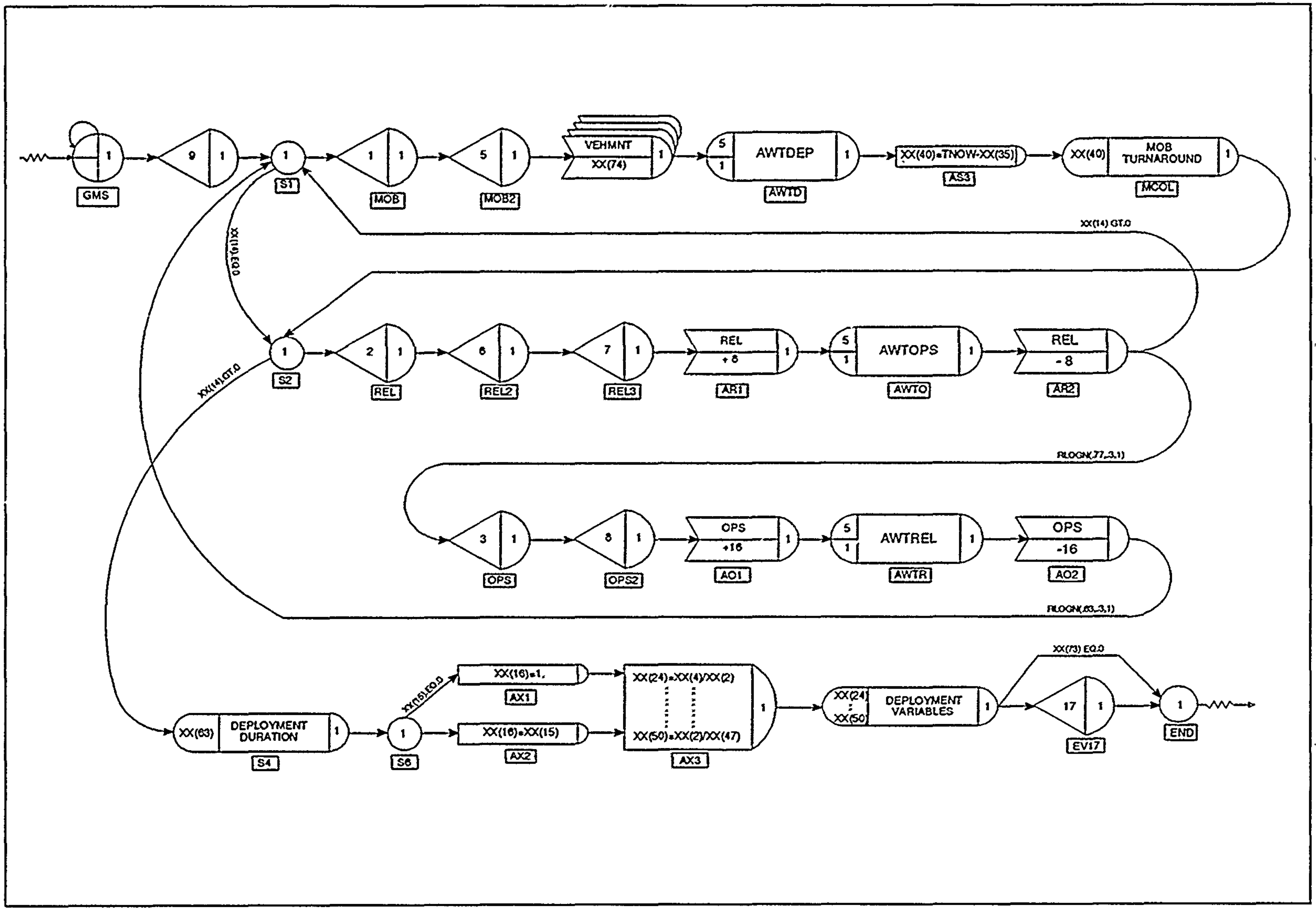

Figure 5. GMS Deployment Network

occurred which causes an abort back to the MOB, the entity skips the operations phase of the deployment and returns to the MOB.

The next phase of the deployment is equipment set-up and check- out. The delay following node S1 represents the physical set- up time of the trucks at the operating site, after which the operations events are initialized. These events call the operations subroutines which determine a failure time for each LRU used in both the SCV and SMV. The failures are categorized and filed according to failure time. Finally, the await operations gate, AWTOPS, is closed forcing the convoy entity to remain stationary at the deployment site while operations take place.

After the OPS subroutines have completed, the entity initializes the OPS resources which allow the field maintenance network to begin. At this point, the GMS begins operations and continues until it is no longer able. The field maintenance network keeps track of the system status (uptime and downtime) and repairs. Once an abort-causing failure occurs, the entity proceeds to S1 where the MOB events are initialized. The MOB subroutines sort the failures into their separate classes for repair by the appropriate MOB repair shop and close the AWTDEP gate to allow MOB maintenance to occur. After the MOB subroutines are complete, the entity reaches the alter nodes which initialize the maintenance resources allowing the MOB maintenance network to begin.

After MOB maintenance is complete and the AWTDEP gate opened, MOB turnaround statistics are calculated at AS3 and collected at MCOL. The entity then proceeds to assign nodes AX1 and AX2 which check for a zero value to avoid a divide error during statistic collection. Statistic calculation and collection occurs at the following assign and collect nodes. Node EV17 controls the printout options selected by the user and node END terminates the deployment.

A.1.1 Relocation Maintenance Network The relocation maintenance network, Figures 6 and 7, performs several functions which are implemented by distinct parts of the network. The first portion from RMQ1 to RG1, controls the sequencing and delaying of failures so they arrive at the correct node at the right time. All transportation system failures which are scheduled to occur during the relocation were placed in file 4 by the relocation subroutines. Once the REL resources are made available, these failures all enter the relocation maintenance network at the same time and are delayed following node RMQ1 by an amount equal to their time-to-failure. Since the time-to- failure for these failure entities is not actually a clock time, but a driving time, their time-to-failures must be pushed back as the convoy is stopped for previous critical failures. The delay following node F5 accounts for accumulated downtime for completed maintenance events. When the entity reaches RG13, it proceeds into the actual maintenance portion of the network if no other failures are currently being repaired. If a failure is currently being repaired, the entity waits at the maintenance-in-progress gate, RGT2. When that maintenance event is completed, an additional delay is invoked to account for that downtime.

The relocation subroutines generate two network control entities. One enters the relocation maintenance network as the first entity and the other as the last entity. The first entity has a time- to-failure of zero, so it passes through the network as the first entity and it passes through in zero simulation time. The purpose of this begin-relocation entity is to initialize the relocation maintenance variables and open the RGT2 gate to prepare the network for the first failure. The purpose of the last entity is to calculate total relocation time and open the AWTREL gate to allow the convoy to proceed to the operation phase of the deployment.

The maintenance portion of the network begins at node RG4, that channels abort-causing failures to the upper portion of the network and the rest to the lower portion. The abort indicator is set and total relocation time calculated at RAS4. A copy of the failure entity is placed in critical-failure file (21) at RG12 for future reference, and a copy is also placed in file 14 for MOB repair. Since the REL

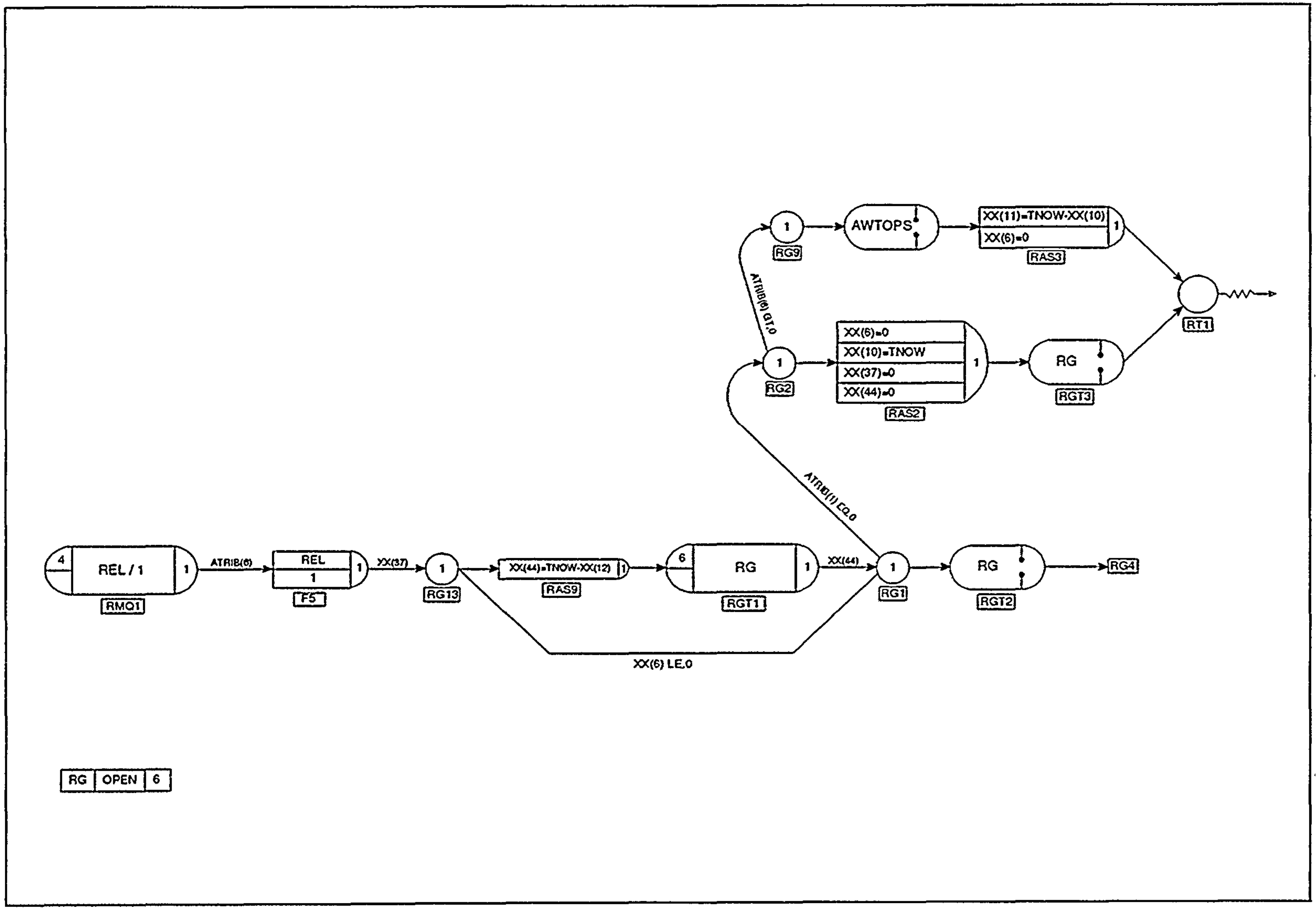

Figure 6. Relocation Maintenance Network (1 of 2)

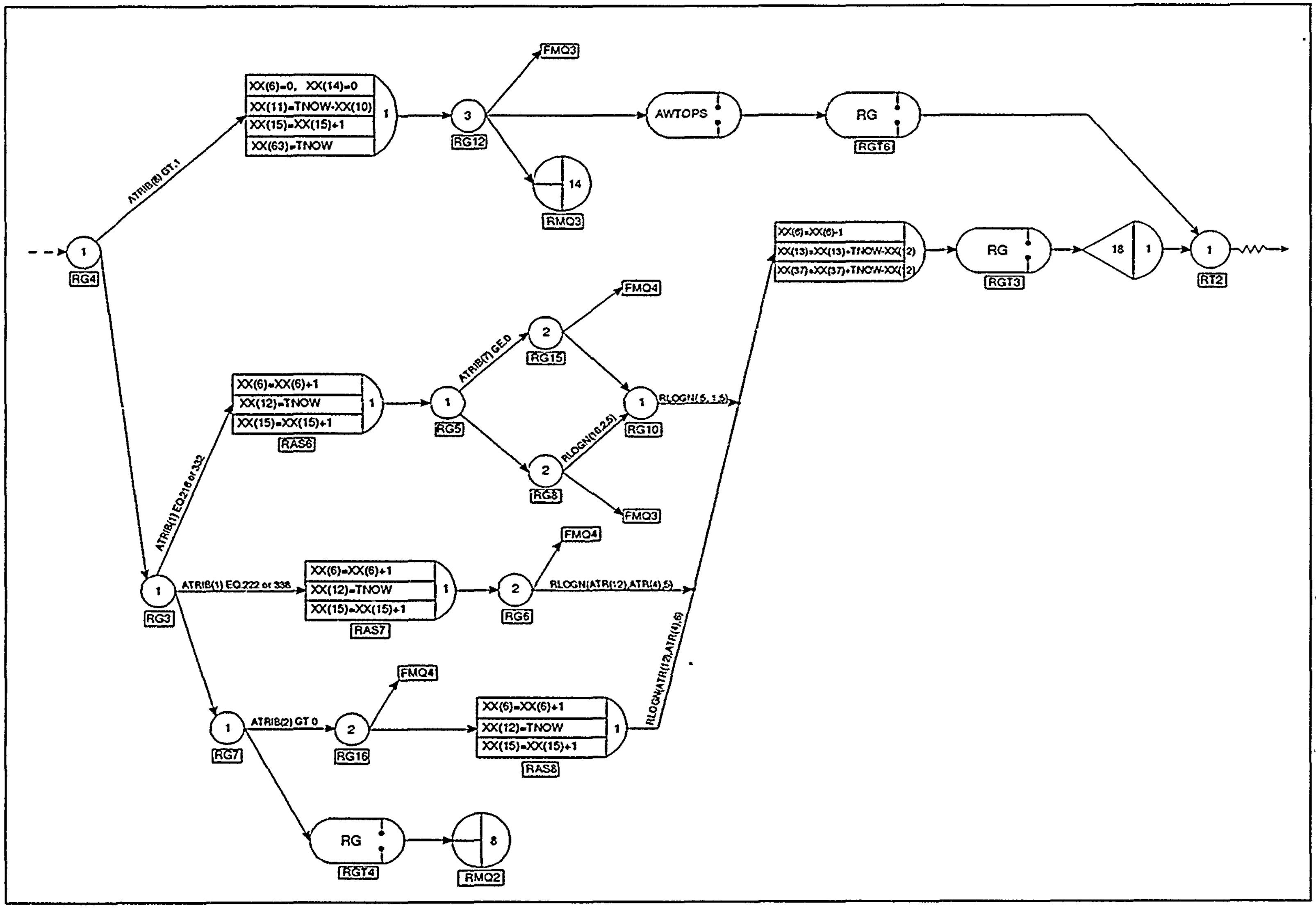

Figure 7. Relocation Maintenance Network (2 of 2)

subroutines have ensured this is last entity, the AWTREL gate is opened to release the GMS convoy to return to base.

Repairable failures proceed to RG3 where repair takes place. Tractor failures take the upper path to RAS6 where downtime counters are initialized. If a replacement tractor is available, the failure entity takes the upper path at RG5. A copy of this failure is placed in the non-critical failure file. A switchover time is incurred on the path to RAS1. If a redundant tractor is not available, the entity goes to RG8 where a copy is placed in the critical failure file and repair time is invoked.

Tire failures are sent to RAS7 where downtime counters are initialized. A copy of the failure is placed in the critical failure file and repair time is invoked.

All other failures take the lower portion of the network. Failure criticality is checked at RG7. Non-critical failures proceed to RGT4 where they open the maintenance-in-progress gate for the next relocation failure and are filed in the repair-later file (8). Critical failures are sent to RG16 where a copy is placed in the critical-failure file. Downtime counters are then initialized at RAS8 and repair time invoked following RAS8.

All repairable failure entities flow through RAS1 where values of the appropriate global variables are assigned. The relocation-in-progress gate is then opened to allow the next failure entity to occur. Following RGT5, a subroutine is called to update the database to show that the minimum number of required units of that type part are now operating. Finally, the entity is terminated.

A.1.2 Field Maintenance Network. The field maintenance network, Figures 8 and 9, is similar in appearance and function to the relocation maintenance network. It has a event sequencing portion, network control portion, and large maintenance portion. It also has a small disjoint network that generates short periods of downtime representative of operator- or system-recoverable software aborts and satellite data dropouts.

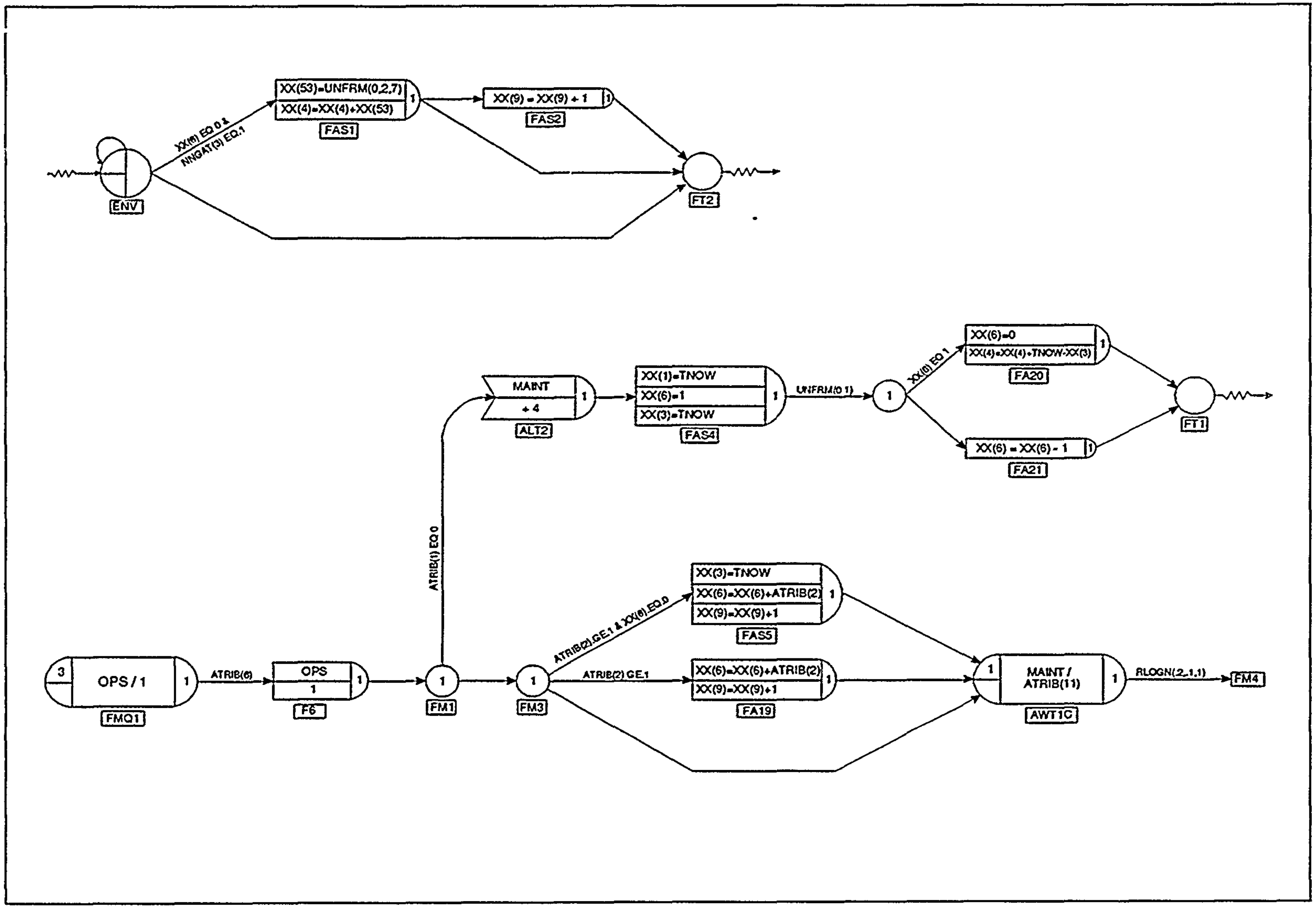

Figure 8. Field Maintenance Network (1 of 2)

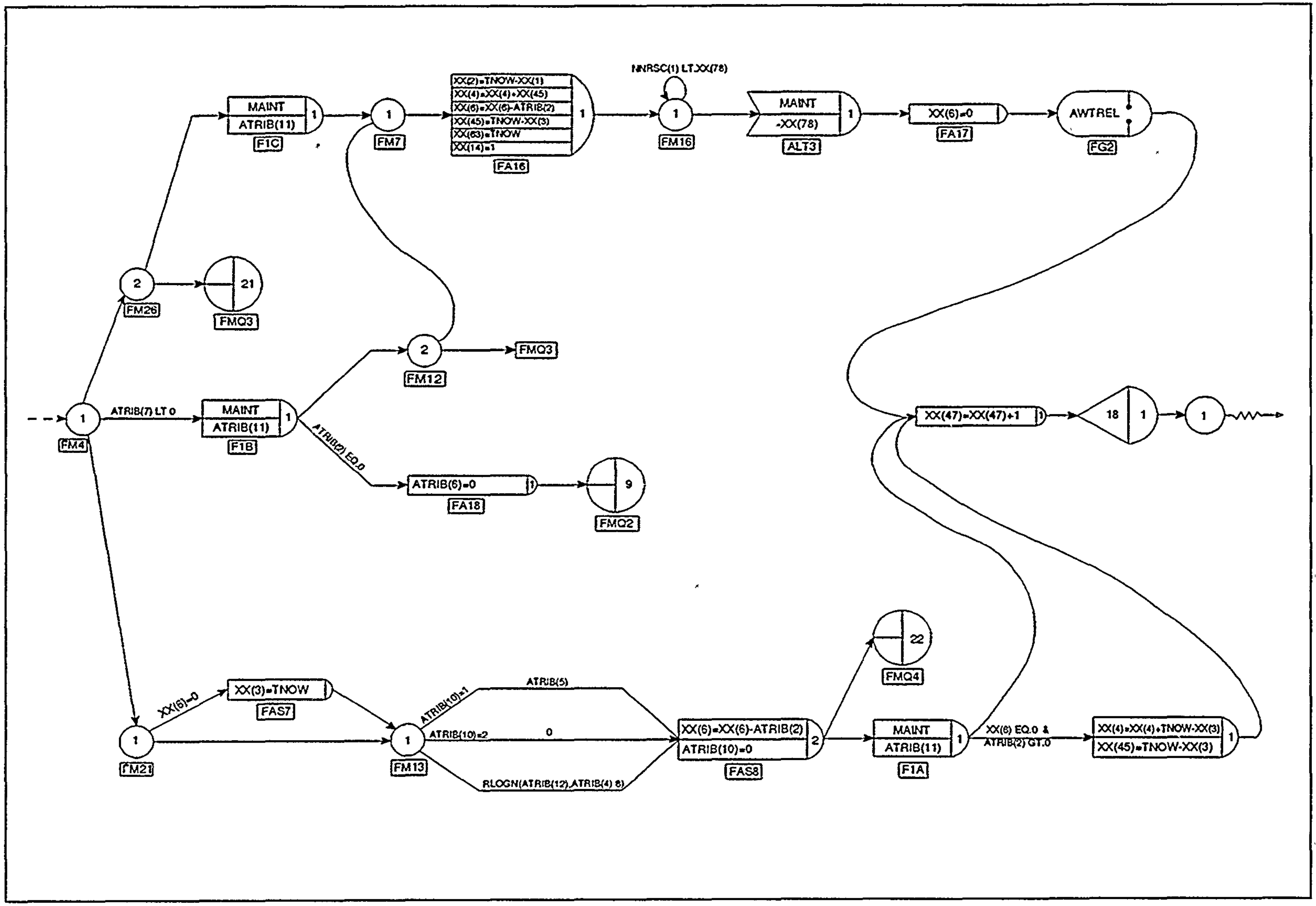

Figure 9. Field Maintenance Network (2 of 2)

The event sequencing segment is much simpler than that of the relocation network. The times-to-failures are given in clock times, rather than driving times, and the system's electronics are assumed to be powered at all times during operations. Thus, LRUs can fail while other downtime is in progress. Again, once the OPS resources are made available, all failures enter the network simultaneously and are delayed by their time-to-failure.

The network control portion only has one path for a begin-operations entity since there is no scheduled end of operations. This entity first makes the resources for maintenance personnel available and initializes field maintenance variables. Note that the relocation maintenance network did not use dedicated manpower resources. Only one relocation failure occurs at a given time and all convoy personnel are assumed available to help with vehicle repair. The delay invoked following FAS4 is to allow SMV satellite acquisition. If no other downtime is in progress, the maintenance-in-progress indicator will be set to zero and the downtime due to satellite acquisition added to the total downtime. If downtime is currently in progress, the downtime indicator is decreased by one and the entity is terminated.

