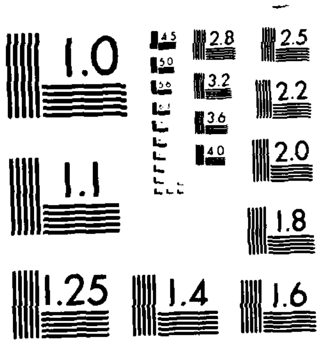
AD-A152 068 A SIMULATION MODEL OF THE COMMON STRATEGIC ROTARY LAUNCHER FOR AVAILABILITY(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. 1/2

UNCLASSIFIED S J GJERSTAD ET AL. NOV 84 F/G 16/1 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

A SIMULATION MODEL OF THE COMMON STRATEGIC

ROTARY LAUNCHER FOR AVAILABILITY

PROJECTIONS

THESIS

Sarah J. Gjerstad — Captain, USAF

Roxann A. Oyler — First Lieutenant, USAF

AFIT/GOR/OS/84D-5

Approved for public release; distribution unlimited

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFIT/GOR/OS/84D-5	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION School of Engineering / 6b. OFFICE SYMBOL (If applicable) AFIT/ENS	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State and ZIP Code) Air Force Institute of Technology Wright Patterson AFB, OH 45433	7b. ADDRESS (City, State and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION / 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State and ZIP Code)	10. SOURCE OF FUNDING NOS. PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT NO.
11. TITLE (Include Security Classification) See Box 19	

12. PERSONAL AUTHOR(S)
[illegible] J. [illegible]stad, B.A., Capt, USAF and Roxann A. O[illegible], B.S., 1Lt, USAF

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
MS Thesis	FROM ____ TO ____	1984 November	121

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	Availability, CSRL, Launcher, [illegible], [illegible], Simulation, Operational Suitability
[illegible]	01		

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

Title: A SIMULATION [illegible] LAUNCHER (CSRL) FOR [illegible]

Advisors: Charles E. [illegible], Lt Col, [illegible]
James L. [illegible]

Approved for public release: IAW AFR 190-17.
LYNN E. WOLAVER
Dean for [illegible] Professional Development
Air Force [illegible] (AIC)
Wright-Patterson [illegible]

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT

22a. NAME OF RESPONSIBLE INDIVIDUAL
Charles E. [illegible]

DD FORM 1473, 83 APR

The Common Strategic Rotary Launcher (CSRL) is a multipurpose launcher that will be used on the B-52 and B-1 aircraft. This study develops a SLAM simulation model of the CSRL and uses two measures of effectiveness, availability and sortie generation time, to determine the operational suitability of the CSRL. Analysis of variance and regression analysis were used to determine what effect the number of load crews, the number of munitions lift trailers, the frequency of launcher inspections, and the level of repair have on the sortie generation time. The repair concept for the SRAM launcher was used as a baseline. The results of this study indicate that a unit increase in the number of load crews (crews range from 8 to 12) would decrease the generation time 1-5%; an increase in the number of MLTs would not significantly decrease the generation time; increasing the frequency of inspections from once a year to twice a year would decrease the time by 2-5%; and allowing flight line repair and exchange of failed [illegible] would decrease the time by 2-5%. These results have been graphically presented in a contour map which shows the various combinations of the above factors which are needed to achieve a [illegible] generation time. [illegible] determined what effect [illegible] had on availability. The results [illegible] load [illegible] small effect on the availability [illegible] frequency from once a year to twice a year [illegible] of available launchers by [illegible]

AFIT/GOR/OS/84D-5

A SIMULATION MODEL OF THE COMMON STRATEGIC ROTARY LAUNCHER FOR AVAILABILITY PROJECTIONS

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Operations Research

Sarah J. Gjerstad, B.A.

Captain, USAF

Roxann A. Oyler, B.S.

First Lieutenant, USAF

NOVEMBER

~~December~~ 1984

Approved for public release; distribution unlimited

Preface

The purpose of this study was to analyze the operational suitability of the Common Strategic Rotary Launcher (CSRL). This was accomplished by developing a simulation model of the CSRL that measured availability and sortie generation time. The model will be used by AFOTEC to analyze the data obtained during the test program. SAC, the ultimate user of the model, can also use the model to experiment with different management policies before and after the system becomes fully operational.

The model was used to determine the effect of several variables on availability and sortie generation time. Specifically, the model was used to answer the following research questions:

1. What is the expected availability of the CSRL when used on the B-52 and when used on the B-1 aircraft?

2. How much effect does the number of load crews, number of munitions lift trailers (MLTs), level of repair, and frequency of launcher inspections have on sortie generation time?

3. How much effect does the frequency of launcher inspections have on availability?

We wish to acknowledge those people that have provided us with guidance and assistance in preparing this thesis. First, a word of thanks to our advisors, Lieutenant Colonel Charles E. Ebeling and Major James K. Feldman and also to Lieutenant Colonel Joseph W. Coleman. We would also like to thank our sponsors at AFOTEC, Major Burton McKenzie, Captains Fred Hulem, Richard Price, and Chuck Wolfe who were very helpful. Finally, Roxann would like to thank her husband Dean for his patience and understanding throughout the whole effort.

Sarah J. Gjerstad
Roxann A. Oyler

Table of Contents

Page

List of Figures

Figure Page

List of Tables

Symbols and Abbreviations

1. AFLC - Air Force Logistics Command
2. AFOTEC - Air Force Operational Test and Evaluation Center
3. AFSC - Air Force Systems Command
4. ALCM - Air Launched Cruise Missile
5. ALI - Annual Launcher Inspection (subroutine in program)
6. ALT - Alert (subroutine in program)
7. AVAIL - Availability (variable used in program)
8. CHK - Check (term used in program)
9. CSRL - Common Strategic Rotary Launcher
10. DF - Degrees of Freedom
11. ESTS - Electronic System Test Set
12. EXCHG - Exchange (subroutine in program)
13. FMC - Fully Mission Capable
14. GEN - Generation (subroutine in program)
15. GENRPT - Generation Report (subroutine in program)
16. GENTIM - Generation Time (variable used in program)
17. IMF - Intermediate Maintenance Facility
18. INSP - Inspection
19. INTLC - Initialize (subroutine in program)
20. LCOM - Logistics Composite Model
21. MLT - Munitions Lift Trailer
22. MTBF - Mean Time Between Failure
23. OINSP - ORI Inspection (subroutine in program)
24. OT&E - Operational Test and Evaluation
25. PDU - Power Drive Unit (component on CSRL)
26. PMC - Partially Mission Capable

27. QINSP - Quarterly Inspection (subroutine in program)

28. REP - Repair (variable used in program)

29. SAC - Strategic Air Command

30. SGR - Sortie Generation Rate

31. SIT - System Interface Test

32. SLAM - Simulation Language for Alternative Modeling

33. SRAM - Short Range Attack Missile

34. SSE - Sum of Squares for Error

35. SSR - Sum of Squares for Regression

36. STG - Storage (variable used in program)

37. TNOW - Time Now (SLAM variable in program)

38. WSA - Weapon Storage Area

Abstract

The Common Strategic Rotary Launcher (CSRL) is a multipurpose launcher that will be used on the B-52 and B-1 aircraft. This study develops a (SLAM) simulation model of the CSRL and uses two measures of effectiveness, availability and sortie generation time, to determine the operational suitability of the CSRL. Analysis of variance and regression analysis were used to determine what effect the number of load crews, the number of munitions lift trailers, the frequency of launcher inspections, and the level of repair have on the sortie generation time. The repair concept for the SRAM launcher was used as a baseline. The results of this study indicate that a unit increase in the number of load crews (crews range from 3 to 12) would decrease the generation time 1-5%; an increase in the number of MLTs would not significantly decrease the generation time; increasing the frequency of inspections from once a year to twice a year would decrease the time by 3-5%; and allowing flight line repair and exchange of failed missiles would decrease the time by 2-6%. These results have been graphically represented in a contour map which shows the various combinations of the above factors which are needed to achieve a specific generation time. This study also determined what effect the frequency of launcher inspections had on availability. The results indicate that frequency of inspections does have a small effect on the availability of the CSRL; increasing the frequency from once a year to twice a year increases the average percentage of available launchers by less than 2%.

A SIMULATION MODEL OF THE COMMON STRATEGIC ROTARY LAUNCHER
FOR AVAILABILITY PROJECTIONS

I. Introduction

Background

The Aircraft Logistics Analysis Branch at the Air Force Operational Test and Evaluation Center (AFOTEC/LG4A) is updating the Logistics Composite Model simulation of the B-1 strategic bomber which will be used to derive Sortie Generation Rate (SGR) and the Fully Mission Capable (FMC) rates as part of the B-1 testing effort. The Common Strategic Rotary Launcher (CSRL) is a separate subsystem which will be used on the B-52 and the B-1 aircraft and will impact the SGR and FMC rates. AFOTEC/LG4A has requested the development of a simulation model for the CSRL that can be used to derive CSRL availability values as an input to the B-1 LCOM simulation model.

Thesis Objective

The objective of this thesis is to analyze the operational suitability of the Common Strategic Rotary Launcher (CSRL), a vital subsystem to be used on the B-52 and the B-1 aircraft. This will be accomplished by developing and implementing a computer simulation model for the CSRL.

The primary measure of operational suitability is availability. According to AFR 800-13, "availability is a measure of the degree to which an item is in an operational and committable state when the mission is called for at a random point in time." For the CSRL this definition of availability was translated into a more specific measure of merit. For our model, availability is the percentage of the total launchers that are in working order. If a launcher has failed in storage, it is not available, even though the failure has not yet been detected (either through annual inspections or sortie generation exercises).

According to the test program outline (1:7), one of the critical operational issues for OT&E is the carrier aircraft sortie generation:

> "the carrier aircraft sortie generation capability is highly dependent on the operational suitability of the CSRL. The ability to generate a sortie within the time specified [by SAC] will directly affect [SAC's] ability to meet wartime missions".

To evaluate the ability to meet wartime missions a second measure of merit has been defined. Sortie generation time is the time required to get all aircraft ready to launch. The sortie generation time is a function of availability, but it is also a function of the number of crews, support equipment, level of repair, load times and repair times. It not only measures how many launchers are available, but how long it takes to get the launchers in a usable condition (i.e. loaded onto an aircraft).

Evaluating availability and generation time can be accomplished by developing and executing a simulation model of the CSRL system using Simulation Language for Alternative Modeling (SLAM). Both quantities are measured at random points in time in the model and satisfy the AFOTEC requirements.

A wing of 16 aircraft is modeled over one year using a scenario specified by AFOTEC. The maintenance for the CSRL is modeled in a way similar to the concept for the Short-Range Attack Missile (SRAM) rotary launcher. Existing SRAM support concepts and resource requirements served as a baseline for modeling the CSRL. The CSRL is modeled for use on the B-52 aircraft. However, the only changes for analysis with the B-1 are with two components; the power drive unit and the power drive unit controller are considered part of the B-1 aircraft system, rather than the CSRL.

In addition to the analysis performed in this thesis, the CSRL model was developed so that it could be used by both AFOTEC and SAC for future analysis.

Currently AFOTEC uses simulation models to analyze the data obtained during the test program. This model was designed to use the outputs from the test program (as defined in the draft test plan) as inputs to the model. Normally, AFSC develops the model and AFOTEC receives it sometime during the test program. By having the CSRL system modeled prior to the start of the test program AFOTEC can exercise the model to identify critical areas of performance before testing begins. This will signal areas that AFOTEC should fully evaluate during testing so that any deficiencies can be corrected before the system is implemented. If necessary, AFOTEC can modify the test plan based on the impacts predicted by the model.

SAC can use the model to experiment with different management policies before and after the system becomes fully operational. This should be an iterative process. As more data becomes available, the model can be updated.

And finally, the availability measures derived from the CSRL model can be used as inputs to the B-52 and B-1 Logistics Composite Models to evaluate the operational readiness of those systems.

Research Questions

The effects of several controllable variables on availability and aircraft generation time were evaluated while simultaneously considering the effects of several estimated reliability and maintainability parameters. Specifically, the analysis focused on how the number of load crews, the number of munitions lift trailers (MLTs), the level of repair (2-level vs. 3-level), and the frequency of launcher inspections affects the measures of operational suitability. Since there are many reliability and maintainability parameters which are estimated and which could affect the results of the analysis, these parameters were included at various levels. These parameters include failure rates, load time for the launcher, time to exchange a missile, and remove and replace times for the relay assembly and missile interface unit. The rationale for choosing these factors is detailed in Chapter III.

The specific questions to be answered in this research are:

1) What is the expected availability of the CSRL when used on the B-52 aircraft; when used on the B-1 aircraft?

2) What is the sortie generation time when used on the B-52; when used on the B-1?

3) How much effect does the number of load crews have on the generation time?

4) How much effect does the number of MLTs have on the generation time?

5) How much effect does the level of repair have on the generation time?

6) How much effect does the frequency of launcher inspections have on the generation time?

7) How much effect does the frequency of launcher inspections have on the availability?

Overview

The remainder of this thesis consists of five chapters. Chapter II gives some background information on the CSRL and discusses in detail the operational environment simulated in this research effort. Also included in this chapter are a description of the support and test equipment critical to the CSRL. This chapter does not try to tie the operational environment to the model, this is reserved for Chapter IV.

Chapter III discusses the rationale for choosing the research questions. It also discusses some factors which may affect availability and generation time, but were not included in this study.

Chapter IV describes the model developed for the CSRL, the assumptions made in the model, the flexibility of the model, and the data sources. It also discusses the steps taken to verify and validate the SLAM model and the computer results.

The analysis and results chapter, Chapter V, describes the research designs which were used in the simulation and the statistical results.

The final chapter discusses the conclusions reached during the course of this research and the recommendations for future analysis. The first section of this chapter reports the significant results obtained from Chapter V. The recommendation section shows how the CSRL model can be further developed to analyze other factors affecting availability when the appropriate data becomes available.

II. Operational Background

This chapter gives a brief description of the CSRL operational environment. There are three major events that affect the CSRL: annual inspections, alert status, and sortie generation exercises. These three events as well as the support and test equipment that are expected to be limiting factors in the availability of the CSRL are described.

CSRL Description

The Common Strategic Rotary Launcher (CSRL) is a multipurpose launcher that accommodates current and projected cruise missiles, short-range attack missiles, and gravity weapons. The CSRL will be compatible with three distinct strategic bomber airframes: B-52, B-1B, and advanced technology bomber. The CSRL has eight weapon stations that can carry any certified weapon. This allows uniform loads of any weapon as well as unrestricted mixed loads. (13:1)

The CSRL consists of a launcher shaft, forward and aft launcher support fittings, weapon ejector assemblies, and avionics components. The CSRL interfaces with the aircraft electrical, hydraulic, environmental, avionics, and weapons control and monitor systems. A diagram of the CSRL is shown in Figure 1. (13:1)

Support Equipment. The CSRL is over 22 feet long and when loaded with 8 ALCM missiles it weighs 25,000 pounds. The launcher requires some massive and expensive support equipment to transport it.

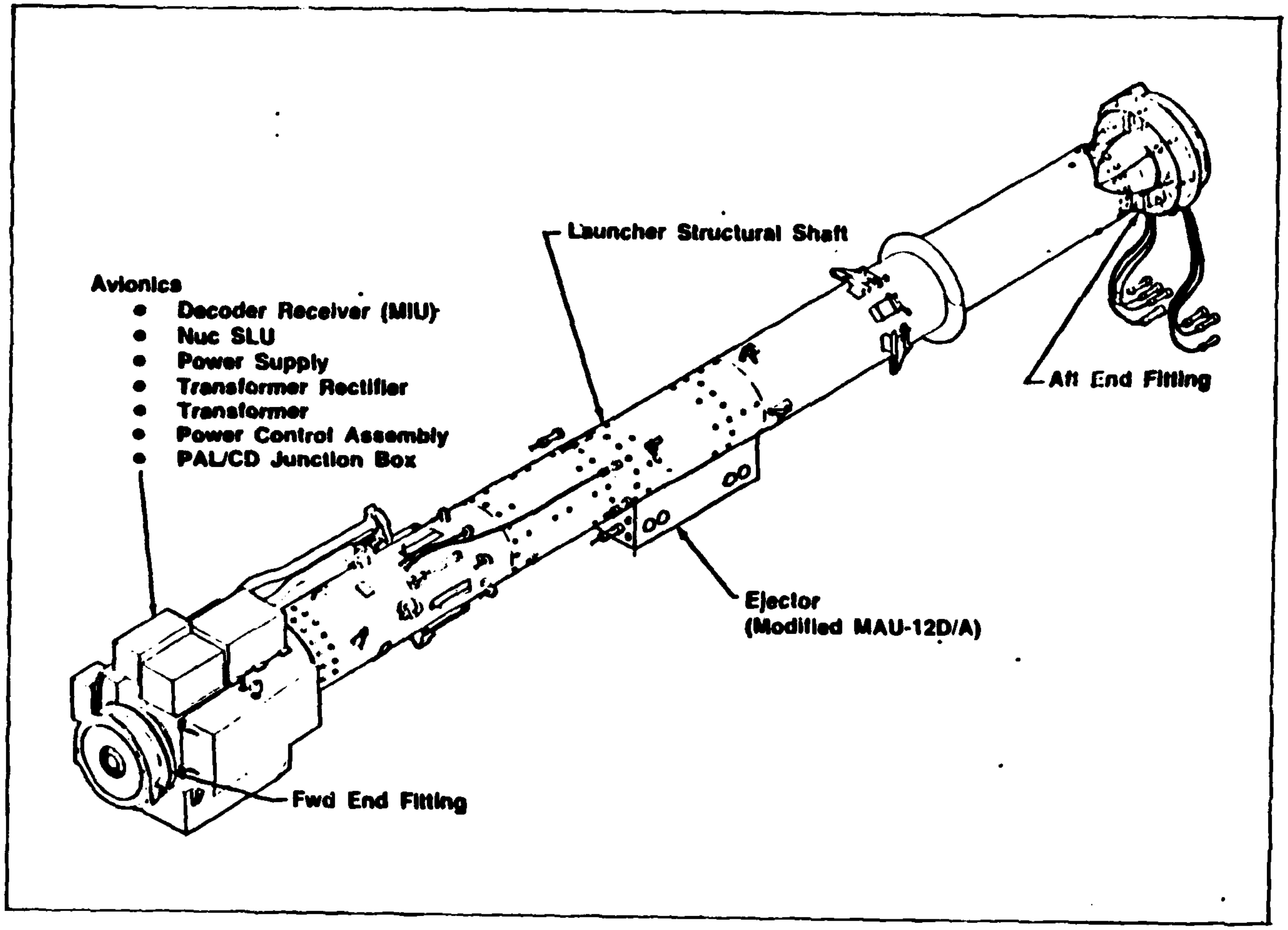


Figure 1. Diagram of the CSRL

Among support equipment, the munitions lift trailer (MLT), due to its low reliability, is currently the biggest constraint when loading the pylons. A modified MLT is planned for use with the CSRL.

Test Equipment. The launcher, along with the pylons and missiles, are tested with the Electronic Systems Test Set (ESTS). Each wing has three ESTSs and each one is wired to test two of the three types of equipment. Each type of equipment has a primary ESTS and a backup ESTS.

Operational Environment

Figure 2 shows a picture of the operational environment of the CSRL.

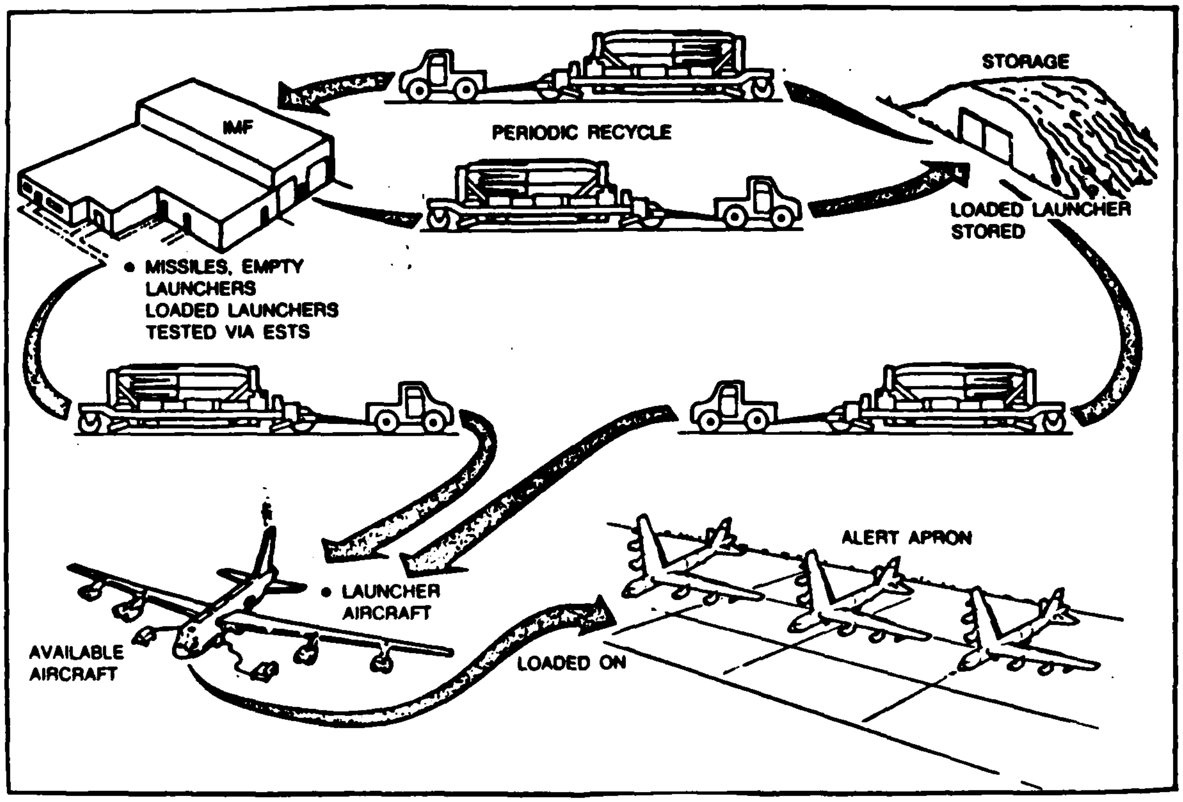


Figure 2. CSRL Operational Environment (3:45)

Unlike other subsystems on the B-52 or B-1, the CSRL will not be operated or flown during peacetime operations. The launchers remain fully loaded in the weapon storage area (WSA) until removed for one of the following three reasons:

1) annual inspection,
2) uploaded to an alert aircraft,
3) sortie generation exercises.

Each of the activities is further described below with the approximate length of the event indicated in parenthesis.

Annual Inspections. Every launcher and missile is inspected annually.

When the launcher is due for an inspection and an Electronic System Test Set (ESTS) is available, the launcher is transported from the WSA to the Intermediate Maintenance Facility (IMF) (.5 hour).

The inspection crew consists of a team chief plus three other members with AFSC 463XX.

Once in the facility, the launcher is loaded into the test frame (1 hour), the warheads are removed from the missiles and the missiles are downloaded from the launcher (1 hour per missile). The empty launcher is connected to the ESTS (.5 hour) and the empty test is performed (12 hours + repair time). When problems are detected, the test is stopped while repairs are made. The missiles are tested separately on another ESTS (3.5 hours per missile + repair time). The missiles are then reloaded onto the launcher (1 hour per missile). The launcher is downloaded from the frame and a postload inspection is performed (2.5 hours). Finally, the launcher is transported back to the WSA (.5 hour) unless needed for an alert aircraft.

Alert Status. Five aircraft remain on alert status at all times. Approximately every three weeks one alert aircraft is exchanged for another. A launcher (which is not due for an inspection within 90 days) is removed from storage and transported to the flight line (.75 hours). The load crew consists of a team chief plus four other members with AFSC 462XX, who have trained together for at least three weeks.

The launcher and two pylons are loaded onto the aircraft (1 hour per launcher, 1 hour per pylon). A systems interface test (SIT), which tests the status of the launchers and the missiles, is performed (1.5 hours). If the launchers and missiles are working, the crew performs the postload work (1 hour) and downloads the other aircraft. If not working, the launcher is removed and transported back to the IMF and another launcher is transported to the flight line.

Once a week, while on alert status, a SIT test is performed by the aircrew to ensure alert status is maintained.