Failures entities (Atrib(1)> 0) take the lower path at FM1 and proceed to FM3. If the failure is critical and no other downtime is in progress, the entity follows the upper path to FAS5. On this path, the downtime counter is started, the maintenance-in- progress indicator is incremented, and the critical-failures counter is also incremented. The entity then proceeds to AWT1C where the appropriate number of maintenance resources are taken to repair the failure. If downtime is already in progress when FM3 is reached, critical entities take the path to FA19. The only difference in the two critical failure paths is that the downtime counter is not started. Non- critical entities take the lower path at FM3.

The actual maintenance portion of the network is entered at FM4. Entities which can only be repaired at the MOB or entities which require MOB support take the upper path at FM4. A copy of the entity is placed in the critical failure file at FM26. The maintenance resources dedicated to this failure are released at F1C.

If spares are not available, entities take the path to F1B where the maintenance released are released. If the failure is non- critical, it is sent to FMQ9 where it is placed in file 9 to be repaired at the MOB. Critical failures take the upper path at F1B where a copy of the entity is placed in the critical failure file. The entity then proceeds to FA15 to take the abort path. Both types of aborts meet at FM7 and proceed to FA15 where the abort indicator is assigned along with other global variables. At FM16, the abort entity determines if other entities are still in the network by checking the number of maintenance resources in use. If all repairs are finished, the entity makes the resource unavailable and opens the AWTOPS gate, allowing the convoy to return to the MOB.

At FM21, field repairable failures initialize the downtime clock if no other repair is in progress. Branching at FM13 is done based on redundancy and criticality. If the failed item is not redundant, the entity takes the path to lower path to FAS8 where repair time is invoked. If the minimum number of LRUs is still operating, no repair action is taken. If a cold spare is available that can be substituted for the failed unit, the upper path to FAS8 is taken where the switchover and system restoral time, if any, is invoked. All the paths meet at FAS8, where the maintenance-in-progress counter is decremented. A copy of the entity is put into the critical failure file at FMQ4, and the maintenance personnel are released at F1A. From there, failures go directly to FM10 for statistics collection, after which they are terminated.

A.1.3 MOB Maintenance Network. The MOB maintenance network, shown in Figure 10, begins repairs after the maintenance resources for each shop have been made available. The network consists largely of four identical branches representing the four maintenance shops at the MOB. All failures which were not repaired in the field are sorted by the MOB subroutines and placed into the appropriate file (10-13).

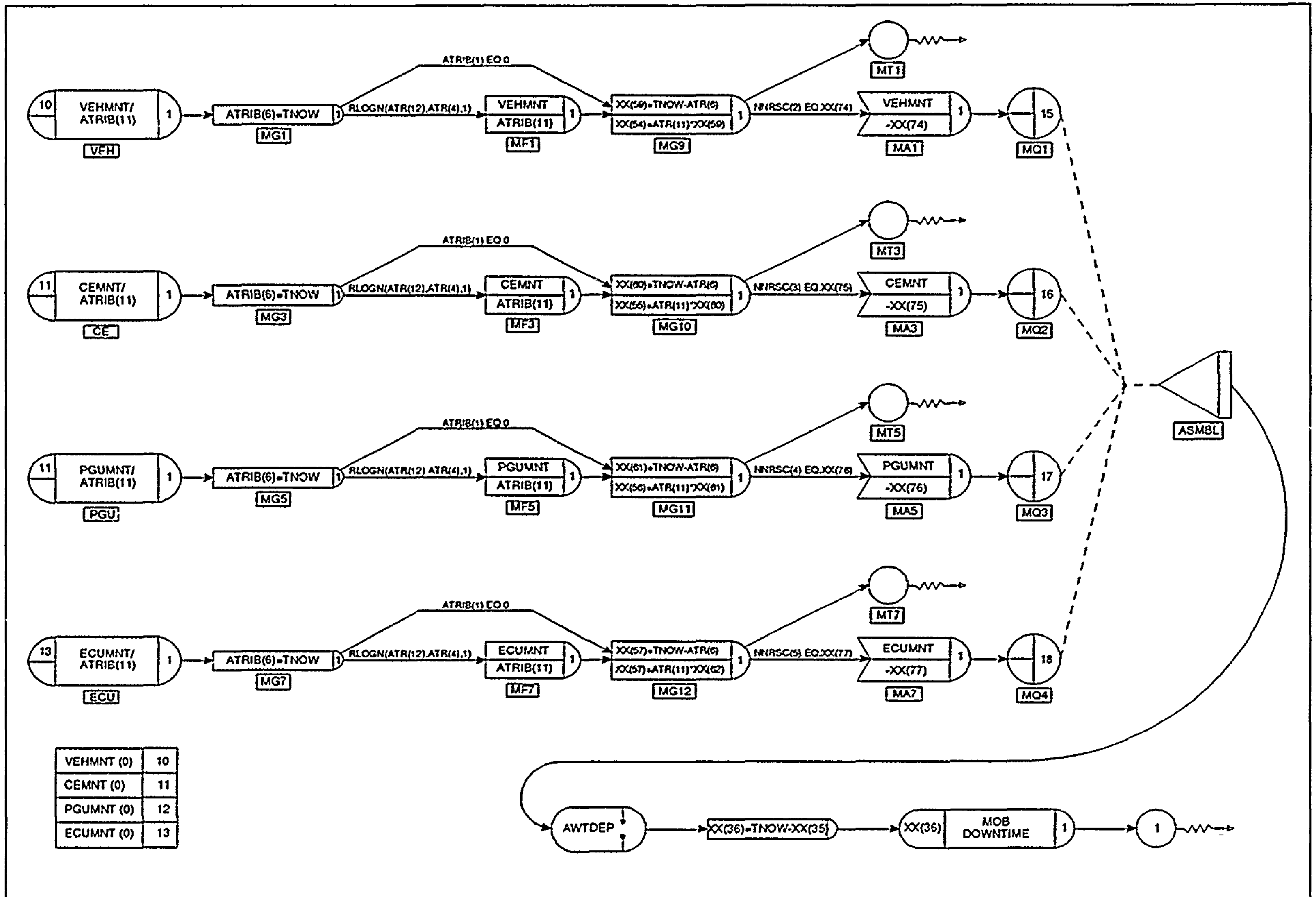

Figure 10. MOB Maintenance Network

These failures enter the network concurrently as the network is initialized. There is no time-to-failure associated with these entities, so they are repaired as resources become available. Once the minimum number of resources required are available, the failure entity takes the resources and enters the network. The start of repair time is assigned at MG1 and the repair time given in the database is then assessed. Once the repair is complete, the resources are released and statistics are collected at MG9. A check is made after MG9 to determine if the maximum number of resources are available. If not, repairs are in progress, and the entity proceeds to MT1 where it is terminated. If the maximum number is available, the entity decrements the resource and waits in the queue, MQ1.

The remaining three branches are identical with the final failure entity being placed in the queue at the end of the branch. The select node ASMBL waits for an entity to be placed in each of the queues at which point repair on the convoy is complete. If there are no failures of a particular type for that run, the MOB subroutines place a "zero" entity in the file to ensure that the ASMBL node operates correctly. After the convoy is reassembled and ready to redeploy, the AWTDEP gate is opened and MOB downtime statistics are collected.

A.2 Fortran Description

All Fortran subroutines are contained in the program GMS. The main program initializes the SLAM parameters and reads in the two user-supplied data files. The first file is a control file which contains sensitivity parameter choices and print options. Once these values are read into program variables, the choices are written into the output file. The second file to be read is the LRU database table which is stored then in the array TABLRU. The final function of the main program is to call SLAM.

A.2.1 Subroutine EVENT. This subroutine is necessary when event nodes are used in the SLAM code. The event nodes control the subroutines by making calls at the appropriate times during the simulation. The event node passes an event number to subroutine EVENT which uses that number to call the appropriate subroutine. Of the 20 events listed in subroutine EVENT, ten are called by event nodes while the others are Fortran file utilities.

A.2.2 MOB Subroutines. The MOB and MOB2 subroutines are called consecutively when the convoy returns to the MOB.

The MOB subroutine sorts deferred maintenance events in files 7, 8, 9, and 14 according to the subsystem of the failed component. Vehicle failures are placed in file 10, communication/electronics failures in file 11, power generation unit failures in file 12, and environmental control unit failures in file 13. Entities are removed using the RMOVE command and placed in the appropriate file using the SCHDL command. Since both subroutines occur in zero simulation time, a small delay (.001 hours) is placed between MOB1 and MOB2 to ensure that all failures have been filed before MOB2 is entered.

MOB2 begins by checking the length of files 10-13. These lengths are then added together and assigned to the variable which tracks the number of failures reaching the MOB. If any of the files have no entities, a "zero" entity is placed in the file to ensure that the ASMBL node in the MOB maintenance network operates correctly. Next, according to the print options selected, the subroutine will print a list of LRUs that failed during deployment. File 21 contains only the critical failures that occurred during the deployment, while file 22 contains all failed LRUs. Either or both of the files can be selected to be printed. MOB2 removes each entity from the file, one at a time, and prints the component number, mean repair time and standard deviation, and time of failure. The final portion of MOB2 initializes the

MOB turnaround time counter, restocks the convoy spares, and closes the AWTDEP gate to allow MOB maintenance repair.

A.2.3 REL Subroutines The REL, REL2, and REL3 subroutines are called as the convoy leaves the MOB to travel to the operating location.

REL begins by picking a random relocation distance from a uniform distribution whose minimum and maximum values are calculated from a minimum and maximum range of travel read in from the control data file. The range of travel is converted to a time by using an average travel speed of 40 miles per hour for the convoy. For this analysis a travel range of 25 to 250 miles was used. The travel time selected, XREL, is also used for the return trip to the MOB. Once a travel time is selected, all LRUs are checked for failure using the mobile failure rates given in the database. If the failure time is less than the relocation time, the attributes of that entity are copied into ATRIB, a buffer file. Failures in redundant systems are checked for criticality before Atrib(2) is assigned. Further checks are made for switchover redundancy of non-repairable systems: if switchover time is non- zero (indicating a redundant system with manual switchover) and if spares do not exist, then repair level is set to the table value and Atrib(10) is set to 1 which indicates that manual switchover is required by the maintenance network. If the number of redundant LRUs powered up and available exceeds the minimum required, then repair level is set to zero. If none of these conditions are satisfied, the default is to set Atrib(8) to the TABLRU repair level value.

Next, failures in transportation subsystems (TSS) are identified by checking subsystem numbers in Atrib(9). These entities are placed in file 4 to be handled during relocation. All other failures have their time-to-failure set to zero, since they will not be discovered until equipment set-up, and are placed in file 7. If more than one of the file 7 failures would cause an abort to the MOB during operations, all but the first have Atrib(10) set to 3 to ensure certain abort associated nodes in the field maintenance network are only executed once.

REL2 begins by checking the relocation failures in file 4. If one of the failures causes an abort, all subsequent failures in the file are removed since they would have never occurred (the failed vehicle is assumed to be towed back to the MOB). Spares are then reduced for all failures that remain in file 4. Spares can be obtained from one of three locations; hot spares, cold spares, or FSV spares. Spares are taken from the closest source, using hot spares first, cold spares second, and FSV spares last. Once a hot spare is used, a cold spare takes its place, and an FSV spare takes the cold spare's place. The code emulates the overall effect by reducing spares from the farthest source first. The last action taken by REL2 is to file the "zero" control entity, which initializes the maintenance network, in file 4.

REL3 begins by checking the last event scheduled in file 4 for an abort to the MOB. If there is no relocation abort, another "zero" control entity is placed in file 4 to signal the end of relocation with its time-to-failure equal to the relocation time. If there is no abort or there are no deferred failures in file 7, the rest of the subroutine is skipped, except to close the AWTOPS gate. Otherwise, file 7 is searched to find any failures that would occur after the relocation abort and they are removed. As in REL2, spares are reduced for failures remaining in file 7. If the failed unit has manual switchover redundancy (Atrib(10)=1), then it is removed and placed in file 14 to be repaired when the convoy returns to the MOB. In either case, the AWTOPS gate is closed to hold the GMS entity while the relocation maintenance networks executes.

A.2.4 OPS Subroutines The OPS and OPS2 subroutines are called when the GMS convoy is preparing to begin operations after a successful relocation.

OPS begins by moving all deferred maintenance events from files 7, 8, and 9 into file 3 for field maintenance repair. Atrib(6) for events in file 8 and 9 is set to zero so they enter the network immediately. Events in file 7 have already had Atrib(6) set to zero by subroutine REL2. This portion of the network corresponds to set-up of the system. Any deferred failures which are critical must be repaired before the system can begin operations.

Next, OPS determines the failure time for all LRUs using the fixed failure rates given in TABLRU. Most attributes come from TABLRU values for that LRU, however, criticality is determined by considering two possible conditions. All LRUs (except TSS subsystem LRUs) are checked to see if the minimum number is still available. If they are not, Atrib(2) is set to the table value; if they are, Atrib(2) is set to zero. Additionally, if the system is not field repairable, but there are sufficient redundant units available, Atrib(10) is set to 2 so that no maintenance is performed on it in the field and no downtime is counted against operations. Second, if the failed LRU has a non- zero manual switchover time to the back-up unit, but the back-up unit is not available, the repair location is set to the TABLRU value. If spares do exist and switchover time is greater than zero, repair level and criticality are set to zero and Atrib(1) is set to 1 for reasons previously discussed. If neither case is true, and if the minimum number of LRUs is still available, repair location is set to zero. Otherwise, the default is to set the repair level to the TABLRU value. This logic ensures that all possible failure cases are assigned the correct attribute values so they will be processed correctly in the networks.

OPS2 begins by sorting through file 3 to find the first abort- causing failure. Failures occurring after the first abort- causing failure are removed from file 3. Spares are then reduced for each failure remaining in file 3. A copy of the abort- causing failure is placed in file 14 for repair at the MOB. The final action taken by OPS2 is to file the "zero" event which initializes the field maintenance network.

A.2.5 INIT1, PARTS and OTPUT Subroutines These are miscellaneous subroutines called at various times during the simulation to perform small tasks.

INIT1 is called only once at the beginning of the simulation. It is used to assign the user-selected values of parameters read in from the control data file to global variables and pass them to SLAM code.

PARTS updates the database after an LRU has been repaired to ensure that the database reflects the correct number of LRUs of that type currently operating.

OTPUT is a subroutine used to produce a formatted output file containing parameters of interest collected upon during the simulation.

Appendix B. *Model Code*

B.1 SLAM II Code

```
GEN,BROWN,GEN MOB SPACE C2 SYS,10/01/91,1,Y,Y,Y,Y,Y/1,132;
LIMITS,22,12,2000;
PRIORITY/1,HVF(2)/3,LVF(6)/NCLNR,LVF(8)/4,LVF(6)/6,LVF(2)/7,LVF(6)/
     10,HVF(2)/11,HVF(2)/12,HVF(2)/13,HVF(2);
INTLC,XX(1)=0.,XX(2)=0.,XX(3)=0.,XX(4)=0.,XX(5)=0.,XX(6)=0.,XX(7)=0.,
     XX(8)=0.,XX(9)=0.,XX(10)=0.,XX(11)=0.,XX(12)=0.,XX(13)=0.;
INTLC,XX(14)=0.,XX(15)=0.,XX(16)=0.,XX(17)=0.,XX(18)=0.,XX(19)=0.,
     XX(20)=0.,XX(21)=0.,XX(22)=0.,XX(23)=0.,XX(24)=0.,XX(25)=0.;
INTLC,XX(26)=0.,XX(27)=0.,XX(28)=0.,XX(29)=0.,XX(30)=0.,XX(31)=0.,
     XX(32)=0.,XX(33)=0.,XX(34)=0.,XX(35)=0.,XX(36)=0.,XX(37)=0.;
INTLC,XX(38)=0.,XX(39)=0.,XX(40)=0.,XX(41)=0.,XX(42)=0.,XX(43)=0.,
     XX(44)=0.,XX(45)=0.,XX(46)=0.,XX(47)=0.,XX(48)=0.,XX(49)=0.;
INTLC,XX(50)=0.,XX(51)=0.,XX(52)=0.,XX(53)=0.,XX(54)=0.,XX(55)=0.,
     XX(56)=0.,XX(57)=0.,XX(58)=0.,XX(59)=0.,XX(60)=0.,XX(61)=0.;
INTLC,XX(62)=0.,XX(63)=0.,XX(64)=0.,XX(65)=0.,XX(66)=0.,XX(67)=0.,
     XX(68)=0.,XX(69)=0.,XX(70)=0.,XX(71)=0.,XX(72)=0.,XX(73)=0.;
INTLC,XX(74)=0.,XX(75)=0.,XX(76)=0.,XX(77)=0.,XX(78)=0.,XX(79)=0.;
INIT,0.,1000.,Y,Y,Y;
NETWORK;
       RESOURCE/MAINT(0),1;
       RESOURCE/VEHMNT(0),10;
       RESOURCE/CEMNT(0),11;
       RESOURCE/PGUMNT(0),12;
       RESOURCE/ECUMNT(0),13;
       RESOURCE/REL(0),4;
       RESOURCE/OPS(0),3;
       GATE/AWTDEP,OPEN,5;
       GATE/AWTOPS,OPEN,5;
       GATE/AWTREL,OPEN,5;
       GATE/RG,OPEN,6;

;*********************************************************************
;                                                                   *
;                       GMS DEPLOYMENT NETWORK                      *
;                                                                   *
;*********************************************************************

GMS    CREATE;
```

```
                :
                :
                :
                :
      ACT;
   EVENT,9,1;
      ACT,,,S1;
S1 GOON,1;
      ACT,.001,XX(14).EQ.0.,S2;
      ACT,.001,,MOB;
MOB  EVENT,1,1;
      ACT,.001,,MOB2;
MOB2 EVENT,5,1;
      ACT,.001;
   ALTER,VEHMNT/XX(74),1;    ** CHANGE VEH MAINTAINERS HERE **
   ALTER,CEMNT/XX(75),1;     ** CHANGE CE MAINTAINERS HERE **
   ALTER,PGUMNT/XX(76),1;    ** CHANGE PGU MAINTAINERS HERE **
   ALTER,ECUMNT/XX(77),1;    ** CHANGE ECU MAINTAINERS HERE **
AWTD AWAIT(5/1),AWTDEP,,1;
      ACT,,,AS3;
AS3  ASSIGN,XX(40)=TNOW-XX(35);
      ACT,,,MCOL;
MCOL COLCT,XX(40),MOB TURNAROUND,,1;
      ACT,,,S2;
S2   GOON,1;
   ACT,,XX(14).GT.0.,S4;
   ACT,,,REL;
REL  EVENT,2,1;
      ACT,.001,,REL2;
REL2 EVENT,6,1;
      ACT,.001,,REL3;
REL3 EVENT,7,1;
      ACT,.001;
AR1  ALTER,REL/8,1;
      ACT;
AWTO AWAIT(5/1),AWTOPS,,1;
      ACT;
AR2  ALTER,REL/-8,1;
      ACT,,XX(14).GT.0.,S1;
      ACT,RLOGN(.77,.3,1),,OPS;
OPS  EVENT,3,1;
      ACT,.001,,OPS2;
OPS2 EVENT,8,1;
      ACT,.001,,A01;
A01  ALTER,OPS/16,1;
      ACT;
AWTR AWAIT(5/1),AWTREL,,1;
      ACT;
A02  ALTER,OPS/-16,1;
```

```
        ACT,RLOGN(.63,.3,1),,S1;
S4    COLCT,XX(63),DEPLOYMENT DUR,,1;
        ACT,,,S6;
S6    GOON,1;
        ACT,,XX(15).EQ.0.,AX1;
        ACT,,,AX2;
AX1   ASSIGN,XX(16)=1.,1;
        ACT,,,AX3;
AX2   ASSIGN,XX(16)=XX(15),1;
        ACT,,,AX3;
AX3   ASSIGN,   XX(24)=1.-XX(4)/XX(2),       XX(42)=XX(11)+XX(13),
                XX(25)=XX(11)/XX(42),        XX(29)=XX(11)/XX(16),
                XX(28)=XX(2)/XX(9)-XX(4)/XX(9),1;
        ACT;
      ASSIGN,   XX(32)=XX(2)+XX(11)-XX(4),   XX(33)=XX(2)+XX(11),
                XX(34)=XX(9)+XX(15),         XX(30)=XX(32)/XX(33),
                XX(31)=XX(32)/XX(34),        XX(50)=XX(2)/XX(47);
      ASSIGN,   XX(58)=XX(54)+XX(55)+XX(56)+XX(57),1;
        ACT;
      COLCT,XX(2),DEPLOYMENT OPERATIONS TIME,,1;
        ACT;
      COLCT,XX(4),DU OPS DOWNTIME,,1;
        ACT;
      COLCT,XX(9),DU CRIT OPS FAIL,,1;
        ACT;
      COLCT,XX(11),REL TIME,,1;
        ACT;
      COLCT,XX(13),REL DOWNTIME,,1;
        ACT;
      COLCT,XX(15),CRIT REL FAIL,,1;
        ACT;
      COLCT,XX(24),DU OPS AVAIL,,1;
        ACT;
      COLCT,XX(25),DU REL AVAIL,,1;
        ACT;
      COLCT,XX(28),CUM OPS MTBCF,,1;
        ACT;
      COLCT,XX(29),CUM REL MTBCF,,1;
        ACT;
      COLCT,XX(30),CUM COMB AVAIL,,1;
        ACT;
      COLCT,XX(31),CUM COMB MTBCF,,1;
        ACT,,XX(73).EQ.1.,EV17;
        ACT,,,END;
EV17  EVENT,17,1;
```

```
         ACT,,,END;
END     TERM,1;            ** CHANGE SIMULATION TERMINATION COUNT HERE **

;**********************************************************************
;                                                                     *
;                      MOB MAINTENANCE NETWORK                        *
;                                                                     *
;**********************************************************************

VEH     AWAIT(10),VEHMNT/ATRIB(11),,1;
         ACT,,,MG1;
MG1     ASSIGN,ATRIB(6)=TNOW,1;
         ACT,0,ATRIB(1).EQ.0,MF1;
         ACT,RLOGN(ATRIB(12),ATRIB(4),1);
MF1     FREE,VEHMNT/ATRIB(11),1;
         ACT,,,MG9;
MG9     ASSIGN,XX(59)=TNOW-ATRIB(6),XX(54)=XX(54)+ATRIB(11)*XX(59),1;
         ACT,0,NNRSC(2).EQ.XX(74),MA1;
         ACT,,,MT1;
MT1     TERM;
MA1     ALTER,VEHMNT/-1*XX(74),1;
         ACT,,,MQ1;
MQ1     QUEUE(15),,,,ASMBL;

CE      AWAIT(11),CEMNT/ATRIB(11),,1;  COMM/ELECTRONIC MAINTENANCE EVENTS
         ACT,,,MG3;
MG3     ASSIGN,ATRIB(6)=TNOW,1;
         ACT,0,ATRIB(1).EQ.0,MF3;
         ACT,RLOGN(ATRIB(12),ATRIB(4),2);
MF3     FREE,CEMNT/ATRIB(11),1;
         ACT,,,MG10;
MG10    ASSIGN,XX(60)=TNOW-ATRIB(6),XX(55)=XX(55)+ATRIB(11)*XX(60),1;
         ACT,0,NNRSC(3).EQ.XX(75),MA2;
         ACT,,,MT2;
MT2     TERM;
MA2     ALTER,CEMNT/-1*XX(75),1;
         ACT,,,MQ2;
MQ2     QUEUE(16),,,,ASMBL;

PGU     AWAIT(12),PGUMNT/ATRIB(11),,1;      PGU MAINTENANCE EVENTS
         ACT,,,MG5;
MG5     ASSIGN,ATRIB(6)=TNOW,1;
         ACT,0,ATRIB(1).EQ.0,MF5;
         ACT,RLOGN(ATRIB(12),ATRIB(4),3);
MF5     FREE,PGUMNT/ATRIB(11),1;
```

```
                .
                :
                .
                .
        ACT,,,MG11;
MG11    ASSIGN,XX(61)=TNOW-ATRIB(6),XX(56)=XX(56)+ATRIB(11)*XX(61),1;
        ACT,0,NNRSC(4).EQ.XX(76),MA3;
        ACT,,,MT3;
MT3     TERM;
MA3     ALTER,PGUMNT/-1*XX(76),1;
        ACT,,,MQ3;
MQ3     QUEUE(17),,,,ASMBL;

ECU     AWAIT(13),ECUMNT/ATRIB(11),,1;          ECU MAINTENANCE EVENTS
        ACT,,,MG7;
MG7     ASSIGN,ATRIB(6)=TNOW,1;
        ACT,0,ATRIB(1).EQ.0,MF7;
        ACT,RLOGN(ATRIB(12),ATRIB(4),4);
MF7     FREE,ECUMNT/ATRIB(11),1;
        ACT,,,MG12;
MG12    ASSIGN,XX(62)=TNOW-ATRIB(6),XX(57)=XX(57)+ATRIB(11)*XX(62),1;
        ACT,0,NNRSC(5).EQ.XX(77),MA4;
        ACT,,,MT4;
MT4     TERM;
MA4     ALTER,ECUMNT/-1*XX(77),1;
        ACT,,,MQ4;
MQ4     QUEUE(18),,,,ASMBL;

ASMBL   SELECT,ASM,,,MQ1,MQ2,MQ3,MQ4;
        ACT;
        OPEN,AWTDEP,1;
        ACT;
        TERM;

;**********************************************************************
;                                                                     *
;                   RELOCATION MAINTENANCE NETWORK                    *
;                                                                     *
;**********************************************************************

RMQ1    AWAIT(4),REL/1,,1;
        ACT,ATRIB(6);
F5      FREE,REL/1,1;
        ACT,XX(37),,RG13;
RG13    GOON,1;
        ACT,,XX(6).LE.0.,RG1;
        ACT,,,RAS9;
RAS9    ASSIGN,XX(44)=TNOW-XX(12),1;
        ACT,,,RGT1;
```

```
RGT1   AWAIT(6),RG,,1;
          ACT,XX(44),,RG1;
RG1    GOON,1;
          ACT,0,ATRIB(1).EQ.0,RG2;
          ACT,,,RGT2;
RG2    GOON,1;
          ACT,0,ATRIB(6).GT.0.,RG9;
          ACT,,,RAS2;
RG9    GOON,1;
          ACT;
       OPEN,AWTOPS,1;
          ACT,,,RAS3;
RAS3   ASSIGN,XX(11)=TNOW-XX(10),XX(6)=0.,1;
          ACT,,,RT1;
RAS2   ASSIGN,XX(10)=TNOW,XX(6)=0.,XX(37)=0.,XX(44)=0.,1;
          ACT,,,RGT3;
RGT3   OPEN,RG,1;
          ACT,,,RT1;
RT1    TERM;
RGT2   CLOSE,RG,1;
          ACT,,,RG4;
RG4    GOON,1;
          ACT,0,ATRIB(8).GT.1,RAS4;
          ACT,0,,RG3;
RAS4   ASSIGN,XX(15)=XX(15)+1,XX(14)=2.,XX(6)=0.,
          XX(63)=TNOW,XX(11)=TNOW-XX(10),1;
          ACT;
RG12   GOON,3;
          ACT,,,FMQ3;
          ACT,,,RMQ3;
          ACT;
       OPEN,AWTOPS,1;
          ACT;
RGT6   OPEN,RG,1;
          ACT,,,RT2;
RT2    TERM;
RMQ3   QUEUE(14);
RG3    GOON,1;
          ACT,0,ATRIB(1).EQ.216. .OR. ATRIB(1).EQ.332.,RAS6;
          ACT,0,ATRIB(1).EQ.222. .OR. ATRIB(1).EQ.338.,RAS7;
          ACT,0,,RG7;
RAS6   ASSIGN,XX(15)=XX(15)+1.,XX(12)=TNOW,XX(6)=XX(6)+1.,1;
          ACT,,,RG5;
RG5    GOON,1;
          ACT,0,ATRIB(7).GE.0.,RG15;
```

```
          ACT,,,RG8;
RG15   GOON,1;
          ACT,,,RG10;
          ACT,,,FMQ4;
RG8    GOON,2;
          ACT,RLOGN(16.,2.,5),,RG10;
          ACT,,,FMQ3;
RG10   GOON,1;
          ACT,RLOGN(.5,.1,5),,RAS1;
RAS7   ASSIGN,XX(15)=XX(15)+1.,XX(12)=TNOW,XX(6)=XX(6)+1.,1;
          ACT,,,RG6;
RG6    GOON,2;
          ACT,,,FMQ4;
          ACT,RLOGN(ATRIB(12),ATRIB(4),5),,RAS1;
RG7    GOON,1;
          ACT,0,ATRIB(2).GT.0.,RG16;
          ACT,,,RGT4;
RG16   GOON,2;
          ACT,,,RAS8;
          ACT,,,FMQ4;
RGT4   OPEN,RG,1;
          ACT,,,RMQ2;
RAS8   ASSIGN,XX(15)=XX(15)+1.,XX(12)=TNOW,XX(6)=XX(6)+1.,1;
          ACT,RLOGN(ATRIB(12),ATRIB(4),6),,RAS1;
RMQ2   QUEUE(8);
RAS1   ASSIGN,XX(37)=XX(37)+TNOW-XX(12),XX(13)=XX(13)+TNOW-XX(12),
          XX(6)=XX(6)-1.,1;
          ACT,,,RGT5;
RGT5   OPEN,RG,1;
          ACT;
       EVENT,18,1;
          ACT,,,RT2;


;*********************************************************************
;                                                                   *
;                     FIELD MAINTENANCE NETWORK                     *
;                                                                   *
;*********************************************************************

ENV    CREATE,RLOGN(XX(71),XX(72),1),5.,,,1;   CREATES DATA DROPOUTS
          ACT,0,XX(6).EQ.0. .AND. NNGAT(3).EQ.1,FAS1;
          ACT,0,,FT2;
FAS1   ASSIGN,XX(53)=UNFRM(0.,.2,7),XX(4)=XX(4)+XX(53),1;
          ACT,0,XX(53).GT..166,FAS2;
```

```
        ACT,0,,FT2;
FAS2    ASSIGN,XX(9)=XX(9)+1,1;
          ACT,,,FT2;
FT2     TERM;

FMQ1    AWAIT(3),OPS/1,,1;
          ACT,ATRIB(6);
F6      FREE,OPS/1,1;
          ACT,,,FM1;
FM1     GOON,1;
          ACT,0,ATRIB(1).EQ.0.,ALT2;
          ACT,0,,FM3;
ALT2    ALTER,MAINT/XX(78),1;
          ACT,,,FAS4;
FAS4    ASSIGN,XX(1)=TNOW,XX(6)=1.,XX(3)=TNOW,1;
          ACT,UNFRM(0.,1.,7);
        GOON,1;
          ACT,,XX(6).EQ.1.,FA20;
          ACT,,,FA21;
FA20    ASSIGN,XX(4)=XX(4)+TNOW-XX(3),XX(6)=0.,1;
          ACT,,,FT1;
FA21    ASSIGN,XX(6)=XX(6)-1.,1;
          ACT,,,FT1;
FT1     TERM;
FM3     GOON,1;
          ACT,0,ATRIB(2).GE.1. .AND. XX(6).EQ.0.,FAS5;
          ACT,0,ATRIB(2).GE.1.,FA19
          ACT,,,AWT1C;
FAS5    ASSIGN,XX(9)=XX(9)+1.,XX(3)=TNOW,XX(6)=XX(6)+ATRIB(2),1;
          ACT,,,AWT1C;
FA19    ASSIGN,XX(6)=XX(6)+ATRIB(2),XX(9)=XX(9)+1,1;
          ACT,,,AWT1C;
AWT1C   AWAIT(1),MAINT/ATRIB(11),,1;
          ACT,RLOGN(.2,.1,1),,FM4;
FM4     GOON,1;
          ACT,0,ATRIB(8).GT.0.,FM26;
          ACT,0,ATRIB(7).LT.0.,F1B;
          ACT,0,,FM21;
FM26    GOON,2;
          ACT,,,F1C;
          ACT,,,FMQ3;
F1C     FREE,MAINT/ATRIB(11),1;
          ACT,,,FM7;
FM7     GOON,1;
          ACT,,,FA16;
```

```
FA16   ASSIGN,XX(14)=1.,XX(63)=TNOW,XX(63)=TNOW,XX(45)=TNOW-XX(3),
         XX(6)=XX(6)-ATRIB(2),XX(4)=XX(4)+XX(45),XX(2)=TNOW-XX(1),1;
         ACT,,,FM16;
FM16   GOON,1;
         ACT,.1,NNRSC(1).LT.XX(78),FM16;
         ACT,,,ALT3;
ALT3   ALTER,MAINT/-1*XX(78),1;
         ACT,,,FA17;
FA17   ASSIGN,XX(6)=0.,1;
         ACT,,,FG2;
FG2    OPEN,AWTREL,1;
         ACT,,,FM10;
F1B    FREE,MAINT/ATRIB(11),1;
         ACT,,ATRIB(2).EQ.0.,FA18;
         ACT,,,FM12;
FA18   ASSIGN,ATRIB(6)=0.,1;
         ACT,,,FMQ2;
FMQ2   QUEUE(9);
FM12   GOON,2;
         ACT,,,FMQ3;
         ACT,,,FM7;
FMQ3   QUEUE(21);
FM21   GOON,1;
         ACT,0.,XX(6).EQ.0.,FAS7;
         ACT,0.,,FM13;
FAS7   ASSIGN,XX(3)=TNOW,1;
         ACT,,,FM13;
FM13   GOON,1;
         ACT,ATRIB(5),ATRIB(10).EQ.1.,FAS8;
         ACT,0.,ATRIB(10).EQ.2.,FAS8;
         ACT,RLOGN(ATRIB(12),ATRIB(4),8),,FAS8;
FAS8   ASSIGN,XX(6)=XX(6)-ATRIB(2),ATRIB(10)=0.,2;
         ACT,,,FMQ4;
         ACT,,,F1A;
FMQ4   QUEUE(22);
F1A    FREE,MAINT/ATRIB(11),1;
         ACT,,XX(6).EQ.0. .AND. ATRIB(2).GT.0.,FAS9;
         ACT,,,FM10;
FAS9   ASSIGN,XX(4)=XX(4)+TNOW-XX(3),XX(45)=TNOW-XX(3),1;
         ACT,,,FM10;
FM10   ASSIGN,XX(47)=XX(47)+1,1;
         ACT,,,EV18;
EV18   EVENT,18,1;
         ACT;
       TERM;
```

```
        ENDNETWORK;
FIN;
```