Sortie Generation Exercise. Sortie generation exercises are conducted on a no-notice basis quarterly by the base and annually by HQ SAC (ORI). This exercise is similar to bringing an aircraft up to alert status except that all aircraft are brought up to alert status. All launchers in storage and in the IMF are uploaded onto aircraft.

When a launcher is not operational, it is returned to the IMF and repaired, while another launcher is uploaded in its place.

When a missile is found to be non-operational, either the entire launcher is returned to the IMF to exchange the failed missile or the launcher is left in a degraded status. This decision is a judgement call by the commander based on the progress of the exercise thus far.

III. Variables in the Analysis

There are many factors which affect the availability and the generation time of the CSRL. This chapter discusses the factors included in the analysis and why. It also discusses those factors which were considered for inclusion but were omitted.

The factors selected are: number of load crews, available support equipment, level of repair, frequency of launcher inspections, repair rates, mean time between failures, mission schedule, available test equipment, number of spare parts, and the number of maintenance personnel. The following paragraphs discuss these factors individually.

The number of load crews was identified by SAC as a limiting factor and is therefore included in this analysis. The load crew is a team of five members that have trained together for at least three weeks before becoming qualified to load the launchers and pylons onto the aircraft. Although a typical base is authorized 12 load crews, at any given time only 3 to 9 are fully qualified and available for duty.

Of the support equipment, the munitions lift trailers (MLTs) were identified as the limiting resource and have been included in the analysis. The MLTs have had a poor reliability. Although a typical base is assigned 12 or 13 MLTs, only 3 or 9 are usually working at a time.

The current maintenance policy for the SRAM launcher does not allow for repair of the launcher or for exchange of a failed missile on the flight line. When a failure is detected, the launcher must be downloaded from the aircraft, transported back to the IMF and repaired. Since a policy change, which would allow flight line maintenance, is under consideration (3) this analysis evaluates the impact of the level of repair (2-level vs 3-level). With two levels of maintenance, the launcher can be repaired at the IMF or at the depot; with three levels of maintenance, the launcher can be repaired on the flight line, at the IMF or at the depot. Depot repair refers to shipping a failed component of the launcher to the depot for repair and using a spare component to repair the launcher at the base (either on the flight line or in the IMF). In simulation models, depot repair is represented by including a time delay before the failed component is available as a spare part.

The SRAM launcher and the ALCM missiles undergo an inspection annually. The maintenance plan for the CSRL also calls for an annual inspection. Since failures which were undetected in storage would be identified and repaired during an inspection, the effect of increasing the number of inspections would be to increase availability. This is included as a factor in order to find out how much of an impact the frequency of inspections has on availability.

Any evaluation of the factors mentioned above must take into consideration the effects of estimated reliability and maintainability parameters. Specifically, these are load time, repair time, and mean time between failure (MTBF) for the seven major subsystems of the launcher and the missiles.

Although the time to load the SRAM launcher is used as a baseline estimate, the CSRL is considerably larger than the SRAM and may take more time than estimated. Therefore, this factor was included in the analysis.

The time to remove and replace a failed missile and the time to remove and replace the missile interface unit (MIU) and the relay assembler are other parameters which were included in the analysis. The MIU and the relay assembler are the only two components of the seven major subsystems of the CSRL which could be repaired on the flight line.

The final parameter studied is the mean time between failure for the launcher. Since there are reliable estimates for the MTBF for missiles, this parameter was excluded from consideration. MTBF is expected to have the most significant impact on availability and generation time. In addition, the interaction of MTBF with other factors may have an impact. For example, the level of repair may not have much impact on the generation time if the MTBF is high since there would be few failures to repair. But if the MTBF is low, there may be a significant difference in the time.

Available test equipment, number of maintenance personnel, and spare parts were considered for inclusion, but were not included for the reasons listed below.

The electronic systems test set (ESTS) is the limiting factor for test equipment. This was included in the model as a constraining resource, but was not evaluated at various levels. The number of ESTSs is limited by the design of the IMFs which have already been constructed. During normal operations the crew work 2 8-hour shifts for 5 days a week; therefore, the maximum ESTS operating time would be 16 hours a day. However, because of low reliability and periodic ESTS inspections, the ESTS is only available 8 to 10 hours a day. The only way to increase the availability would be to increase the reliability. Although that may be possible, this analysis does not evaluate the availability of the ESTS since only the CSRL was modeled. Since the three ESTSs at a typical base are used to test the launchers, pylons and missiles, any analysis on this would have to include the pylons and missiles as well as the CSRL to be meaningful.

The number of maintenance personnel was not included as a constraint or as a factor for evaluation, because this was not considered a limiting factor in discussions with SAC personnel. However, this resource could be added to the model in the future.

Spare part stockage levels for the MIU and relay assembler were not evaluated because the maintenance concept for the SRAM launcher is to repair it in the IMF, rather than to remove and replace failed components on the flight line. For this reason, there was no baseline data to use for the number of spares. The CSRL model is set up so that spares could be added for future analysis. This is discussed further in Chapter VI.

To summarize, there are four factors to be examined in this analysis - number of load crews, number of MLTs, level of repair, and the frequency of inspections. These will be evaluated while also measuring the effects of four estimated reliability and maintainability parameters - load time for the launcher, remove and replace time for the missile, remove and replace time for the MIU and relay assembler, and MTBF for the launcher.

IV. Model

The first section of this chapter briefly describes the SLAM simulation language and how it was used to develop the CSRL model. The second section gives an overview of the CSRL model while the third section gives a more detailed narrative description of the model and describes the interaction of the FORTRAN and the SLAM network sections of the CSRL model. The last four sections discuss the assumptions made, the flexibility of the model, the data sources, and verification and validation of the model.

SLAM Background

Rather than present a detailed description of SLAM, this section provides a simplified description of SLAM that is necessary for understanding the development of the CSRL model. Further detail concerning SLAM can be found in Pritsker and Pegden (14) and Banks and Carson (2).

SLAM is a special purpose FORTRAN-based simulation language which allows an event-scheduling and/or a process-interaction orientation toward modeling (2:99). The type of orientation one uses depends on the level of complexity needed to model the system and the extent to which the model will have to be embellished for future uses (14:315).

The event-scheduling orientation concentrates on events and how they affect the state of the system. This method uses a FORTRAN model to schedule events to occur and then process the events at the right time. FORTRAN subroutines are used to control the changes associated with each event type, which may entail manipulating files, collecting statistics, and/or printing status reports (14:73). This is called a discrete-event model because changes in the model occur at discrete points in time.

The process-interaction approach concentrates on entities and the sequence of events and activities they undergo as they flow through the system. The processes are represented by the nodes and branches of a network. Consequently, a network model represents the processes that an entity goes through as it passes through the system. (14:73) The symbols used to describe the processes in the network are included in Table A.1 in Appendix A.

The ability in SLAM to combine the FORTRAN and network models "with interactions between each orientation greatly enhances the modeling power . . . (14:74)". The interaction of the FORTRAN and network models allows events to alter the flow of entities in the network model and it also allows entities in the network to initiate events in the FORTRAN model.

The SLAM model developed for the CSRL employs both orientations toward modeling. The events are the ORI and the quarterly generation exercises, the annual launcher inspections and the exchange of launchers on alert aircraft. These events are scheduled in the FORTRAN program and when called, cause the launchers to flow through the appropriate segment of the SLAM network. The launchers are modeled as entities and the network represents the process the launchers must go through for each event. This type of model is called a discrete-event network simulation.

Model Overview

In Chapter II a macro view of the CSRL operational environment was presented and was diagramed in Figure 2. To summarize, the diagram showed that at base level the launchers could be in one of three locations for a variety of reasons. While at the base the CSRLs can either be in storage, on the flight line, or in the IMF. There are several reasons launchers transfer location. These include but are not limited to: repair of launcher components, required inspection, and generation exercises. The model subdivides the launcher into the seven major subsystems so that the MTBF for each of the components can be checked during testing (refer to Table C.1 for a listing of the subsystems). The launchers that are in storage (and have not failed) or are awaiting inspection are considered available. The next section uses flow charts to show the major decision structures involved in the day-to-day operation of the CSRL. Only the significant decision structures were included; for more specific details on the model refer to Appendix B where the FORTRAN and SLAM network codes a listed. The network flow diagrams are also included in Appendix B. The computer used to implement the simulation model is the VAX 11/780; however, it has also been run on the IBM 4321 computer.

Narrative Description

The CSRL model is a composite discrete-event network simulation that consists of two parts; a FORTRAN model and a SLAM network model. The FORTRAN model interacts with the SLAM network model to simulate the CSRL system. The FORTRAN code consists of two major parts; initialization and assignment of launchers, and event scheduling. The network model consists of five major sections that represent the different activities that the launchers go through during alert, generation exercises, and launcher inspections. The five major sections are: checking for failed components (CHK), repairing failed components

(REP), generating aircraft (GEN), performing post generation work (PSTG), and performing annual launcher inspections (ALI).

In the initialization and assignment section of the FORTRAN model the 16 launchers are created and assigned failure times. Each launcher has seven major subsystems and eight missiles; therefore, all seven components and eight missiles are assigned failure times. Whenever a component fails the launcher is considered unavailable. Each launcher is then assigned an annual inspection time with one launcher scheduled every three weeks so that the work load is evenly spread throughout the year.

The first five launchers that are not due an annual launcher inspection within 90 days are put on alert aircraft with the remaining launchers put in storage. The launchers stay in storage (STG) or on alert (ALT) until scheduled for the next event. This is shown in Figure 3, Flowchart for Main Program.

The next part of the code, as illustrated in Figure 4, schedules the events for the CSRL for the simulation time specified by the user. The events are scheduled in decreasing order of importance so that any conflicts can easily be resolved. For example, if there was a conflict between an annual launcher inspection and an ORI the former would be deferred until after the generation exercise was completed. The first event scheduled is the ORI which occurs randomly every 10 to 15 months. The quarterly inspections (QINSPs) are scheduled next, one per quarter but not overlapping the ORIs since this would not occur in reality. The launchers are then scheduled for an annual launcher inspection (ALI) corresponding to the inspection times assigned earlier, unless the inspection time conflicts with a generation exercise, in which case the

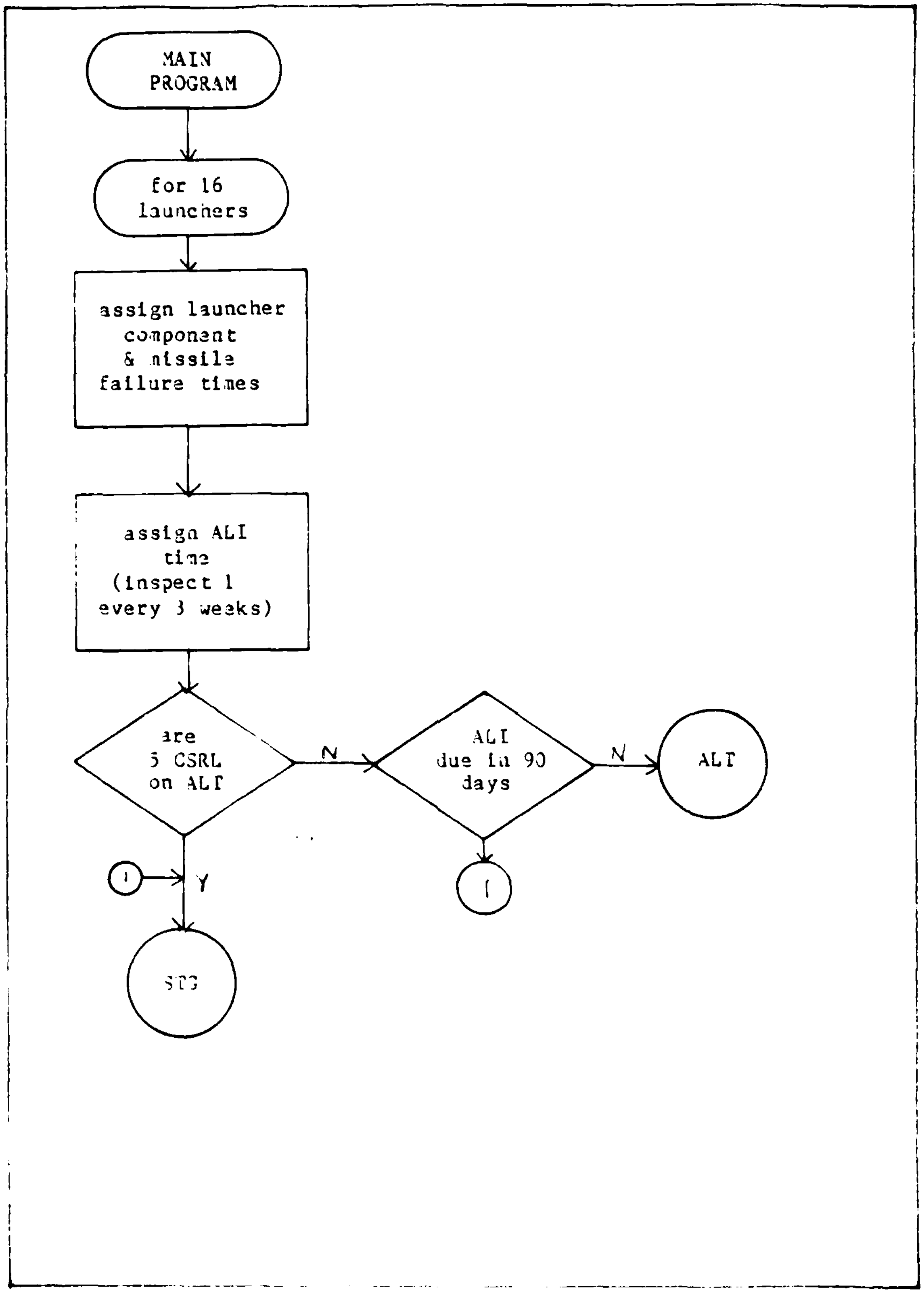


Figure 3. Flowchart for Main Program, Initialization and Assignment

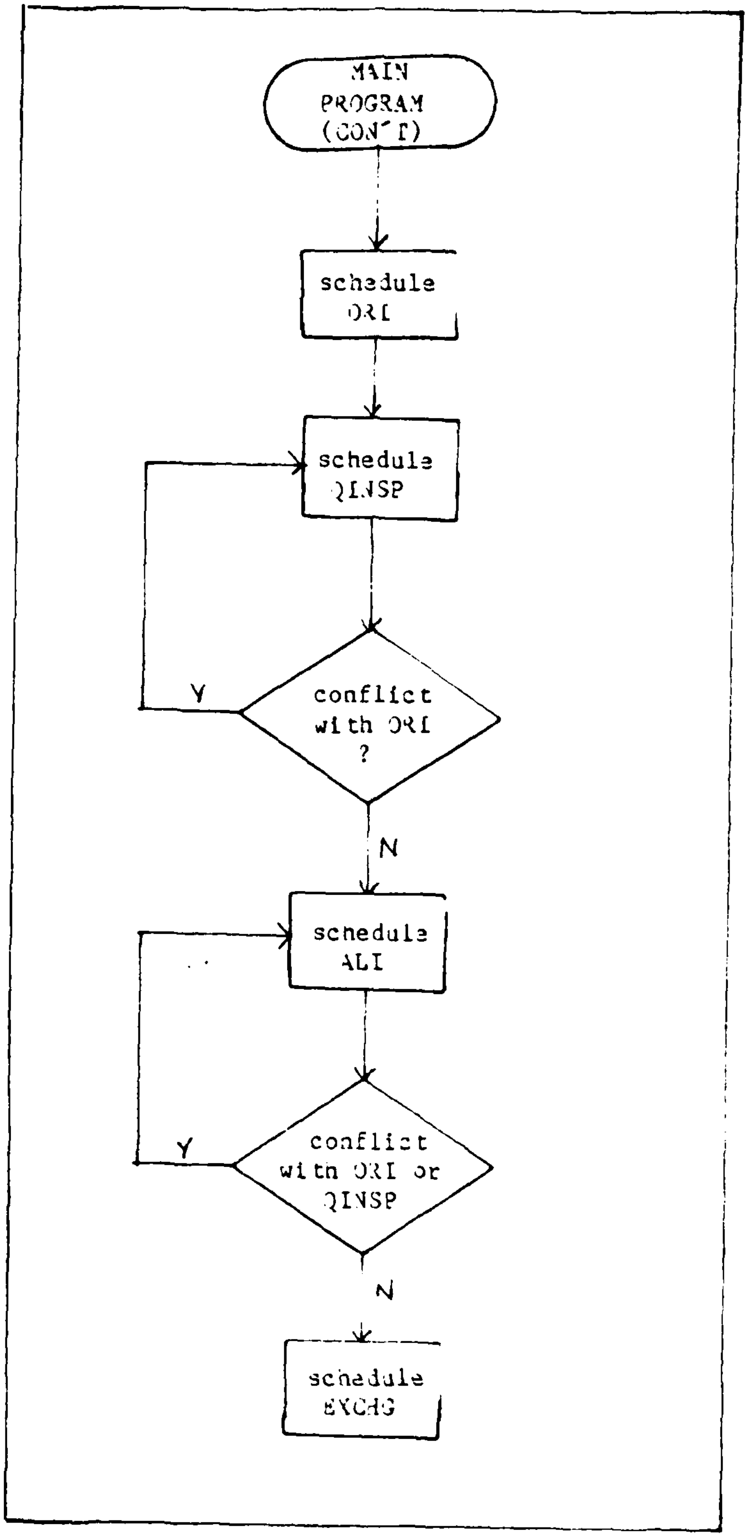


Figure 4. Flowchart for Main Program, Event Scheduling

inspection is rescheduled until after the generation exercise. The last event scheduled is the weekly status check of alert aircraft. This event (EXCHG) exchanges failed launchers and launchers that have been on alert for 90 days with launchers from storage or the IMF.

In addition to initializing the model and scheduling events, the FORTRAN code performs the availability checks and prints the results. Since availability is the number of launchers in working order at random points in time, the availability checks are conducted randomly once a month. The availability of launchers in storage and on alert aircraft are checked. The model does not count launchers with undetected storage failures as being available. The number of available launchers is computed to be the percentage of the 16 launchers that are actually in working order.

After scheduling the events to occur the FORTRAN code calls the SLAM input code which processes the events in chronological order. When an event is scheduled to occur the FORTRAN code is called to remove launchers from one file and place them into another file in the network where the processing of the event continues. For example, when an ORI is scheduled the FORTRAN code removes the launchers that are in storage from file 2 and puts them into file 3 where the network processes the launchers and upgrades them to alert status.

When an ORI or quarterly inspection exercise occurs all 11 aircraft not on alert must be readied and upgraded to alert status. Both inspections are collectively referred to as generation exercises. See Figure 5 for the flowchart for generation exercises.

During a generation exercise the launchers and two pylons are the last items loaded onto the aircraft. These are not loaded until all the other equipment has been loaded and verified as being operational. Once the aircraft is ready and a load crew and a MLT are available the launcher is loaded and each of the pylons are loaded onto the aircraft. The launcher which holds eight missiles is loaded into the bomb bay of the aircraft and the pylons which hold six missiles each are loaded onto the wings of the aircraft. Once the launcher or pylon is loaded the MLT is then returned to the storage area or to the IMF for loading of the next launcher or pylon. Once fully loaded on the aircraft a SIT test is performed to detect any failures on the launcher or the missiles. The SIT test can detect multiple failures; therefore, all failures are repaired before releasing the launcher for the next event. A SIT test is also performed on the pylons but this is not modeled. The pylons are partially modeled during generation exercises because they tie up two of the critical resources for the CSRL (load crews and MLTs) which affect the sortie generation rate for the CSRL. Otherwise, the pylons do not constrain the generation or the availability of the CSRL and are not modeled.

If a failure is detected on the launcher and the component is repairable on the flight line, it will be repaired on the spot. If the component can not be repaired on the flight line, the launcher or pylon will be transported to the IMF, loaded onto the ESTS (when one is available), repaired, and returned to the flight line to be loaded onto an aircraft.

If a missile has failed, one of two things can happen which is left to the discretion of the wing commander. Either the whole launcher (including missiles) is returned to the IMF to exchange the failed missile or the launcher is left in a degraded status. The first option

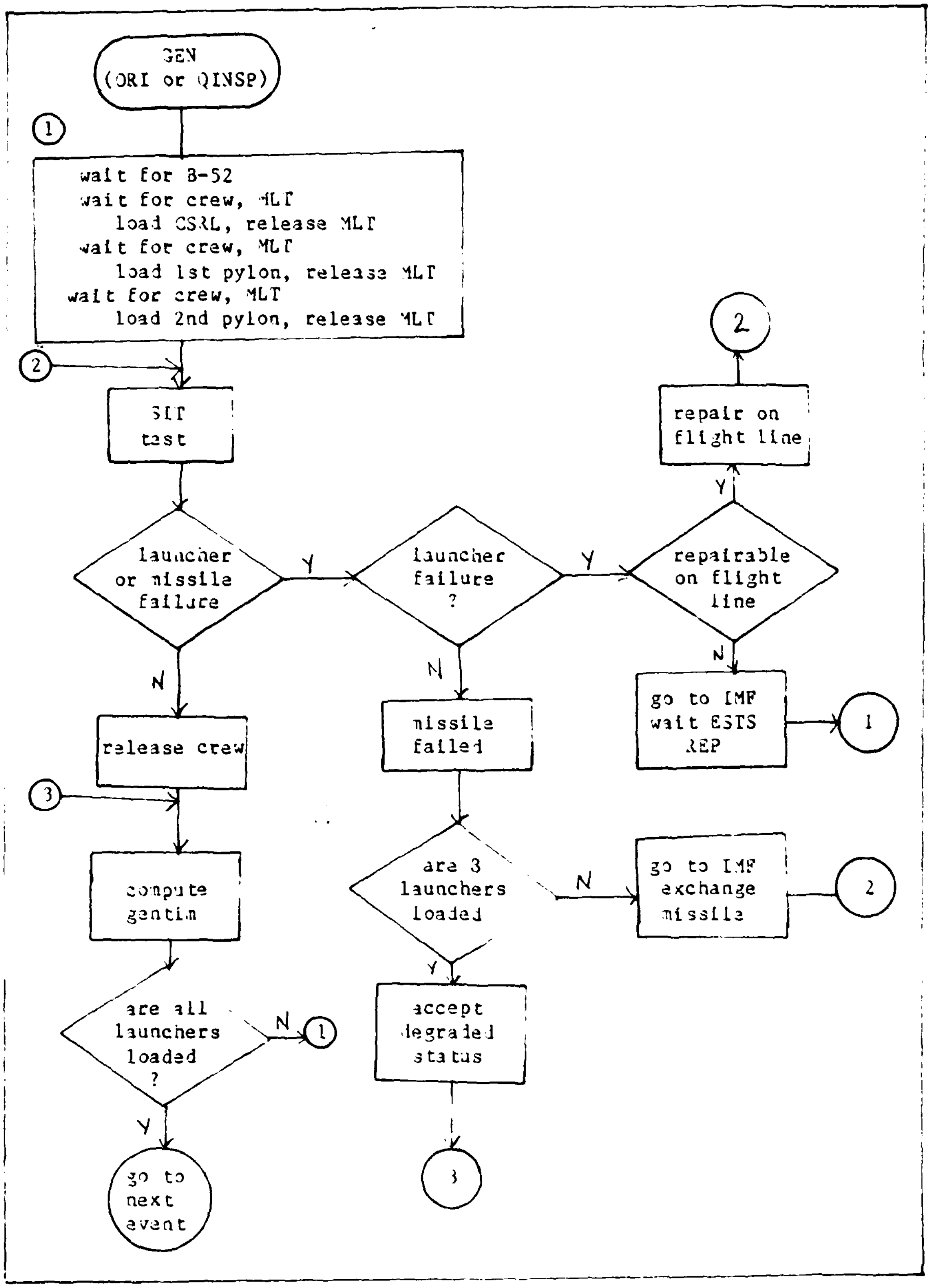


Figure 5. Flowchart for Generation (GEN) Subroutine

would normally occur early in the exercise while the last option would probably occur later in the exercise. The model assumes that this change in decision would occur halfway through the exercise after 8 of 16 launchers have been loaded. This seems like a reasonable assumption but may lead to an inaccurate prediction of availability and thus wartime capability, since at the end of the generation exercise all launchers and missiles are expected to be fully operational.

Once the launcher and pylons are fully loaded onto the aircraft and all have passed the SIT test, the network calls the FORTRAN generation report (GENRPT) subroutine which computes the time it took to generate the aircraft. This is the process followed to generate all aircraft for either an ORI or a quarterly inspection exercise (QINSP). The time to generate each aircraft and the total time to generate all 16 aircraft are used by the inspection team to rate the operational readiness of the unit.

Figure 6 shows the flow chart for the annual launcher inspection (ALI). When a launcher is scheduled for its annual inspection it is transported to the IMF where it waits for an ESTS to become available. Although it is not modeled, the inspection can not start until the inspection crew is available. This is not modeled because launcher inspections will occur during normal working hours when an inspection crew will be available. Once the ESTS is available, the launcher is loaded onto the test frame, the warheads are removed from the missiles, the missiles are downloaded from the launcher and an empty test is performed to check for any failures on the launcher. The missiles are also going through their annual inspection on another ESTS (this is not modeled because missile inspections are not constraining). Any failures

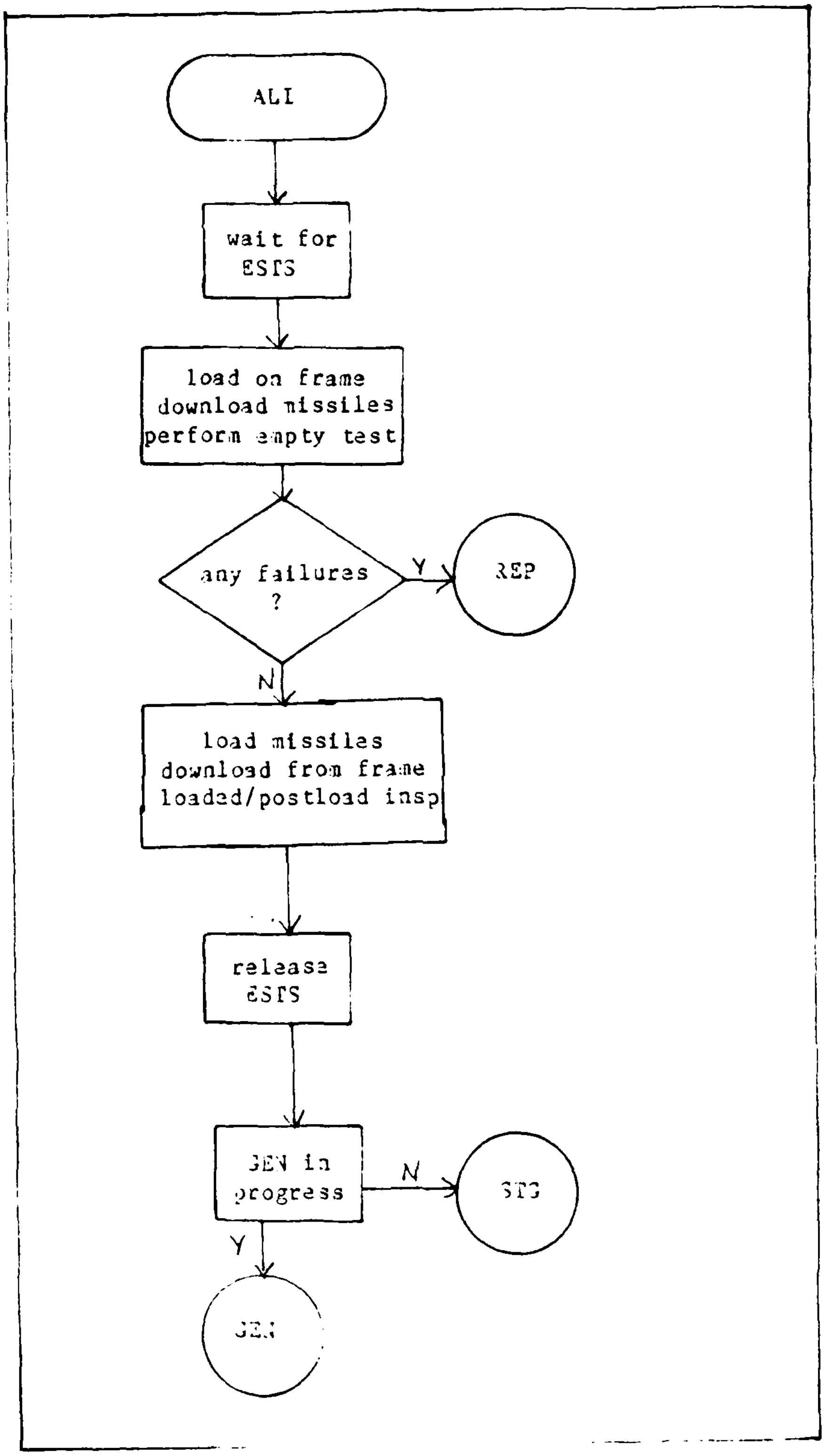


Figure 5. Flowchart for Annual Launcher Inspection (ALI) Subroutine

that are detected are then repaired. Once all repairs are completed the missiles are then reloaded onto the launcher, the launcher is downloaded from the frame and a loaded test or postload inspection is performed. Again, any failures that are detected are repaired. This completes the annual launcher inspection and the ESTS is released for use for other work.

The next event, Exchange (EXCHG), is shown in figure 7. The EXCHG event occurs every week unless there is a generation exercise in progress. Every week the launchers on alert aircraft are checked to see if they are still operational by performing a SIT test and they are also checked to see if their 90 day alert time has expired.

If the launcher is operational and it has been on alert for 90 days it is exchanged with a launcher from storage that is not scheduled for an annual launcher inspection within the next 90 days. The new alert launcher and two pylons are transported to the flight line, loaded onto the aircraft, and checked for failures (a SIT test is performed). If the launcher and missiles are operational a postload check is accomplished and the old launcher and pylons are taken off alert and sent to the IMF for a visual recertification before going back to storage. Otherwise, the failed launcher is removed and transported back to the IMF while another launcher is transported to the flight line.

If the launcher or missiles are found to be non-operational the launcher will be downloaded and sent to repair after another launcher is put on alert.

The three major events affecting the CSRL were modeled in sufficient detail in order to provide an experimental framework for which to test the critical factors affecting availability and sortie

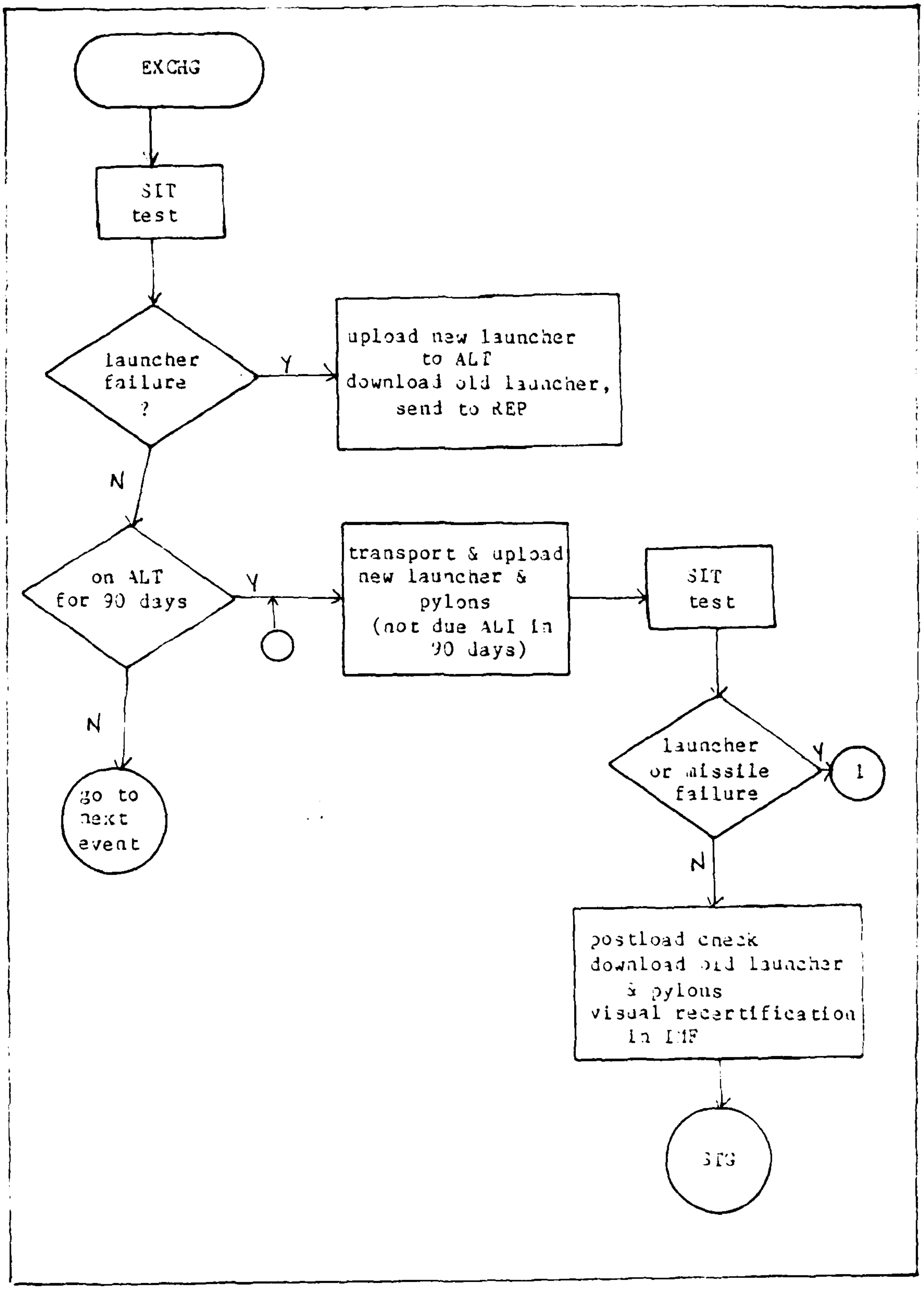


Figure 7. Flowchart for Exchange (EXCHG) Subroutine

generation time. However, certain assumptions were made that may affect the actual prediction of availability and sortie generation time.

Assumptions

In addition to the assumptions mentioned in the development of the model, the following assumptions were necessary to limit the scope of the CSRL system in order to focus on the major factors affecting availability and sortie generation time. These assumptions can be changed by modifying the computer code if further analysis requires such changes.

The major assumption in this model is that all other resources (ie. spare parts, flight line support equipment, and munitions) besides the ones explicitly specified in the model are noncritical. That is, they are available when needed and will not affect availability or sortie generation time.

A second assumption is that all component failures are of equal importance. This seems reasonable since launchers only have two states -- available or unavailable. Therefore, no single component receives priority maintenance.

Since there is no data available on the different failure rates, storage versus operational, they were modeled as being equal. Since storage failures remain undetected, whereas operational failures are detected and sent to repair the different rates would affect the true availability measure. Once the data becomes available it could easily be incorporated into the model which would give a more accurate prediction of availability.

Another assumption involves the load crew. The load crew is fully modeled during generation exercises when four crews are available around the clock. There are 2 12-hour shifts during generations. However, during normal operations the crew is not modeled because it is assumed that a load crew will be available when needed for loading launchers on alert aircraft or for loading launchers requiring annual inspections. This is a reasonable assumption because during normal operations the crew are scheduled for two eight-hour shifts for five days a week which coincides with when all the repair work and inspection work is scheduled.

Even with the limiting assumptions the scenario is still representative of a normal day-to-day operation as well as a typical generation operation and will be sufficient to meet the objectives of this study.

Flexibility

The CSRL model is inherently flexible due to the SLAM language and the modular way it was written. The SLAM code was separated into sections according to the function being performed. The functions include: checking for failed components, repairing failed components, generating aircraft (ORI and QINSP), performing post generation work, and performing launcher inspections. The FORTRAN program was broken into subroutines according to the events that the launchers go through. Because of its modularity the CSRL model can be easily expanded by adding events to the FORTRAN code. These events can be scheduled to occur at specific or random times in the initialization subroutine (INTLC). If new policies require incrementing existing resources or adding additional resources, these resources can be included in the SLAM code.

There are several internal options that can be initialized to different values before a run. These include level of repair, frequency of launcher inspections, number of crews, number of MLTs, number of ESTSs as well as any of the estimated parameters. All of the estimated parameters can also be made global variables in order to facilitate the experimental design.

In addition to changing input parameters and resources, the model is flexible enough to evaluate measures of effectiveness other than the ones chosen for this study. For example, the model could evaluate the fully mission capable (FMC) rate and the partially mission capable (PMC) rate of the CSRL by changing the generation report (GENRPT) subroutine in the main program to calculate and print the number of launchers loaded in a specific amount of time:

1. with all missiles functioning,
2. with at least five missiles functioning.

In addition to the standard SLAM output file, the model creates two user defined output files that aid in the analysis of the model results. The first output file contains the generation times for each launcher and the availability values taken randomly. This file is useful for monitoring the status of the generation exercises. The second output file records the average availability of the launchers for the simulation time and the average generation time for the launchers. This file is more useful than the average availability and generation values calculated by SLAM because it does not weight the statistics over time.

Data

This section briefly discusses the sources for the input data for the model. Most of the data came from four sources: Boeing Document No. D495-10350-1, Reliability/Maintainability Allocations, Assessment and Analysis Report - CSRL; AFLC D056 Data for SRAM Missile Work Unit Code (BA000), from 1 Oct 83 to 31 Mar 84; SAC maintenance personnel familiar with the SRAM rotary launcher system; and AFOTEC personnel familiar with both the SRAM rotary launcher and the specifications for the CSRL. None of the sources distinguished between storage failure rates and operational failure rates. The Activities Table in Appendix C lists most of the data and the data sources used in the model. The only data not included in this table are the mean time between failure (MTBF) rates for each subsystem. The values used are the predicted and allocated values from the Boeing report. The Boeing report only gives one MTBF for the electronic and electrical systems. Since the Missile Interface Unit (MIU) and the relay assembler can be repaired on the flight line, a MTBF for each component was calculated by using the Boeing MTBF and the percentage of failures for each component obtained from the D056 data. The MTBF rates used in the model are summarized in the MTBF Table in Appendix C. In addition, comments have been included in the model in Appendix B which lists the source for the particular data used.

Verification and Validation

The utility of this research effort depends heavily on the validity of the simulation model and on the assumptions on which it is based. Numerous methods have been developed to aid in the verification and validation process; most are informal subjective comparisons, while a few are formal statistical procedures (2:376-377). Verification and validation were conducted simultaneously and two steps were used to validate the projections of availability and sortie generation times for the CSRL. First, the SLAM simulation model was examined to verify that it operated as intended. Then the simulation results were examined for validity. The following sections describe both steps in further detail.

Verification

In order to verify that the simulation model behaved as intended two of the SLAM output options were used; trace and summary report. The SLAM trace routine lists the sequence in which activities are performed and portrays the decision, variable assignments, and branching that occurs at nodes. The trace was used at the beginning of the simulation and at times when major events occurred in order to verify that the simulation was starting out correctly and continuing to operate properly. The traces were thoroughly examined from various simulation runs and it showed that the simulation model accurately reflected the processing of the launchers through the various activities. Therefore it was concluded that the model performed as designed.

Validation

In order to validate the model it is necessary to examine the simulation results and compare it with reality. Comparing the model results with reality can be accomplished using subjective tests and/or objective tests. Subjective tests require the judgements of experts of the system, to determine the validity of the model and its output. Objective tests are more concrete and are used to compare the system's actual performance with the performance produced by the model. Since the CSRL is not yet operational, the validity cannot be checked with objective tests. Therefore only subjective tests were used to validate the model results. (2:335)

The degree of validity when using subjective tests is highly dependent on the acceptance by future users of the model, of the assumptions made and the extent to which the results agree with perceived expectations. Throughout the development of the model, the potential users of the model (AFOTEC) were conferred with to ensure that a realistic model was being built using reasonable assumptions and reliable data. The users concurred with the assumptions. The logic of the model was also checked by using extreme values for critical inputs. These include reliabilities, number of crews, number of MLTs, and type of management policy.

The availability measure seemed to be accurately portrayed when the critical factors were increased or decreased.

The sortie generation times when compared with expectations were a little high with variations of certain factors. This could be attributed to conservative estimates by maintenance personnel on the time to perform certain tasks on a system not yet operational. However, the sortie generation times did increase or decrease as expected when critical factors were changed.

The results from varying the inputs for the most part yielded reasonable output, consistent with expectations. Therefore, the model is considered valid.

V. Analysis and Results

Research Design

The purpose of this research is to evaluate how various factors effect availability and generation time while simultaneously considering variations in several estimated reliability and maintainability parameters. Using regression analysis, the relationships between availability and generation time (dependent variables) and the set of factors and interactions (independent variables) are quantified.

The four factors evaluated are: the number of load crews, the number of munitions lift trailers, the level of repair, and the frequency of launcher inspections. The estimated parameters are: time to load the launchers, time to exchange a missile, time to remove and replace a component on the flight line, and the mean time between failures for the seven subsystems. These MTBFs are combined into one parameter by calculating the MTBF of the launcher:

$$1/MTBF_{launcher} = \sum_{i=1}^{7} 1/MTBF_i$$

where

$MTBF_i$ is the MTBF of subsystem i
- 1 = structure
- 2 = power drive unit
- 3 = power drive unit controller
- 4 = missile interface unit
- 5 = relay assembler
- 6 = other electronic/electrical
- 7 = electronic control system

It is difficult to judge, without some preliminary analysis, which of the eight factors and 28 possible two-way interactions significantly impact availability and generation time. With so many potential independent variables a stepwise regression procedure would be necessary. A stepwise regression procedure, which is notorious for capitalizing on chance, ideally should have 40 times more cases than the number of independent variables.(16:92) Even if the interactions could be narrowed down to 8, through judgement and logic, the regression would require 640 (=16x40) runs.

By dividing the experimental design into two parts, the number of runs needed for the regression is reduced, since the number of factors and interactions simultaneously analyzed is reduced and the number of cases per independent variable is reduced from 40 to 20.

The initial set of runs is based upon a fractional factorial design which evaluates 8 factors at two levels and 28 first-order (two way) interactions. From this design, those factors and interactions which significantly affect the dependent variables were identified.

Once the independent variables which will most likely enter the regression equation have been identified, a regression procedure without the stepwise option can be used to develop a functional relationship between the dependent and independent variables. Without the stepwise option the regression procedure ideally should have 20 times more cases than the number of independent variables. (16:91)

Structural Model

The structural model is composed of three types of variables which include response variables, control variables, and stochastic variables. The following table lists by type the variables used in the model.

Table 1

Variables Used in Model

Response	Control	Stochastic
% of launchers available generation time	# of crews # of MLTs maintenance policy frequency of inspection	*failure rates *load times *remove/replace times **repair rates random avail checks inspection times

* launcher components and missiles
** launcher components only

Initial Run

The initial run was used for three purposes:

1) To test for autocorrelation in the availability checks,

2) To evaluate the warm-up period needed to avoid initialization bias,

3) To determine the number of observations needed in each run.

The initial run was for 20,000 hours (approximately 9 quarters) and it checked availability 57 times and generation time 11 times.

The existence of autocorrelation means that an observation is related to the previous observation. Since the number of observations needed is calculated using the assumption of independent observations, the presence of autocorrelation has the effect of overstating the sample size. In simulation autocorrelation can be reduced by increasing the amount of simulated time between observations. (2:434)

To test for autocorrelation, the SPSS regression package on the ASD Cyber computer was used. By requesting a plot of availability (AVAIL) versus time (TNOW) the program calculated a Durbin-Watson statistic. Initially, availability was checked randomly between 0 and 650 hours. The Durbin-Watson statistic was .931 which was clearly in the unacceptable range. Taking observations half as often decreased the number of observations to 29 and increased the Durbin-Watson statistic to 1.605. The acceptable range for this statistic with more than two variables and 29 observations is 1.58 to 2.42 (11:539). This indicated that with observations taken randomly between 0 and 1,300 hours, auto-correlation is not a problem.

To avoid having the observations biased because of initializing the failures at time zero, a warmup period of 720 hours was used. After 720 hours the network has completed several cycles. The status of the launchers on alert aircraft has been checked four times and repaired, if necessary, and the first launcher has gone through an annual inspection. From the results of the trialrun, the designated warmup period is considered more than adequate because the initial values obtained for both availability and generation time were neither the high, nor the low results.

Since availability and generation exercise time are stochastic processes and are checked at random points in time, the initial run was used to calculate the number of observations necessary for analysis. The number of observations needed is based on the variation in the observations of the initial run and the confidence that the sample mean is a good estimate of the population mean. This can be calculated using the following formula (2:439):

$$\text{number of observations: } N = [ts/g]^2$$

where

t is the t-statistic for confidence level α and n-1 degrees of freedom
s is the standard deviation of the sample
g is the half width of the confidence interval

A confidence interval of $\pm$ .02 for availability and an interval of $\pm$ 4 hours (~ 10% of 39.5 hours) for generation time were used in determining the number of observations needed for analysis. These values were considered adequate for an initial study effort when considering the uncertainty of the estimated parameters and the amount of computer time needed to achieve these results.

Table 2 contains the calculations for availability and generation time. To achieve the chosen confidence interval, the simulation time must be 1 year or 8,760 hours for generation time, but it must be 116 weeks (29 x 4) or 19,488 hours for availability.

Table 2

Calculations for Number of Observations

Availability	Generation Time
$n = 29, \ \alpha = .10$	$n = 11, \ \alpha = .10$
$t_{.10,28} = 1.31$	$t_{.10,10} = 1.37$
$\bar{x} = 37.93$	$\bar{x} = 37.93$
$s = .032$	$s = 39.5$
$d = .02$	$d = 4$
$N = \left[\frac{(1.31)(.032)}{(.02)}\right]^2$	$N = \left[\frac{(1.37)(6.3)}{4}\right]^2$
$N = 29$	$N = 5$

Fractional Factorial

Factorial designs are useful when there is more than one factor which affects the response variable. This type of design will measure the effects of the main factors and the interactions among these factors. With 8 factors, a full factorial design would require 2^8 or 256 combinations or runs of the model. However, it is not necessary to include all of these combinations to obtain enough information to answer the research questions posed in Chapter I.

A reduced factorial design is called a fractional factorial. By not including all possible combinations, "loss of information results from main effects and interactions being entangled [confounded] with other main effects and interactions" (17:1). But with properly chosen combinations these entanglements can be limited to higher order interactions. This is acceptable because "in many experiments, interactions among three or more factors can be considered negligible" (18:2).

Since the higher order interactions in this system should be negligible, this design is a one-fourth of a 2^8 factorial. This will provide information on the main factors and the first order interactions.

The design used was published as part of the National Bureau of Standard Applied Mathematics Series (18:2). The details are provided in Appendix D.

Results

The fractional factorial design was done using the BMDP2V statistical package on the ASD Cyber Computer. The data, input program and output table are included as Appendix E.

At the 90% confidence level there were three main effects which affected the availability: level of repair, frequency of inspections, and MTBF. In addition to these three main effects, the interaction of the number of crew, and the frequency of inspections affected availability.

At the 90% confidence level there were five main effects which affected generation time: number of crew, level of repair, time to load the launcher, time to remove and replace components, and MTBF. In addition to the main effects, the generation time is affected by the interactions with the number of crew and: level of repair, frequency of inspection, time to exchange a failed missile, and MTBF.

Regression Analysis

The fractional factorial design indicated that there are four potential independent variables needed to explain availability; nine needed to explain generation time. With 9 potential independent variables and 20 cases per independent variable, 180 runs are needed. The following are the factors that were varied and the names given to them for the rest of the analysis:

- number of load crews (CREW)
- level of repair (LEVEL)
- frequency of inspections (INSP)
- time to load the launcher (LOAD)
- time to remove and replace a component (COMP)
- time to exchange a missile (MISL)
- mean time between failures (MTBF)

When two terms interact, the effect of the first term is dependent upon the level of the second term and vice versa. This type of relationship can be represented be a cross-product term. (12:232) From the previous variables, the interaction variables were calculated:

CWXLEVL = crew x level
CWXINSP = crew x insp
CWXMSL = crew x misl
CWXMTBF = crew x mtbf

The names used during the rest of the analysis for the dependent variables are:

average percentage of available launchers (AVAIL)
sortie generation time (GENTIM)

The regression analysis was done using the SPSS statistical package on the ASD Cyber Computer. The input data, input program and summary output tables are included in Appendix E.