B.2 Fortran Code

```
      PROGRAM GMS

************************************************************************
*  THIS PROGRAM EXECUTES THE SLAM SIMULATION MODEL FOR THE GENERIC     *
*  MOBILE SPACE C2 SYSTEM.  THE MAIN ROUTINE DECLARES AND DIMENSIONS   *
*  VARIABLES, ESTABLISHES COMMON BLOCKS, SETS INITIAL PROGRAM CONSTANT *
*  VALUES, AND READS IN THE GMS DATA FILES.                            *
************************************************************************

      REAL TABLRU
      INTEGER PRNT1,PRNT2,VEH,CE,PGU,ECU
      CHARACTER*1 BASE
      DIMENSION NSET(50000)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNTO,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT
      COMMON QSET(50000)
      EQUIVALENCE (NSET(1),QSET(1))
      NNSET=50000
      NCRDR=5
      NPRNT=6
      NTAPE=7

************************************************************************
*  READ CONTROL DATA INPUT FILE                                        *
************************************************************************

      OPEN(UNIT=4,FILE='CONTROL.DAT',STATUS='OLD')
      READ(4,21) BASE
      IF (BASE .EQ. 'A') THEN
         OPEN(UNIT=3,FILE='GMS_A.DAT',STATUS='OLD')
      ELSE
         OPEN(UNIT=3,FILE='GMS_B.DAT',STATUS='OLD')
      END IF
      READ(4,22) MAXLRU
      READ(4,23) RELN,RLSD
      READ(4,23) SFACT,RFACT
      READ(4,23) ABRT,ABSD
      READ(4,24) VEH,CE,PGU,ECU
      READ(4,25) MNT
      READ(4,26) PRNT1,PRNT2
      READ(4,27) PRNTO
```

```
      CLOSE UNIT=4

************************************************************************
*  WRITE OPTIONS TO THE SLAM OUTPUT FILE                               *
************************************************************************

      WRITE(6,30)
      WRITE(6,31) BASE
      WRITE(6,32) MAXLRU
      WRITE(6,33) SFACT
      WRITE(6,34) RFACT
      WRITE(6,35)
      WRITE(6,36) VEH
      WRITE(6,37) PGU
      WRITE(6,38) ECU
      WRITE(6,39) CE
      WRITE(6,40) MNT
      WRITE(6,41) RELN,RLSD
      WRITE(6,42) ABRT,ABSD
      WRITE(6,43) PRNT1,PRNT2
      WRITE(6,44) PRNTO

************************************************************************
*  READ IN THE DATABASE                                                *
************************************************************************

      DO 10 I=1,MAXLRU,1
      READ(3,20) (TABLRU(I,J),J=1,17)
10    CONTINUE
      CLOSE UNIT=3
      CALL SLAM
      STOP

20    FORMAT(1X,6F4.0,5F6.3,6F4.0)
21    FORMAT(1X,A1)
22    FORMAT(1X,I3)
23    FORMAT(1X,2F5.1)
24    FORMAT(4I3)
25    FORMAT(1X,I1)
26    FORMAT(1X,I1,1X,I1)
27    FORMAT(1X,F2.0)

30    FORMAT(5X,'OPTIONS SELECTED FOR THIS RUN ARE:',/)
31    FORMAT(8X,'THE GMS CONVOY IS DEPLOYING FROM BASE ',A1)
32    FORMAT(8X,'THE NUMBER OF LRUS IN THE DATA BASE IS ',I3)
```

```
33    FORMAT(8X,'THE FAILURE RATE SCALE FACTOR IS',F5.2)
34    FORMAT(8X,'THE REPAIR RATE SCALE FACTOR IS',F5.2)
35    FORMAT(8X,'MOB MAINTENANCE PERSONNEL AVAILABLE ARE:')
36    FORMAT(15X,'VEHICLE REPAIR - ',I2)
37    FORMAT(15X,'POWER GENERATION REPAIR - ',I2)
38    FORMAT(15X,'ENVIRONMENTAL CONTROL REPAIR - ',I2)
39    FORMAT(15X,'COMMMUNICATIONS/ELECTRONICS REPAIR - ',I2)
40    FORMAT(8X,'FIELD MAINTENANCE PERSONNEL AVAILABLE ARE: ',I1)
41    FORMAT(8X,'RELOCATION DUR IS ',F5.1,' HOURS; STD DEV IS ',F5.1)
42    FORMAT(8X,'ABENDS OCCUR EVERY',F5.1,' HOURS; STD DEV IS',F5.1)
43    FORMAT(8X,'FILE PRINT OPTIONS ARE',I2,' FOR FILE 21 AND',I2,
     &' FOR FILE 22')
44    FORMAT(8X,'DEPLOYMENT SUMMARY REPORT OPTION IS ',F2.0,/,/)
      END

*************************************************************************

      SUBROUTINE EVENT(I)

      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNT0,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT
      GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20),I
1     CALL MOB
      RETURN
2     CALL REL
      RETURN
3     CALL OPS
      RETURN
4     CALL FILEM(4,ATRIB)
      RETURN
5     CALL MOB2
      RETURN
6     CALL REL2
      RETURN
7     CALL REL3
      RETURN
8     CALL OPS2
      RETURN
9     CALL INIT1
      RETURN
10    CALL FILEM(10,ATRIB)
      RETURN
```

```
11    CALL FILEM(11,ATRIB)
      RETURN
12    CALL FILEM(12,ATRIB)
      RETURN
13    CALL FILEM(13,ATRIB)
      RETURN
14    CALL FILEM(8,ATRIB)
      RETURN
15    CALL FILEM(3,ATRIB)
      RETURN
16    CALL FILEM(14,ATRIB)
      RETURN
17    CALL OTPUT
      RETURN
18    CALL PARTS
      RETURN
19    CALL FILEM(7,ATRIB)
      RETURN
20    CALL FILEM(2,ATRIB)
      RETURN
      END

************************************************************************

      SUBROUTINE MOB

************************************************************************
*  THIS SUBROUTINE PERFORMS PROCESSING OF THE MGS WHEN IT RETURNS TO   *
*  THE MAIN OPERATING BASE (MOB) BECAUSE OF A FAILURE THAT CANNOT BE   *
*  REPAIRED IN THE FIELD.  MAINTENANCE PERSONNEL ARE MADE AVAILABLE BY *
*  THE 'ALTER' NODES TO PERFORM MAINTENANCE ONCE THE MGS ARRIVES AT    *
*  THE MOB.  DEFERRED MAINTENANCE EVENTS STORED IN FILES 8, 9 AND 14   *
*  ARE SORTED INTO THE APPROPRIATE MOB FILES (VEHICLE, ELECTRONIC,     *
*  PGU, AND ECU) FOR REPAIR.                                           *
************************************************************************

      INTEGER PRNT1,PRNT2,VEH,CE,ECU,PGU
      CHARACTER*1 BASE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNTO,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT

************************************************************************
```

```
*  SORT DEFERRED MAINTENANCE EVENTS INTO MOB MAINTENANCE FILES          *
************************************************************************

      DO 3 K=7,14
      IF (K.EQ.10 .OR. K.EQ.11 .OR. K.EQ.12 .OR. K.EQ.13) GO TO 3
      L=NNQ(K)
      IF (L.EQ.0) GO TO 3
      DO 4 KK=1,L
         CALL RMOVE(1,K,ATRIB)

************************************************************************
*  PUT ECU EVENTS INTO FILE 13                                          *
************************************************************************

      IF (ATRIB(9).EQ.11. .OR. ATRIB(1).EQ.518. .OR. ATRIB(1).EQ.519.)
     & THEN
         CALL SCHDL(13,0.,ATRIB)

************************************************************************
*  PUT PGU EVENTS INTO FILE 12                                          *
************************************************************************

      ELSE IF (ATRIB(9).EQ.12. .OR. ATRIB(9).EQ.17.) THEN
         CALL SCHDL(12,0.,ATRIB)

************************************************************************
*  PUT ELECTRONICS EVENTS INTO FILE 11                                  *
************************************************************************

      ELSE IF (ATRIB(9).EQ.1. .OR. ATRIB(9).EQ.2. .OR. ATRIB(9).EQ.3.
     &.OR. ATRIB(9).EQ.4. .OR. ATRIB(9).EQ.5. .OR. ATRIB(9).EQ.6. .OR.
     & ATRIB(9).EQ.7. .OR. ATRIB(9).EQ.18. .OR. ATRIB(9).EQ.19. .OR.
     & ATRIB(9).EQ.20. .OR. ATRIB(9).EQ.21. .OR. ATRIB(9).EQ.22. .OR.
     & ATRIB(9).EQ.23. .OR. ATRIB(9).EQ.24. .OR. ATRIB(9).EQ.25. .OR.
     & ATRIB(9).EQ.26) THEN
         CALL SCHDL(11,0.,ATRIB)

************************************************************************
*  PUT OTHER EVENTS INTO FILE 10                                        *
************************************************************************

      ELSE
         CALL SCHDL(10,0.,ATRIB)
      END IF
4     CONTINUE
```

```
3     CONTINUE
      RETURN
      END

************************************************************************

      SUBROUTINE MOB2
      INTEGER PRNT1,PRNT2,VEH,CE,ECU,PGU
      CHARACTER*1 BASE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNTO,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT                                            .

************************************************************************
*  PUT 'ZERO' EVENTS INTO FILES 10-13 IF THEY ARE EMPTY TO TRIGGER MOB *
*  MAINTENANCE NETWORK.                                                *
************************************************************************

      ATRIB(1)=0.
      ATRIB(2)=0.
      ATRIB(3)=0.
      ATRIB(4)=0.
      ATRIB(5)=0.
      ATRIB(6)=0.
      ATRIB(8)=0.
      ATRIB(11)=1.
      ATRIB(12)=0.
      XX(46)=NNQ(10)+NNQ(11)+NNQ(12)+NNQ(13)
      IF (NNQ(10).EQ.0) THEN
         CALL SCHDL(10,0.,ATRIB)
      END IF
      IF (NNQ(11).EQ.0) THEN
         CALL SCHDL(11,0.,ATRIB)
      END IF
      IF (NNQ(12).EQ.0) THEN
         CALL SCHDL(12,0.,ATRIB)
      END IF
      IF (NNQ(13).EQ.0) THEN
         CALL SCHDL(13,0.,ATRIB)
      END IF

************************************************************************
*  PRINT OUT CONTENTS OF FILE 21 (CRITICAL FAILURE LRUS) AND FILE 22   *
```

```
*  (ALL FAILED LRUS) IF REQUESTED, THEN CLEAR THE FILES.                *
************************************************************************

      IF (PRNT1.NE.0) THEN
         OPEN(UNIT=3,FILE='FILE_21.DAT',STATUS='NEW')
         WRITE(3,1)
         WRITE(3,2)
         WRITE(3,3)
1        FORMAT(21X,'CRITICAL FAILURES DURING DEPLOYMENT',/)
2        FORMAT(1X,'COMPONENT',5X,'SUBSYSTEM',5X,'CRITICALITY',6X,
     &          'REPAIR',7X,'SPARES',7X,'FAILURE')
3        FORMAT(2X,'NUMBER',8X,'NUMBER',23X,'LOCATION',5X,'REMAINING',
     &          6X,'TIME')
         IF (NNQ(21).NE.0) THEN
            LL=NNQ(21)
            DO 4 K=1,LL,1
               CALL RMOVE(1,21,ATRIB)
               WRITE(3,5)ATRIB(1),ATRIB(9),ATRIB(2),ATRIB(8),ATRIB(7),
     &                   ATRIB(6)
4           CONTINUE
         END IF
5        FORMAT(4X,F4.0,10X,F4.0,10X,F4.0,11X,F4.0,4X,F7.1)
         CLOSE UNIT=3
      END IF

      IF (PRNT2.NE.0) THEN
         OPEN(UNIT=4,FILE='FILE_22.DAT',STATUS='NEW')
         WRITE(4,6)
         WRITE(4,7)
         WRITE(4,8)
6        FORMAT(19X,'NON-CRITICAL FAILURES DURING DEPLOYMENT',/)
7        FORMAT(1X,'COMPONENT',5X,'SUBSYSTEM',5X,'CRITICALITY',6X,
     &          'REPAIR',7X,'SPARES',7X,'FAILURE')
8        FORMAT(2X,'NUMBER',8X,'NUMBER',23X,'LOCATION',5X,'REMAINING',
     &          6X,'TIME')
         IF (NNQ(22).NE.0) THEN
            LL=NNQ(22)
            DO 9 K=1,LL,1
               CALL RMOVE(1,22,ATRIB)
               WRITE(4,10)ATRIB(1),ATRIB(9),ATRIB(2),ATRIB(8),ATRIB(7),
     &                   ATRIB(6)
9           CONTINUE
         END IF
10       FORMAT(4X,F4.0,10X,F4.0,10X,F4.0,11X,F4.0,4X,F7.1)
         CLOSE UNIT=4
```

```
      END IF
      XX(35)=TNOW

************************************************************************
*  RESTOCK SPARE PARTS CONSUMED                                        *
************************************************************************

      DO 30 M=1,MAXLRU,1
         TABLRU(M,5)=TABLRU(M,12)
         TABLRU(M,6)=TABLRU(M,13)
         TABLRU(M,16)=TABLRU(M,17)
30    CONTINUE

************************************************************************
*  CLOSE GATE TO HOLD MGS ENTITY WHILE MOB MAINTENANCE OCCURS          *
************************************************************************

      CALL CLOSX(1)
      RETURN
      END

************************************************************************

      SUBROUTINE REL

************************************************************************
*  THIS SUBROUTINE GENERATES A RANDOM RELOCATION TIME AND CHECKS ALL   *
*  LRUS FOR FAILURE DURING THIS TIME USING THE APPROPRIATE MOBILE      *
*  FAILURE RATE.  FAILURES THAT ARE NOT CRITICAL FOR THE RELOCATION    *
*  MISSION ARE PLACED IN FILE 8, WHILE THOSE THAT OCCUR IN SUBSYSTEMS  *
*  ESSENTIAL TO THE RELOCATION MISSION ARE PUT IN FILE 4.  FILE 4 IS   *
*  THEN SEARCHED TO DETERMINE THE FIRST FAILURE (IF ANY) THAT CAUSES A *
*  RELOCATION ABORT.  ALL SUBSEQUENT FAILURES ARE ELEMINATED, SINCE IT *
*  IS ASSUMED THAT AFTER THE CRITICAL FAILURE THE SYSTEM IS TURNED OFF *
*  AND NO FURTHER FAILURES CAN OCCUR.  SPARE PARTS COUNTS ARE DECREASED*
*  BY ONE FOR THOSE LRUS WHICH HAVE SPARES ON BOARD.  BOGUS EVENTS ARE *
*  THEN INSERTED INTO THOSE FILES TO CAUSE THE SLAM MAINTENANCE CODE   *
*  TO FUNCTION PROPERLY.  FINALLY, THE GATE AFTER THE EVENT NODE IS    *
*  CLOSED.                                                             *
************************************************************************

      INTEGER PRNT1,PRNT2,VEH,CE,ECU,PGU
      CHARACTER*1 BASE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
```

```
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNT0,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT

************************************************************************
*  PICK RANDOM RELOCATION DURATION                                    *
************************************************************************

      XREL=RNORM(RELN,RLSD,9)
      IF (XREL.LT.1.) XREL=1.0

************************************************************************
*  SAMPLE ALL LRUS USING THE MOBILE FAILURE RATES                     *
************************************************************************

      LX=0
      DO 10 N=1,MAXLRU,1
         IF (TABLRU(N,5).EQ.0.) GO TO 10
         XMN=1000000./(TABLRU(N,5)*TABLRU(N,8)*SFACT)
         XSMPL=EXPON(XMN,9)

************************************************************************
*  IF LRU TIME TO FAILURE IS GREATER THAN RELOCATION DURATION, SAMPLE *
*  NEXT LRU. IF NOT, COPY ATTRIBUTES OF FAILURE EVENT INTO BUFFER FILE *
************************************************************************

         IF (XSMPL.GT.XREL) GO TO 10
         ATRIB(1)=TABLRU(N,1)
         ATRIB(3)=TABLRU(N,9)
         ATRIB(4)=TABLRU(N,10)
         ATRIB(5)=TABLRU(N,11)+TABLRU(N,14)
         ATRIB(6)=XSMPL
         ATRIB(7)=TABLRU(N,6)+TABLRU(N,5)+TABLRU(N,16)-TABLRU(N,4)-1.
         ATRIB(9)=TABLRU(N,2)
         ATRIB(10)=0.
         ATRIB(11)=1.
         ATRIB(12)=TABLRU(N,9)*RFACT

************************************************************************
*  IF NUMBER OF POWERED (REDUNDANT) LRUS IS LESS THAN OR EQUAL TO THE *
*  NUMBER REQUIRED, SET CRITICALITY FLAG TO THE TABLE VALUE. OTHERWISE *
*  MAKE THE FAILURE NONCRITICAL.                                      *
************************************************************************

         IF (TABLRU(N,5).LE.TABLRU(N,4)) THEN
```

```
            ATRIB(2)=TABLRU(N,3)
         ELSE
            ATRIB(2)=0.
            IF (TABLRU(N,15).GT.0.) ATRIB(10)=2.
         END IF

************************************************************************
*  IF A NON-FIELD REPAIRABLE FAILURE OCCURS, BUT THE UNIT HAS          *
*  SWITCHOVER REDUNDANCY, SET THE REPAIR LEVEL TO ZERO UNLESS NO       *
*  REDUNDANT SPARES REMAIN.  FOR NONREDUNDANT SYSTEMS (TABLRU(14)=0)   *
*  SET ATRIB(8) TO THE TABLE VALUE.                                    *
************************************************************************

         IF (TABLRU(N,14).GT.0. .AND. ATRIB(7).LT.0.) THEN
            ATRIB(8)=TABLRU(N,15)
         ELSE IF (TABLRU(N,14).GT.0.) THEN
            ATRIB(8)=0.
            ATRIB(2)=0.
            ATRIB(10)=1.
         ELSE IF (TABLRU(N,5)-TABLRU(N,4).GT.0.) THEN
            ATRIB(8)=0.
         ELSE
            ATRIB(8)=TABLRU(N,15)
         END IF

************************************************************************
*  FILE TSS FAILURES IN FILE 4                                         *
************************************************************************

         IF (ATRIB(9).EQ.9. .OR. ATRIB(9).EQ.10. .OR. ATRIB(9).EQ.14.
     &   .OR. ATRIB(9).EQ.15.) THEN
            ATRIB(11)=2.
            CALL SCHDL(4,0.,ATRIB)

************************************************************************
*  FILE ALL OTHER FAILURES IN FILE 7 FOR FUTURE ACTION                 *
************************************************************************

         ELSE
            ATRIB(6)=0.
            IF (ATRIB(8).GT.0. .OR. (ATRIB(2).GT.0..OR.ATRIB(7).LT.0.))
     &   THEN
            LX=LX+1
            IF (LX.GT.1) ATRIB(10)=3.
         END IF
```

```
         CALL SCHDL(19,0.,ATRIB)
      END IF
10    CONTINUE
25    RETURN
      END

**********************************************************************

      SUBROUTINE REL2

      INTEGER PRNT1,PRNT2,VEH,CE,ECU,PGU
      CHARACTER*1 BASE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNT0,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT

**********************************************************************
*  IF AN ABORT-CAUSING EVENT OCCURS, REMOVE REMAINING FAILURES IN FILE.*
**********************************************************************

      NEXT=1
30    IF (NEXT.GT.NNQ(4)) GO TO 40
      CALL COPY(NEXT,4,ATRIB)
      LL=NNQ(4)
      IF (ATRIB(8).EQ.2. .AND. NNQ(4).GE.NEXT+1) THEN
         DO 37 I=NEXT+1,LL,1
            CALL RMOVE(NEXT+1,4,ATRIB)
37       CONTINUE
      END IF

**********************************************************************
*  REDUCE SPARES BY ONE FOR EACH FAILURE FOR WHICH SPARES EXIST. PRIOR-*
*  ITY IS FSV SPARES FIRST, COLD SPARES SECOND, AND HOT SPARES THIRD.  *
**********************************************************************

      CALL COPY(NEXT,4,ATRIB)
      IT=INT(ATRIB(1))
      IF (IT.EQ.0) GO TO 38
      IF (TABLRU(IT,16).GT.0.) THEN
         TABLRU(IT,16)=TABLRU(IT,16)-1.
      ELSE IF(TABLRU(IT,6).GT.0.) THEN
         TABLRU(IT,6)=TABLRU(IT,6)-1.
      ELSE IF (TABLRU(IT,5).GT.0.) THEN
```

```
         TABLRU(IT,5)=TABLRU(IT,5)-1.
      END IF
38    NEXT=NEXT+1
      GO TO 30

************************************************************************
*  FILE A 'ZERO' EVENT TO ACTIVATE RELOCATION MAINTENANCE NETWORK.     *
************************************************************************

40    ATRIB(1)=0.
      ATRIB(2)=0.
      ATRIB(6)=0.
      ATRIB(8)=0.
      CALL SCHDL(4,0.,ATRIB)
      RETURN
      END

************************************************************************

      SUBROUTINE REL3

      INTEGER PRNT1,PRNT2,VEH,CE,ECU,PGU
      CHARACTER*1 BASE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNTO,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT

************************************************************************
*  IF NO ABORT OCCURS, FILE AN END OF RELOCATION EVENT.                *
************************************************************************

      CALL COPY(NNQ(4),4,ATRIB)
      IF (ATRIB(8).LT.1.) THEN
         ATRIB(1)=0.
         ATRIB(2)=0.
         ATRIB(6)=XREL
         ATRIB(8)=0.
         ATRIB(10)=0.
         CALL SCHDL(4,0.,ATRIB)
      END IF
      IF (NNQ(7).EQ.0.) GO TO 15
      XS=ATRIB(6)
      DO 10 I=1,NNQ(7)
```

```
         IF (I.GT.NNQ(7)) GO TO 10
         CALL COPY(I,7,ATRIB)
         IF (ATRIB(6).LT.XS) THEN
            IT=INT(ATRIB(1))
            IF (TABLRU(IT,16).GT.0.) THEN
               TABLRU(IT,16)=TABLRU(IT,16)-1
            ELSE IF (TABLRU(IT,6).GT.0.) THEN
               TABLRU(IT,6)=TABLRU(IT,6)-1.
            ELSE IF (TABLRU(IT,5).GT.0.) THEN
               TABLRU(IT,5)=TABLRU(IT,5)-1
            END IF
            IF (ATRIB(10).EQ.1) CALL SCHDL(16,0.,ATRIB)
         ELSE
            DO 5 J=1,NNQ(7)
               CALL RMOVE(LAST,7,ATRIB)
5           CONTINUE
         END IF
10    CONTINUE

***********************************************************************
*  CLOSE GATE TO HOLD MGS ENTITY WHILE RELOCATION MAINTENANCE OCCURS.  *
***********************************************************************

15    CALL CLOSX(2)
      RETURN
      END

***********************************************************************

      SUBROUTINE OPS

***********************************************************************
*  THIS SUBROUTINE PERFORMS FUNCTIONS ASSOCIATED WITH FAILURE PROCESS- *
*  ING WHILE THE GMS IS IN THE FIELD AND PERFORMING MISSION OPERATIONS.*
*  IT BEGINS BY SORTING DEFERRED FAILURES FROM RELOCATION (FILE 8) OR  *
*  NON-CRITICAL FAILURES DEFERRED DUE TO LACK OF PARTS INTO FILE 3 FOR *
*  FIELD MAINTENANCE.  THEN ALL LRUS ARE CHECKED TO DETERMINE TIME OF  *
*  FAILURE BY USING THE APPROPRIATE FIXED FAILURE RATE.  FAILURES ARE  *
*  PLACED INTO FILE 3, WHICH IS THEN SEARCHED FOR THE FIRST ABORT      *
*  CAUSING FAILURE.  ALL SUBSEQUENT FAILURES ARE ELIMINATED, SINCE AN  *
*  ABORT THAT REQUIRES PARTS OR PERSONNEL TO BE BROUGHT OUT FROM THE   *
*  MOB, OR CAUSES A RETURN TO THE MOB, TERMINATES THE DEPLOYMENT AND   *
*  NECESSITATES A RELOCATION.  SPARES COUNT FOR LRUS WITH FIELD SPARES *
*  ARE DECREMENTED, AND THE GATE FOLLOWING OPS IS CLOSED.              *
***********************************************************************
```

```
      INTEGER PRNT1,PRNT2,VEH,CE,ECU,PGU
      CHARACTER*1 BASE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNTO,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT

************************************************************************
*  FILE DEFERRED MAINTENANCE EVENTS INTO FILE 3 FOR FIELD MAINTENANCE. *
************************************************************************

      K=NNQ(9)
      IF (K.EQ.0.) GO TO 5
      DO 2 L=1,K
         CALL RMOVE(1,9,ATRIB)
         ATRIB(6)=0.
         IT=INT(ATRIB(1))
         ATRIB(7)=TABLRU(IT,6)+TABLRU(IT,5)+TABLRU(IT,16)-TABLRU(IT,4)
         CALL SCHDL(15,0.,ATRIB)
2     CONTINUE
5     K=NNQ(8)
      IF (K.EQ.0.) GO TO 15
      DO 10 L=1,K
         CALL RMOVE(1,8,ATRIB)
         ATRIB(6)=0.
         IT=INT(ATRIB(1))
         ATRIB(7)=TABLRU(IT,6)+TABLRU(IT,5)+TABLRU(IT,16)-TABLRU(IT,4)
         CALL SCHDL(15,0.,ATRIB)
10    CONTINUE
15    K=NNQ(7)
      IF (K.EQ.0.) GO TO 18
      DO 18 I=1,K
         CALL RMOVE(1,7,ATRIB)
         CALL SCHDL(15,0.,ATRIB)
18    CONTINUE

************************************************************************
*  SAMPLE ALL LRUS FOR FAILURE TIME WITH THE FIXED FAILURE RATE.       *
************************************************************************

      DO 30 J=1,MAXLRU,1
         IF (TABLRU(J,5).EQ.0.) GO TO 30
         XMN=1000000./(TABLRU(J,5)*TABLRU(J,7)*SFACT)
```

```
      XSMPL=EXPON(XMN,10)

************************************************************************
*  FILE ATTRIBUTES OF EACH FAILURE ENTITY.                             *
************************************************************************

      ATRIB(1)=TABLRU(J,1)
      ATRIB(3)=TABLRU(J,9)
      ATRIB(4)=TABLRU(J,10)
      ATRIB(5)=TABLRU(J,11)+TABLRU(J,14)
      ATRIB(6)=XSMPL
      ATRIB(7)=TABLRU(J,6)+TABLRU(J,5)+TABLRU(J,16)-TABLRU(J,4)-1.
      ATRIB(9)=TABLRU(J,2)
      ATRIB(10)=0.
      ATRIB(11)=1.
      ATRIB(12)=TABLRU(J,9)*RFACT

************************************************************************
*  DETERMINE FAILURE CRITICALITY BASED ON SPARES REMAINING AND TABLE   *
*  VALUE.                                                              *
************************************************************************

      IF (TABLRU(J,5)-TABLRU(J,4).LE.0. .AND. TABLRU(J,2).NE.9. .AND.
     &  TABLRU(J,2).NE.10. .AND. TABLRU(J,2).NE.14. .AND. TABLRU(J,2)
     & .NE.15.) THEN
         ATRIB(2)=TABLRU(J,3)
      ELSE
         ATRIB(2)=0.
         IF (TABLRU(J,5).GT.TABLRU(J,4) .AND. TABLRU(J,15).GT.0.)
     &      ATRIB(10)=2.
      END IF

************************************************************************
*  IF A NON-FIELD REPAIRABLE FAILURE OCCURS BUT THE UNIT HAS SWITCH-   *
*  OVER REDUNDANCY, SET THE REPAIR LEVEL TO ZERO UNLESS NO REDUNDANT   *
*  SPARES REMAIN.  FOR NONREDUNDANT SYSTEMS (TABLRU(14)=0) SET         *
*  ATRIB(8) TO THE TABLE VALUE.                                        *
************************************************************************

      IF (TABLRU(J,14).GT.0. .AND. ATRIB(7).LT.0.) THEN
         ATRIB(8)=TABLRU(J,15)
      ELSE IF (TABLRU(J,14).GT.0.) THEN
         ATRIB(8)=0.
         ATRIB(2)=0.
         ATRIB(10)=1.
```

```
            CALL SCHDL(20,0.,ATRIB)
         ELSE IF (TABLRU(J,5)-TABLRU(J,4).GE.0.) THEN
            ATRIB(8)=0.
         ELSE
            ATRIB(8)=TABLRU(J,15)
         END IF

************************************************************************
*  FILE FAILURE ENTITY IN FILE 3.                                      *
************************************************************************

         CALL SCHDL(15,0.,ATRIB)
30    CONTINUE
      RETURN
      END

************************************************************************

      SUBROUTINE OPS2

      INTEGER PRNT1,PRNT2,VEH,CE,ECU,PGU
      CHARACTER*1 BASE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNTO,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT

************************************************************************
*  SORT THROUGH FILE 3 IF NONZERO                                      *
************************************************************************

      NEXT=1
      K=2
      IX=0
      LX=0
40    IF (NEXT.GT.NNQ(3)) GO TO 46
      CALL COPY(NEXT,3,ATRIB)
      IT=INT(ATRIB(1))
      XT=ATRIB(6)
      IF (IT.EQ.0.) GO TO 45

************************************************************************
*  REMOVE ALL REMAINING FILE ENTRIES AFTER THE FIRST ABORT-CAUSING     *
*  FAILURE.                                                            *
```

```
************************************************************************

      IF (((ATRIB(7).LT.0. .AND. ATRIB(2).GT.0.) .OR. ATRIB(8).GT.0.)
     & .AND. NNQ(3).GE.NEXT+1) THEN
         ABORT=ATRIB(6)
         J=NNQ(3)
         IX=NEXT
         DO 43 I=NEXT+1,J,1
            CALL COPY(K,3,ATRIB)
            CALL RMOVE(K,3,ATRIB)
43       CONTINUE
      LX=1
      CALL COPY(IX,3,ATRIB)
      END IF

************************************************************************
*   REMOVE MOB FAILURES SCHEDULED AFTER ABORT TIME                     *
************************************************************************

      IF (NNQ(2) .GT. 0) THEN
         DO 44 II=1,NNQ(2)
            CALL RMOVE(1,2,ATRIB)
            IF (ATRIB(6) .LE. ABORT) CALL SCHDL(16,0.,ATRIB)
44       CONTINUE
      END IF

************************************************************************
*  REDUCE SPARES FOR FAILED LRUS.                                      *
************************************************************************

      IF (TABLRU(IT,16).GT.0.) THEN
         TABLRU(IT,16)=TABLRU(IT,16)-1.
      ELSE IF (TABLRU(IT,6).GT.0.) THEN
         TABLRU(IT,6)=TABLRU(IT,6)-1.
      ELSE IF (TABLRU(IT,5).GT.0.) THEN
         TABLRU(IT,5)=TABLRU(IT,5)-1.
      END IF
      IF (LX.EQ.1) GO TO 46
45    NEXT=NEXT+1
      K=K+1
      GO TO 40
46    IF (NNQ(3).EQ.0) GO TO 47
      IF (IX.EQ.0) THEN
         IX=NNQ(3)
         CALL COPY(IX,3,ATRIB)
```

```
      END IF

************************************************************************
*  IF FAILURE CAUSES ABORT TO MOB, FILE FAILURE IN FILE 14 FOR MOB     *
*  MAINTENANCE.                                                        *
************************************************************************

      IF (ATRIB(8).GE.1. .OR. (ATRIB(7).LT.0. .AND. ATRIB(2).GT.0.))THEN
         ATRIB(11)=2.
         CALL SCHDL(16,0.,ATRIB)
         XX(39)=XX(39)+1.
      END IF

*************************************************************************
*  FILE A 'ZERO' EVENT TO ACTIVATE THE FIELD MAINTENANCE NETWORK.       *
*************************************************************************

47    ATRIB(1)=0.
      ATRIB(2)=0.
      ATRIB(6)=0.
      ATRIB(7)=0.
      ATRIB(8)=0.
      CALL SCHDL(15,0.,ATRIB)

************************************************************************
*  CLOSE GATE TO HOLD MGS ENTITY WHILE THE FIELD MAINTENANCE OCCURS.   *
************************************************************************

      CALL CLOSX(3)
      RETURN
      END

***********************************************************************

      SUBROUTINE PARTS

***********************************************************************
*  THIS EVENT UPDATES THE DATABASE TO REFLECT THAT THE MINIMUM NUMBER *
*  OF LRUS ARE NOW AVAILABLE.                                         *
***********************************************************************

      INTEGER PRNT1,PRNT2,VEH,CE,ECU,PGU
      CHARACTER*1 BASE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
```

```
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNT0,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT

      IT=INT(ATRIB(1))
      TABLRU(IT,5)=TABLRU(IT,4)
      RETURN
      END

************************************************************************

      SUBROUTINE OTPUT

      INTEGER PRNT1,PRNT2,VEH,CE,ECU,PGU
      CHARACTER*1 BASE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNT0,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT

      WRITE(6,1)
1     FORMAT('1',28X,'DEPLOYMENT STATISTICS',/)
      WRITE(6,2)
2     FORMAT(2X,'Options:')
      WRITE(6,3) BASE
3     FORMAT(5X,'Base: ',A1)
      WRITE(6,4) SFACT,RFACT
4     FORMAT(5X,'SFACT:',F5.1,', RFACT:',F5.1)
      WRITE(6,5) VEH,CE,PGU,ECU
5     FORMAT(5X,'VEH: ',I2,', CE: ',I2,', PGU: ',I2,', ECU: ',I2)
      WRITE(6,6) MNT
6     FORMAT(5X,'MNT: ',I1,/)
      WRITE(6,7)
7     FORMAT(2X,'Relocation Statistics:')
      WRITE(6,8) XX(11)
8     FORMAT(5X,'Total relocation time was ',F5.2,' hours.')
      WRITE(6,9) XX(13)
9     FORMAT(5X,'Relocation downtime totaled ',F5.2,' hours.')
      WRITE(6,10) XX(15)
10    FORMAT(5X,'Relocation downing events totaled ',F2.0)
      WRITE(6,11) XX(29)
11    FORMAT(5X,'MTBCF during relocation was ',F5.2,' hours.',/)
      WRITE(6,12)
12    FORMAT(2X,'Operations Statistics:')
```

```
      WRITE(6,13) XX(2)
13    FORMAT(5X,'Total operations time was ',F8.2,' hours.')
      WRITE(6,14) XX(4)
14    FORMAT(5X,'Operations downtime totaled ',F8.2,' hours.')
      WRITE(6,15) XX(9)
15    FORMAT(5X,'Operations downing events totaled ',F4.0)
      WRITE(6,16) XX(47)
16    FORMAT(5X,'Field maintenance actions totaled ',F4.0)
      WRITE(6,17) XX(28)
17    FORMAT(5X,'MTBCF during operations was ',F8.2,' hours.',/)
      WRITE(6,18)
18    FORMAT(2X,'MOB Statistics:')
      WRITE(6,19) XX(54)
19    FORMAT(5X,'MOB VEH manhours totaled ',F5.1)
      WRITE(6,20) XX(55)
20    FORMAT(5X,'MOB CE manhours totaled ',F5.1)
      WRITE(6,21) XX(56)
21    FORMAT(5X,'MOB PGU manhours totaled ',F5.1)
      WRITE(6,22) XX(57)
22    FORMAT(5X,'MOB ECU manhours totaled ',F5.1)
      WRITE(6,23) XX(46)
23    FORMAT(5X,'MOB maintenance actions totaled ',F5.0,/)
      WRITE(6,24)
24    FORMAT(2X,'Overall Statistics:')
      CYCLE = (2*XX(11))+XX(2)+XX(36)
      WRITE(6,25) CYCLE
25    FORMAT(5X,'Length of deployment cycle was',F8.2,' hours.')
      IF (XX(14).EQ.1.) THEN
         WRITE(6,26)
26       FORMAT(5X,'Abort-causing failure occurred during operations.')
      ELSE
         WRITE(6,27)
27       FORMAT(5X,'Abort-causing failure occurred during relocation.')
      END IF
      WRITE(6,28) XX(2)-XX(4)
28    FORMAT(5X,'Adjusted System endurance was ',F8.2,/)
      WRITE(6,29) XX(25)
29    FORMAT(5X,'Relocation availability was ',F6.4)
      WRITE(6,30) XX(24)
30    FORMAT(5X,'Operational availability was ',F6.4)
      WRITE(6,31) (XX(2)-XX(4))/CYCLE
31    FORMAT(5X,'Overall system availability was ',F6.4)
      RETURN
      END
```

```
************************************************************************

      SUBROUTINE INIT1

************************************************************************
*  THIS SUBROUTINE INITIALIZES USER SUPPLIED CONTROL VARIABLES USED IN *
*  THE SLAM CODE.                                                      *
************************************************************************

      INTEGER PRNT1,PRNT2,VEH,CE,ECU,PGU
      CHARACTER*1 BASE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR,
     &NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/TABLRU(550,17),XREL,XSORTY,MAXLRU,RELN,VEH,CE,PGU,
     &RLSD,SFACT,RFACT,DULN,ABRT,ABSD,RESUPL,PRNT1,PRNT2,PRNTO,ECU,MNT,
     &SRTL,SLSD,BASE,ABORT

      XX(71)=ABRT
      XX(72)=ABSD
      XX(73)=PRNTO
      XX(74)=VEH
      XX(75)=CE
      XX(76)=PGU
      XX(77)=ECU
      XX(78)=MNT
      XX(79)=RFACT
      RETURN
      END
```