To determine if a linear relationship between the independent and dependent variables was appropriate, a scattergram function of SPSS was used to produce plots of each independent variable with the dependent variables. All the plots indicated linear relationships except the plot of AVAIL vs. MTBF. To obtain linearity, new variables were created by using logarithmic transformations:

$$LNMTBF = LN(MTBF)$$
$$LGMTBF = LG10(MTBF)$$

The scattergram function was rerun and the plot of AVAIL vs. LGMTBF appeared to have a linear relationship.

Availability

Availability can be explained with the following equation:

$$AVAIL = 1.034 + 0.395(LGMTBF) + 0.016(INSP)$$

where

Variable	Definition	Range
AVAIL	% of launchers available	
LGMTBF	log of the MTBF in years	.15,.51*
INSP	# of times each launcher is inspected per year	.54,2.13

*LGMTBF will be negative for this range of MTBF.

Almost 95% of the variation in availability can be explained by this regression equation. Although the initial results indicated that LEVEL and CWXINSP were significant, these did not enter the regression equation.

Generation Time

Generation time can be explained with the following equation:

$$\begin{aligned} GENTIM = 74.919 &- 2.738(CREW) + 2.051(LOAD) - 37.194(MTBF) \\ &- 5.317(LEVEL) - 0.171(CWXINSP) + 0.143(CWXMSL) \\ &+ 1.629(CWXMTBF) + 0.377(CWXLEVL) \end{aligned}$$

where

Variable	Definition	Range
GENTIM	generation time in hours	
CREW	# of crews	3,12
LOAD	most likely time in hours to load a launcher	1.0,1.5
MTBF	mean time between failures in years	.15,.51
LEVEL	level of repair (flight line repair =3, otherwise =2)	2 or 3
CWXINSP	# of load crews x frequency of inspections	.54,2.13.
CWXMSL	# of load crews x most likely time to exchange a missile	1.5,3.5.
CWXMTBF	# of load crews x MTBF	
CWXLEVL	# of load crews x level of repair	

This regression equation explains 75% of the variation in generation time. Although the initial results indicated that COMP was significant, it did not enter the regression equation. The easiest way to evaluate how much effect each of the factors being evaluated has, is to take the partial derivative and compute its value by holding the other factors at their high, most likely, and low values:

$$\frac{\partial GENTIM}{\partial CREW} = -2.798-0.171(INSP)+0.143(MISL)+1.629(MTBF)+0.377(LEVEL)$$

$$\frac{\partial GENTIM}{\partial LEVEL} = -5.317+0.377(CREW)$$

$$\frac{\partial GENTIM}{\partial INSP} = -0.171(CREW)$$

These effects are summarized in Tables 3 and 4.

Table 3

Effects of Unit Changes in Input Levels

	Change in GENTIM/Unit Change in Factor		
	high	medium	low
CREW	-1.8	-1.0	-0.5
LEVEL	-2.3	-1.5	-0.8
INSP	-2.0	-1.7	-1.4

Table 4

Effects of Potential Changes in Input Levels.

	potential change		change in gentim		
	from	to	high	medium	low
CREW	8	12	-7.2	-4.0	-2.0
LEVEL	2	3	-2.3	-1.5	-0.8
INSP	.5	2.0	-3.0	-2.5	-2.1

The results of this regression can be represented graphically with a contour map (15:613). The map shown in Figure 6 shows the contours for various combinations of number of crew, frequency of inspections, level of repair, and MTBF which are needed to achieve a 35 hour average generation time.

Figure 9 shows how to read the graph when the MTBF is .3 years (or 2,630 hours). The MTBF line intersect four contours, which means there are four possible combinations which yield the same generation time.

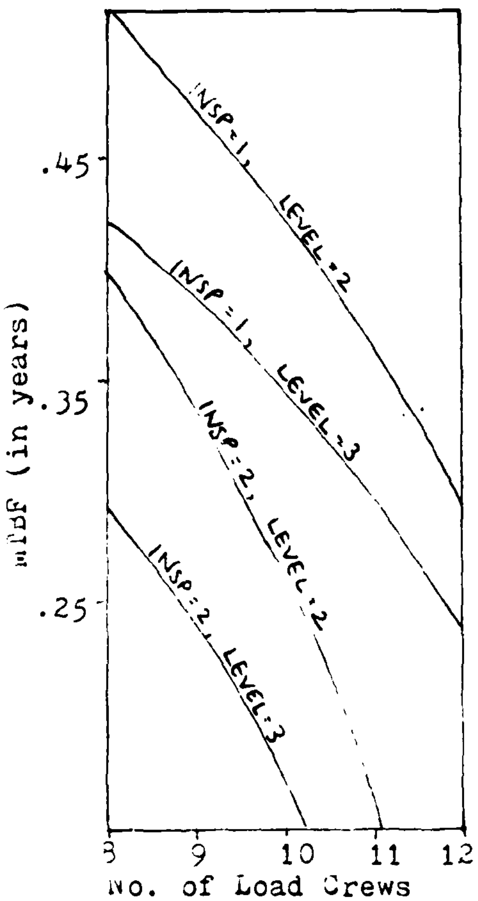


Figure 8. 35 Hour Gentim Contour Map

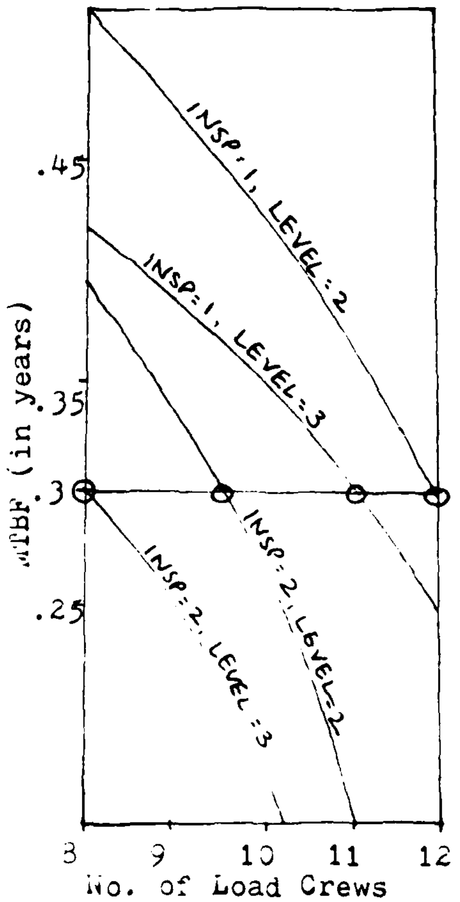


Figure 9. 35 Hour Contour Map at MTBF = .3

The combinations from Figure 9 are summarized in Table 5.

Table 5

Combinations Yielding a 35 Hour GENTIM (MTBF=.3)

	1	2	3	4
CREW	8	10	11	12
INSP	2	2	1	1
LEVEL	3	2	3	2

Contour Maps can be drawn for any level of GENTIM, and can be useful when dealing with the question "what is needed to achieve a specific generation time?"

VI. Conclusions and Recommendations

Conclusions

The research questions posed in Chapter I can be answered from the analysis in Chapter V.

1) What is the expected availability of the CSRL when used on the B-52 aircraft; when used on the B-1 aircraft? The average percentage of launchers in working order at any given time, using the failure rates predicted by Boeing, is .902 for the B-52 and .917 for the B-1. With less optimistic failures rates (Boeing's allocated rates) the availability drops to .746 for the B-52 and .848 for the B-1. The B-1 is higher because the power drive unit (PDU) and the PDU controller are considered a part of the aircraft, rather than part of the launcher.

2) What is the sortie generation time when used on the B-52; when used on the B-1? Using the maintenance concept and the current resources for the SRAM launcher as a baseline for prediction, the average sortie generation time predicted by the model is approximately 39.5 hours for the B-52 and 39.3 hours for the B-1. However, as mentioned in the validation section, the generation times appear to be about 10-20% too high. Although the availability of the B-52 was lower (caused by the PDU and PDU controller), this does not have much effect in the generation time. This is because failures on the PDU controller can be detected and repaired (if necessary) every time the aircraft is flown, whereas failures on the other subsystems are detected only during the generation exercises or inspections.

3) How much effect does the number of load crews have on the generation time? Of all the factors in this analysis, the number of

load crews can have the most significant impact. For every unit increase in the number of crews, there is a 1-5% decrease in the generation time. This decrease is more pronounced when the MTBF is low and/or when the maintenance concept does not permit flight line repair.

4) How much effect does the number of MLTs have on the generation time? The results of this analysis indicate that increasing the number of available MLTs above eight does not significantly reduce the generation time. Although a launcher might have to wait for an MLT at the weapon storage area, it may have to wait for a load crew or for a B-52, if an MLT were available and the launcher were transported to the flight line.

5) How much effect does the level of repair have on the generation time? Changing to a 3-level maintenance policy causes a 2-6% decrease in the generation time. The maximum decrease occurs when there are only eight load crews.

6) How much effect does the frequency of launcher inspections have on the generation time? Increasing the frequency of inspections from once a year to twice a year decreases the time by 3-5%. Decreasing the frequency to once every two years increases the time by 1-3%.

7) How much effect does the frequency of launcher inspections have on the availability? The regression equation indicates the frequency of inspections has an effect on the availability, but this effect is very small. Increasing the frequency from once a year to twice a year increases the average percentage of available launchers by less than 2%.

In summary, the number of load crews has the most impact on generation time. Trade-offs can be made among the number of crews, the level of repair and the frequency of inspections in order to achieve a specific generation time. Availability can be explained almost entirely as a function of MTBF, with the frequency of inspections having a slight impact.

Recommendations for Future Analysis

There are three areas which warrant more analysis - the number of MLTs, spare parts, and the frequency of inspections.

The fact that the number of MLTs did not affect the generation times, even though people who work with the system feel they are a limiting resource, may indicate that the MLTs were not modeled correctly or that the transport time estimates are too low. This area could be re-evaluated.

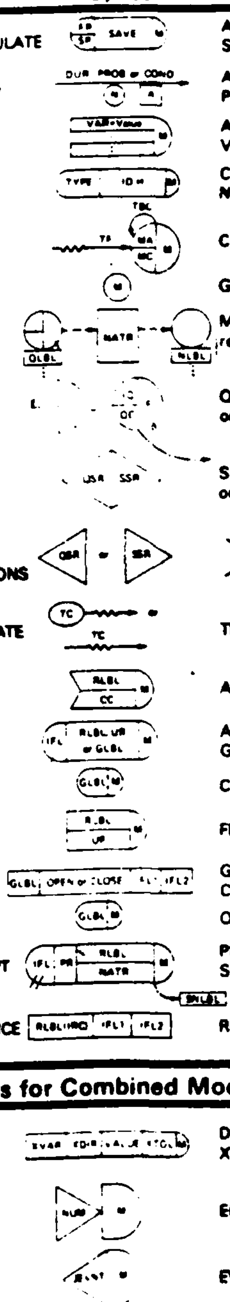
The inclusion of spare parts for the two components which can be removed and replaced on the flight line (MIU and relay assembler) could be added with minor changes to the network. The spare parts could be modeled as entities which would be held in a queue node until needed; a match node would match the spare with the launcher when a failure has occurred; the entity representing the failed spare would flow through a decision node which would represent whether the spare was to be repaired at the depot or at the IMF; after repair it would be routed back to the queue node.

The CSRL was modeled so that when the launcher was inspected, the missiles were inspected also. The fact that the frequency of periodic inspections had more effect on the generation time than the availability (which only checks the status of the launchers) indicates that the inspections had more of an impact on the missiles than on the launchers. The analysis could be repeated testing the effects of inspecting the missiles twice a year, but only inspecting the launchers once a year.

Appendix A

SLAM Network Symbols

SLAM Network Symbols and Statements for Discrete Modeling



Name	Statement
ACCUMULATE	ACCUMULATE, FR, SR, SAVE, M,
ACTIVITY	ACTIVITY (N) A, DUR, PROB or COND, NLBL,
ASSIGN	ASSIGN, VAR=VALUE, VAR=VALUE, M,
COLCT	COLCT, TYPE or VAR, ID, NCEL/HLOW/HWID, M;
CREATE	CREATE, TBC, TF, MA, MC, M,
GOON	GOON, M,
MATCH	MATCH, NATR, QLBL/NLBL, repeats . . . .
QUEUE	QUEUE (IFL), IQ, QC, BLOCK or BALK (NLBL), SLBLs,
SELECT	SELECT, QSR, SSR, BLOCK or BALK (NBL), QLBLs;
SELECT VARIATIONS	
TERMINATE	TERMINATE, TC;
ALTER	ALTER, RLBL/CC,M;
AWAIT	AWAIT (IFL), RLBL/UR or GLBL, M;
CLOSE	CLOSE, GLBL,M,
FREE	FREE, RLBL/UF, M;
GATE	GATE/GLBL, OPEN or CLOSE, IFLs,
OPEN	OPEN, GLBL, M,
PREEMPT	PREEMPT (IFL)/PR, RLBL, SNLBL, NATR, M;
RESOURCE	RESOURCE/RLBL (IRC), IFLs,

Nodes for Combined Modeling

Name	Statement
DETECT	DETECT,XVAR,XDIR,VALUE, XTOL,M;
ENTER	ENTER,NUM,M;
EVENT	EVENT,JEVNT,M;

List of variables/functions from which assignment values can be obtained.

Variable Function	Definition
Constant	A constant real value
TNOW	Current time
ATRIB(I)	Attribute I of current entity
SS(I)	Value of state variable I
DD(I)	Value of the derivative of state variable I
XX(I)	Value of global variable I
NNACT(I)	Number of active entities in activity I at current time
NNCNT(I)	The number of entities that have completed activity I
NNGAT(GLBL)	Status of gate GLBL at current time 0 → open, 1 → closed
NNRSC(RLBL)	Current number of units of resource type RLBL available
NNQ(I)	Number of entries in file I at the current time
STOPA(J)	Specifies the end of an activity upon a call to subroutine STOPA(J)
II	An integer global variable
USERF(I)	A sample obtained from the user-written function I
REL(I)	Specifies the completion of an activity upon release of node I

Definitions of some important discrete event variables.

Variable	Definition
ATRIB(I)	Buffer for the Ith attribute value of an entry to be inserted or removed from the file storage area
MSTOP	Set by the user to -1 to stop a simulation run before time TTFIN
NCLNR	The file number of the event calendar
NCRDR	The unit number from which SLAM input statements are read Normally set to 5 to denote the cardreader
NNRUN	The number of the current simulation run
NNSET	The dimension of the arrays NSET/QSET
NPRNT	The unit number to which SLAM output is to be written. Normally set to 6 to denote the lineprinter
NSET/QSET	Equivalenced arrays employed by SLAM for storing file entries
NTAPE	The unit number of a scratch tape
TNOW	The value of current simulated time
TNEXT	The time of the next scheduled discrete event
XX(I)	The Ith global variable. Time persistent statistics will be collected if XX(I) is specified on the TIMST input statement

Random Sampling Functions

Function	Definition
DRAND(IS)	A pseudo-random number
EXPON (XMEAN,IS)	A sample from an exponential distribution
UNFRM (ULO,UHI,IS)	A sample from a uniform distribution
WEIBL (BETA, ALPHA, IS)	A sample from a Weibull distribution
TRIAG (XLO,XMODE,XHI,IS)	A sample from a triangular distribution
RNORM (XMN,STD,IS)	A sample from a normal distribution
RLOGN (XMN, STD, IS)	A sample from a lognormal distribution
ERLNG (EMN,XK,IS)	A sample from an Erlang distribution
GAMA (BETA,ALPHA,IS)	A sample from a gamma distribution
BETA (THETA,PHI,IS)	A sample from a beta distribution
NPSSN (XMN,IS)	A sample from a Poisson distribution

SLAM Library of Subprograms

Subroutine COLCT (XVAL, ICLCT)
Subroutine COPY (NRANK, IFILE, A)
Subroutine FILEM (IFILE, A)
Function NFIND (NRANK, IFILE, NATR, MCODE, X, TOL)
Subroutine RMOVE (NRANK, IFILE, A)
Subroutine SCHDL (JEVNT, DT, A)
Subroutine STOPA(I)

Appendix B

CSRL Model and Output

This appendix contains the CSRL simulation model developed for this study. Both the input and output files are listed.

The first section lists the CSRL FORTRAN code which is composed of the following subroutines:

INTLC	EVENT	AVAIL
EXCHG	NEWALT	PDUCHK
ORIGEN	QTRGEN	ANINSP
AVGPRT	CHKMIS	CHKSCH

All of the subroutines are explained in the FORTRAN code.

The next section lists the CSRL SLAM code and the CSRL SLAM network diagrams. The SLAM code has been modularized into the following functions:

- simulation control statements - beginning
- definitions of variables, files, and resources
- storage (STG) and alert (ALT) queques
- repair network (REP)
- missile exchange network (EXCHG)
- generation network (GEN)
- post generation network (PSTG)
- annual launcher inspection (ALI) network
- shift network
- simulation control statements - ending

The last section lists the significant output generated by the CSRL model. The model generates three output files; "csrl.out", "csrlall", and "csrlavg". The "csrl.out" file is a SLAM generated output file which contains the following:

1. statistics for time-persistent variables
2. file statistics (queque and await files)
3. activity statistics
4. resource statistics
5. gate statistics (shift control gate)
6. table and/or plot of AVAIL vs TNOW

Only the statistics for items 1, 4, and 6 are included in this appendix.

The "csrlall" and "csrlavg" files are output files generated by the FORTRAN code. The "csrlall" file contains the generation times for each launcher and the availability values taken randomly. This appendix only lists a sample of the output contained in this file. The "csrlavg" file contains the average generation time and average availability for the simulation run time.

To run the CSRL model on the VAX 11/730 computer at AFIT, the user must first create the two FORTRAN files "csrlall" and "csrlavg", and compile the FORTRAN model. The compile command is given below:

```
f77 -c csrl.f&
```

The run command for the CSRL model is as follows:

```
slamlc -i csrl -m csrl.o -o csrl.out&
```

where

```
csrl is the SLAM input code,
csrl.o is the compiled FORTRAN code,
csrl.out is the output file the SLAM code writes to.
```