Appendix C. *SLAM Attributes, Files and Global Variables*

Slam Attributes

Attribute	Usage
1	Contains LRU number for failed unit read in from database. Current range is 1-535.
2	Criticality indicator. (0 = not mission critical; 1 = mission critical during exercise scenario; 2 = mission critical during wartime scenario; 3 = mission critical during both.
3	Mean repair time read in from TABLRU.
4	Repair time standard deviation.
5	System restoral time. Certain LRUs require system downtime to repair–this time is required to restart/reinitialize system after maintenance or to bring it back up after switching to a redundant unit.
6	Time to failure. Time from the start of current ops or relocation cycle until an LRU will fail. Selected by the ops and rel subroutines.
7	Spares remaining. A value of 0 or higher means at least the minimum required number of units is operating.
8	Repair location. (0 = can be repaired in the field with convoy resources; 1 = repairable in field with MOB support; 2 = repairable at MOB only.)
9	Subsystem number. (1-12 for SCV, 14-27 for SMV)
10	Redundancy processing flag. Discussed in text.
11	Number of maintainers required.

Slam Files

File	Purpose	Network
1	Failures awaiting field maintenance	Field Maint
2	Temporary storage	OPS Sub
3	All failures	Field Maint
4	Failures scheduled during relocation	Rel Maint
5	Storage for GMS entity	Deploymet
6	Delayed maintenance events	Rel Maint
7	Non-TSS maintenance events	Rel Maint
8	Non-critical deferred relocation failures	Rel Maint
9	Non-critical failures (spares not available)	Field Maint
10	MOB vehicle maintenance events	MOB Maint
11	MOB CE maintenance events	MOB Maint
12	MOB PGU maintenance events	MOB Maint
13	MOB ECU maintenance events	MOB Maint
14	Failures for MOB repair	Rel Maint
		Field Maint
15	Storage queue for ASMBL node	MOB Maint
16	Storage queue for ASMBL node	MOB Maint
17	Storage queue for ASMBL node	MOB Maint
18	Storage queue for ASMBL node	MOB Maint
19	Not used	
20	Not used	
21	Critical failed LRUs (spares not available)	Rel Maint
		Field Maint
22	Critical failed LRUs (spares available)	Rel Maint
		Field Maint

Slam Global Variables

XX()	Usage
1	Operation start time
2	Total operations time
3	Start of current operaions downtime
4	Total operations downtime
6	Critical downtime flag (¿0 if downtime in progress)
9	Number of critical operations failures
10	Relocation start time
11	Total relocation time
12	Start of current relocation downtime
13	Total relocation downtime
14	Abort flag (1 - field abort, 2 - relocation abort)
15	Number of critical relocation failures
16	Temporary storage
24	Operational availability during current deployment
25	Relocation availability during deployment
28	Operations MTBCF
29	Relocation MTBCF
30	Combined availability (operations and relocation)
31	Combined MTBCF
32	Temporary storage
33	Temporary storage
34	Temporary storage
35	Start of downtime at MOB
36	Total MOB downtime
37	Relocation downtime counter
39	Number of abort failures in subroutines
40	MOB turnaround

Slam Global Variables (continued)

XX()	Usage
42	Temporary storage
44	Relocation downtime delay accumulator
45	Mean repair time of critical failures
46	Number of maintenance actions at the MOB
47	Number of field maintenance repairs
50	Operations MTBM
53	Length of current data dropout
54	VEH maintenance manhours at the MOB
55	CE maintenance manhours at the MOB
56	PGU maintenance manhours at the MOB
57	ECU maintenance manhours at the MOB
58	Total maintenance manhours at the MOB
59	Temporary storage
60	Temporary storage
61	Temporary storage
62	Temporary storage
63	Deployment duration
71	Mean time between software aborts
72	Standard deviation for XX(71)
73	Print flag for OTPUT
74	Number of VEH maintenance personnel
75	Number of CE maintenance personnel
76	Number of PGU maintenance personnel
77	Number of ECU maintenance personnel
78	Number of field maintenance personnel
79	Scaling factor for repair rates

Slam Random Number Streams

Sream	Usage	Network
1	VEH repair times	MOB Maint
2	CE repair times	MOB Maint
3	PGU repair times	MOB Maint
4	ECU repair times	MOB Maint
5	Tractor repair times, tractor switchover times, tire replacement times	Rel Maint
6	Relocation maintenance repair times	Rel Maint
7	Data dropouts, software aborts, satellite acquisition	Field Maint
8	Field maintenance repair times	Field Maint
9	Relocation duration, LRU failure times	REL Subroutine
10	LRU failure times	OPS Subroutine

Appendix D. *LRU Database*

This file contains all the information about essential components contained in the SCV and SMV. It is never directly manipulated during the simulation. Instead, it contents are written into an array, which is altered during the simulation. This file is unclassified.

D.1 Database Assumptions

The database contains data for the SCV and SMV only; the other vehicles are not considered mission essential and will not force an abort to the MOB. Tractors for the non-essential vehicles are considered back-ups for the SCV and SMV.

Each row in the database represents a component or piece of equipment in the SCV and SMV. The term LRU is used loosely in this application since an LRU can describe anything from a field- replaceable circuit card to a large, non-repairable power generation unit. All components are included in the database whether mission critical or not.

The design of the model allows the LRUs to be tested in groups during periods for which they might fail. This group testing allows LRUs to be easily added or deleted from the database without necessitating changes in the code. The lowest failure rate allowed in the database is one per million hours.

D.2 Description of Database Columns

A brief discussion of each of the database columes is given below.

Column 1. LRU Number. This is the sequential number of the LRU as it appears in the database. SCV LRUs are listed first (1-331) and SMV LRUs (332-535) are appended to them.

Column 2. Subsystem Number. Each LRU is assigned to a major subsystem. The 27 different subsystems are shown below. Subsystem numbers are used for sorting failures in the model.

Subsystem	Description
Satellite Command Vehicle (SCV):	
1	Communications Subsystem (CSS)
2	Display Unit (DU)
3	Peripheral Controller Processor Unit (PCPU)
4	Mass Memory Unit (MMU)
5	Magnetic Tape Unit (MTU)
6	Line Printer (LP)
7	Phased Array Subsystem (PASS)
8	Transportation subsystems (TSS) required for mission data processing
9	TSS elements required for relocation
10	TSS elements required for both relocation and operations
11	TSS Environmental Control Unit (ECU)
12	TSS Power Generation Unit (PGU)
Satellite Mission Vehicle (SMV):	
14	TSS elements required for relocation
15	TSS elements required for relocation and operations

Subsystem	Description
17	TSS PGU
18	Jam Resistant Secure Communications Terminal (JRSCT) Antenna Assembly
19	JRSCT RF/IF Rack Group
20	JRSCT Baseband Rack Group
21	JRSCT USC/28 Operator Interface Unit
22	JRSCT USC/28 CSU (Unique)
23	JRSCT USC/28 R/T (Unique)
24	JRSCT USC/28 CSU and R/T (Common)
25	JRSCT USC/28 Chassis
26	JRSCT Shelter Electrical Equipment
27	SMV Unique Equipment

Column 3. Criticality Number. Indicates criticality of the LRU to the mission. Values are:

0 - LRU not mission critical

1 - Mission critical during exercise scenario

2 - Mission critical during wartime scenario

3 - Mission critical during both scenarios

Column 4. Required number of units. For redundant subsystems, this is the minimum required number that must be operating to perform their function.

Column 5. Number of units powered. Number of redundant units that are powered and functional in the racks. This column is changed as components fail; initially, it is equal to the minimum number required plus any hot spares.

Column 6. Number of cold spares. This represents additional spares in storage on-board the SCV or SMV. This number is reduced as failures occur.

Column 7. Fixed failure rate. This is the exponential failure rate when the LRU is operating at a fixed site.

Column 8. Mobile failure rate. This is the exponential LRU failure rate during relocation.

Column 9. Mean repair time. The is the mean lognormal repair time for the LRU.

Column 10. Repair time standard deviation. Because a lognormal distribution is used when sampling the LRU repair time, the standard deviation must be supplied.

Column 11. System restoral time. Some failed LRUs require the system to be restarted after the LRU is repaired. This is generally taken to be the time to warm-start the system (approximately 5 minutes).

Column 12. Initial number powered. This number represents the ideal state when all redundant units are functional and all hot spares are available. This number is copied into column 5 when the convoy is restocked at the MOB.

Column 13. Initial Number of cold spares. Maximum number of cold spares carried. Copied into column 6 when the convoy is restocked.

Column 14. Redundant unit switch-over time. Certain LRUs (usually tractors or PGUs) require system downtime for the redundant unit to be brought on-line. This time is distinct from any time to repair the failed unit.

Column 15. Repair location. This value indicates where a unit can be repaired once it fails. Values are:

0 - Repairable in the field by convoy maintainers

1 - Repairable in the field, but requiring MOB equipment or maintenance personnel to be brought out

2 - Repairable at the MOB only

Column 16. FSV spares. Additional spares carried in the field support vehicle.

Column 17. Initial FSV spares. Maximum number of FSV spares available when it is fully stocked. This number is copied into column 16 when the convoy is restocked.

D.3 Database Files

There two files stored for use with this model; GMS_A.DAT and GMS_B.DAT. The difference between the two files is the base from which the convoy is deploying. Convoys deploying from base A have no FSV support and thus all entries in columns 15 and 16 are zero. The file shown in this appendix is for base B with the FSV spares shown in columns 15 and 16.

1.	1.	3.	1.	2.	0.	16.9	42.2	.008	.1	.083	2.	0.	0.	0.	0.	0.
2.	1.	3.	1.	2.	0.	118.6	296.5	.008	.1	.083	2.	0.	0.	0.	0.	0.
3.	1.	3.	1.	2.	0.	51.7	129.3	.008	.1	.083	2.	0.	0.	0.	0.	0.
4.	1.	3.	1.	2.	0.	12.4	30.9	.008	.1	.083	2.	0.	0.	0.	0.	0.
5.	1.	3.	1.	2.	0.	15.5	38.6	.008	.1	.083	2.	0.	0.	0.	0.	0.
6.	1.	3.	1.	1.	0.	10.0	25.0	.275	.1	.083	1.	0.	0.	0.	0.	0.
7.	1.	3.	1.	3.	0.	8.0	20.0	.008	.1	.083	3.	0.	0.	0.	0.	0.
8.	1.	3.	3.	3.	0.	1.0	1.0	.096	.1	.0	3.	0.	0.	0.	0.	0.
9.	1.	3.	1.	1.	0.	1.0	1.0	.096	.1	.0	1.	0.	0.	0.	0.	0.
10.	1.	3.	1.	1.	0.	1.0	1.0	.096	.1	.0	1.	0.	0.	0.	0.	0.
11.	1.	3.	1.	1.	0.	1.0	1.0	.096	.1	.0	1.	0.	0.	0.	0.	0.
12.	1.	3.	1.	1.	0.	1.0	1.0	.272	.1	.0	1.	0.	0.	0.	0.	0.
13.	1.	3.	1.	1.	0.	1.0	1.0	.203	.1	.0	1.	0.	0.	0.	0.	0.
14.	1.	3.	1.	2.	0.	11.4	28.6	.288	.1	.0	2.	0.	0.	0.	0.	0.
15.	1.	3.	5.	6.	0.	25.0	62.5	.008	.1	.0	6.	0.	0.	0.	0.	0.
16.	1.	3.	1.	1.	1.	10.9	27.2	.237	.1	.083	1.	1.	0.	0.	0.	0.
17.	1.	3.	1.	2.	0.	40.9	101.0	.008	.1	.083	2.	0.	0.	0.	0.	0.
18.	1.	0.	1.	1.	0.	32.0	80.1	.314	.1	.0	1.	0.	0.	0.	0.	0.
19.	1.	0.	1.	1.	0.	10.0	25.0	.314	.1	.0	1.	0.	0.	0.	0.	0.
20.	1.	0.	1.	1.	0.	104.5	261.3	.008	.1	.0	1.	0.	0.	0.	0.	0.
21.	1.	0.	1.	1.	0.	6.0	15.0	.279	.1	.0	1.	0.	0.	0.	1.	1.
22.	1.	0.	1.	1.	0.	7.1	17.7	.507	.2	.0	1.	0.	0.	0.	0.	0.
23.	1.	0.	1.	1.	0.	100.0	250.0	.145	.1	.0	1.	0.	0.	0.	0.	0.
24.	1.	0.	1.	1.	0.	87.0	217.4	.220	.1	.083	1.	0.	0.	0.	0.	0.
25.	1.	0.	1.	1.	0.	259.0	647.5	.175	.1	.0	1.	0.	0.	0.	0.	0.
26.	1.	0.	1.	1.	0.	12.8	32.1	.145	.1	.0	1.	0.	0.	0.	0.	0.
27.	1.	0.	1.	1.	0.	66.7	166.7	.234	.1	.0	1.	0.	0.	0.	0.	0.
28.	1.	0.	1.	1.	0.	3.1	7.7	.234	.1	.0	1.	0.	0.	0.	0.	0.
29.	1.	0.	1.	1.	0.	8.2	20.4	.175	.1	.0	1.	0.	0.	0.	0.	0.
30.	1.	0.	1.	1.	0.	95.7	239.4	.240	.1	.0	1.	0.	0.	0.	0.	0.
31.	1.	0.	2.	2.	0.	61.0	160.3	.150	.1	.0	2.	0.	0.	0.	0.	0.
32.	1.	0.	1.	1.	0.	40.0	100.0	.240	.1	.0	1.	0.	0.	0.	0.	0.
33.	1.	0.	1.	1.	0.	4.4	11.1	.150	.1	.0	1.	0.	0.	0.	0.	0.
34.	1.	0.	1.	1.	0.	1.0	1.0	.600	.3	.0	1.	0.	0.	0.	0.	0.
35.	1.	0.	1.	1.	0.	80.0	200.0	.347	.1	.0	1.	0.	0.	0.	0.	0.
36.	1.	0.	4.	4.	1.	68.0	641.7	.261	.1	.0	4.	1.	0.	0.	0.	0.
37.	1.	0.	2.	2.	1.	64.1	160.3	.150	.1	.0	2.	1.	0.	0.	0.	0.
38.	1.	0.	4.	4.	0.	6.6	16.5	.385	.2	.0	4.	0.	0.	0.	0.	0.
39.	1.	0.	1.	1.	0.	46.0	115.0	.262	.1	.0	1.	0.	0.	0.	0.	0.
40.	1.	0.	2.	2.	0.	32.4	80.9	.224	.1	.0	2.	0.	0.	0.	0.	0.
41.	1.	0.	1.	1.	0.	13.6	34.0	.337	.1	.0	1.	0.	0.	0.	0.	0.
42.	1.	0.	1.	1.	0.	1.0	1.0	.600	.3	.0	1.	0.	0.	0.	0.	0.
43.	1.	0.	1.	1.	0.	13.2	33.0	.347	.1	.0	1.	0.	0.	0.	0.	0.
44.	1.	0.	1.	1.	0.	1.0	1.0	.251	.1	.0	1.	0.	0.	0.	0.	0.
45.	1.	0.	1.	1.	1.	155.4	388.4	.351	.2	.0	1.	1.	0.	0.	1.	1.

46.	2.	3.	1.	1.	0.	9.1	1.7	.075	.3	.083	1.	0.	0.	0.	1.	1.
47.	2.	3.	1.	1.	1.	12.6	2.0	.820	.4	.083	1.	1.	0.	0.	1.	1.
48.	2.	3.	1.	1.	1.	20.0	1.0	.213	.1	.083	1.	1.	0.	0.	0.	0.
49.	2.	3.	1.	1.	0.	1.0	1.0	.095	.1	.083	1.	0.	0.	0.	0.	0.
50.	2.	3.	1.	1.	0.	1.0	1.0	.300	.1	.083	1.	0.	0.	0.	0.	0.
51.	2.	3.	1.	1.	0.	3.5	1.3	.323	.1	.083	1.	0.	0.	0.	0.	0.
52.	2.	3.	1.	1.	0.	15.0	10.4	.397	.2	.083	1.	0.	0.	0.	0.	0.
53.	2.	3.	1.	1.	0.	1.0	1.0	1.23	.6	.083	1.	0.	0.	0.	0.	0.
54.	2.	3.	1.	1.	1.	55.2	15.1	.500	.2	.083	1.	1.	0.	0.	1.	1.
55.	2.	3.	1.	1.	1.	3.0	1.0	.191	.1	.083	1.	1.	0.	0.	0.	0.
56.	2.	3.	1.	1.	1.	5.0	1.0	.191	.1	.083	1.	1.	0.	0.	0.	0.
57.	2.	3.	1.	1.	1.	14.7	1.5	.253	.1	.083	1.	1.	0.	0.	0.	0.
58.	2.	3.	1.	1.	1.	4.8	1.6	.191	.1	.083	1.	1.	0.	0.	0.	0.
59.	2.	3.	1.	1.	1.	4.8	1.0	.192	.1	.083	1.	1.	0.	0.	0.	0.
60.	2.	3.	1.	1.	1.	8.0	2.0	.192	.1	.083	1.	1.	0.	0.	0.	0.
61.	2.	3.	1.	1.	1.	6.4	1.1	.192	.1	.083	1.	1.	0.	0.	0.	0.
62.	2.	3.	1.	1.	1.	4.5	1.0	.192	.1	.083	1.	1.	0.	0.	0.	0.
63.	2.	3.	1.	1.	1.	4.8	1.0	.243	.1	.083	1.	1.	0.	0.	0.	0.
64.	2.	3.	1.	1.	1.	6.4	1.1	.243	.1	.083	1.	1.	0.	0.	0.	0.
65.	2.	3.	1.	1.	1.	4.6	1.0	.243	.1	.083	1.	1.	0.	0.	0.	0.
66.	2.	3.	1.	1.	1.	4.8	1.0	.243	.1	.083	1.	1.	0.	0.	0.	0.
67.	2.	3.	1.	1.	1.	9.4	2.9	.192	.1	.083	1.	1.	0.	0.	0.	0.
68.	2.	3.	1.	1.	1.	3.4	1.0	.192	.1	.083	1.	1.	0.	0.	0.	0.
69.	2.	3.	1.	1.	1.	5.1	1.0	.192	.1	.083	1.	1.	0.	0.	0.	0.
70.	2.	3.	1.	1.	1.	1.0	1.0	.192	.1	.083	1.	1.	0.	0.	0.	0.
71.	2.	3.	1.	1.	0.	10.3	10.3	1.50	.5	.083	1.	0.	0.	0.	0.	0.
72.	3.	3.	91.	91.	4.	6.5	10.9	.077	.1	.083	91.	4.	0.	0.	0.	0.
73.	3.	3.	5.	5.	1.	3.0	5.0	.092	.1	.083	5.	1.	0.	0.	0.	0.
74.	3.	3.	5.	5.	1.	3.1	5.2	.092	.1	.083	5.	1.	0.	0.	0.	0.
75.	3.	3.	5.	5.	1.	3.8	5.2	.092	.1	.083	5.	1.	0.	0.	0.	0.
76.	3.	3.	5.	5.	1.	3.6	6.0	.106	.1	.083	5.	1.	0.	0.	0.	0.
77.	3.	3.	5.	5.	1.	3.2	5.4	.092	.1	.083	5.	1.	0.	0.	0.	0.
78.	3.	3.	5.	5.	1.	3.3	5.4	.092	.1	.083	5.	1.	0.	0.	0.	0.
79.	3.	3.	5.	5.	1.	3.1	5.2	.092	.1	.083	5.	1.	0.	0.	0.	0.
80.	3.	3.	5.	5.	1.	5.4	9.0	.176	.1	.083	5.	1.	0.	0.	1.	1.
81.	3.	3.	10.	10.	1.	5.1	8.5	.073	.1	.083	10.	1.	0.	0.	0.	0.
82.	3.	3.	2.	2.	1.	1.8	3.0	.239	.1	.083	2.	1.	0.	0.	0.	0.
83.	3.	3.	5.	5.	1.	4.9	8.2	.086	.1	.083	5.	1.	0.	0.	0.	0.
84.	3.	3.	10.	10.	1.	4.1	6.8	.106	.1	.083	10.	1.	0.	0.	0.	0.
85.	3.	3.	5.	5.	1.	3.0	5.0	.106	.1	.083	5.	1.	0.	0.	0.	0.
86.	3.	3.	5.	5.	1.	4.0	6.7	.106	.1	.083	5.	1.	0.	0.	0.	0.
87.	3.	3.	4.	4.	1.	2.2	3.7	.086	.1	.083	4.	1.	0.	0.	0.	0.
88.	3.	3.	4.	4.	1.	6.0	10.0	.122	.1	.083	4.	1.	0.	0.	0.	0.
89.	3.	3.	4.	4.	1.	5.2	8.7	.122	.1	.083	4.	1.	0.	0.	0.	0.
90.	3.	3.	4.	4.	1.	4.5	7.5	.127	.1	.083	4.	1.	0.	0.	0.	0.

91.	3.	3.	1.	1.	1.	4.7	7.8	.107	.1	.083	1.	1.	0.	0.	0.	0.
92.	3.	3.	1.	1.	1.	2.7	4.5	.107	.05	.083	1.	1.	0.	0.	0.	0.
93.	3.	3.	1.	1.	1.	4.7	7.8	.107	.05	.083	1.	1.	0.	0.	0.	0.
94.	3.	3.	1.	1.	1.	5.3	8.9	.107	.05	.083	1.	1.	0.	0.	0.	0.
95.	3.	3.	1.	1.	1.	4.6	7.7	.107	.05	.083	1.	1.	0.	0.	0.	0.
96.	3.	0.	1.	1.	1.	3.5	5.9	.107	.05	.083	1.	1.	0.	0.	0.	0.
97.	3	3.	3.	3.	1.	4.1	6.9	.107	.05	.167	3.	1.	0.	0.	0.	0.
98.	3.	3.	3.	3.	1.	2.2	3.7	.107	.05	.167	3.	1.	0.	0.	0.	0.
99.	3.	3.	5.	5.	1.	3.3	5.5	.122	.06	.083	5.	1.	0.	0.	0.	0.
100.	3.	3.	5.	5.	1.	2.6	4.4	.122	.06	.083	5.	1.	0.	0.	0.	0.
101.	3.	3.	5.	5.	1.	4.8	8.0	.116	.05	.0	3.	1.	0.	0.	0.	0.
102.	3.	3.	3.	3.	1.	3.6	6.0	.099	.05	.0	3.	1.	0.	0.	0.	0.
103.	3.	3.	3.	3.	1.	3.0	5.0	.085	.04	.0	3.	1.	0.	0.	0.	0.
104.	3.	3.	3.	3.	1.	2.7	4.5	.073	.03	.083	3.	1.	0.	0.	0.	0.
105.	3.	3.	3.	3.	1.	3.1	5.1	.073	.03	.083	3.	1.	0.	0.	0.	0.
106.	3.	3.	3.	3.	1.	3.3	5.6	.073	.03	.083	3.	1.	0.	0.	0.	0.
107.	3.	3.	3.	3.	1.	3.3	5.4	.073	.03	.083	3.	1.	0.	0.	0.	0.
108.	3.	3.	3.	3.	1.	2.7	4.5	.074	.03	.083	3.	1.	0.	0.	0.	0.
109.	3.	3.	3.	3.	1.	2.9	4.8	.074	.03	.083	3.	1.	0.	0.	0.	0.
110.	3.	3.	3.	3.	1.	1.0	1.5	.072	.03	.083	3.	1.	0.	0.	0.	0.
111.	3.	3.	3.	3.	1.	1.4	2.3	.073	.03	.083	3.	1.	0.	0.	0.	0.
112.	3.	3.	3.	3.	1.	2.3	3.9	.124	.06	.083	3.	1.	0.	0.	0.	0.
113.	3.	3.	3.	3.	1.	2.0	3.3	.126	.06	.083	3.	1.	0.	0.	0.	0.
114.	3.	3.	3.	3.	1.	3.2	5.4	.125	.06	.083	3.	1.	0.	0.	0.	0.
115.	3.	3.	3.	3.	1.	2.6	4.3	.127	.06	.083	3.	1.	0.	0.	0.	0.
116.	3.	3.	3.	3.	1.	2.1	3.5	.126	.06	.083	3.	1.	0.	0.	0.	0.
117.	3.	3.	3.	3.	1.	2.4	4.1	.126	.06	.083	3.	1.	0.	0.	0.	0.
118.	3.	3.	3.	3.	1.	3.3	5.5	.125	.06	.083	3.	1.	0.	0.	0.	0.
119.	3.	3.	3.	3.	1.	3.3	5.5	.124	.06	.083	3.	1.	0.	0.	0.	0.
120.	3.	3.	3.	3.	1.	3.1	5.1	.128	.06	.083	3.	1.	0.	0.	0.	0.
121.	3.	3.	6.	6.	1.	7.1	11.9	.073	.03	.083	6.	1.	0.	0.	0.	0.
122.	3.	3.	6.	6.	1.	9.8	16.3	.050	.02	.083	6.	1.	0.	0.	0.	0.
123.	3.	3.	5.	5.	1.	8.1	13.5	.235	.1	.083	5.	1.	0.	0.	0.	0.
124.	3.	3.	8.	8.	1.	4.8	7.5	.235	.1	.083	8.	1.	0.	0.	0.	0.
125.	3.	3.	13.	13.	1.	7.5	12.4	.235	.1	.083	13.	1.	0.	0.	0.	0.
126.	3.	3.	5.	5.	1.	1.7	2.9	.235	.1	.083	5.	1.	0.	0.	0.	0.
127.	3.	3.	5.	5.	1.	10.9	18.2	.212	.1	.083	5.	1.	0.	0.	0.	0.
128.	3.	3.	5.	5.	1.	6.9	11.5	.212	.1	.083	5.	1.	0.	0.	0.	0.
129.	3.	3.	5.	5.	1.	1.1	1.9	.152	.07	.083	5.	1.	0.	0.	0.	0.
130.	3.	3.	5.	5.	1.	2.7	4.5	.152	.07	.083	5.	1.	0.	0.	0.	0.
131.	3.	3.	5.	5.	0.	6.0	10.0	.152	.07	.083	5.	0.	0.	0.	0.	0.
132.	3.	3.	5.	5.	0.	2.4	4.0	1.35	.5	.083	5.	0.	0.	0.	0.	0.
133.	3.	3.	2.	2.	0.	2.9	4.9	1.35	.5	.083	2.	0.	0.	0.	0.	0.
134.	3.	3.	3.	3.	0.	2.9	4.9	1.35	.5	.083	3.	0.	0.	0.	0.	0.
135.	3.	3.	5.	5.	0.	1.5	2.5	1.35	.5	.083	5.	0.	0.	0.	0.	0.