If the last option (-o csrl.out) is omitted from the run command, SLAM will write to a file called SLAMOUT.

```
**********************************************************************
*                                                                    *
*              Main program for csrl slam network                    *
*                                                                    *
*     Contents of Output Files:                                      *
*        CSRLAVG - this contains the average availability and        *
*                  the average generation times                      *
*        CSRLALL - this contains the generation times for each       *
*                  launcher, and the availability values taken       *
*                  randomly                                          *
**********************************************************************
      program main
      dimension nset(12000)
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common qset(12000)
      equivalence(nset(1),qset(1))
      equivalence(simend,xx(8))
      nnset=12000
      ncrdr=5
      open(8,file='csrlavg',status='old')
      open(9,file='csrlall',status='old')
      nprnt=6
      ntape=7
      open(7,status='scratch')
      call slam
      stop
      end
***********************************************************************
*                              INTLC                                  *
***********************************************************************

      subroutine intlc
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common/ucom1/nogen,totgen,avgen
      common/ucom2/avctr,totavl,avavl
      equivalence(simend,xx(8))
***********************************************************************
* variables:                                                          *
*  oinsp = ORI insp time                qinsp = qtrly insp time       *
*  qctr  = qtrly insp ctr               ali   = annual launcher insp time*
*  achk  = availability check time      simend= sim end time = xx(8)  *
*  altchk = alert time for schding      avchk = avail. time for schding *
*  bgyr  = time at beg of yr            bgqtr = time at beg of qtrs   *
*  k,l   = ctrs                         xx(i) = mean failure for ith part*
*  totgen= sum of generation times      totavl= sum of avail. checks  *
*  nogen = # of generations             avctr = # of avail. checks    *
*  avgen = average generation time      avavl = average availability  *
***********************************************************************
```

```
      real simend,oinsp,qinsp,ali,avchk,altchk
      integer k,l
       qinsp=0.0
       oinsp=0.0
       qctr =0.0
       bgqtr=0.0
       l=0
       k=0
       ali=0.0
       achk=0.0
       avchk=0.0
       altchk=0.0
       totgen=0.0
       nogen=0.0
       avgen=0.0
       avctr=0.0
       totavl=0.0
       avavl=0.0
***
***    assign launcher #,subsystem and missile failures for 16 launchers
***
       do 10 i =1,16
             atrib(1)=i
             do 20 j=6,13
                   atrib(j)=tnow+expon(xx(13),1)
 20          continue
             do 25 j=14,20
                   atrib(j)=tnow+expon(xx(j),1)
 25          continue
***    assign annual launcher inspection every 3 weeks***
       k=k+1
       atrib(2)=k*xx(7)
***    assign 5 launchers to alert aircraft that aren't due an annual
***    inspection for 90 days(file 3) - assign the rest to storage
***    (file 1)***
       if(l.lt.5.and.atrib(2).gt.2160.0) then
           atrib(4)=tnow-xx(7)*1
***        atrib(4) is the time the launcher went on alert***
           atrib(5)=3.0
           l=l+1
           call filem(3,atrib)
       else
           atrib(5)=0.)
           call filem(2,atrib)
       endif
 10    continue
****** end assigning atribs to launchers *****
******                 ******
****** schedule events ******
******                 ******
***    schedule to print averages ***
       call schdl(7,simend,atrib)
***    schedule first ori during second quarter ***
       oinsp=unfrm(2160.0,4320.0,6)
```

```
      call schdl(4,oinsp,atrib)
***   schedule subsequent ori's 10-15 months apart ***
 30   if(oinsp.le.simend)then
           oinsp=oinsp+unfrm(7320.0,10980.0,6)
           call schdl(4,oinsp,atrib)
           go to 30
      endif


***    schedule quarterly inspection ***
 40    if(qinsp.le.simend) then
          qinsp=bgqtr+unfrm(0.0,2160.0,6)
          evtlng=100.0
          call chksch(qinsp,evtlng)
          call schdl(5,qinsp,atrib)
          qctr=qctr+1.0
          bgqtr=qctr*2160.0
          go to 40
       endif

***    schedule annual launcher inspection
       k=0
 50    if(ali.le.simend) then
          k=k+1
          if (k.gt.100) then
             print*,'more than 100 inspections scheduled'
             go to 60
          endif
          ali=k*xx(7)
          evtlng=20.0
          call chksch(ali,evtlng)
          call schdl(6,ali,atrib)
          go to 50
       endif
***   schedule check and exchange  of alert launcher weekly (168 hrs)
***   launcher is exchanged after 90 days or if failure has occured***
 60   if(altchk.le.simend) then
         altchk=altchk+168.0
         call schdl(3,altchk,atrib)
         go to 60
       endif

***    schedule random availability checks***
 70    if(avchk.le.simend) then
          avchk=avchk+unfrm(0.0,1300.0,5)
          call schdl(1,avchk,atrib)
          go to 70
       endif

***    This section will print the event calendar by deleting "*" in
***    col 1.
*       next=mmfe(nclnr)
* 80    if(next.eq.0.0) go to 90
*       call copy(-next,1,atrib)
```

```
*        print*,'event code = ',atrib(xx(25)+1)
*        print*,'event time = ',atrib(xx(25)+2)
*        next=nsucr(next)
*        go to 80
* 90     continue

****    set up output file ***
        write(unit=9,fmt=100)
 100    format(1x,1x,'TNOW',3x,'AVAIL',3x,'# OBS',2x,'TOTAL',3x,'TNOW',
     +      3x,'# GEN',1x,'GENTIM',1x,'#OBS',' TOTAL')
       write(unit=9,fmt=110) xx(39),xx(40)
 110    format(1x,2x,2f5.4)
        return
        end

**********************************************************************
*                             event                                  *
**********************************************************************
        subroutine event(i)
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)

      equivalence(simend,xx(3))
      go to (1,2,3,4,5,6,7,8),i
 1    call avail
      return
 2    call genrpt
      return
 3    call exchg
      return
 4    call origen
      return
 5    call qtrgen
      return
 6    call aninsp
      return
 7    call avgprt
      return
 8    call ckmis
      return
      end


**********************************************************************
*                           AVAIL  (event 1)                         *
**********************************************************************
*     This subroutine checks the status of the launchers in storage  *
*   (file 2) and on alert(file 3) to see if any have failed; it      *
*   calculates the percent available.                                *
**********************************************************************
       subroutine avail
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
       common/ucom2/avctr,totavl,avavl
```

```
      equivalence(simend,xx(3))
      if (tnow.le.720.0.or.xx(12).gt.0.0) go to 50
****** Determine availabilty of launchers in storage *****
 1    next = mmfe(2)
      xx(1) = 0.0
 10   if (next .eq. 0.0) go to 20
******    have accessed last entry - search ends
      call copy(-next,2,atrib)
      do 12 i=14,20
         if(atrib(i).lt.tnow) go to 17
*         if component has failed its not avail, check next launcher
 12   continue
*         no failures for this launcher - increment # avail
      xx(1)=xx(1)+1.0
 17   next = nsucr(next)
      go to 10
 20   continue
*     determine avail of launchers on ALT
      next = mmfe(3)
 30   if (next .eq. 0.0) go to 40
******    have accessed last entry - search ends
      call copy(-next,3,atrib)
      do 32 i=14,20
         if(atrib(i).lt.tnow) go to 37
 32   continue
      xx(1)=xx(1)+1.0
 37   next = nsucr(next)
      go to 30
 40   continue
*     compute % avail
      xx(2) = xx(1)/16.0
*     update average avail
      avctr=avctr+1.0
      totavl=totavl+xx(2)
      avavl=totavl/avctr
      write(unit=9,fmt=200) tnow,xx(2),avctr,totavl
 200  format(1x,f6.0,2x,f5.3,2x,f3.0,2x,f7.3)
 50   continue
      return
      end
*************************************************************************
*                           GENRPT   (event 2)                          *
*************************************************************************
*     This subroutine calculates the time it took to generate each     *
*  aircraft and computes the average time to generate ll aircraft.      *
*************************************************************************
       subroutine genrpt
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common/ucom1/nogen,totgen,avgen
      equivalence(simend,xx(3))
       if (atrib(3) .eq. 1.0) then
*****        ORI GENERATION
             gentim=tnow-xx(22)
```

```
      endif
      if (atrib(3) .eq. 2.0) then
*****       QUARTERLY GENERATION
            gentim=tnow-xx(21)
      endif
      if(xx(3).gt.10.0) then
*          update average gentim
           nogen=nogen+1.0
           totgen=totgen+gentim
           avgen=totgen/nogen
      endif
      write(unit=9,fmt=300)atrib(1),tnow,xx(3),gentim,nogen,
     +  totgen
 300  format(1x,27x,f3.0,1x,f6.0,2x,f3.0,1x,f5.1,2x,i3,1x,f6.1)
      return
      end

*********************************************************************
*                           EXCHG    (event 3)                      *
*********************************************************************
*    This subroutine checks to see how long an aircraft has been on *
*  alert; if more than 90 days, it goes to storage and NEWALT is    *
*  called.  If less than 90 days, it is checked for failures.  All  *
*  the launchers are checked for pdu failures.                      *
*********************************************************************
      subroutine exchg
      common/scom1/atrib(100),dd(100),dd1(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ss1(100),tnext,tnow,xx(100)
      equivalence(simend,xx(8))
      if (xx(12).ge.1.0) go to 30
*     when GEN is in progress EXCHG is not performed
      call pduchk
*     check for pdu failures
      nochgd=0
*     check alt time for alt a/c & check all alt a/c for failures
  5   next=mmfe(3)
      if (next.eq.0) go to 10
      call rmove(-next,3,atrib)
      alttim=tnow-atrib(4)
      if (alttim.ge.2016.0) then
              atrib(5)=0.0
              nochgd=nochgd+1.0
              call filem(13,atrib)
      else
           call filem(13,atrib)
      endif
      go to 5
 10   continue
      if (nochgd.lt.1) go to 30
      do 20 i=1,nochgd
*        replace every a/c coming off alt with a new one
         call newalt
 20   continue
 30   continue
```

```
      return
      end
************************************************************************
*                          NEWALT                                      *
************************************************************************
*     This subroutine finds a launcher which is not due an annual      *
*  inspection in the next 90 days and removes it from storage(file 2)  *
*  and places it on alert(file 3).                                     *
************************************************************************
      subroutine newalt
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      equivalence(simend,xx(8))
      i=0
*     check storage for new alert a/c
      next=mmfe(2)
 10   continue
      call copy(-next,2,atrib)
      if (atrib(2).gt.tnow+2160.0) then
         call rmove(-next,2,atrib)
*        found launcher not due ALI in 90 days for ALT duty
         atrib(4)=tnow
         atrib(5)=3.0
         call filem(3,atrib)
         go to 20
      endif
      i=i+1.0
      if (i.gt.16) go to 20
*     error check- at most should check 16 launchers
      next=nsucr(next)
      go to 10
20    continue
      return
      end
************************************************************************
*                           PDUCHK                                     *
************************************************************************
*     This subroutine checks for pdu failures by removing the          *
*  the launcher from storage(file 2) and putting it in the network     *
*  (file 14).                                                          *
************************************************************************
      subroutine pduchk
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)

      equivalence(simend,xx(8))
*     checks launchers in storage for pdu failure
  5   next=mmfe(2)
  10  if (next.eq.0) go to 30
      call copy(-next,2,atrib)
      if (atrib(16).gt.tnow) then
          next=nsucr(next)
          go to 10
      else
```

```
*     failure detected - send to REP
         call rmove(-next,2,atrib)
         atrib(3)=1.0
         atrib(5)=5.0
         call filem(5,atrib)
   20  continue
xx(22)=tnow
       xx(3)=0.0
       go to 50
   40  print*,'******no launchers in storage when ori called',tnow
   50  continue
       return
       end
*************************************************************************
*                               QTRGEN   (event 5)                     *
*************************************************************************
*     This subroutine starts the generation by placing the launcher     *
*  in file 5.                                                           *
*************************************************************************
      subroutine qtrgen
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)

      equivalence(simend,xx(3))
       xx(12)=1.0
       xx(21)=tnow
       xx(3)=0.0
       k=nnq(2)
       if (k.eq.0) go to 40
       do 20 i=1,k
            call rmove(1,2,atrib)
            atrib(3)=2.0
            atrib(5)=5.0
            call filem(5,atrib)
   20  continue
       xx(21)=tnow
       xx(3)=0.0
       go to 50
   40  print*,'*****No launchers in storage for qtrgen*****'
   50  continue
       return
       end
*************************************************************************
*                               ANINSP  (event 6)                      *
*************************************************************************
*     This subroutine finds the launcher which is due an inspection    *
*  and puts it in the inspection part of the network(file 4).          *
*************************************************************************
      subroutine aninsp
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      equivalence(simend,xx(3))
      if (xx(12).ge.1.0) go to 50
*     when GEN is in progress, ANINSP is not performed
```

```
*     find the launcher due an annual inspection and send it to aninsp
      nrank=nfind(1,2,2,0,tnow,5.0)
*     searches for ALI time = tnow + 5
      if(nrank.eq.0.0) go to 40
      go to 43
 40   nrank=nfind(1,2,2,-2,tnow,5.0)
*     searches for ALI time < tnow
      if(nrank.eq.0.0)go to 45
*     sending launcher with atrib(2) = tnow  to be inspected
 43   call rmove(nrank,2,atrib)
*     remove from storage; assign next insp time based insp policy
      atrib(2)=atrib(2)+(16*xx(7))
      atrib(5)=4.0
      do 44 i=6,13
            if(atrib(i).lt.tnow) atrib(i)=tnow+expon(xx(13),1)
*           missile has failed & was detected & repaired during ali
*           assign next failure
 44   continue
      call filem(4,atrib)
*     send to ALI
      go to 50
 45   print*,' ******no launcher in stg with aninsp =',tnow
 50   continue
       return
       end
*************************************************************************
*                             AVGPRT  (event 7)                         *
*************************************************************************
*     This subroutine prints the averages for generation time and       *
*  availability.  It also prints a counter for run # and a code.        *
*************************************************************************
      subroutine avgprt
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common/ucom1/nogen,totgen,avgen
       common/ucom2/avctr,totavl,avavl

      equivalence(simend,xx(3))
      ctr=ctr+.01
      write(unit=8,fmt=200)
 200  format(1x,'# OBS',1x,' RUN CODE',1x,'AVGEN',1x,'AVAVL')
       write(unit=8,fmt=300)ctr,xx(39),xx(40),avgen,avavl
 300  format(2x,f4.3,1x,2f5.4,1x,f5.2,1x,f5.4)
      return
      end
*************************************************************************
*                             CHKMIS  (event 8)                         *
*************************************************************************
*     This subroutine checks for missile failures and counts how        *
*  many need repair.                                                    *
*************************************************************************
      subroutine chkmis
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
```

```
      equivalence(simend,xx(3))
      do 10 i=6,13
***   count # of missile failures & reassign failure time
          if(atrib(i).lt.tnow)then
             atrib(22)=atrib(22)+1.0
             atrib(i)=tnow+expon(xx(13),1)
          endif
 10   continue
      return
      end

**************************************************************************
*                              CHKSCH                                    *
**************************************************************************
*   This subroutine checks the event calendar for schedule conflicts.   *
*   Events are rescheduled based on a conservative estimate for the     *
*  longest generation time.   Events are scheduled so that nothing else *
*  occurs during a GEN exercise.                                         *
**************************************************************************
       subroutine chksch(time,evtlng)
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr
     1,ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)

      equivalence(simend,xx(3))
       next=mmfe(nclnr)
 10    if(next.eq.0) go to 20
       call copy(-next,nclnr,atrib)
*****  if evt code is .le. 0 then it is a system defined code so
*****  we want to ignore it for schdl conflicts
       if(atrib(xx(25)+1).le.0.0) go to 13
       evttim=atrib(xx(25)+2)
       if((evttim.le.time+evtlng).and.(time+evtlng.le.evttim+50.0))then
            time=evttim+51.0
       endif
 15    if((evttim .le. time) .and. (time .le. evttim+50.0))then
            time=evttim+51.0
        endif
 13    next=nsucr(next)
       go to 10
 20    continue
       return
       end
```

```
;*****************************************************************
;                  THIS IS THE CSRL SLAM INPUT CODE              *
;                                                                *
;  Variables xx(8) & xx(25) must be initialized in intlc stmt before*
;  running the  CSRL SLAM model.  xx(8) = simulation end time; must *
;  be set to the value declared in the INIT stmt (this is used to   *
;  schedule events for the entire simulation time).  xx(25) = MATR  *
;  which is the second value declared on the LIMITs card.           *
;*****************************************************************
gen,gjerstad and oyler,csrl,10/06/84,1,yes,no,yes,no,yes,72;
limits,21,23,300;
intlc,xx(1)=0.0,xx(2)=0.0,xx(3)=0.0,xx(4)=0.0,xx(5)=0.0,;
intlc,xx(6)=2.0,xx(7)=504.0,xx(8)=20000.0,
   xx(12)=0.0,xx(13)=11300.0;
intlc,xx(14)=120232.0,xx(15)=23090.0,xx(16)=10674.0,
   xx(17)=48016.0,xx(18)=83744.0,xx(19)=41971.0,xx(20)=23034.0;
intlc,xx(25)=23.0;
record,tnow,time,0,b,640.0,720.0,,yes;
var,xx(2),a,availability,0,1;
timst,xx(1),launchers avail;
timst,xx(2),availability;
timst,xx(3),avail in gen;
timst,xx(5),time completed;
network;
;*****************************************************************
;
;    Variables:
;     xx(1) launchers available (in storage & on alert aircraft)
;     xx(2)  % of launchers available
;     xx(3)  # of launchers available at end of generation
;     xx(4)  tnow, used to calculate end of generation
;     xx(5)  time to complete generation exercise
;     xx(6)  maintenance policy (1= flt line remove & replace,
;                                2= no flt line repair)
;     xx(7)  time between annual launcher inspections
;     xx(8)  simulation end time, used for scheduling = simend
;     xx(12) flag for generation exercises
;            0.0 = no generation exercises in progress
;            1.0 = generation exercise is in progress
;     xx(13) missile  mean failure rate = 11300.0,used for atrib(6-13)
;                  est. from AFOTEC
;     xx(14) to xx(20) mean failure rates - Boeing estimates
;     xx(14) structure mean = 120232.0
;     xx(15) power drive unit = 23090.0
;     xx(16) power drive unit controller = 10674.0
;     xx(17) missile interface unit = 48016.0
;     xx(18) relay assembly = 83744.0
;     xx(19) other electronic/electrical = 41971.0
;     xx(20) electronic control system = 23034.0
;     xx(21) quarterly inspection time
;     xx(22) ori inspection time
;     xx(23) time ests is available for use
;     xx(24) time ests is unavailable for use = 24.0 - xx(23)
;     xx(25) matr
```

```
;
;

Atributes:
;
;    (1)  launcher number
;    (2)  time of launcher yearly inspection on ESTS
;       (a launcher is inspected approx every 3 wks = 504 hrs)
;    (3)  is a code for type of generation
;    (4) is the time an launcher went on alert
;    (5) is the file a launcher should be returned to after repair
;           0.0 - stg queue        4.0 - in repair
;           3.0 - alt queue        5.0 - done (in gen network)
;     (6) time of failure for missile 1
;     (7) time of failure for missile 2
;     (8) time of failure for missile 3
;     (9) time of failure for missile 4
;    (10) time of failure for missile 5
;    (11) time of failure for missile 6
;    (12) time of failure for missile 7
;    (13) time of failure for missile 8
;    (14) time of structure failure
;    (15) time of power drive unit failure
;    (16) time of PDU controller failure
;    (17) time of missile interface unit failure
;    (18) time of relay assembly failure
;    (19) time of other electrical/electronic failure
;    (20) time of environmental control system failure
;    (21) # of failures found at one time
;    (22) # of non-working missiles during generation
;    (23) # of failed missiles left unexchanged during generation
;
;    Files:
;      1 - waiting for alt for missile exchg
;      2 - in storage queue until scheduled to go elsewhere
;      3 - sent from storage to alert (alt)
;      4 - sent from storage to annual inspection (ali)
;      5 - sent from storage to generation exercise
;      6 - waiting for alt for electronic repair
;      7 - shift clock gate
;      8 - crew
;      9 - ests
;      10- waiting for alt
;      11- waiting for alt
;      12- waiting for alt
;      13- waiting for alt for structure repair
;      14- pdu queue
;      15- waiting for ests (dummy after generation exercise)
;      16- waiting for ests
```

```
;        17- waiting for ests
;        18- repair queue
;        19- waiting for mlt for acs repair
;        20- waiting for mlt for miu repair
;        21- waiting for mlt for relay assembly repair
;
;     Random Number Streams:
;        1 - failures                4 - transport
;        2 - repair times            5 - availability clock
;        3 - load times              6 - inspections
;                                    7 - ests shift clock
;
;     Events:
;       1 - availability check         5 - ori exercise
;       2 - generation report          6 - annual launcher inspection
;       3 - exchange alert launcher    7 - average gentim & avg avail
;       4 - ori exercise               8 - checks missile failures
;*******************************************************************

      resource/crew(4),8;
      resource/mlt(9),21,20,1,19,13,12,11,10,6;
      resource/ests(1),15,17,16,9;
      gate/shft,open,7;
;
;    Storage Network - The launchers are stored here until scheduled
;      for a generation exercise, an annual inspection, or until they
;      are needed on alert.
;
 stg  queue(2);
;
;   Alert Network - 5 launchers remain on alert.  Every week they
;      are checked (evt3) for repairs and for length of time on alert.
;
 alt  queue(3);
;
;     Repair Network
; The repair network identifies the type of failure and whether it can
; be repaired on the flight line.  If so, the launcher is repaired or a
;single missile is exchanged, the launcher is uploaded, and returns to
;the point where the Systems Interface Test is performed (g31). If not,
;it must be returned to the IMF and repaired.
;
 chk  queue(13);
      act;
      goon,1;
      act/1,,atrib(14).lt.tnow,rep1;
      act/2,,atrib(15).lt.tnow,rep2;
      act/3,,atrib(17).lt.tnow,rep4;
      act/4,,atrib(18).lt.tnow,rep5;
      act/5,,atrib(19).lt.tnow,rep6;
      act/6,,atrib(20).lt.tnow,rep7;
      act;
  ckm event,3; determines # of missile failures
      goon,1;
```

```
     act/7,,atrib(22).gt.0.0,gnis; there are failed missiles
     act;
 pdu queue(14); checked once a week
     act/8;
     goon,1;
     act/9,,atrib(16).lt.tnow,rep3;
     act,,,ok;
ok   goon,1;
     act/10,,atrib(5).eq.3.0,alt;
     act/11,,atrib(5).eq.5.0,done;
     act/12,,atrib(5).eq.0.0,stg;
repl goon,1;
     await(13),mlt,1;
     act/13,unfrm(1.25,1.5,4);     Transport time back to IMF.
     goon;
     act/14,triag(6.0,8.0,10.0,2);   download and upload missiles
     goon;
 asl act/15,triag(1.9,2.4,2.9,2);  structure repair, D056 data
     assign,atrib(14)=tnow+expon(xx(14),1),atrib(21)=atrib(21)+1.0;
     free,mlt/1,1;
     act,,,chk;
rep2 assign,atrib(15)=tnow+expon(xx(15),1),atrib(21)=atrib(21)+1.0;
     goon;
     act/16,triag(3.5,4.5,6.0,2),,chk; repair
rep3 assign,atrib(16)=tnow+expon(xx(16),1);
     goon,1;
     act/17,triag(3.5,4.5,6.0,2),atrib(5).eq.0.0,stg; repair
     act/18,triag(3.5,4.5,6.0,2),,chk; repair
rep4 assign,atrib(17)=tnow+expon(xx(17),1),atrib(21)=atrib(21)+1.0;
     goon,1;
     act/19,,xx(6).ge.2.0,rp4a;
     act/20,triag(3.0,6.0,9.0,2);remove and replace missiles for access
     goon;
     act/21,triag(1.0,1.5,2.0,2),,chk; r/r MIU, wag
rp4a await(20),mlt,1;
     act/22,unfrm(1.25,1.5,4);
     goon;
     act/23,triag(3.0,6.0,9.0,2);
     goon;
     act/24,triag(1.0,1.5,2.0,2); r/r relay assblr, wag
fm0  free,mlt/1,1;
     act,,,chk;
rep5 assign,atrib(18)=tnow+expon(xx(18),1),atrib(21)=atrib(21)+1.0;
     goon,1;
     act/25,,xx(6).ge.2.0,rp5a;
     act/26,triag(3.0,6.0,9.0,2);remove and replace missiles for access
     goon;
     act/27,triag(1.5,2.0,3.0,2),,chk; remove and replace relay ass.
rp5a await(21),mlt,1;
     act/28,unfrm(1.25,1.5,4);
     goon;
     act/29,triag(3.0,6.0,9.0,2);
     goon;
fm00 act/30,triag(1.5,2.0,3.0,2);
```

```
      free,mlt/1,1;
      act,,,chk;
 rep6 await(6),mlt,1;
      act/31,unfrm(1.25,1.5,4); back to IMF
      goon;
      act/32,triag(3.0,6.0,9.0,2); remove and replace missiles
      goon;
      act/33,triag(10.3,13.8,16.8,2); repair electrical
 as2  assign,atrib(19)=tnow+expon(xx(19),1),atrib(21)=atrib(21)+1.0;
      free,mlt/1,1;
      act,,,chk;
 rep7 await(19),mlt,1;
      act/34,unfrm(1.25,1.5,4); back to IMF
      goon;
      act/35,triag(3.0,6.0,9.0,2); remove and replace missiles
      goon;
 as3  act/36,triag(3.5,4.5,6.0,2); repair ecs, est from D056 data
      assign,atrib(20)=tnow+expon(xx(20),1),atrib(21)=atrib(21)+1.0;
      free,mlt/1,1;
      act,,,chk;
;                                   Missile Exchange
;     This network exchanges a failed missile on the flight line.
;
 gmis goon,1;
      act/37,,xx(3).ge.3.0,lvms;
      act/38,,xx(6).eq.1.0,gms1;
      act/39,,xx(6).eq.2.0,gms2;
 gms1 goon;
      act/40,triag(xx(33),xx(34),xx(35),3);time to exchange 1 missile
      assign,atrib(22)=atrib(22)-1.0,1;
      act/41,,atrib(22).gt.0.0,gms1;
      act,,,chk;
 lvms assign,atrib(23)=atrib(23)+1.0,atrib(22)=atrib(22)-1.0,1;
      act/43,,atrib(22).gt.0.0,lvms;
      act,,,chk;
 gms2 await(1),mlt,1;
      act/44,unfrm(1.25,1.5,4);      transporting  to/from to imf
 g3   goon;
      act/45,triag(2.5,3.0,3.5,3); exchg 1 msl, est from SAC base
      assign,atrib(22)=atrib(22)-1.0,1;
      act/46,,atrib(22).gt.0.0,g3;
      act;
 fm01 free,mlt/1,1;
      act,,,chk;
;
;                                 Generation Network
;
;      This group of networks is used to estimate the time to generate
;all 16 aircraft (representing the ORI and the quarterly readiness
;inspections.
;
 gen  queue(5);
      act(1)/47,triag(1.0,2.0,4.0,4);  waiting for b-52.
 aw3  await(3),crew/1;
```

```
awl0 await(10),mlt/1;
     act/48,triag(.75,1.0,1.25,3);  estimate from SAC base
g20  goon,2;
     act/49,,,awl1;
     act/50,unfrm(1.25,1.5,4);  delay for mlt, estimate from SAC base
fm1  free,mlt/1,1;
     term;
awl1 await(11),mlt/1;
     act/51,triag(1.0,1.25,1.5,3); pylon
     goon,2;
     act/52,,,awl2;
     act/53,unfrm(1.25,1.5,4);  delay for mlt, estimate from SAC base
fm2  free,mlt/1,1;
     term;
awl2 await(12),mlt/1;
     act/54,triag(1.0,1.25,1.5,3); estimate from SAC base
     goon,2;
     act/55,,,g21;
     act/56,unfrm(1.25,1.5,4);  delay for mlt, est. from SAC base
fm3  free,mlt/1,1;
     term;
g21  goon;
     act/57,1.5,,chk;                    SIF
;    At this point an aircraft is finished and the number available
; (xx(3)) can be incremented, the time to generate is computed in
; event2.
done goon;
     act/58,triag(.75,1.0,1.5,3); postload, est. from SAC base
fc1  free,crew/1,1;
asl0 assign,xx(3)=xx(3)+1.0,xx(4)=tnow;
     goon,1;
     act/59,,xx(21).gt.xx(22),asl5;
     act/60,,xx(22).gt.xx(21);
asl4 assign,xx(5)=xx(4)-xx(21);
     act/61,,,evt2;
asl5 assign,xx(5)=xx(4)-xx(22);
evt2 event,2;
     goon;
     act/62,,,pstg;
;
;    post generation
;
pstg goon;
     act/63;
     assign,atrib(5)=0.0,atrib(21)=0.0,atrib(22)=0.0,atrib(23)=0.0;
     goon,2;
     act/64,,,stg;
     act/65,,xx(3).le.10,trm;
     act/66,,xx(3).gt.10;
asl6 assign,xx(12)=0.0;   generation exercise is over
     await(15),ests/1,1;  delay other work
     act/67,34.0;
fe1  free,ests/1,1;
trm  term;
```

```
;
;     annual launcher inspection
;
 ali  queue(4);
      act/68,,,aw7;
 fe2  free,ests/1,1;
 aw7  await(7),shft,1;
 aw2  await(9),ests/1,1;                      wait for ests
      act/69,,nngat(shft).eq.1.0,fe2;
      act/70,,nngat(shft).eq.0.0;
 g22  goon;
      act/71,triag(.75,1.0,1.25,6);                upload to ests
      goon;
      act/72,triag(6.0,8.0,10.0,6);  download missiles
      goon;
      act/73,triag(12.0,12.5,13.0,6);  empty test
 fe3  free,ests/1,1;
 aw7a await(7),shft,1;
 aw16 await(16),ests/1,1;                     wait for ests
      act/74,,nngat(shft).eq.1.0,fe3;
      act/75,,nngat(shft).eq.0.0;
 get  goon,1;
      act/76,triag(1.9,2.4,3.4,2),atrib(14).lt.tnow,asa1;
      act/77,triag(3.5,4.5,6.0,2),atrib(15).lt.tnow,asa2;
      act/78,triag(3.5,4.5,6.0,2),atrib(16).lt.tnow,asa3;
      act/79,triag(6.4,7.4,8.9,2),atrib(17).lt.tnow,asa4;
      act/80,triag(5.2,6.2,7.7,2),atrib(18).lt.tnow,asa5;
      act/81,triag(10.8,13.8,16.8,2),atrib(19).lt.tnow,asa6;
      act/82,triag(3.5,4.5,6.0,2),atrib(20).lt.tnow,asa7;
      act;
 fe4  free,ests/1,1;
 aw9  await(7),shft,1;
 aw17 await(17),ests/1,1;                     wait for ests
      act/83,,nngat(shft).eq.1.0,fe4;
      act/84,,nngat(shft).eq.0.0;
 g23  goon;
      act/85,triag(6.0,8.0,10.0,6);  upload and SST
      goon;
      act/86,triag(2.5,3.0,3.5,6);   loaded test
      goon;
      act/87,triag(6.0,8.0,10.0,6);  load warheads
      goon;
      act/88,triag(2.0,2.5,3.0,6);download from frame and postload insp.
fe5   free,ests/1,1;
      act;
      assign,atrib(5)=0.0;
      act/89,,xx(12).eq.0.0,stg;    go to stg, no gen in progress
      act/90,,xx(12).eq.1.0,gen;    gen exercise in progress, go to gen
 asa1 assign,atrib(14)=tnow+expon(xx(14),1),1;
      act/91,,,get;
 asa2 assign,atrib(15)=tnow+expon(xx(15),1),1;
      act/91,,,get;
 asa3 assign,atrib(16)=tnow+expon(xx(16),1),1;
      act/91,,,get;
```

```
 asa4 assign,atrib(17)=tnow+expon(xx(17),1),1;
      act/91,,,get;
 asa5 assign,atrib(18)=tnow+expon(xx(18),1),1;
      act/91,,,get;
 asa6 assign,atrib(19)=tnow+expon(xx(19),1),1;
      act/91,,,get;
 asa7 assign,atrib(20)=tnow+expon(xx(20),1),1;
      act/91,,,get;
;
;    shift network
;
      create;
 gt4  close,shft;
      assign,xx(23)=unfrm(8.0,10.0,7),xx(24)=24.0-xx(23);
      act/92,xx(24),xx(12).eq.0.0;
      act/93,0.0,xx(12).eq.1.0;
 ogt4 open,shft;
      act/94,xx(23),,gt4;
;
;*****************************************************************
      endnetwork;
;     simulation time for CSRL model = 20,001.0 hours = 833 days
;     = 2.28 years
init,0,20001.0;
montr,clear,720.0;
fin;
```

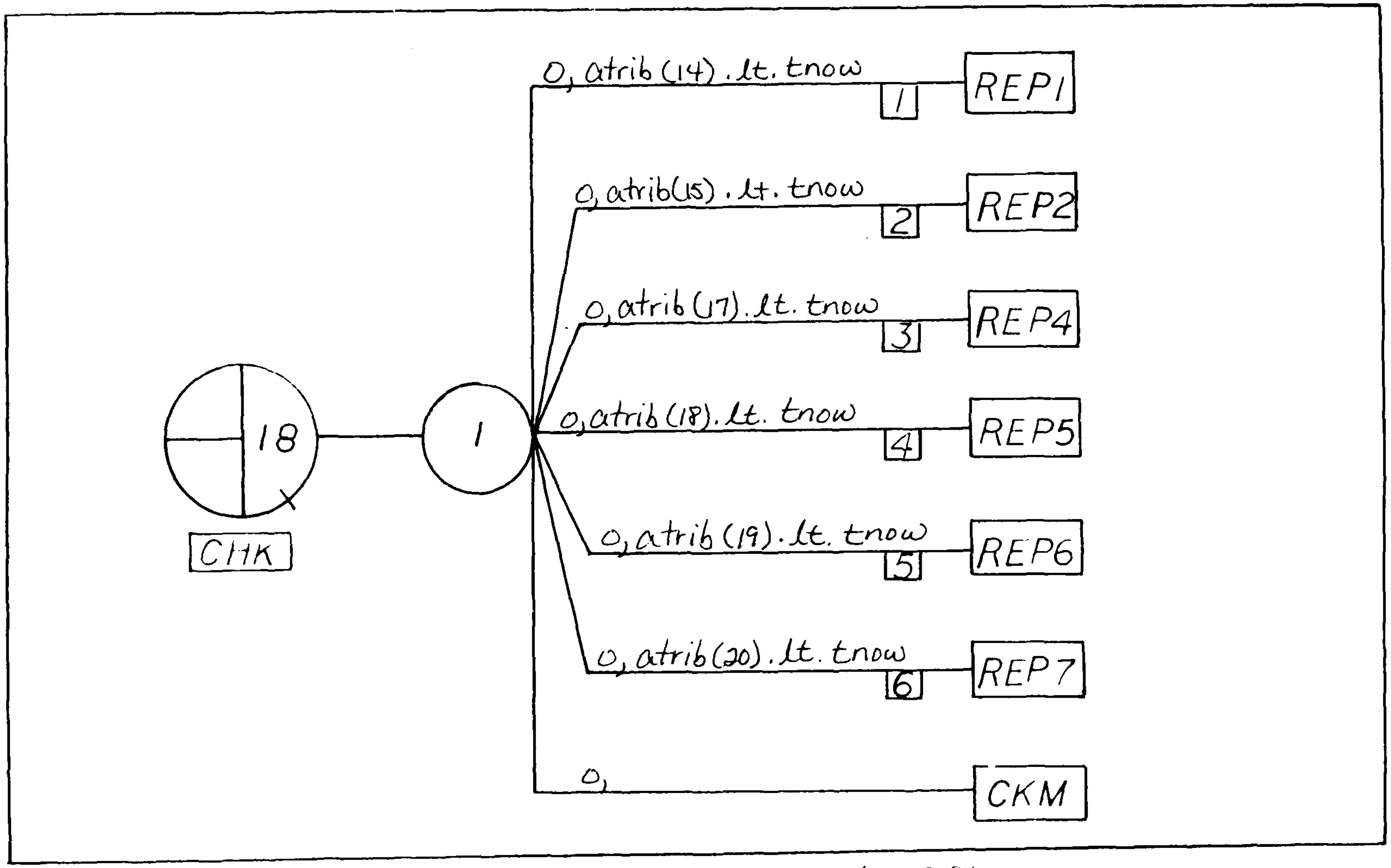


Figure B.1. Repair Network (1 of 8)

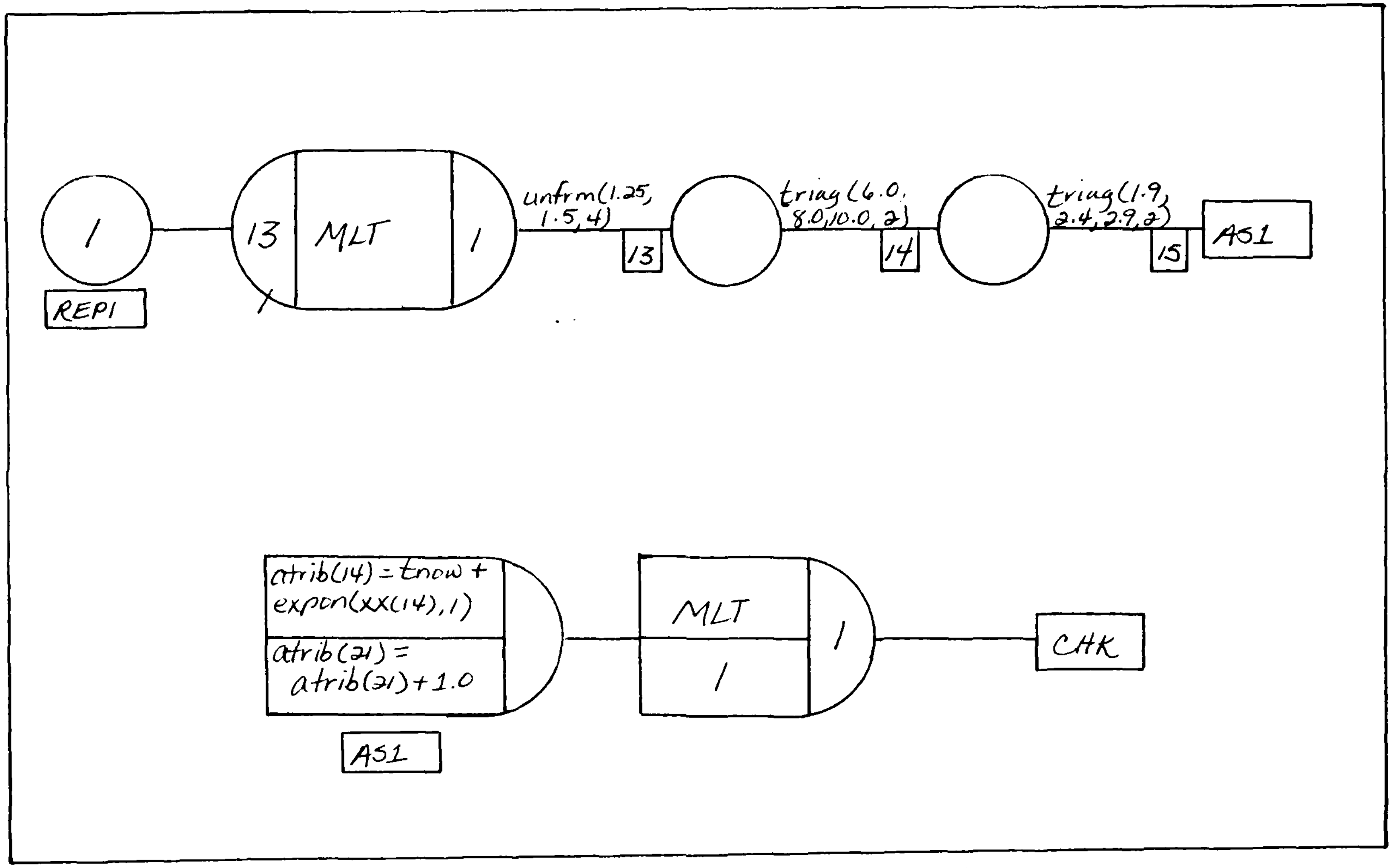


Figure B.2. Repair Network (2 of 8)

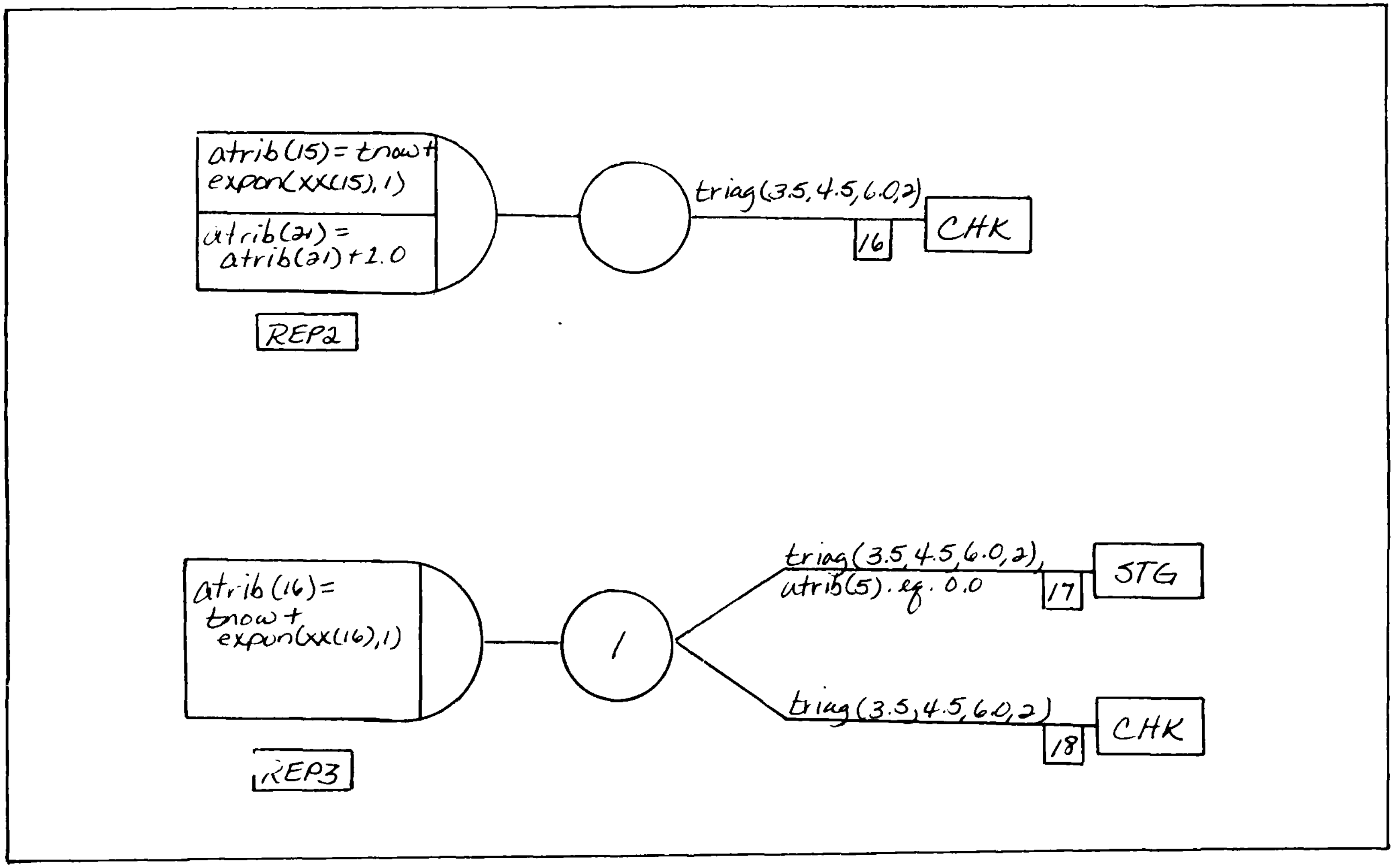


Figure B.3. Repair Network (3 of 8)

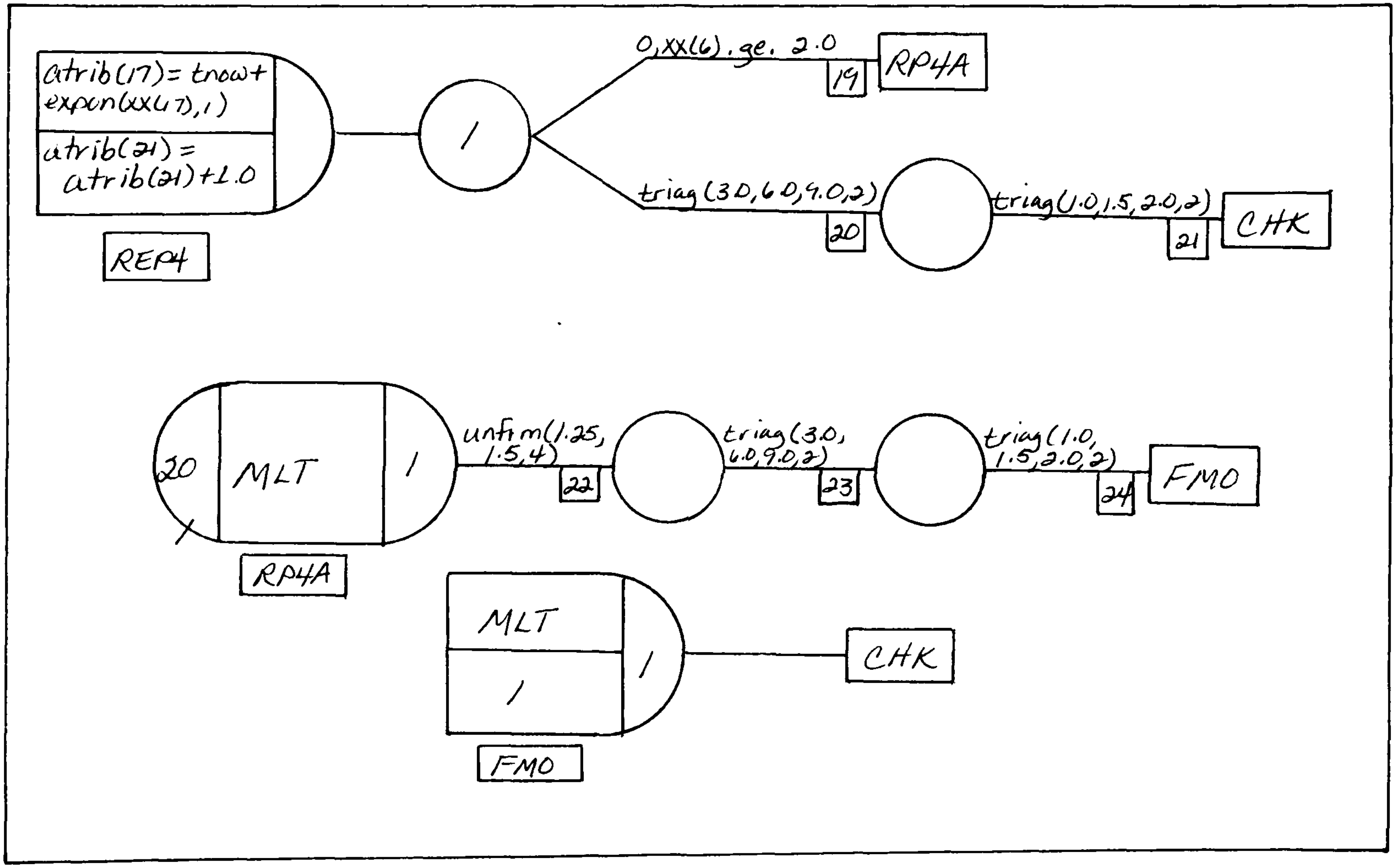


Figure B.4. Repair Network (4 of 8)

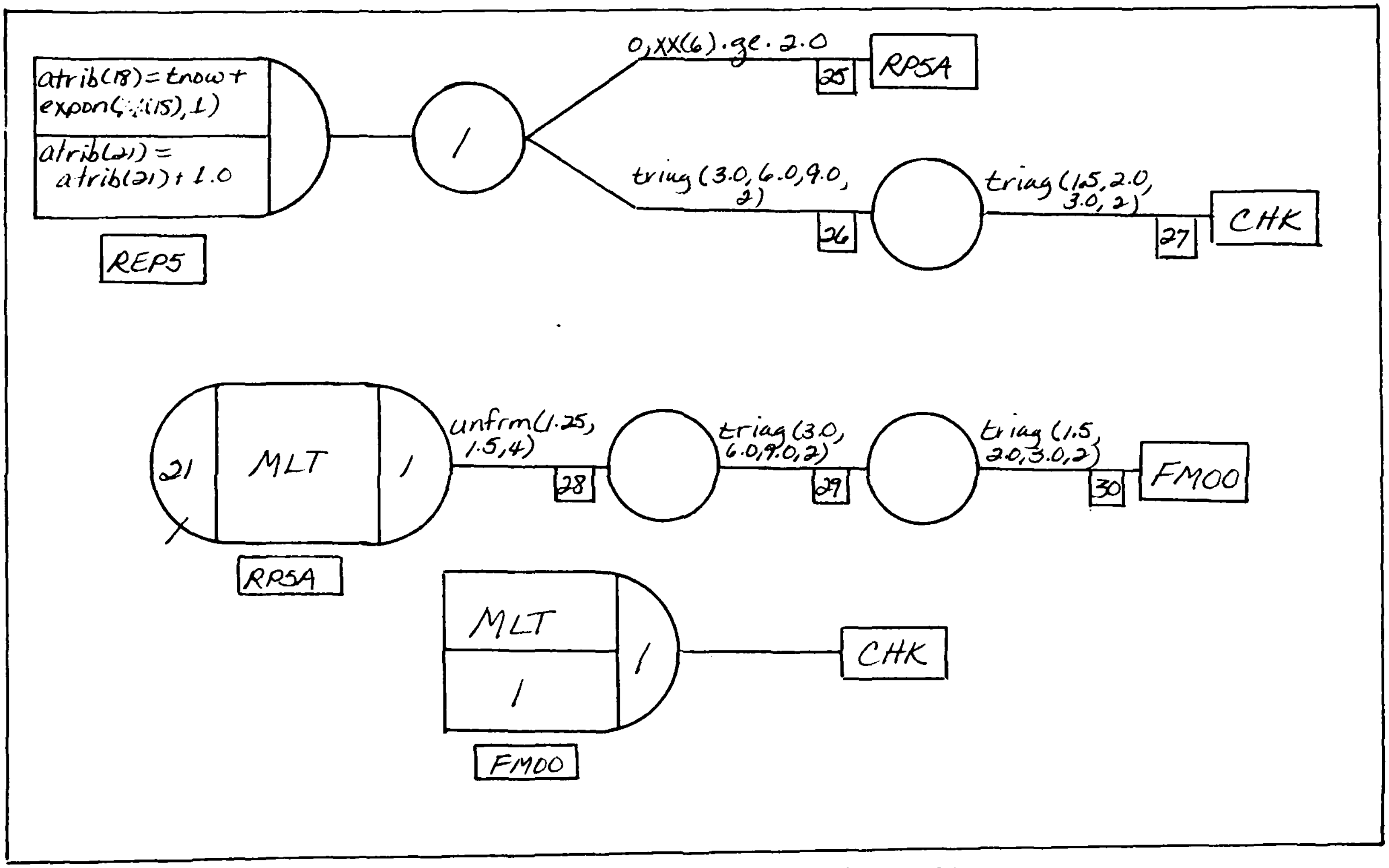


Figure B.5. Repair Network (5 of 8)

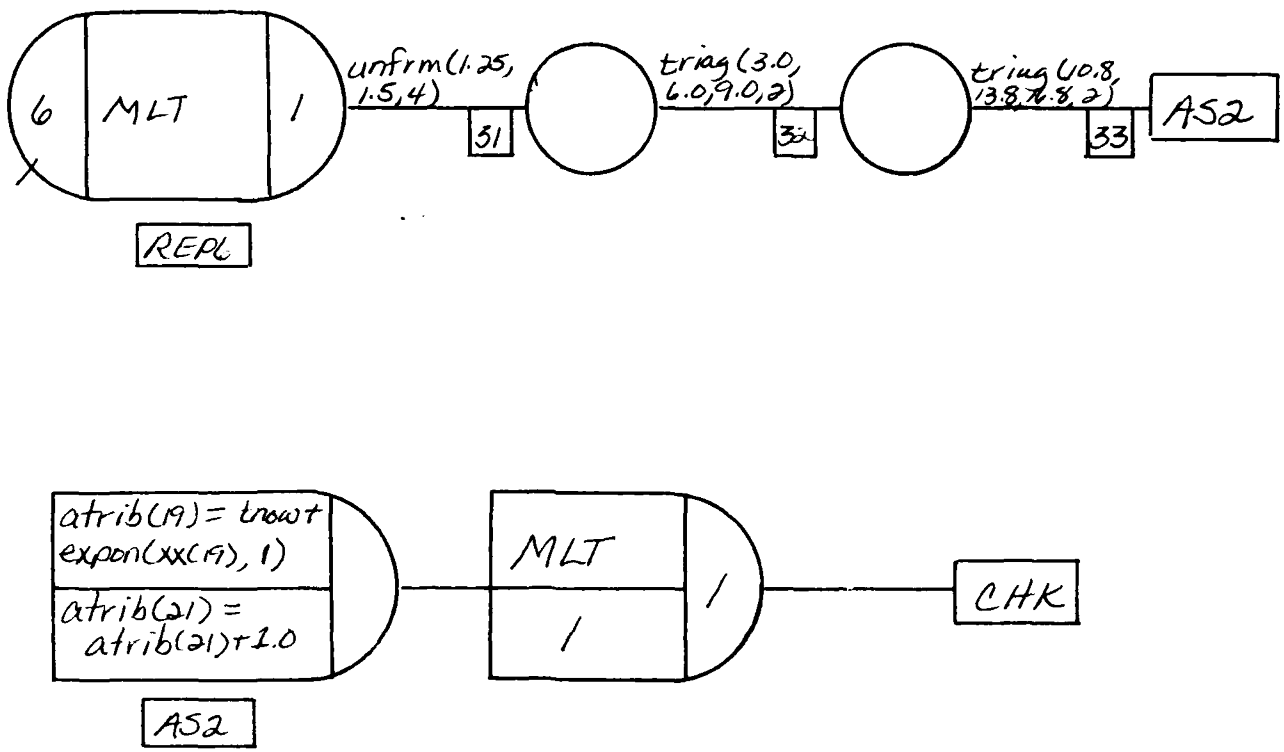


Figure B.6. Repair Network (6 of 8)