136.	3.	3.	5.	5.	0.	1.3	2.1	1.35	.5	.083	5.	0.	0.	0.	0.	0.
137.	3.	3.	5.	5.	0.	5.9	9.8	2.35	1.0	.083	5.	0.	0.	0.	0.	0.
138.	4.	3.	15.	15.	1.	3.4	13.8	.400	.2	.167	15.	1.	0.	0.	0.	0.
139.	4.	3.	3.	3.	1.	6.3	18.6	.333	.2	.167	3.	1.	0.	0.	0.	0.
140.	4.	3.	1.	1.	0.	10.0	10.4	.367	.2	.0	1.	0.	0.	0.	0.	0.
141.	4.	3.	1.	1.	0.	1.0	1.0	.500	.2	.0	1.	0.	0.	0.	0.	0.
142.	5.	3.	1.	1.	0.	2.6	1.0	.333	.2	.0	1.	0.	0.	0.	0.	0.
143.	5.	3.	1.	2.	0.	61.1	12.7	.008	.01	.0	2.	0.	0.	0.	1.	1.
144.	5.	3.	1.	1.	1.	1.0	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
145.	5.	3.	1.	1.	1.	1.0	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
146.	5.	3.	1.	1.	1.	1.0	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
147.	5.	3.	1.	1.	1.	1.0	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
148.	5.	3.	1.	1.	1.	1.3	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
149.	5.	3.	1.	1.	1.	1.0	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
150.	5.	3.	1.	1.	1.	1.9	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
151.	5.	3.	1.	1.	1.	2.5	0.8	.430	.2	.0	1.	1.	0.	0.	0.	0.
152.	5.	3.	1.	1.	1.	6.2	1.4	.430	.2	.0	1.	1.	0.	0.	0.	0.
153.	5.	3.	1.	1.	1.	1.7	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
154.	5.	3.	1.	1.	1.	1.0	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
155.	5.	3.	1.	1.	1.	1.4	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
156.	5.	3.	1.	1.	1.	2.0	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
157.	5.	3.	1.	1.	1.	1.0	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
158.	5.	3.	1.	1.	1.	1.4	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
159.	5.	3.	1.	1.	1.	0.6	1.0	.430	.2	.0	1.	1.	0.	0.	0.	0.
160.	5.	3.	1.	1.	1.	4.6	1.4	.623	.3	.0	1.	1.	0.	0.	0.	0.
161.	5.	3.	1.	1.	0.	1.0	1.0	.523	.3	.0	1.	0.	0.	0.	1.	1.
162.	6.	3.	1.	1.	0.	35.7	35.7	.500	.2	.0	1.	0.	0.	0.	1.	1.
163.	7.	3.	1.	1.	0.	3.2	3.2	1.15	.5	.0	1.	0.	0.	2.	0.	0.
164.	7.	3.	1.	1.	0.	6.3	6.3	1.43	.5	.0	1.	0.	0.	2.	0.	0.
165.	7.	3.	1.	1.	0.	1.8	1.8	24.0	1.0	.0	1.	0.	0.	2.	0.	0.
166.	7.	3.	1.	1.	0.	1.0	1.0	120.0	1.0	.0	1.	0.	0.	2.	0.	0.
167.	8.	3.	1.	1.	0.	1.0	1.0	.300	.1	.2	1.	0.	0.	0.	0.	0.
168.	8.	3.	1.	1.	0.	1.0	3.0	.500	.2	.2	1.	0.	0.	0.	0.	0.
169.	8.	3.	8.	8.	1.	2.0	2.0	.580	.3	.2	8.	1.	0.	0.	0.	0.
170.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
171.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
172.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
173.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
174.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
175.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
176.	8.	3.	1.	1.	0.	1.0	1.0	.300	.1	.2	1.	0.	0.	0.	0.	0.
177.	8.	3.	1.	1.	0.	1.0	1.7	.500	.2	.2	1.	0.	0.	0.	0.	0.
178.	8.	3.	2.	2.	1.	2.0	2.0	.580	.3	.2	2.	1.	0.	0.	0.	0.
179.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
180.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.

181.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
182.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
183.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
184.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
185.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
186.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
187.	8.	3.	1.	1.	0.	5.5	5.5	.300	.1	.2	1.	0.	0.	0.	0.	0.
188.	8.	3.	1.	1.	0.	1.3	8.0	.500	.2	.2	1.	0.	0.	0.	0.	0.
189.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
190.	8.	3.	1.	1.	0.	1.0	1.0	1.0	.5	.2	1.	0.	0.	0.	0.	0.
191.	8.	3.	1.	3.	0.	1.0	1.0	.352	.2	.0	3.	0.	0.	0.	0.	0.
192.	8.	3.	1.	1.	0.	2.1	4.6	1.0	.5	.2	1.	0.	0.	0.	0.	0.
193.	8.	1.	1.	1.	1.	1.6	4.9	.167	.1	.0	1.	1.	0.	0.	0.	0.
194.	8.	1.	1.	1.	1.	2.6	7.6	.167	.1	.0	1.	1.	0.	0.	0.	0.
195.	8.	1.	1.	1.	1.	1.5	5.3	.167	.1	.0	1.	1.	0.	0.	0.	0.
196.	8.	1.	1.	1.	1.	1.2	3.3	.167	.1	.0	1.	1.	0.	0.	0.	0.
197.	8.	1.	1.	1.	1.	4.7	10.7	.167	.1	.0	1.	1.	0.	0.	0.	0.
198.	8.	1.	1.	1.	1.	3.3	9.8	.167	.1	.0	1.	1.	0.	0.	0.	0.
199.	8.	3.	1.	1.	0.	1.0	1.0	24.0	1.0	.0	1.	0.	0.	0.	0.	0.
200.	8.	3.	1.	1.	0.	1.0	1.0	24.0	1.0	.0	1.	0.	0.	0.	0.	0.
201.	8.	3.	1.	1.	0.	1.0	1.0	24.0	1.0	.0	1.	0.	0.	0.	0.	0.
202.	8.	3.	1.	1.	0.	1.0	1.0	24.0	1.0	.0	1.	0.	0.	0.	0.	0.
203.	8.	3.	1.	1.	0.	5.7	5.7	24.0	1.0	.0	1.	0.	0.	0.	0.	0.
204.	8.	3.	1.	1.	0.	1.0	1.0	8.0	1.0	.0	1.	0.	0.	0.	0.	0.
205.	8.	3.	1.	1.	0.	1.0	1.0	3.0	1.0	.0	1.	0.	0.	0.	0.	0.
206.	8.	3.	1.	1.	0.	10.0	10.0	1.0	.5	.0	1.	0.	0.	0.	0.	0.
207.	8.	3.	1.	1.	0.	1.0	1.0	3.0	1.0	.0	1.	0.	0.	0.	0.	0.
208.	8.	3.	1.	1.	0.	1.0	1.0	.5	.2	.0	1.	0.	0.	0.	0.	0.
209.	8.	3.	1.	1.	0.	2.1	2.1	.5	.2	.0	1.	0.	0.	0.	0.	0.
210.	8.	3.	1.	1.	0.	1.0	1.0	8.0	1.0	.0	1.	0.	0.	0.	0.	0.
211.	8.	3.	1.	1.	0.	1.0	1.0	3.0	1.0	.0	1.	0.	0.	0.	0.	0.
212.	8.	3.	1.	1.	0.	5.0	5.0	1.0	.5	.0	1.	0.	0.	0.	0.	0.
213.	8.	3.	1.	1.	0.	2.0	2.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
214.	8.	3.	1.	1.	0.	2.1	2.1	.500	.2	.0	1.	0.	0.	0.	0.	0.
215.	8.	3.	1.	1.	0.	5.0	5.0	5.0	1.0	.0	1.	0.	0.	0.	0.	0.
216.	9.	3.	1.	2.	0.	1.0	809.6	6.65	1.0	.0	2.	0.	.5	0.	0.	0.
217.	9.	3.	2.	3.	0.	1.0	15.7	.500	.2	.0	3.	0.	0.	0.	0.	0.
218.	9.	3.	1.	2.	1.	1.0	666.7	.250	.1	.0	2.	1.	0.	0.	0.	0.
219.	9.	3.	1.	1.	0.	1.0	1.0	2.0	1.0	.0	1.	0.	0.	1.	0.	0.
220.	9.	3.	1.	1.	0.	1.0	3.8	24.0	1.0	.0	1.	0.	0.	2.	0.	0.
221.	9.	3.	1.	1.	0.	1.0	25.6	5.0	1.0	.0	1.	0.	0.	2.	0.	0.
222.	9.	3.	18.	18.	1.	5.0	10.0	.750	.3	.0	18.	1.	0.	0.	0.	0.
223.	10.	3.	1.	1.	0.	1.0	1.0	24.0	1.0	.0	1.	0.	0.	2.	0.	0.
224.	11.	3.	1.	1.	0.	0.9	2.1	.679	.3	.0	1.	0.	0.	0.	0.	0.
225.	11.	3.	1.	1.	0.	1.1	2.7	.778	.3	.0	1.	0.	0.	0.	0.	0.

181.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
182.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
183.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
184.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
185.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
186.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
187.	8.	3.	1.	1.	0.	5.5	5.5	.300	.1	.2	1.	0.	0.	0.	0.	0.
188.	8.	3.	1.	1.	0.	1.3	8.0	.500	.2	.2	1.	0.	0.	0.	0.	0.
189.	8.	3.	1.	1.	1.	2.0	2.0	.580	.3	.2	1.	1.	0.	0.	0.	0.
190.	8.	3.	1.	1.	0.	1.0	1.0	1.0	.5	.2	1.	0.	0.	0.	0.	0.
191.	8.	3.	1.	3.	0.	1.0	1.0	.352	.2	.0	3.	0.	0.	0.	0.	0.
192.	8.	3.	1.	1.	0.	2.1	4.6	1.0	.5	.2	1.	0.	0.	0.	0.	0.
193.	8.	1.	1.	1.	1.	1.6	4.9	.167	.1	.0	1.	1.	0.	0.	0.	0.
194.	8.	1.	1.	1.	1.	2.6	7.6	.167	.1	.0	1.	1.	0.	0.	0.	0.
195.	8.	1.	1.	1.	1.	1.5	5.3	.167	.1	.0	1.	1.	0.	0.	0.	0.
196.	8.	1.	1.	1.	1.	1.2	3.3	.167	.1	.0	1.	1.	0.	0.	0.	0.
197.	8.	1.	1.	1.	1.	4.7	10.7	.167	.1	.0	1.	1.	0.	0.	0.	0.
198.	8.	1.	1.	1.	1.	3.3	9.8	.167	.1	.0	1.	1.	0.	0.	0.	0.
199.	8.	3.	1.	1.	0.	1.0	1.0	24.0	1.0	.0	1.	0.	0.	0.	0.	0.
200.	8.	3.	1.	1.	0.	1.0	1.0	24.0	1.0	.0	1.	0.	0.	0.	0.	0.
201.	8.	3.	1.	1.	0.	1.0	1.0	24.0	1.0	.0	1.	0.	0.	0.	0.	0.
202.	8.	3.	1.	1.	0.	1.0	1.0	24.0	1.0	.0	1.	0.	0.	0.	0.	0.
203.	8.	3.	1.	1.	0.	5.7	5.7	24.0	1.0	.0	1.	0.	0.	0.	0.	0.
204.	8.	3.	1.	1.	0.	1.0	1.0	8.0	1.0	.0	1.	0.	0.	0.	0.	0.
205.	8.	3.	1.	1.	0.	1.0	1.0	3.0	1.0	.0	1.	0.	0.	0.	0.	0.
206.	8.	3.	1.	1.	0.	10.0	10.0	1.0	.5	.0	1.	0.	0.	0.	0.	0.
207.	8.	3.	1.	1.	0.	1.0	1.0	3.0	1.0	.0	1.	0.	0.	0.	0.	0.
208.	8.	3.	1.	1.	0.	1.0	1.0	.5	.2	.0	1.	0.	0.	0.	0.	0.
209.	8.	3.	1.	1.	0.	2.1	2.1	.5	.2	.0	1.	0.	0.	0.	0.	0.
210.	8.	3.	1.	1.	0.	1.0	1.0	8.0	1.0	.0	1.	0.	0.	0.	0.	0.
211.	8.	3.	1.	1.	0.	1.0	1.0	3.0	1.0	.0	1.	0.	0.	0.	0.	0.
212.	8.	3.	1.	1.	0.	5.0	5.0	1.0	.5	.0	1.	0.	0.	0.	0.	0.
213.	8.	3.	1.	1.	0.	2.0	2.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
214.	8.	3.	1.	1.	0.	2.1	2.1	.500	.2	.0	1.	0.	0.	0.	0.	0.
215.	8.	3.	1.	1.	0.	5.0	5.0	5.0	1.0	.0	1.	0.	0.	0.	0.	0.
216.	9.	3.	1.	2.	0.	1.0	809.6	6.65	1.0	.0	2.	0.	.5	0.	0.	0.
217.	9.	3.	2.	3.	0.	1.0	15.7	.500	.2	.0	3.	0.	0.	0.	0.	0.
218.	9.	3.	1.	2.	1.	1.0	666.7	.250	.1	.0	2.	1.	0.	0.	0.	0.
219.	9.	3.	1.	1.	0.	1.0	1.0	2.0	1.0	.0	1.	0.	0.	1.	0.	0.
220.	9.	3.	1.	1.	0.	1.0	3.8	24.0	1.0	.0	1.	0.	0.	2.	0.	0.
221.	9.	3.	1.	1.	0.	1.0	25.6	5.0	1.0	.0	1.	0.	0.	2.	0.	0.
222.	9.	3.	18.	18.	1.	5.0	10.0	.750	.3	.0	18.	1.	0.	0.	0.	0.
223.	10.	3.	1.	1.	0.	1.0	1.0	24.0	1.0	.0	1.	0.	0.	2.	0.	0.
224.	11.	3.	1.	1.	0.	0.9	2.1	.679	.3	.0	1.	0.	0.	0.	0.	0.
225.	11.	3.	1.	1.	0.	1.1	2.7	.778	.3	.0	1.	0.	0.	0.	0.	0.

226.11.	3.	1.	1.	0.	6.2	6.6	.763	.3	.0	1.	0.	0.	[illegible]	0.	0.
227.11.	3.	1.	1.	0.	8.8	13.0	.958	.4	.0	1.	0.	0.	0.	0.	0.
228.11.	1.	1.	1.	0.	6.1	6.1	.758	.3	.0	1.	0.	0.	0.	0.	0.
229.11.	1.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
230.11.	1.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
231.11.	1.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
232.11.	1.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
233.11.	3.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
234.11.	3.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
235.11.	1.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
236.11.	1.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
237.11.	3.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
238.11.	3.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
239.11.	1.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
240.11.	2.	1.	1.	0.	1.0	1.0	.372	.2	.0	1.	0.	0.	0.	0.	0.
241.11.	1.	1.	1.	0.	5.1	28.6	1.38	.6	.0	1.	0.	0.	0.	0.	0.
242.11	3.	1.	1.	0.	2.0	2.0	.750	.3	.2	1.	0.	0.	0.	0.	0.
243.11.	3.	1.	1.	0.	1.7	9.4	1.01	.5	.0	1.	0.	0.	0.	0.	0.
244.11.	1.	1.	1.	0.	1.0	1.0	1.02	.5	.0	1.	0.	0.	0.	0.	0.
245.11.	1.	1.	1.	0.	5.0	28.3	1.20	.6	.0	1.	0.	0.	0.	0.	0.
246.11.	3.	1.	1.	0.	1.7	9.4	1.02	.5	.0	1.	0.	0.	0.	0.	0.
247.11.	1.	1.	1.	0.	5.7	11.5	1.21	.6	.0	1.	0.	0.	0.	0.	0.
248.11.	1.	1.	1.	0.	25.7	30.8	1.10	.5	.0	1.	0.	0.	0.	0.	0.
249.11.	1.	1.	1.	0.	25.7	30.8	1.60	.5	.0	1.	0.	0.	0.	0.	0.
250.11.	1.	1.	1.	0.	13.6	13.6	1.10	.5	.0	1.	0.	0.	0.	0.	0.
251.11.	3.	1.	1.	0.	8.0	9.6	.660	.3	.0	1.	0.	0.	0.	0.	0.
252.11.	3.	1.	1.	0.	1.0	2.4	1.00	.5	.2	1.	0.	0.	0.	0.	0.
253.11.	3.	1.	1.	0.	1.2	1.5	12.0	1.0	.0	1.	0.	0.	0.	0.	0.
254.11.	3.	1.	1.	0.	1.2	1.5	12.0	1.0	.0	1.	0.	0.	0.	0.	0.
255.11.	3.	1.	1.	0.	6.0	7.2	1.72	.8	.0	1.	0.	0.	0.	0.	0.
256.11.	3.	1.	1.	0.	6.0	22.8	1.03	.5	.0	1.	0.	0.	0.	0.	0.
257.11.	3.	1.	1.	0.	3.0	11.4	1.60	.8	.0	1.	0.	0.	0.	0.	0.
258.11.	3.	1.	1.	0.	2.2	4.5	.955	.4	.0	1.	0.	0.	0.	0.	0.
259.11.	3.	1.	1.	0.	1.0	1.0	.300	.1	.2	1.	0.	0.	0.	0.	0.
260.11.	3.	1.	1.	0.	1.0	1.0	.700	.3	.0	1.	0.	0.	0.	0.	0.
261.11.	3.	1.	1.	0.	1.0	1.0	3.00	1.0	.0	1.	0.	0.	0.	0.	0.
262.11.	3.	1.	1.	0.	1.0	1.0	2.00	1.0	.0	1.	0.	0.	0.	0.	0.
263.11.	3.	1.	1.	0.	1.0	1.0	1.10	.5	.0	1.	0.	0.	0.	0.	0.
264.11.	3.	1.	1.	0.	4.1	4.9	1.10	.5	.0	1.	0.	0.	0.	0.	0.
265.11.	3.	1.	1.	0.	4.5	4.5	1.96	.9	.0	1.	0.	0.	0.	0.	0.
266.11.	3.	1.	1.	0.	2.2	2.2	1.77	.8	.0	1.	0.	0.	0.	0.	0.
267.11.	3.	1.	1.	0.	4.8	33.9	1.85	.9	.0	1.	0.	0.	0.	0.	0.
268.11.	3.	1.	1.	0.	1.4	2.8	1.50	.7	.0	1.	0.	0.	0.	0.	0.
269.11.	3.	1.	1.	0.	9.7	19.4	1.22	.6	.0	1.	0.	0.	0.	0.	0.
270.11.	3.	1.	1.	0.	1.0	1.0	1.23	.6	.0	1.	0.	0.	0.	0.	0.

271.11.	3.	1.	1.	0.	6.7	6.7	2.28	1.0	.0	1.	0.	0.	0.	0.	0.
272.11.	3.	1.	1.	0.	15.7	15.7	1.09	.5	.0	1.	0.	0.	0.	0.	0.
273.11.	3.	1.	1.	0.	6.8	6.8	1.14	.5	.0	1.	0.	0.	0.	0.	0.
274.11.	3.	1.	1.	0.	2.3	2.3	2.46	1.0	.0	1.	0.	0.	0.	0.	0.
275.11.	3.	1.	1.	0.	5.0	5.0	2.46	1.0	.0	1.	0.	0.	0.	0.	0.
276.11.	3.	1.	1.	0.	2.5	19.1	2.24	1.0	.0	1.	0.	0.	0.	0.	0.
277.11.	3.	1.	1.	0.	1.2	9.5	1.24	.6	.0	1.	0.	0.	0.	0.	0.
278.11.	3.	1.	1.	0.	1.0	1.0	6.00	1.0	.0	1.	0.	0.	0.	0.	0.
279.11.	3.	1.	1.	0.	1.0	1.0	2.00	1.0	.0	1.	0.	0.	0.	0.	0.
280.11.	3.	1.	1.	0.	3.2	3.8	2.46	1.0	.0	1.	0.	0.	0.	0.	0.
281.11.	3.	1.	1.	0.	1.0	1.0	3.00	1.0	.0	1.	0.	0.	0.	0.	0.
282.11.	3.	1.	1.	0.	6.4	7.7	2.00	1.0	.0	1.	0.	0.	0.	0.	0.
283.11.	3.	1.	1.	0.	4.2	6.8	0.7	.3	.0	1.	0.	0.	0.	0.	0.
284.11.	3.	1.	1.	0.	1.0	1.0	.398	.2	.0	1.	0.	0.	0.	0.	0.
285.11.	0.	1.	1.	0.	1.0	1.3	.643	.3	.0	1.	0.	0.	0.	0.	0.
286.11.	0.	1.	1.	0.	1.1	2.7	.679	.3	.0	1.	0.	0.	0.	0.	0.
287.11.	0.	1.	1.	0.	1.0	1.0	.300	.1	.0	1.	0.	0.	0.	0.	0.
288.11.	0.	1.	1.	0.	19.4	40.2	.955	.4	.0	1.	0.	0.	0.	0.	0.
289.11.	0.	1.	1.	0.	1.0	1.0	.322	.1	.0	1.	0.	0.	0.	0.	0.
290.11.	0.	1.	1.	0.	15.1	85.5	1.02	.5	.0	1.	0.	0.	0.	0.	0.
291.11.	0.	1.	1.	0.	2.2	4.5	.955	.4	.0	1.	0.	0.	0.	0.	0.
292.11.	0.	1.	1.	0.	1.0	1.0	.300	.1	.0	1.	0.	0.	0.	0.	0.
293.11.	0.	1.	1.	0.	1.0	1.0	.372	.1	.0	1.	0.	0.	0.	0.	0.
294.11.	0.	1.	1.	0.	2.4	16.9	1.85	.9	.0	1.	0.	0.	0.	0.	0.
295.11.	0.	1.	1.	0.	2.4	16.9	1.85	.9	.0	1.	0.	0.	0.	0.	0.
296.11.	0.	1.	1.	0.	2.4	16.9	1.85	.9	.0	1.	0.	0.	0.	0.	0.
297.11.	0.	1.	1.	0.	7.5	9.0	1.08	.5	.0	1.	0.	0.	0.	0.	0.
298.11.	0.	1.	1.	0.	3.0	3.6	1.72	.8	.0	1.	0.	0.	0.	0.	0.
299.11.	1.	1.	1.	0.	6.6	9.2	.083	.1	.0	1.	0.	0.	0.	0.	0.
300.11.	1.	1.	1.	0.	3.1	8.2	.167	.1	.0	1.	0.	0.	0.	0.	0.
301.11.	1.	1.	1.	0.	2.3	6.8	.167	.1	.0	1.	0.	0.	0.	0.	0.
302.11.	1.	1.	1.	0.	1.0	2.2	.167	.1	.0	1.	0.	0.	0.	0.	0.
303.11.	1.	1.	1.	0.	6.7	37.8	1.02	.5	.0	1.	0.	0.	0.	0.	0.
304.11.	1.	1.	1.	0.	3.3	9.5	.167	.1	.0	1.	0.	0.	0.	0.	0.
305.12.	3.	1.	3.	0.	2.3	9.2	1.30	.6	.2	3.	0.	0.	1.	0.	0.
306.12.	3.	1.	1.	0.	76.1	76.1	2.36	1.0	.2	1.	0.	0.	0.	0.	0.
307.12.	3.	1.	1.	0.	1.0	7.4	1.00	.5	.2	1.	0.	0.	1.	0.	0.
308.12.	3.	1.	1.	0.	3.0	64.2	.500	.2	.2	1.	0.	0.	0.	1.	1.
309.12.	3.	1.	1.	0.	3.2	3.2	.500	.2	.2	1.	0.	0.	0.	0.	0.
310.12.	3.	1.	1.	0.	13.3	13.3	.500	.2	.2	1.	0.	0.	0.	0.	0.
311.12.	3.	1.	2.	0.	6.0	40.4	.667	.3	.2	2.	0.	0.	0.	0.	0.
312.12.	3.	8.	8.	0.	3.0	8.4	.500	.2	.2	8.	0.	0.	0.	0.	0.
313.12.	3.	1.	1.	0.	3.0	8.4	.500	.2	.2	1.	0.	0.	0.	0.	0.
314.12.	3.	1.	1.	1.	526.2	695.6	7.65	1.0	.2	1.	1.	.08	2.	0.	0.
315.12.	1.	1.	1.	0.	4.1	11.3	1.00	.5	.2	1.	0.	0.	0.	0.	0.