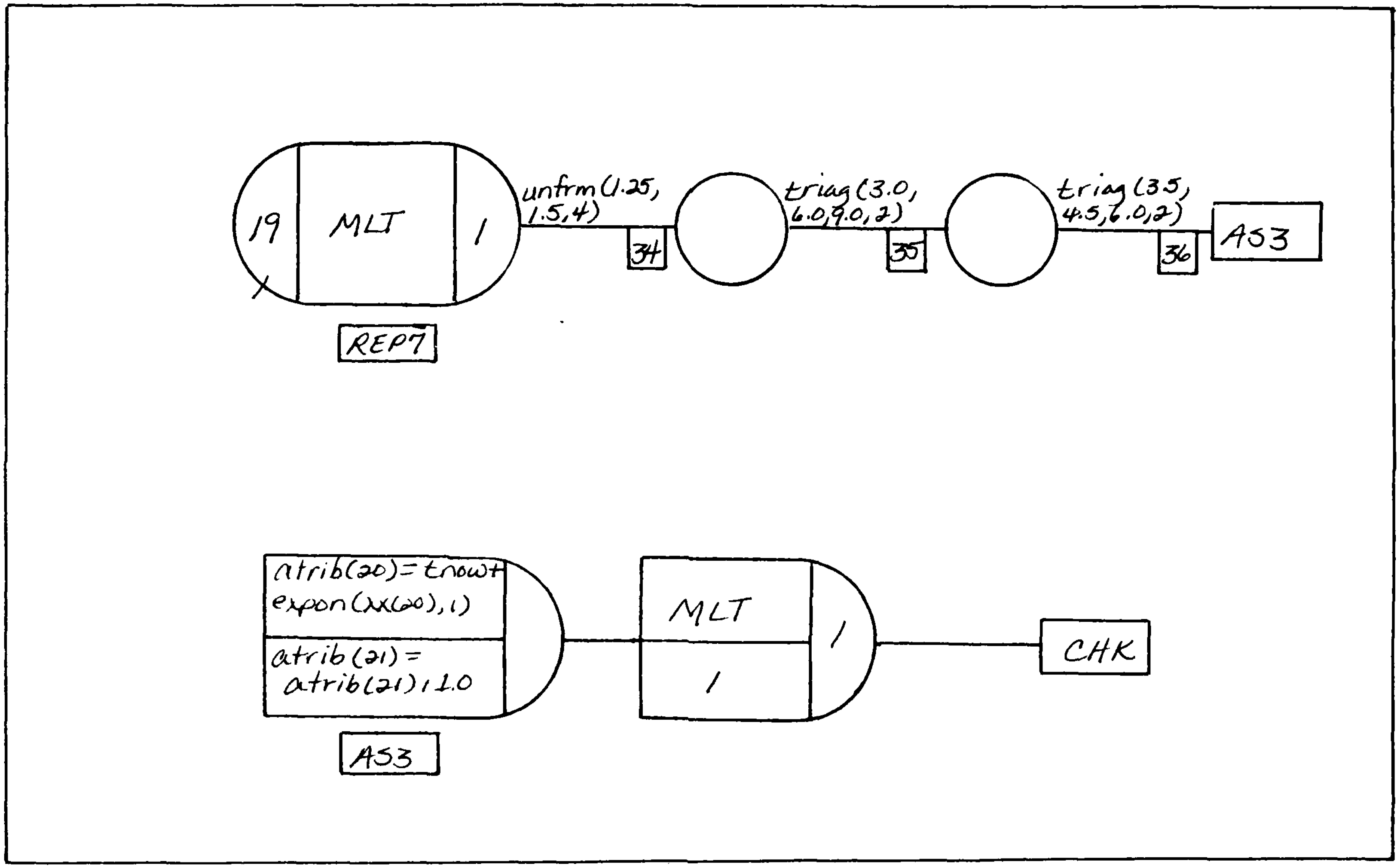


Figure B.7. Repair Network (7 of 8)

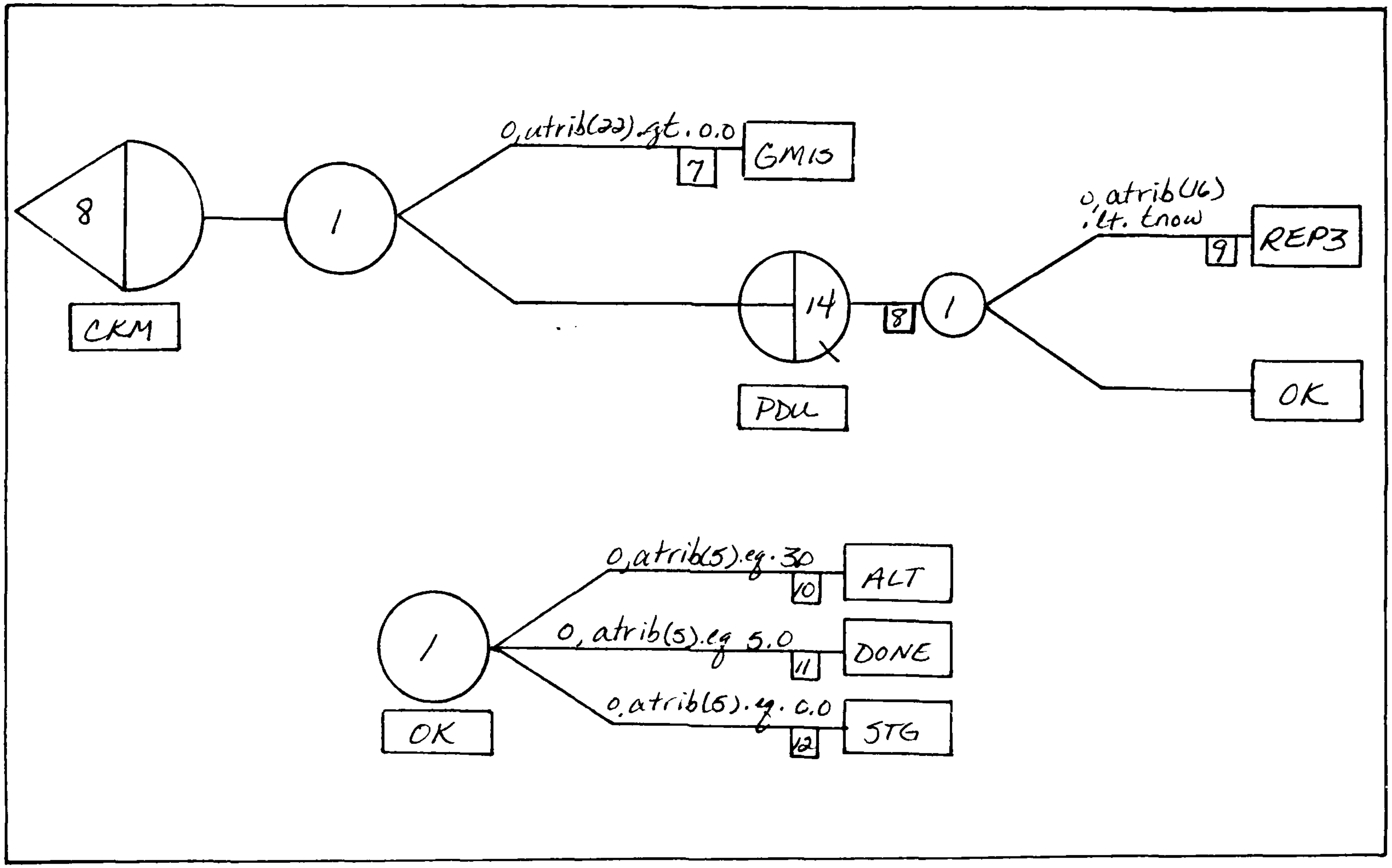


Figure B.8. Repair Network (8 of 8)

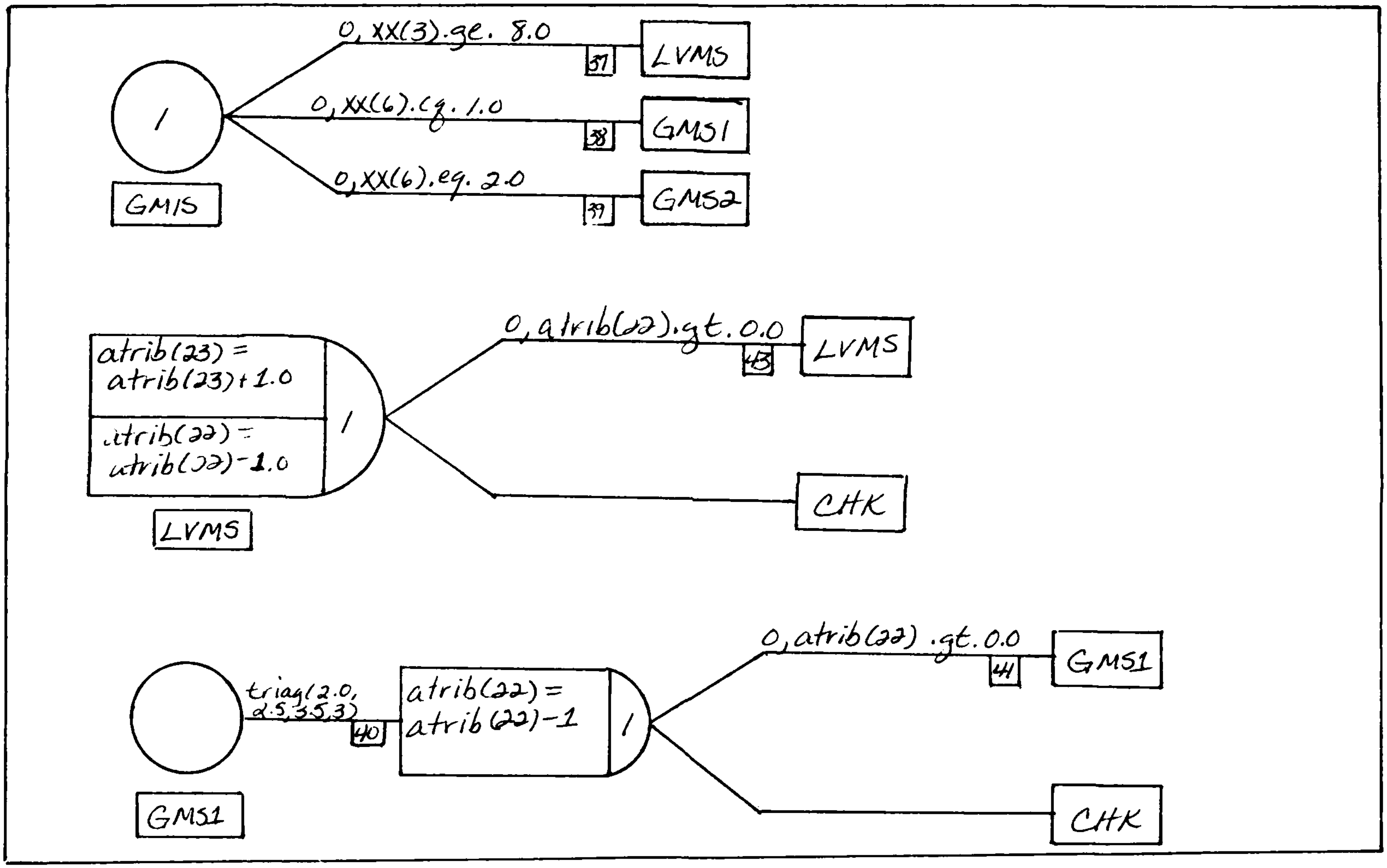


Figure B.9. Missile Exchange Network (1 of 2)

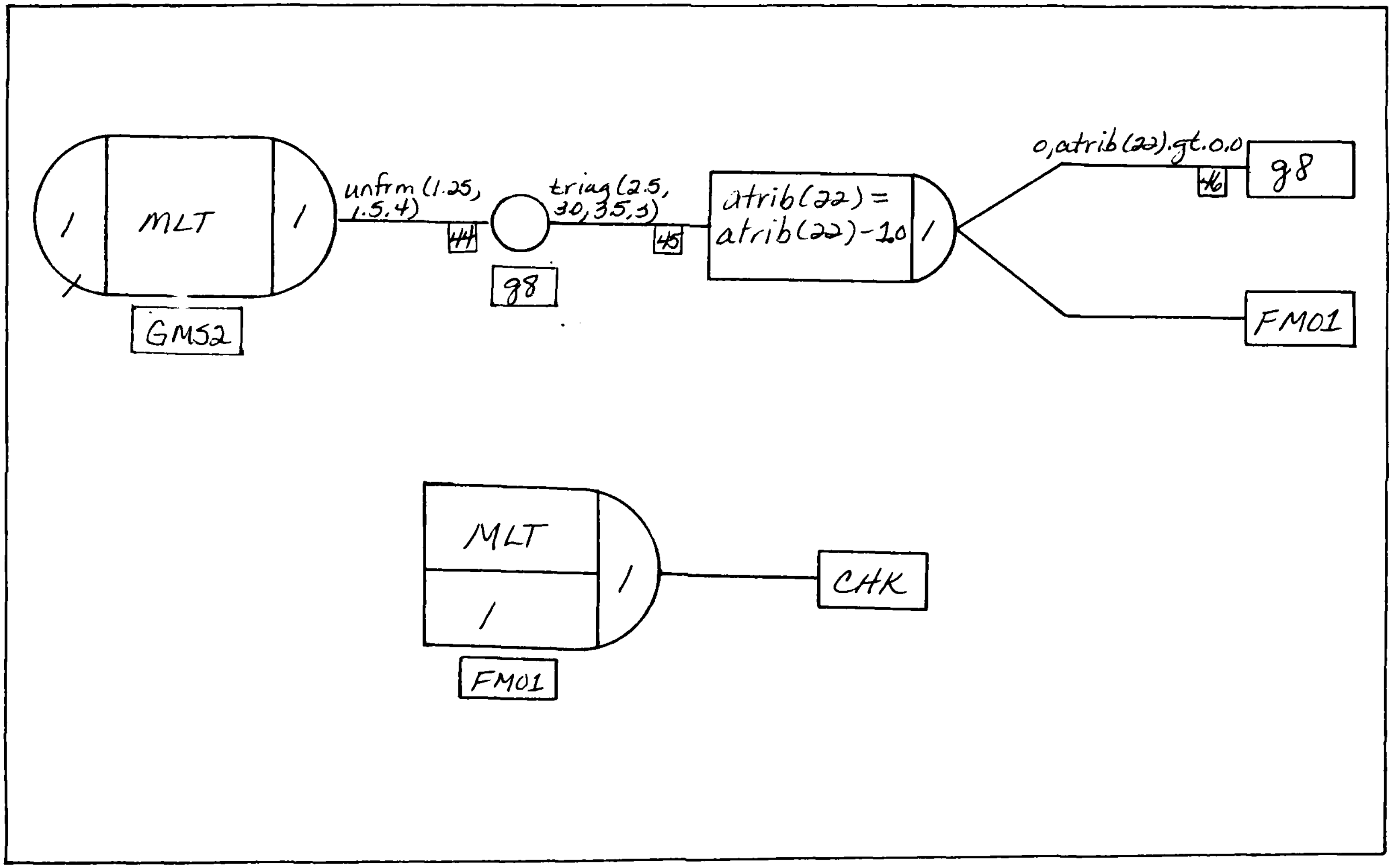


Figure B.10. Missile Exchange Network (2 of 2)

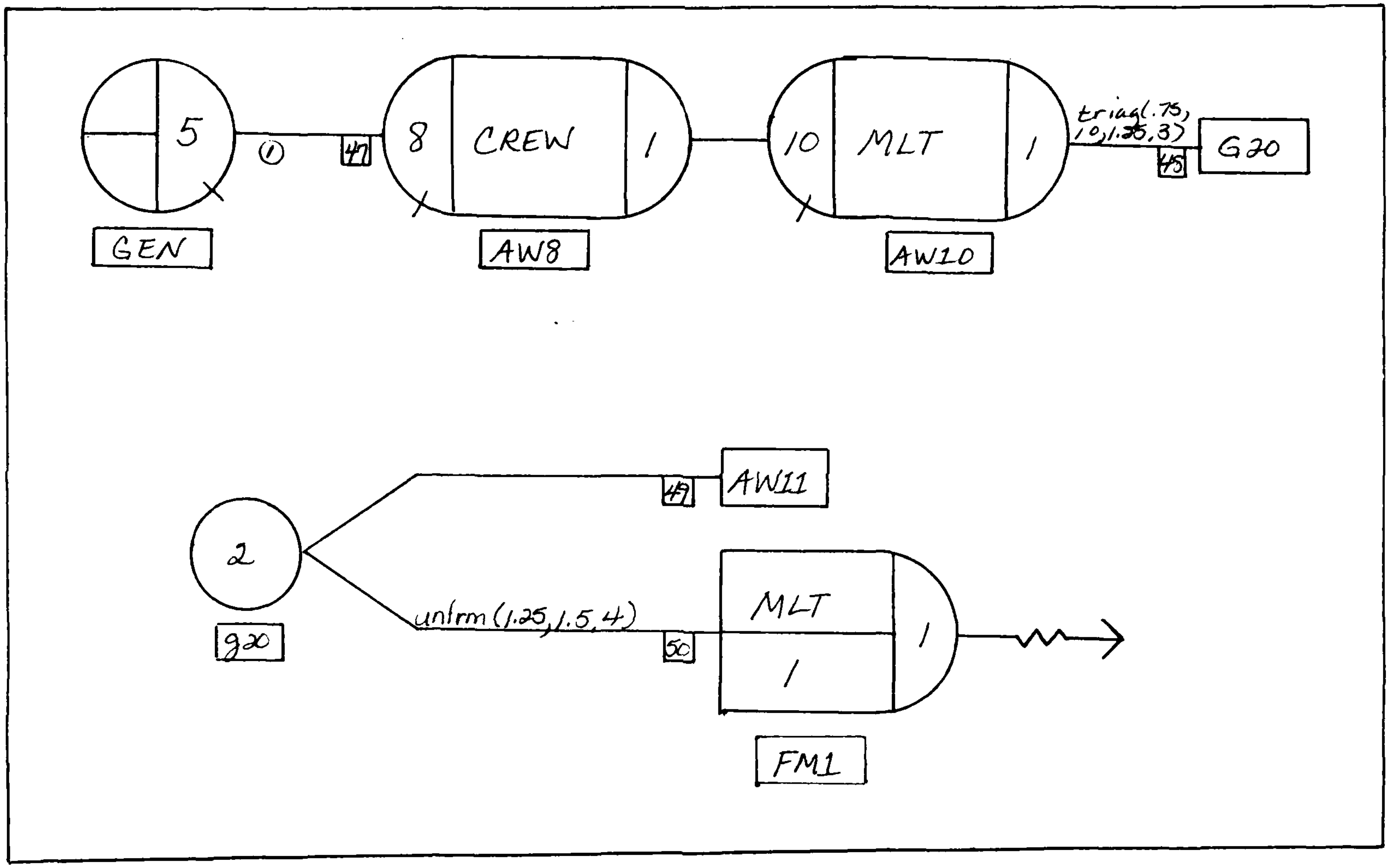


Figure B.11. Generation (GEN) Network (1 of 3)

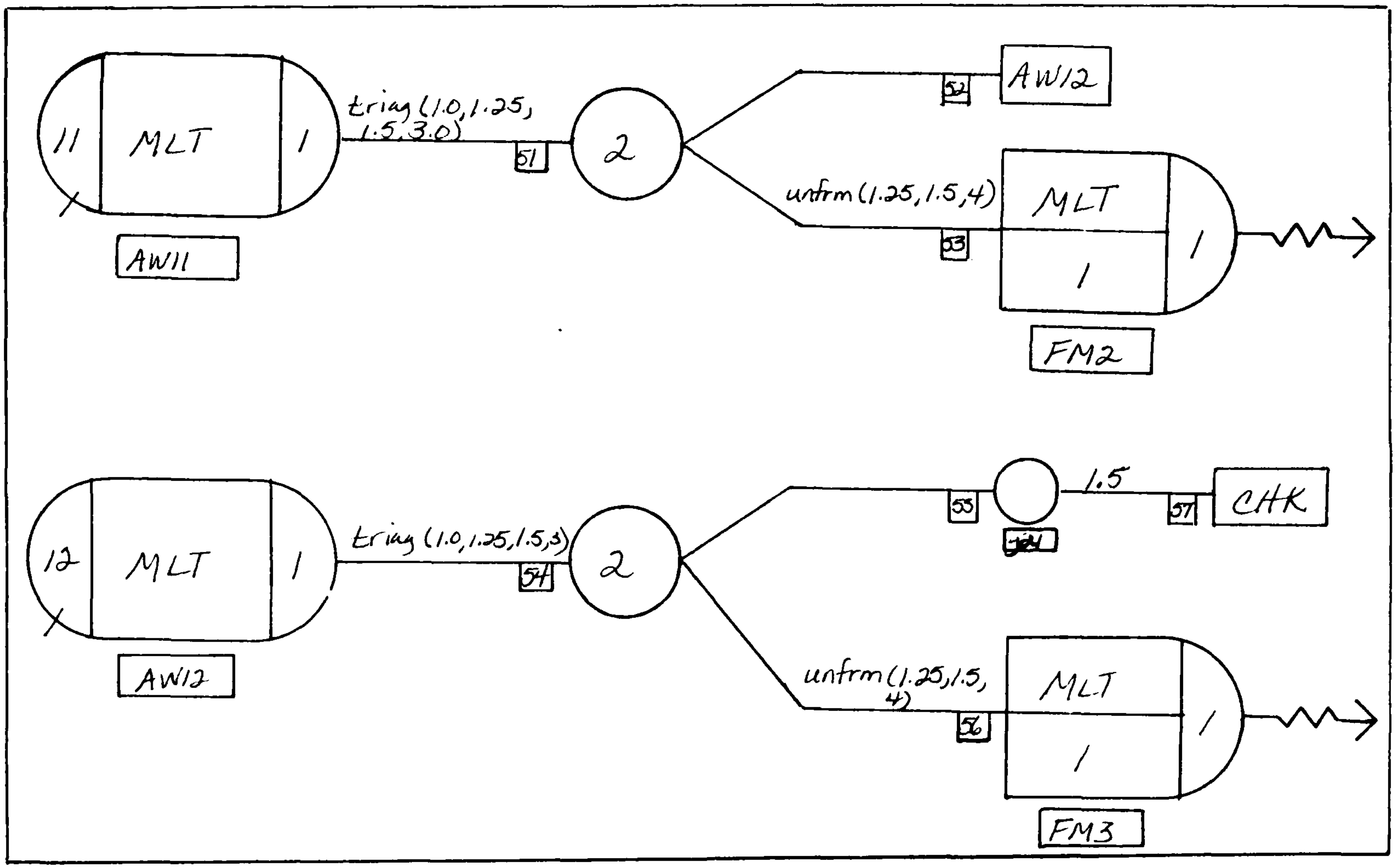


Figure B.12. Generation (GEN) Network (2 of 3)