316.12.	1.	1.	1.	1.	7.0	16.5	.167	.1	.0	1.	1.	0.	0.	0.	0.
317.12.	1.	1.	1.	1.	3.3	5.0	.167	.1	.0	1.	1.	0.	0.	0.	0.
318.12.	1.	1.	1.	1.	3.0	9.2	.167	.1	.0	1.	1.	0.	0.	0.	0.
319.12.	1.	1.	1.	1.	12.4	27.3	.167	.1	.1	1.	1.	0.	0.	0.	0.
320.12.	1.	1.	1.	1.	10.0	22.3	.167	.1	.0	1.	1.	0.	0.	0.	0.
321.12.	3.	1.	1.	1.	18.3	197.1	.167	.1	.0	1.	1.	0.	0.	0.	0.
322.12.	1.	1.	1.	1.	3.4	9.6	.167	.1	.0	1.	1.	0.	0.	0.	0.
323.12.	1.	1.	1.	1.	1.2	3.8	.167	.1	.0	1.	1.	0.	0.	0.	0.
324.12.	1.	1.	1.	1.	4.5	12.3	.167	.1	.0	1.	1.	0.	0.	0.	0.
325.12.	1.	1.	1.	0.	1.7	5.1	.167	.1	.0	1.	0.	0.	0.	0.	0.
326.12.	1.	1.	1.	1.	3.5	10.4	.167	.1	.0	1.	1.	0.	0.	0.	0.
327.12.	0.	1.	1.	0.	10.3	18.0	2.00	1.0	.0	1.	0.	0.	0.	0.	0.
328.12.	0.	1.	1.	0.	1.0	1.2	12.0	1.0	.0	1.	0.	0.	0.	0.	0.
329.12.	0.	1.	1.	0.	1.0	4.2	12.0	1.0	.0	1.	0.	0.	0.	0.	0.
330.12.	1.	1.	1.	0.	2.0	5.5	.167	.1	.0	1.	0.	0.	0.	0.	0.
331.12.	1.	1.	1.	0.	2.7	7.6	.167	.1	.0	1.	0.	0.	0.	0.	0.
332.14.	3.	1.	2.	0.	1.0	809.6	6.65	1.0	.0	2.	0.	5.	0.	0.	0.
333.14.	3.	2.	3.	0.	1.0	15.7	.500	.2	.0	3.	0.	0.	0.	0.	0.
334.14.	3.	1.	2.	1.	1.0	666.7	.250	.1	.0	2.	1.	0.	0.	0.	0.
335.14.	3.	1.	1.	0.	1.0	1.0	2.00	1.0	.0	1.	0.	0.	1.	0.	0.
336.14.	3.	1.	1.	0.	1.0	3.8	24.0	1.0	.0	1.	0.	0.	2.	0.	0.
337.14.	3.	1.	1.	0.	1.0	25.6	5.00	1.0	.0	1.	0.	0.	2.	0.	0.
338.14.	3.	18.	18.	1.	1.0	10.0	.750	.3	.0	18.	1.	0.	0.	0.	0.
339.15.	3.	1.	1.	0.	1.0	1.0	24.0	1.0	.0	1.	0.	0.	2.	0.	0.
340.17.	3.	1.	3.	0.	2.3	9.2	1.30	.6	.2	3.	0.	0.	1.	1.	1.
341.17.	3.	1.	1.	0.	76.1	76.1	2.36	1.0	.2	1.	0.	0.	0.	0.	0.
342.17.	3.	1.	1.	0.	1.0	7.4	1.00	.5	.2	1.	0.	0.	1.	0.	0.
343.17.	3.	1.	1.	0.	3.0	64.2	.500	.2	.2	1.	0.	0.	0.	0.	0.
344.17.	3.	1.	1.	0.	3.2	3.2	.500	.2	.2	1.	0.	0.	0.	0.	0.
345.17.	3.	1.	1.	0.	13.3	13.3	.500	.2	.2	1.	0.	0.	0.	0.	0.
346.17.	3.	1.	2.	0.	6.0	40.4	.667	.3	.2	2.	0.	0.	0.	0.	0.
347.17.	3.	8.	8.	0.	3.0	8.4	.500	.2	.2	8.	0.	0.	0.	1.	1.
348.17.	3.	1.	1.	0.	3.0	8.4	.500	.2	.2	1.	0.	0.	0.	1.	1.
349.17.	3.	1.	1.	1.	526.2	695.6	7.66	1.0	.2	1.	1.	.08	2.	0.	0.
350.17.	0.	1.	1.	0.	10.3	18.0	2.00	1.0	.0	1.	0.	0.	0.	0.	0.
351.17.	0.	1.	1.	0.	1.0	1.2	12.0	1.0	.0	1.	0.	0.	0.	0.	0.
352.17.	0.	1.	1.	0.	1.0	4.2	12.0	1.0	.0	1.	0.	0.	0.	0.	0.
353.18.	1.	1.	1.	0.	35.7	10.7	1.72	.8	.0	1.	0.	0.	1.	0.	0.
354.18.	3.	1.	1.	0.	14.6	36.6	.100	.1	.0	1.	0.	0.	0.	0.	0.
355.19.	3.	1.	1.	1.	6.0	1.5	.218	.1	.0	1.	1.	0.	0.	0.	0.
356.19.	3.	1.	1.	1.	4.0	1.0	.218	.1	.0	1.	1.	0.	0.	0.	0.
357.19.	3.	1.	1.	1.	3.0	0.7	.197	.1	.0	1.	1.	0.	0.	0.	0.
358.19.	3.	1.	1.	0.	15.4	3.9	.142	.1	.0	1.	0.	0.	0.	0.	0.
359.19.	3.	1.	1.	0.	2.6	1.6	.385	.1	.0	1.	0.	0.	0.	0.	0.
360.19.	1.	1.	1.	0.	36.2	22.1	.750	.3	.0	1.	0.	0.	0.	0.	0.

361.19.	3.	1.	1.	0.	1.0	2.2	.750	.3	.0	1.	0.	0.	0.	0.	0.
362.19.	3.	1.	1.	0.	1.0	1.0	.750	.3	.0	1.	0.	0.	0.	0.	0.
363.19.	3.	2.	2.	1.	3.9	1.0	.008	.1	.0	2.	1.	0.	0.	0.	0.
364.19.	3.	2.	2.	1.	1.1	1.0	.008	.1	.0	2.	1.	0.	0.	0.	0.
365.19.	3.	2.	2.	1.	3.4	1.0	.008	.1	.0	2.	1.	0.	0.	0.	0.
366.19.	3.	2.	2.	1.	125.0	31.3	.008	.1	.0	2.	1.	0.	0.	1.	1.
367.19.	3.	2.	2.	0.	7.0	1.7	.008	.1	.0	2.	0.	0.	0.	0.	0.
368.19.	3.	2.	2.	1.	3.9	1.0	.008	.1	.0	2.	1.	0.	0.	0.	0.
369.19.	3.	2.	2.	1.	1.8	1.0	.008	.1	.0	2.	1.	0.	0.	0.	0.
370.19.	3.	2.	2.	1.	5.5	1.4	.008	.1	.0	2.	1.	0.	0.	0.	0.
371.19.	3.	2.	2.	1.	1.1	1.0	.008	.1	.0	2.	1.	0.	0.	0.	0.
372.19.	3.	2.	2.	1.	13.8	3.5	.008	.1	.0	2.	1.	0.	0.	0.	0.
373.19.	3.	2.	2.	1.	16.5	4.1	.008	.1	.0	2.	1.	0.	0.	1.	1.
374.19.	3.	2.	2.	1.	5.9	1.5	.008	.1	.0	2.	1.	0.	0.	0.	0.
375.19.	3.	2.	2.	1.	7.6	1.9	.008	.1	.0	2.	1.	0.	0.	0.	0.
376.19.	3.	2.	2.	1.	1.4	1.0	.008	.1	.0	2.	1.	0.	0.	0.	0.
377.19.	3.	2.	2.	0.	14.6	3.7	.008	.1	.0	2.	0.	0.	0.	1.	1.
378.19.	3.	2.	2.	1.	2.0	1.0	.008	.1	.0	2.	1.	0.	0.	0.	0.
379.19.	3.	2.	2.	1.	13.2	3.3	.008	.1	.0	2.	1.	0.	0.	0.	0.
380.19.	3.	2.	2.	1.	1.0	1.0	.008	.1	.0	2.	1.	0.	0.	0.	0.
381.19.	3.	2.	2.	1.	3.3	1.0	.008	.1	.0	2.	1.	0.	0.	0.	0.
382.19.	3.	2.	2.	1.	2.8	1.0	.008	.1	.0	2.	1.	0.	0.	0.	0.
383.19.	3.	2.	2.	0.	23.3	5.8	.008	.1	.0	2.	0.	0.	0.	0.	0.
384.19.	3.	2.	2.	0.	48.7	12.1	.008	.1	.0	2.	0.	0.	0.	1.	1.
385.19.	3.	2.	2.	0.	1.1	1.0	.008	.1	.0	2.	0.	0.	0.	0.	0.
386.19.	3.	1.	1.	0.	2.0	1.0	.362	.1	.0	1.	0.	0.	0.	0.	0.
387.19.	3.	2.	2.	1.	2.0	1.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
388.19.	3.	2.	2.	1.	13.2	3.3	.253	.1	.0	2.	1.	0.	0.	0.	0.
389.19.	3.	2.	2.	0.	48.7	12.2	.472	.2	.0	2.	0.	0.	0.	1.	1.
390.19.	3.	2.	2.	1.	4.4	1.1	.749	.3	.0	2.	1.	0.	0.	0.	0.
391.19.	3.	2.	2.	1.	1.0	1.0	.574	.2	.0	2.	1.	0.	0.	0.	0.
392.19.	3.	2.	2.	1.	5.8	1.5	.517	.2	.0	2.	1.	0.	0.	0.	0.
393.19.	3.	2.	2.	1.	5.0	1.3	.533	.2	.0	2.	1.	0.	0.	0.	0.
394.19.	3.	2.	2.	0.	1.0	1.0	.600	.3	.0	2.	0.	0.	0.	0.	0.
395.19.	3.	1.	1.	0.	15.4	5.8	.326	.1	.0	1.	0.	0.	0.	1.	1.
396.20.	3.	1.	1.	0.	7.0	24.4	.750	.3	.0	1.	0.	0.	0.	0.	0.
397.20.	3.	1.	1.	0.	7.0	24.4	.750	.3	.0	1.	0.	0.	0.	0.	0.
398.20.	3.	1.	2.	0.	250.0	625.0	.100	.1	.0	2.	0.	0.	0.	1.	1.
399.20.	3.	1.	1.	0.	11.0	27.5	.100	.1	.0	1.	0.	0.	0.	0.	0.
400.20.	3.	2.	2.	0.	155.6	38.8	.200	.1	.0	2.	0.	0.	0.	1.	1.
401.20.	3.	2.	2.	0.	25.0	6.3	.330	.2	.0	2.	0.	0.	0.	1.	1.
402.20.	1.	1.	1.	0.	97.8	24.4	.190	.1	.0	1.	0.	0.	0.	1.	1.
403.20.	3.	1.	2.	1.	13.2	3.3	.441	.2	.0	2.	1.	0.	0.	0.	0.
404.20.	3.	6.	6.	0.	2.6	1.0	.284	.1	.0	6.	0.	0.	0.	0.	0.
405.20.	3.	1.	1.	1.	4.1	1.0	.184	.1	.0	1.	1.	0.	0.	0.	0.

406.20.	3.	20.	20.	1.	1.6	1.0	.566	.2	.0	20.	1.	0.	0.	0.	0.
407.20.	3.	1.	1.	0.	4.2	1.1	.566	.2	.0	1.	0.	0.	0.	0.	0.
408.20.	3.	5.	5.	0.	25.0	6.3	.100	.1	.0	5.	0.	0.	0.	1.	1.
409.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
410.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
411.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
412.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
413.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
414.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
415.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
416.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
417.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
418.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
419.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
420.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
421.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
422.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
423.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
424.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
425.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
426.21.	1.	1.	1.	0.	4.0	10.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
427.21.	1.	1.	1.	0.	7.0	17.5	.250	.1	.0	1.	0.	0.	0.	0.	0.
428.21.	1.	1.	1.	0.	10.0	25.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
429.21.	1.	1.	1.	0.	10.0	25.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
430.22.	3.	4.	4.	1.	7.0	17.4	.250	.1	.0	4.	1.	0.	0.	0.	0.
431.22.	3.	4.	4.	1.	6.9	17.1	.250	.1	.0	4.	1.	0.	0.	0.	0.
432.22.	3.	1.	1.	1.	5.6	13.9	.250	.1	.0	1.	1.	0.	0.	0.	0.
433.22.	3.	1.	1.	1.	12.4	31.0	.250	.1	.0	1.	1.	0.	0.	0.	0.
434.22.	3.	2.	2.	1.	34.9	87.1	.250	.1	.0	2.	1.	0.	0.	0.	0.
435.22.	3.	2.	2.	1.	34.9	87.1	.250	.1	.0	2.	1.	0.	0.	0.	0.
436.22.	3.	1.	1.	1.	2.9	7.3	.250	.1	.0	1.	1.	0.	0.	0.	0.
437.22.	3.	1.	1.	1.	2.8	7.1	.250	.1	.0	1.	1.	0.	0.	0.	0.
438.22.	3.	2.	2.	1.	7.1	17.8	.250	.1	.0	2.	1.	0.	0.	0.	0.
439.22.	3.	1.	1.	1.	3.6	8.9	.250	.1	.0	1.	1.	0.	0.	0.	0.
440.22.	3.	1.	1.	1.	3.3	8.2	.250	.1	.0	1.	1.	0.	0.	0.	0.
441.22.	3.	1.	1.	1.	5.1	12.8	.250	.1	.0	1.	1.	0.	0.	0.	0.
442.22.	3.	1.	1.	1.	3.4	8.4	.250	.1	.0	1.	1.	0.	0.	0.	0.
443.22.	3.	1.	1.	1.	6.0	15.0	.250	.1	.0	1.	1.	0.	0.	0.	0.
444.22.	3.	1.	1.	1.	3.2	8.0	.250	.1	.0	1.	1.	0.	0.	0.	0.
445.22.	3.	1.	1.	1.	4.8	12.0	.250	.1	.0	1.	1.	0.	0.	0.	0.
446.22.	3.	1.	1.	1.	3.1	7.7	.250	.1	.0	1.	1.	0.	0.	0.	0.
447.22.	3.	1.	1.	1.	2.9	7.3	.250	.1	.0	1.	1.	0.	0.	0.	0.
448.22.	3.	1.	1.	1.	3.5	8.6	.250	.1	.0	1.	1.	0.	0.	0.	0.
449.22.	3.	1.	1.	1.	4.3	10.7	.250	.1	.0	1.	1.	0.	0.	0.	0.
450.22.	3.	1.	1.	1.	6.2	15.6	.250	.1	.0	1.	1.	0.	0.	0.	0.

451.22.	3.	1.	1.	1.	6.6	16.5	.250	.1	.0	1.	1.	0.	0.	0.	0.
452.22.	3.	1.	1.	1.	1.0	0.6	.250	.1	.0	1.	1.	0.	0.	0.	0.
453.22.	3.	1.	1.	1.	40.5	101.2	.250	.1	.0	1.	1.	0.	0.	0.	0.
454.22.	3.	1.	3.	1.	4.6	11.5	.250	.1	.0	3.	1.	0.	0.	0.	0.
455.22.	3.	1.	1.	1.	1.0	1.0	.250	.1	.0	1.	1.	0.	0.	0.	0.
456.22.	3.	1.	1.	1.	2.9	7.2	.250	.1	.0	1.	1.	0.	0.	0.	0.
457.22.	3.	1.	1.	1.	1.9	4.8	.250	.1	.0	1.	1.	0.	0.	0.	0.
458.22.	3.	1.	1.	1.	2.1	5.2	.250	.1	.0	1.	1.	0.	0.	0.	0.
459.22.	3.	1.	1.	1.	1.1	2.8	.250	.1	.0	1.	1.	0.	0.	0.	0.
460.22.	0.	1.	1.	0.	1.2	3.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
461.22.	3.	1.	1.	1.	7.4	18.6	.250	.1	.0	1.	1.	0.	0.	0.	0.
462.22.	3.	1.	1.	1.	7.7	19.4	.250	.1	.0	1.	1.	0.	0.	0.	0.
463.22.	3.	1.	1.	1.	7.3	18.2	.250	.1	.0	1.	1.	0.	0.	0.	0.
464.22.	3.	1.	1.	1.	7.2	18.1	.250	.1	.0	1.	1.	0.	0.	0.	0.
465.22.	3.	1.	1.	1.	4.8	12.0	.250	.1	.0	1.	1.	0.	0.	0.	0.
466.22.	3.	1.	1.	1.	5.1	12.8	.250	.1	.0	1.	1.	0.	0.	0.	0.
467.22.	3.	1.	1.	1.	3.7	9.3	.250	.1	.0	1.	1.	0.	0.	0.	0.
468.22.	3.	1.	1.	1.	4.9	12.3	.250	.1	.0	1.	1.	0.	0.	0.	0.
469.22.	3.	1.	1.	1.	5.3	13.3	.250	.1	.0	1.	1.	0.	0.	0.	0.
470.23.	3.	1.	1.	1.	9.4	23.6	.250	.1	.0	1.	1.	0.	0.	0.	0.
471.23.	3.	4.	4.	1.	4.6	11.5	.250	.1	.0	4.	1.	0.	0.	0.	0.
472.23.	3.	4.	4.	1.	12.2	30.5	.250	.1	.0	4.	1.	0.	0.	0.	0.
473.23.	3.	4.	4.	1.	3.8	9.4	.250	.1	.0	4.	1.	0.	0.	0.	0.
474.23.	3.	4.	4.	1.	6.1	15.3	.250	.1	.0	4.	1.	0.	0.	0.	0.
475.23.	3.	8.	8.	1.	17.9	44.6	.250	.1	.0	8.	1.	0.	0.	1.	1.
476.23.	3.	4.	4.	1.	6.0	14.9	.250	.1	.0	4.	1.	0.	0.	0.	0.
477.23.	3.	4.	4.	1.	7.1	17.8	.250	.1	.0	4.	1.	0.	0.	0.	0.
478.24.	3.	11.	11.	1.	15.3	38.2	.250	.1	.0	11.	1.	0.	0.	1.	1.
479.24.	3.	11.	11.	1.	14.8	37.1	.250	.1	.0	11.	1.	0.	0.	1.	1.
480.24.	3.	10.	10.	1.	8.2	20.6	.250	.1	.0	10.	1.	0.	0.	1.	1.
481.24	3.	8.	8.	1.	27.8	69.5	.250	.1	.0	8.	1.	0.	0.	1.	1.
482.24.	3.	8.	8.	1.	11.7	29.2	.250	.1	.0	8.	1.	0.	0.	1.	1.
483.24.	3.	18.	18.	1.	7.8	19.4	.250	.1	.0	18.	1.	0.	0.	1.	1.
484.24.	3.	3.	3.	1.	6.2	15.4	.250	.1	.0	3.	1.	0.	0.	0.	0.
485.24.	3.	2.	2.	1.	9.8	24.5	.250	.1	.0	2.	1.	0.	0.	0.	0.
486.24.	3.	2.	2.	1.	7.4	18.6	.250	.1	.0	2.	1.	0.	0.	0.	0.
487.24.	3.	10.	10.	1.	5.8	14.6	.250	.1	.0	10.	1.	0.	0.	0.	0.
488.24.	3.	11.	11.	1.	15.5	38.8	.250	.1	.0	11.	1.	0.	0.	0.	0.
489.24.	3.	9.	9.	1.	14.8	37.0	.250	.1	.0	9.	1.	0.	0.	0.	0.
490.24.	3.	3.	3.	1.	10.2	25.4	.250	.1	.0	3.	1.	0.	0.	0.	0.
491.24.	3.	3.	3.	1.	5.8	14.5	.250	.1	.0	3.	1.	0.	0.	0.	0.
492.24.	3.	2.	2.	1.	6.9	17.3	.250	.1	.0	2.	1.	0.	0.	0.	0.
493.24.	3.	8.	8.	1.	27.8	69.5	.250	.1	.0	8.	1.	0.	0.	0.	0.
494.24.	3.	6.	6.	1.	5.7	14.2	.250	.1	.0	6.	1.	0.	0.	0.	0.
495.24.	3.	11.	11.	0.	7.3	18.1	.250	.1	.0	11.	0.	0.	0.	1.	1.

496.	24.	3.	4.	4.	1.	10.3	25.8	.250	.1	.0	4.	1.	0.	0.	0.	0.
497.	24.	3.	4.	4.	1.	10.3	25.8	.250	.1	.0	4.	1.	0.	0.	0.	0.
498.	25.	3.	1.	1.	0.	22.0	54.9	.250	.1	.0	1.	0.	0.	0.	0.	0.
499.	25.	3.	1.	1.	0.	2.4	6.0	.250	.1	.0	1.	0.	0.	0.	0.	0.
500.	25.	3.	1.	1.	0.	4.5	11.2	.250	.1	.0	1.	0.	0.	0.	0.	0.
501.	25.	3.	1.	1.	0.	4.5	11.2	.250	.1	.0	1.	0.	0.	0.	0.	0.
502.	25.	3.	2.	2.	0.	4.3	10.7	.250	.1	.0	2.	0.	0.	0.	0.	0.
503.	25.	3.	1.	1.	0.	15.7	39.3	.250	.1	.0	1.	0.	0.	0.	0.	0.
504.	25.	3.	1.	1.	0.	13.2	33.1	.250	.1	.0	1.	0.	0.	0.	0.	0.
505.	25.	3.	4.	4.	0.	4.2	10.4	.250	.1	.0	4.	0.	0.	0.	0.	0.
506.	26.	3.	2.	2.	0.	2.0	5.0	.600	.3	.0	2.	0.	0.	0.	0.	0.
507.	26.	3.	5.	5.	0.	2.0	5.0	.600	.3	.0	5.	0.	0.	0.	0.	0.
508.	26.	3.	2.	2.	1.	2.0	5.0	.600	.3	.0	2.	1.	0.	0.	0.	0.
509.	26.	3.	2.	2.	0.	2.0	5.0	.600	.3	.0	2.	0.	0.	0.	0.	0.
510.	26.	3.	2.	2.	0.	2.0	5.0	.600	.3	.0	2.	0.	0.	0.	0.	0.
511.	26.	3.	2.	2.	0.	2.0	5.0	.600	.3	.0	2.	0.	0.	0.	0.	0.
512.	26.	3.	1.	1.	0.	1.1	2.8	.796	.4	.0	1.	0.	0.	0.	0.	0.
513.	26.	3.	2.	2.	1.	2.0	5.0	.450	.2	.0	2.	1.	0.	0.	0.	0.
514.	26.	3.	4.	4.	1.	1.7	4.3	.600	.3	.0	4.	1.	0.	0.	0.	0.
515.	26.	3.	1.	1.	0.	4.8	12.1	.861	.4	.0	1.	0.	0.	0.	0.	0.
516.	26.	1.	1.	1.	0.	3.6	9.0	.500	.2	.0	1.	0.	0.	0.	0.	0.
517.	26.	1.	1.	1.	0.	3.6	9.0	.500	.2	.0	1.	0.	0.	0.	0.	0.
518.	26.	1.	1.	1.	0.	3.6	9.0	.500	.2	.0	1.	0.	0.	0.	0.	0.
519.	26.	1.	1.	1.	0.	1.0	1.0	.500	.2	.0	1.	0.	0.	0.	0.	0.
520.	27.	3.	13.	13.	0.	2.0	2.0	.701	.3	.0	13.	0.	0.	0.	1.	1.
521.	7.	3.	16.	18.	0.	13.8	3.8	2.00	1.0	.0	18.	0.	0.	2.	0.	0.
522.	17.	1.	1.	1.	0.	4.1	11.3	1.00	.5	.2	1.	0.	0.	0.	0.	0.
523.	17.	1.	1.	1.	1.	7.0	16.5	.167	.1	.0	1.	1.	0.	0.	0.	0.
524.	17.	1.	1.	1.	1.	3.3	5.0	.167	.1	.0	1.	1.	0.	0.	0.	0.
525.	17.	1.	1.	1.	1.	3.0	9.2	.167	.1	.0	1.	1.	0.	0.	0.	0.
526.	17.	1.	1.	1.	1.	12.4	27.3	.167	.1	.0	1.	1.	0.	0.	0.	0.
527.	17.	1.	1.	1.	1.	10.0	22.3	.167	.1	.0	1.	1.	0.	0.	0.	0.
528.	17.	3.	1.	1.	1.	18.3	197.1	.167	.1	.0	1.	1.	0.	0.	0.	0.
529.	17.	1.	1.	1.	1.	3.4	9.6	.167	.1	.0	1.	1.	0.	0.	0.	0.
530.	17.	1.	1.	1.	1.	1.2	3.8	.167	.1	.0	1.	1.	0.	0.	0.	0.
531.	17.	1.	1.	1.	1.	4.5	12.3	.167	.1	.0	1.	1.	0.	0.	0.	0.
532.	17.	1.	1.	1.	0.	1.7	5.1	.167	.1	.0	1.	0.	0.	0.	0.	0.
533.	17.	1.	1.	1.	1.	3.5	10.4	.167	.1	.0	1.	1.	0.	0.	0.	0.
534.	17.	1.	1.	1.	0.	2.0	5.5	.167	.1	.0	1.	0.	0.	0.	0.	0.
535.	17.	1.	1.	1.	0.	2.7	7.6	.167	.1	.0	1.	0.	0.	0.	0.	0.

Appendix E. *Using the Model*

E.1 Input Files

Three input files are needed to run this model. Each of the files must be located in the same directory as the SLAM and Fortran files used to run the model. The first data file used for input must be named CONTROL.DAT and take the following form:

```
    A
535
25. 250.
1. 1.
4. 1.
5 6 8 4
4
0 0
1.
```

The first row designates the MOB as A or B and tells the model which LRU database to use. The second row is the integer number of LRUs in the LRU database. As rows in the LRU database are added or deleted, this number must be changed. The third row contains the minimum and maximum distances to be traveled for deployment. These number are distances used in a uniform distribution to choose a random relocation duration. The fourth row contains the scaling factors for the failure and repair rates, respectively. The fifth row contains the mean and standard deviation used to determine when software aborts occur. The fifth row gives the number of maintenance personnel available at each shop in the following order: VEH, CE, PGU, and ECU. Row six is the number of field maintenance personnel to be deployed during this run. Row seven contains the print options for file 21 and file 22, respectively. Zero means do not print while 1 will cause a printout. The last row is the printout option for subroutine OTPUT.

In addition to CONTROL.DAT, the two database files must also be in place for the model to run. GMS_A.DAT is used for the base A database and GMS_B.DAT for base B, with the only difference being columns used for FSV spares. The file is formatted and must be of the form of the GMS_B.DAT file shown in Appendix D.

E.2 Running the Model

The model consists of a SLAM program and supporting Fortran subroutines. The SLAM program is contained in the file GMS.DAT. The entire group of supporting Fortran subroutines are contained in the file GMS.FOR. The model was designed using SLAM II and Fortran 77 and ran on a VAX 6080, although there should be no VAX specific commands in any of the files. Once the necessary files are in place, the GMS model can be run through SLAM by giving the names of the SLAM and Fortran files. The data files will be accessed from within the code.

E.3 Output Files

Depending on the output options selected, up to three output files can be obtained. The normal SLAM output file is named GMS.OUT and contains the standard SLAM output such as resource, file, and server utilizations. The output obtained from subroutine OTPUT is also appended to GMS.OUT. The other two files are the critical failures and all failures files. The file containing only critically failed components is named FILE_21.DAT while the file containing all failed components is called FILE_22.DAT.

E.4 Performing Sensitivity Analysis

This model was designed with a great deal of flexibility for performing sensitivity analysis. In almost all cases, the necessary parameters can be altered without necessitating a recompilation of the Fortran code. The majority of the changes can be easily made to the control file described above and the database. However, there are also values in the SLAM code which can be altered for analysis. The delays invoked during certain activities such as equipment set-up or satellite acquisition can be changed. Multiple runs can also be accomplished by changing the GEN statement.

Appendix F. *Model Output*

F.1 Component Failures by Type

Component Number	Base A Number Failed	Base A Percent of Total	Number in FSV	Base B Number Failed	Base B Percent of Total	Combined Total Failed	Combined Percent of Total
2	1	0.15	0	0	0	1	0.08
6	2	0.29	0	1	0.18	2	0.16
13	1	0.15	0	0	0	1	0.08
15	1	0.15	0	0	0	1	0.08
18	3	0.44	0	6	1.07	9	0.72
19	1	0.15	0	0	0	1	0.08
20	15	2.18	0	14	2.49	29	2.32
21	2	0.29	1	0	0	2	0.16
22	1	0.15	0	0	0	1	0.08
23	19	2.76	0	12	2.14	31	2.48
24	14	2.03	0	10	1.78	24	1.92
25	37	5.38	0	25	4.45	62	4.96
26	4	0.58	0	0	0	4	0.32
27	5	0.73	0	5	0.89	10	0.80
29	2	0.29	0	0	0	2	0.16
30	17	2.47	0	12	2.14	29	2.32
31	13	1.89	0	22	3.91	35	2.80
32	6	0.87	0	0	0	6	0.48
35	11	1.60	0	11	1.96	22	1.76
36	3	0.44	0	7	1.25	10	0.80
37	1	0.15	0	0	0	1	0.08
38	1	0.15	0	3	0.53	4	0.32
39	7	1.02	0	8	1.42	15	1.20
40	8	1.16	0	13	2.31	21	1.68
41	1	0.15	0	2	0.36	3	0.24
42	1	0.15	0	0	0	1	0.08
168	0	0	0	1	0.18	1	0.08
176	1	0.15	0	0	0	1	0.08
177	1	0.15	0	1	0.18	2	0.16
187	0	0	0	3	0.53	3	0.24
188	0	0	0	2	0.36	2	0.16
192	0	0	0	1	0.18	1	0.08
200	1	0.15	0	0	0	1	0.08

Component Number	Base A		Number in FSV	Base B		Combined	
	Number Failed	Percent of Total		Number Failed	Percent of Total	Total Failed	Percent of Total
201	0	0	0	1	0.18	1	0.08
203	0	0	0	1	0.18	1	0.08
205	1	0.15	0	0	0	1	0.08
206	2	0.29	0	0	0	2	0.16
208	0	0	0	1	0.18	1	0.08
209	0	0	0	1	0.18	1	0.08
212	0	0	0	2	0.36	2	0.16
215	2	0.29	0	2	0.36	4	0.32
223	0	0	0	1	0.18	1	0.08
332	0	0	0	2	0.36	2	0.16
337	1	0.15	0	0	0	1	0.08
339	1	0.15	0	0	0	1	0.08
520	3	0.44	1	0	0	3	0.24

F.2 GMS3.OUT Example Output Files

```
OPTIONS SELECTED FOR THIS RUN ARE:

   THE GMS CONVOY IS DEPLOYING FROM BASE A
   THE NUMBER OF LRUS IN THE DATA BASE IS 535
   THE FAILURE RATE SCALE FACTOR IS 1.00
   THE REPAIR RATE SCALE FACTOR IS 1.00
   MOB MAINTENANCE PERSONNEL AVAILABLE ARE:
          VEHICLE REPAIR -  5
          POWER GENERATION REPAIR -  8
          ENVIRONMENTAL CONTROL REPAIR -  4
          COMMMUNICATIONS/ELECTRONICS REPAIR -  6
   FIELD MAINTENANCE PERSONNEL AVAILABLE ARE: 4
   RELOCATION DUR IS   6.0 HOURS; STD DEV IS   1.0
   ABENDS OCCUR EVERY  4.0 HOURS; STD DEV IS  1.0
   FILE PRINT OPTIONS ARE 1 FOR FILE 21 AND 1 FOR FILE 22
   DEPLOYMENT SUMMARY REPORT OPTION IS 1.

Relocation Statistics:
   Total relocation time was  5.82 hours.
   Relocation downtime totaled  0.00 hours.
   Relocation downing events totaled 0.
   MTBCF during relocation was  5.82 hours.

Operations Statistics:
   Total operations time was   594.85 hours.
   Operations downtime totaled    15.14 hours.
   Operations downing events totaled  24.
   Field maintenance actions totaled   6.
   MTBCF during operations was    24.15 hours.

MOB Statistics:
   MOB VEH manhours totaled   0.0
   MOB CE manhours totaled   0.0
   MOB PGU manhours totaled   0.0
   MOB ECU manhours totaled   4.5
   MOB maintenance actions totaled    1.

Overall Statistics:
   Length of deployment cycle was  608.75 hours.
   Abort-causing failure occurred during operations.
   Adjusted System endurance was   579.71
   Relocation availability was 1.0000
   Operational availability was 0.9745
   Overall system availability was 0.9523
```

DEPLOYMENT STATISTICS

Options:
Base: A
SFACT: 1.0, RFACT: 1.0
VEH: 5, CE: 6, PGU: 8, ECU: 4
MNT: 4

Relocation Statistics:
Total relocation time was 7.30 hours.
Relocation downtime totaled 0.00 hours.
Relocation downing events totaled 0.
MTBCF during relocation was 7.30 hours.

Operations Statistics:
Total operations time was 386.21 hours.
Operations downtime totaled 10.66 hours.
Operations downing events totaled 19.
Field maintenance actions totaled 2.
MTBCF during operations was 19.77 hours.

MOB Statistics:
MOB VEH manhours totaled 0.8
MOB CE manhours totaled 0.2
MOB PGU manhours totaled 0.0
MOB ECU manhours totaled 0.0
MOB maintenance actions totaled 2.

Overall Statistics:
Length of deployment cycle was 401.24 hours.
Abort-causing failure occurred during operations.
Adjusted System endurance was 375.55

Relocation availability was 1.0000
Operational availability was 0.9724
Overall system availability was 0.9360

DEPLOYMENT STATISTICS

Options:
- Base: A
- SFACT: 1.0, RFACT: 1.0
- VEH: 5, CE: 6, PGU: 8, ECU: 4
- MNT: 4

Relocation Statistics:
- Total relocation time was 7.89 hours.
- Relocation downtime totaled 0.00 hours.
- Relocation downing events totaled 0.
- MTBCF during relocation was 7.89 hours.

Operations Statistics:
- Total operations time was 45.78 hours.
- Operations downtime totaled 1.62 hours.
- Operations downing events totaled 4.
- Field maintenance actions totaled 2.
- MTBCF during operations was 11.04 hours.

MOB Statistics:
- MOB VEH manhours totaled 0.0
- MOB CE manhours totaled 0.0
- MOB PGU manhours totaled 8.1
- MOB ECU manhours totaled 1.7
- MOB maintenance actions totaled 2.

Overall Statistics:
- Length of deployment cycle was 69.64 hours.
- Abort-causing failure occurred during operations.
- Adjusted System endurance was 44.17

- Relocation availability was 1.0000
- Operational availability was 0.9647
- Overall system availability was 0.6342

DEPLOYMENT STATISTICS

Options:
Base: A
SFACT: 1.0, RFACT: 1.0
VEH: 5, CE: 6, PGU: 8, ECU: 4
MNT: 4

Relocation Statistics:
Total relocation time was 7.97 hours.
Relocation downtime totaled 0.00 hours.
Relocation downing events totaled 0.
MTBCF during relocation was 7.97 hours.

Operations Statistics:
Total operations time was 501.98 hours.
Operations downtime totaled 14.88 hours.
Operations downing events totaled 24.
Field maintenance actions totaled 6.
MTBCF during operations was 20.30 hours.

MOB Statistics:
MOB VEH manhours totaled 0.0
MOB CE manhours totaled 0.0
MOB PGU manhours totaled 9.3
MOB ECU manhours totaled 0.0
MOB maintenance actions totaled 2.

Overall Statistics:
Length of deployment cycle was 527.24 hours.
Abort-causing failure occurred during operations.
Adjusted System endurance was 487.10

Relocation availability was 1.0000
Operational availability was 0.9704
Overall system availability was 0.9239

F.3 FILE_21 and FILE_22 Example Files

CRITICAL FAILURES DURING DEPLOYMENT

COMPONENT NUMBER	SUBSYSTEM NUMBER	CRITICALITY	REPAIR LOCATION	SPARES REMAINING	FAILURE TIME
266.	11.	3.	0.	-1.0	595.

NON-CRITICAL FAILURES DURING DEPLOYMENT

COMPONENT NUMBER	SUBSYSTEM NUMBER	CRITICALITY	REPAIR LOCATION	SPARES REMAINING	FAILURE TIME
521.	7.	0.	0.	1.0	31.
15.	1.	0.	0.	0.0	34.
2.	1.	0.	0.	0.0	279.
398.	20.	0.	0.	0.0	297.
403.	20.	0.	0.	1.0	553.

F.4 Failures Categorized by MOB Repair Shop

FILE 10 - Vehicle Failures

Component	Mean Rpr Time	Std Dev	Endurance	Availability
167.0000	0.3000000	0.1000000		
222.0000	0.7500000	0.3000000	293.2373	0.9352286
203.0000	24.00000	1.000000		
332.0000	6.650000	1.000000		
203.0000	24.00000	1.000000		

FILE 11 - Comm/Electronics Failures

Component	Mean Rpr Time	Std Dev	Endurance	Availability
504.0000	0.2500000	0.1000000	195.4158	0.9238052
39.00000	0.2620000	0.1000000	231.3265	0.9169260
383.0000	8.0000004E-03	0.1000000		
32.00000	0.2400000	0.1000000	705.2491	0.9540572
23.00000	0.1450000	0.1000000		
30.00000	0.2400000	0.1000000		
383.0000	8.0000004E-03	0.1000000		
39.00000	0.2620000	0.1000000	470.2220	0.9404315
101.0000	0.1160000	5.0000001E-02		
31.00000	0.1500000	0.1000000	921.6683	0.9536038
135.0000	1.350000	0.5000000		
39.00000	0.2620000	0.1000000	67.49047	0.8332806
135.0000	1.350000	0.5000000		
353.0000	1.720000	0.8000000	67.23328	0.8077416
387.0000	0.2500000	0.1000000	105.4804	0.8635531
24.00000	0.2200000	0.1000000	775.8593	0.9582262
25.00000	0.1750000	0.1000000		
38.00000	0.3850000	0.2000000	225.0151	0.9277698
422.0000	0.2500000	0.1000000		
23.00000	0.1450000	0.1000000	637.6629	0.9459805
507.0000	0.6000000	0.3000000		
503.0000	0.2500000	0.1000000	94.52229	0.8601159
30.00000	0.2400000	0.1000000	416.7472	0.9380321
24.00000	0.2200000	0.1000000	593.3261	0.9551091
25.00000	0.1750000	0.1000000		
31.00000	0.1500000	0.1000000		
507.0000	0.6000000	0.3000000		
31.00000	0.1500000	0.1000000	373.4958	0.9305987
23.00000	0.1450000	0.1000000		
24.00000	0.2200000	0.1000000	223.7206	0.9250454
505.0000	0.2500000	0.1000000		
25.00000	0.1750000	0.1000000		
504.0000	0.2500000	0.1000000		
354.0000	0.1000000	0.1000000		

505.0000	0.2500000	0.1000000	30.04443	0.6156837
360.0000	0.7500000	0.3000000	331.6232	0.9370424
31.00000	0.1500000	0.1000000	211.9077	0.9000943
19.00000	0.3140000	0.1000000		
428.0000	0.2500000	0.1000000		
23.00000	0.1450000	0.1000000	212.6240	0.9118178
399.0000	0.1000000	0.1000000		
32.00000	0.2400000	0.1000000	642.8879	0.9486519
35.00000	0.3470000	0.1000000		
31.00000	0.1500000	0.1000000		
510.0000	0.6000000	0.3000000		
31.00000	0.1500000	0.1000000	20.08102	0.6106812
140.0000	0.3670000	0.2000000		
40.00000	0.2240000	0.1000000	145.3047	0.8910974
511.0000	0.6000000	0.3000000		
504.0000	0.2500000	0.1000000	407.2641	0.9355996
71.00000	1.500000	0.5000000	328.3808	0.9330740
37.00000	0.1500000	0.1000000	807.2757	0.9514933
25.00000	0.1750000	0.1000000	546.8899	0.9473166
31.00000	0.1500000	0.1000000		
40.00000	0.2240000	0.1000000		
400.0000	0.2000000	0.1000000	6.104765	0.3596644
27.00000	0.2340000	0.1000000	815.1250	0.9573579
503.0000	0.2500000	0.1000000		
31.00000	0.1500000	0.1000000	194.8850	0.9156073
25.00000	0.1750000	0.1000000		
505.0000	0.2500000	0.1000000		
23.00000	0.1450000	0.1000000	313.4753	0.9268028
360.0000	0.7500000	0.3000000		
137.0000	2.350000	1.000000	73.08743	0.8235191
140.0000	0.3670000	0.2000000	325.8970	0.9402915
2.000000	8.0000004E-03	0.1000000		
40.00000	0.2240000	0.1000000	320.3885	0.9414222
353.0000	1.720000	0.8000000		
20.00000	8.0000004E-03	0.1000000	591.4771	0.9453542
23.00000	0.1450000	0.1000000	612.0058	0.9531348
31.00000	0.1500000	0.1000000	192.1822	0.8935046
35.00000	0.3470000	0.1000000		
30.00000	0.2400000	0.1000000		
505.0000	0.2500000	0.1000000		
30.00000	0.2400000	0.1000000	478.8820	0.9442912
140.0000	0.3670000	0.2000000	144.3491	0.8987836
20.00000	8.0000004E-03	0.1000000		
360.0000	0.7500000	0.3000000		
20.00000	8.0000004E-03	0.1000000	295.0000	0.9338898

18.00000	0.3140000	0.1000000		
30.00000	0.2400000	0.1000000	877.1727	0.9552383
101.0000	0.1160000	5.0000001E-02		
429.0000	0.2500000	0.1000000		
40.00000	0.2240000	0.1000000	359.2151	0.9378453
415.0000	0.2500000	0.1000000	163.9877	0.9011771
517.0000	0.5000000	0.2000000	125.0313	0.8674886
358.0000	0.1420000	0.1000000	211.1342	0.8985726
41.00000	0.3370000	0.1000000	465.2853	0.9421268
35.00000	0.3470000	0.1000000	286.0551	0.9230582
51.00000	0.3230000	0.1000000	155.2107	0.9053085
25.00000	0.1750000	0.1000000	241.0254	0.9198455
502.0000	0.2500000	0.1000000		
503.0000	0.2500000	0.1000000		
30.00000	0.2400000	0.1000000	702.1740	0.9502713
20.00000	8.0000004E-03	0.1000000	650.1677	0.9477875
31.00000	0.1500000	0.1000000		
24.00000	0.2200000	0.1000000		
25.00000	0.1750000	0.1000000		
101.0000	0.1160000	5.0000001E-02		
25.00000	0.1750000	0.1000000	869.9105	0.9566940
38.00000	0.3850000	0.2000000		
141.0000	0.5000000	0.2000000		
25.00000	0.1750000	0.1000000	279.6186	0.9208731
505.0000	0.2500000	0.1000000		

FILE 12 - ECU Failures

Component	Mean Rpr Time	Std Dev	Endurance	Availability
314.0000	7.650000	1.000000	97.85818	0.8744207
341.0000	2.360000	1.000000		
314.0000	7.650000	1.000000		
349.0000	7.660000	1.000000		
349.0000	7.660000	1.000000	21.37528	0.5531636
349.0000	7.660000	1.000000		
314.0000	7.650000	1.000000		
349.0000	7.660000	1.000000		
343.0000	0.5000000	0.2000000		
349.0000	7.660000	1.000000		
349.0000	7.660000	1.000000	193.8706	0.9007077
341.0000	2.360000	1.000000		
314.0000	7.650000	1.000000		
341.0000	2.360000	1.000000	462.9216	0.9439793
314.0000	7.650000	1.000000		
349.0000	7.660000	1.000000	62.41695	0.7389486
314.0000	7.650000	1.000000		

341.0000	2.360000	1.000000		
314.0000	7.650000	1.000000		
349.0000	7.660000	1.000000	28.81260	0.6740723
349.0000	7.660000	1.000000		
311.0000	0.6670000	0.3000000		
306.0000	2.360000	1.000000	188.1866	0.9220306
349.0000	7.660000	1.000000	158.6025	0.9205600
350.0000	2.000000	1.000000	103.0314	0.8829444
314.0000	7.650000	1.000000		
349.0000	7.660000	1.000000		
314.0000	7.650000	1.000000	106.4596	0.8477694
306.0000	2.360000	1.000000		
314.0000	7.650000	1.000000	68.48358	0.8200644
314.0000	7.650000	1.000000		
349.0000	7.660000	1.000000	757.0334	0.9525552
341.0000	2.360000	1.000000		
314.0000	7.650000	1.000000		
349.0000	7.660000	1.000000		
306.0000	2.360000	1.000000		
314.0000	7.650000	1.000000		
314.0000	7.650000	1.000000		
349.0000	7.660000	1.000000		
341.0000	2.360000	1.000000		
349.0000	7.660000	1.000000		
341.0000	2.360000	1.000000		
349.0000	7.660000	1.000000	87.77642	0.8476263
314.0000	7.650000	1.000000	52.03022	0.7945314
314.0000	7.650000	1.000000		
349.0000	7.660000	1.000000		
312.0000	0.5000000	0.2000000	94.37817	0.8634775
327.0000	2.000000	1.000000		
349.0000	7.660000	1.000000		
349.0000	7.660000	1.000000	179.2537	0.9033089
314.0000	7.650000	1.000000	45.49187	0.7869613
314.0000	7.650000	1.000000	67.49736	0.7844943

FILE 13 - PGU Failures

Component	Mean Rpr Time	Std Dev	Endurance	Availability
266.0000	1.770000	0.8000000	290.3885	0.9395842
228.0000	0.7580000	0.3000000		
290.0000	1.020000	0.5000000	277.5919	0.9205194
248.0000	1.100000	0.5000000		
283.0000	0.7000000	0.3000000	476.5685	0.9432006
288.0000	0.9550000	0.4000000		
275.0000	2.460000	1.000000		

284.0000	0.3980000	0.2000000		
288.0000	0.9550000	0.4000000	340.4430	0.9426787
288.0000	0.9550000	0.4000000	169.6754	0.9159511
261.0000	3.000000	1.000000		
302.0000	0.1670000	0.1000000	166.7324	0.9009030
262.0000	2.000000	1.000000	67.18889	0.8342130
256.0000	1.030000	0.5000000		
235.0000	0.3720000	0.2000000		
264.0000	1.100000	0.5000000	267.9114	0.9209288
250.0000	1.100000	0.5000000		
291.0000	0.9550000	0.4000000		
290.0000	1.020000	0.5000000		
297.0000	1.080000	0.5000000		
288.0000	0.9550000	0.4000000	243.8207	0.9179319
244.0000	1.020000	0.5000000		
275.0000	2.460000	1.000000		
250.0000	1.100000	0.5000000		
301.0000	0.1670000	0.1000000		

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Vita

Captain Steven O. Brown was born on 26 November 1963 in St. Louis, Missouri. He graduated from Greene County High School in Paragould, Arkansas in 1982 and attended Memphis State University, graduating with a Bachelor of Science in Electrical Engineering in August 1986. Upon graduation, he received a reserve commission in the USAF and served his first tour of duty at Electronic Security Command Headquarters, Kelly AFB, Texas. He served as a radar systems analyst with duties including testing and evaluating ground threat radar simulators. He also served as test engineer in evaluating threat databases used in aircrew training devices. In August of 1990, he entered the School of Engineering, Air Force Institute of Technology, pursuing the degree of Master of Science in Operations Research.

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13. ABSTRACT *(Maximum 200 words)*

This study investigated the endurance of a single deployed generic mobile space (GMS) command and control (C^2) system. Specifically, factors which affect overall system performance were examined. The analysis began with the development of a simulation model for a GMS C^2 system. Optimal settings of factor levels were determined by using the model to find peak system endurance and availability. Factors set were field support vehicle (FSV) access, numbers of maintenance personnel, and numbers of spare components available. After optimum values were chosen for these factors, an experimental design was conducted to determine factor effects between maintenance manpower and the component failure and repair rates. It was determined that access to the FSV increases system endurance by 6.1 percent. Increasing maintenance manpower does not significantly affect system availability. Eight components, most in the communications subsystems, were identified for increased spares levels which could increase system endurance by an additional 2.8 percent. Of all factors and combination of factors considered in the experimental design, only the rate of component failures significantly affected system performance.

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