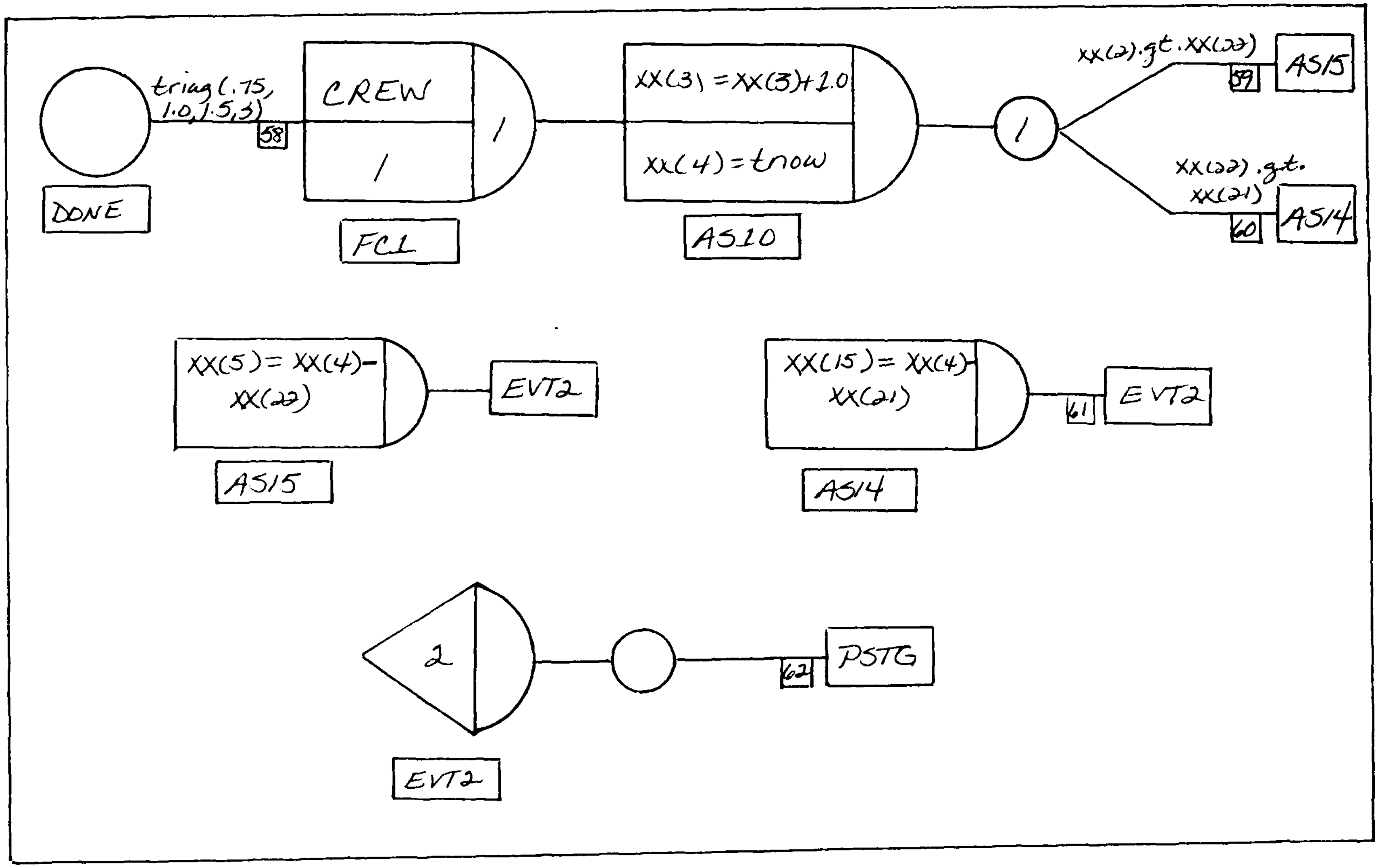


Figure B.13. Generation (GEN) Network (3 of 3)

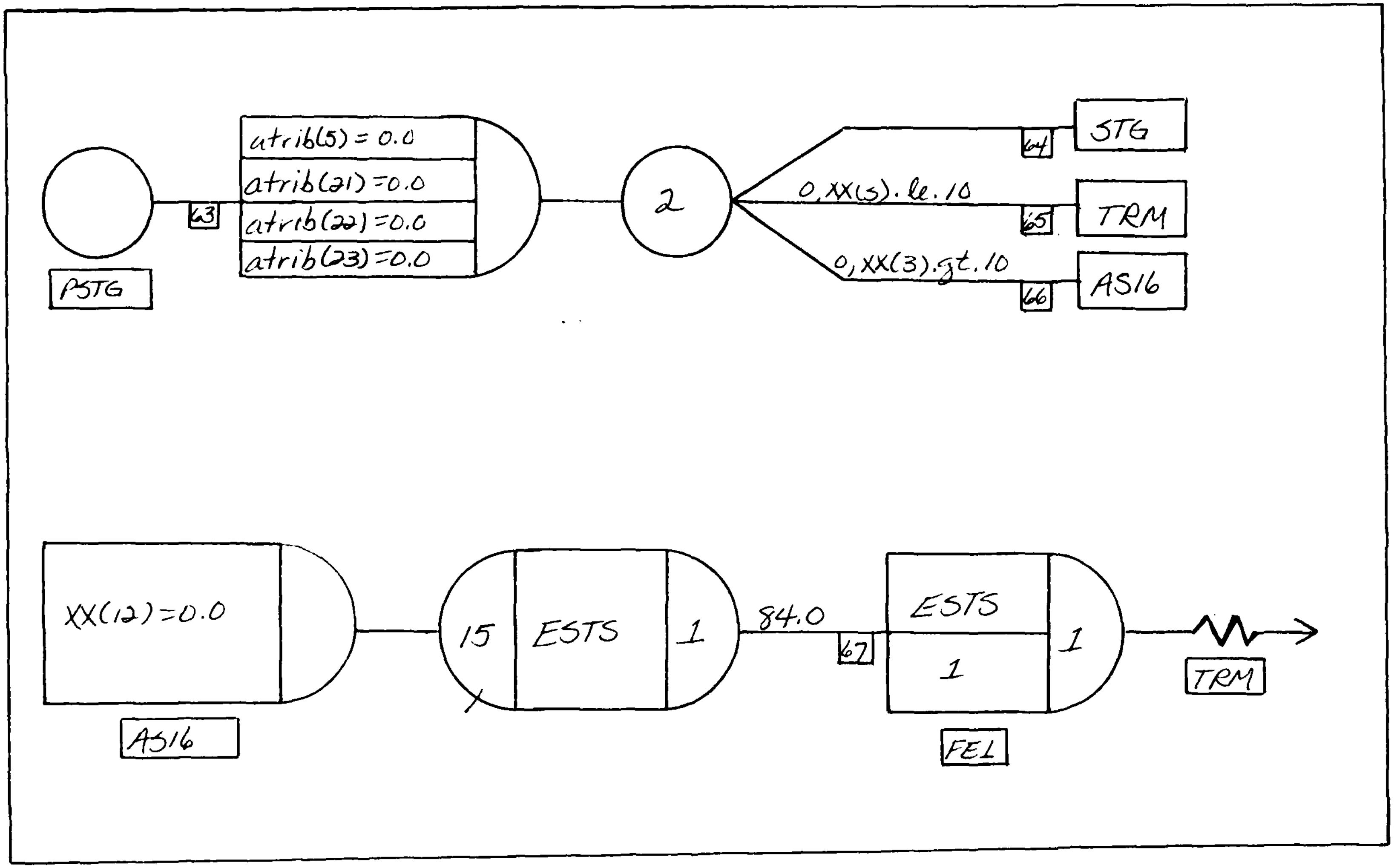


Figure B.14. Post Generation (PSTG) Network

AD-A152 068 A SIMULATION MODEL OF THE COMMON STRATEGIC ROTARY LAUNCHER FOR AVAILABILITY(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. 2/2

UNCLASSIFIED S J GJERSTAD ET AL. NOV 84 F/G 16/1 NL

END

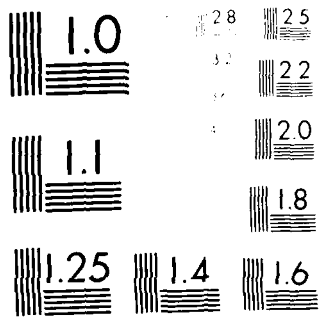
FILMED

DTIC

END

FILMED

DTIC


1.0
2.8
2.5
3.2
2.2
2.0
1.1
1.8
1.25
1.4
1.6

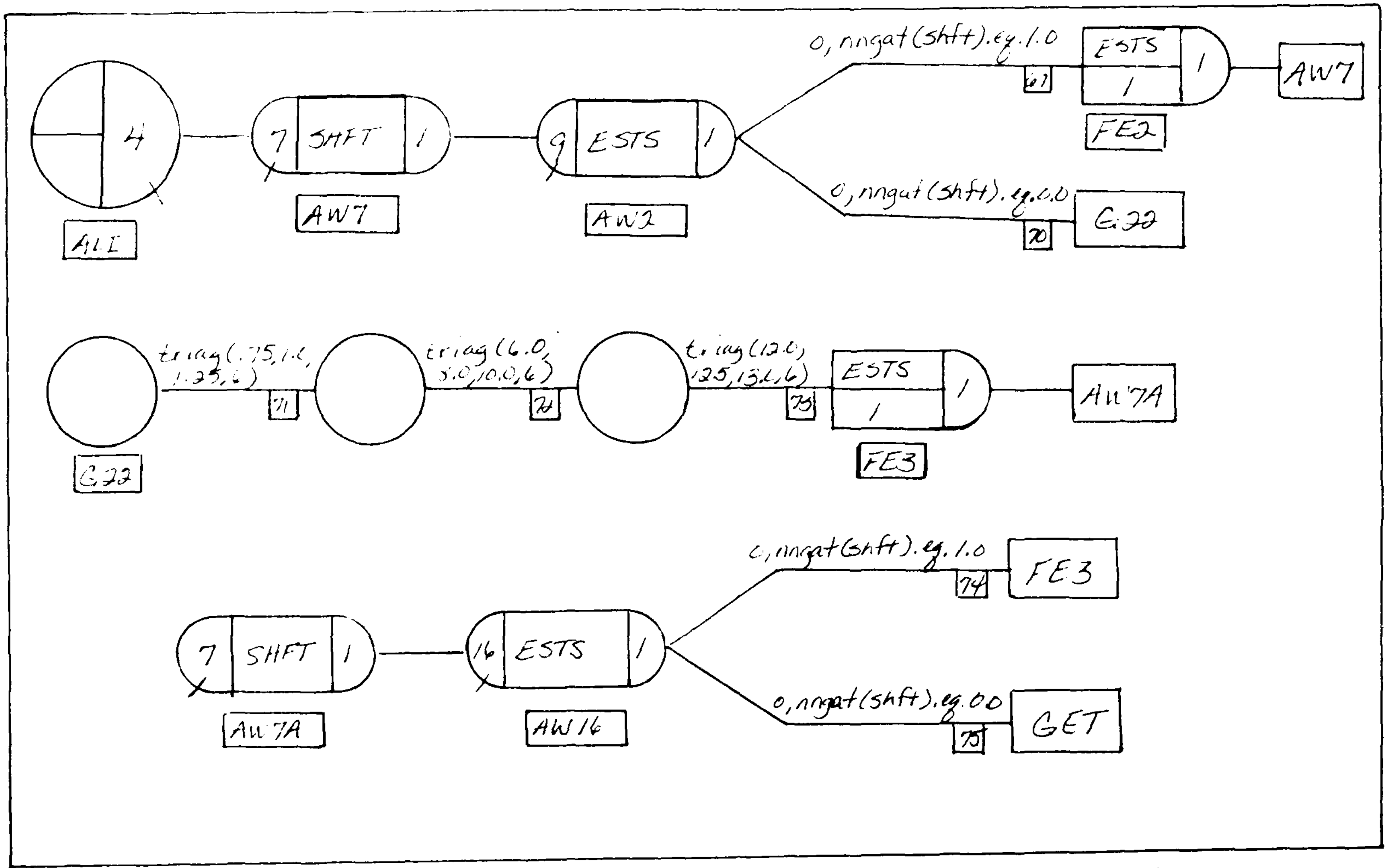


Figure 5.15. Annual Launcher Inspection (ALI) Network (1 of 3)

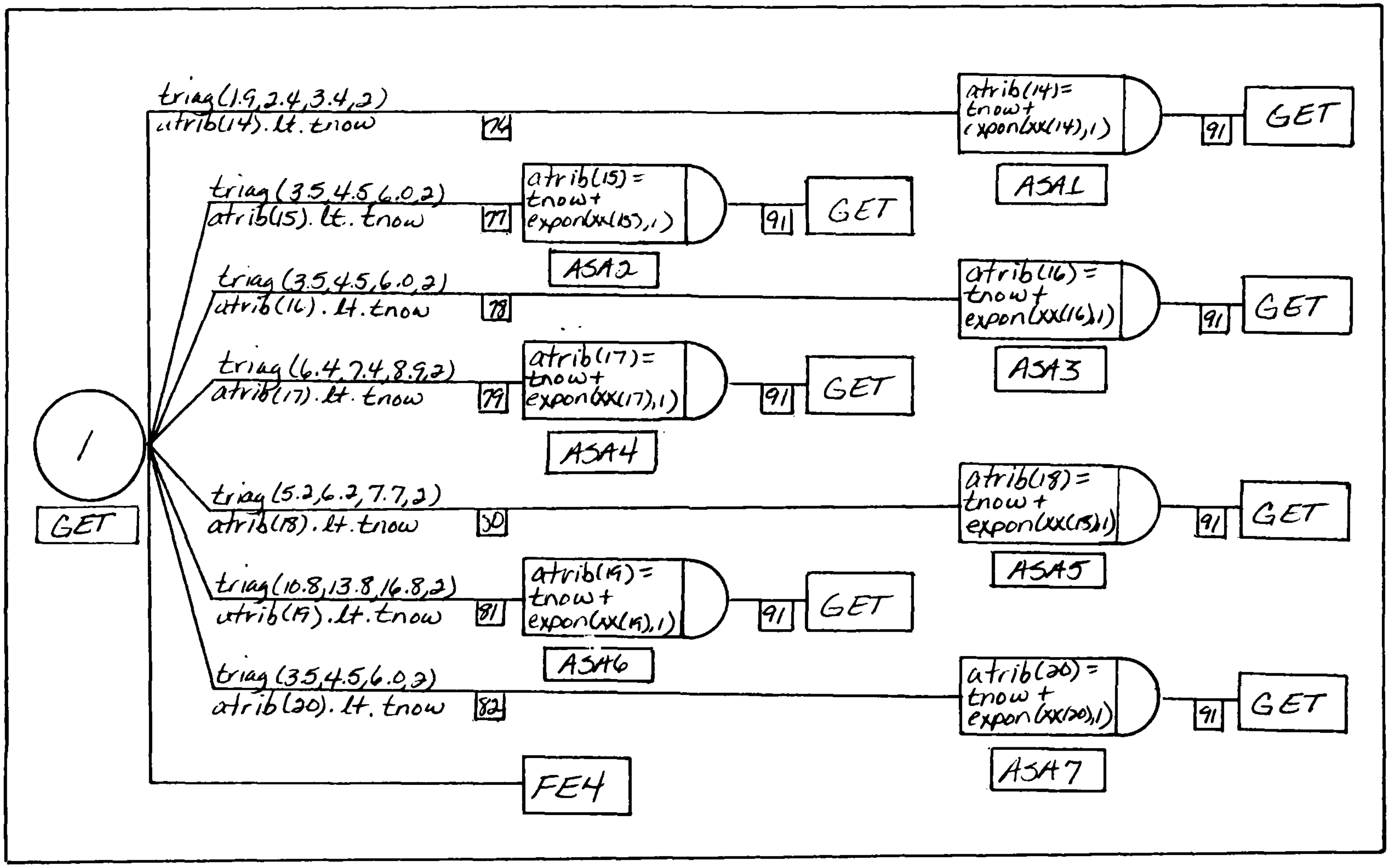


Figure B.16. Annual Launcher Inspection (ALI) Network (2 of 3)

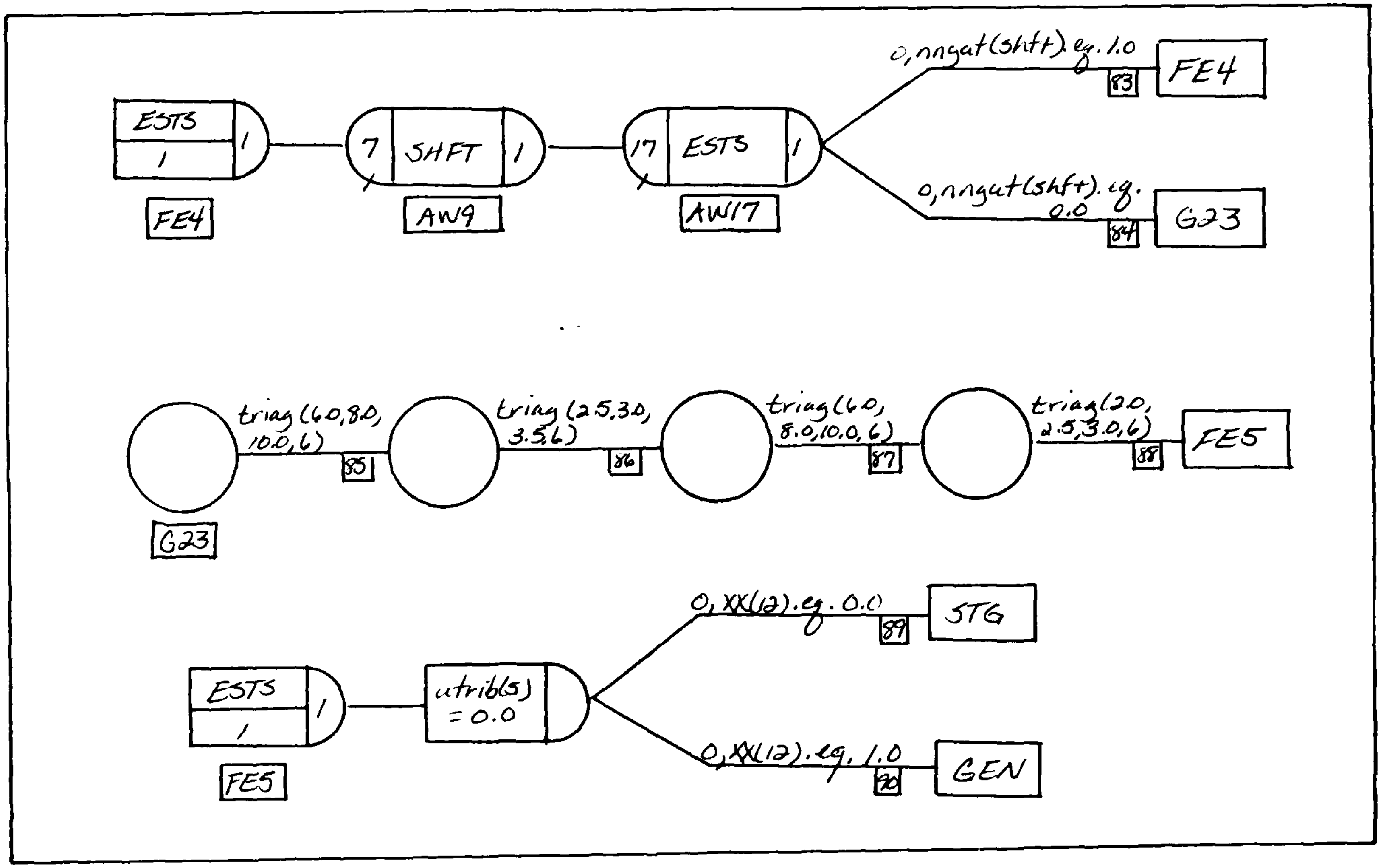


Figure B.17. Annual Launcher Inspection (ALI) Network (3 of 3)

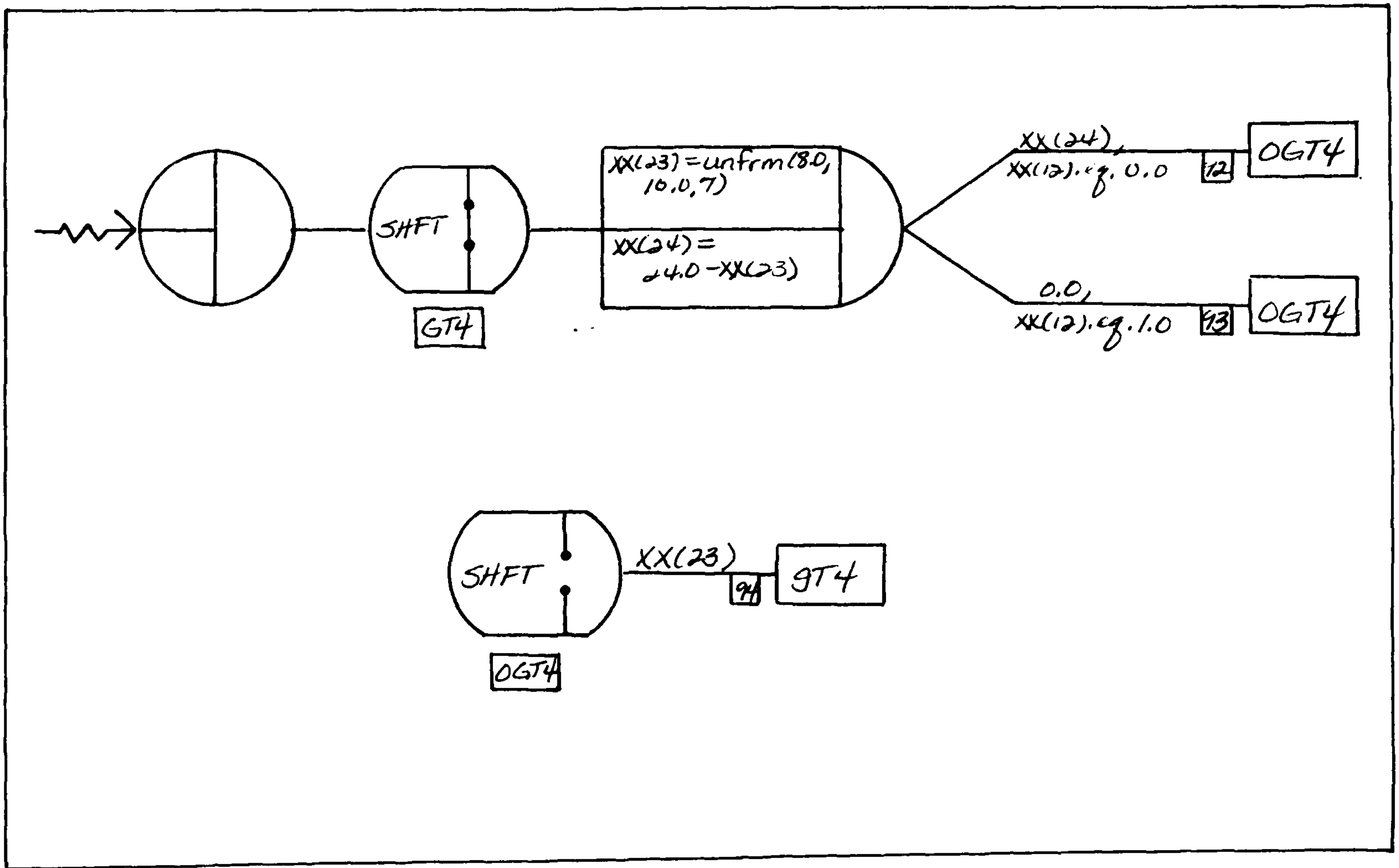


Figure B.18. Shift (SHFT) Network

THIS IS FROM THE CSRL.OUT FILE

s l a m   s u m m a r y   r e p o r t

current time .2000e+05
statistical arrays cleared at time .7200e+03

statistics for time-persistent variables

	mean value	standard deviation	minimum value	maximum value	time interval	current value
launchers avail	14.191	2.377	.00	16.00	19281.000	16.00
availability	.887	.149	.00	1.00	19281.000	1.00
avail in gen	10.691	1.730	.00	11.00	19281.000	11.00
time completed	3046.945	2218.702	.00	7358.07	19281.000	7353.07

resource statistics

resource number	resource label	current capacity	average util	standard deviation	maximum util	current util
1	crew	4	.06	.467	4	0
2	mlt	9	.09	.561	8	0
3	ests	1	.13	.341	1	0

resource number	resource label	current available	average available	minimum available	maximum available
1	crew	4	3.9362	0	4
2	mlt	9	8.9143	1	9
3	ests	1	.8654	0	1

PLOT OF AVAIL VS TNOW

```
                                          scales of plot
a=availability .000e+00                    .500e+00                 .100e+01
              0     10    20    30    40    50    60    70    80    90    100 dups
time

    .1280e+04 +                             +                          a  +
    .1920e+04 +                             +                             a
    .2560e+04 +                             +                       a     +
    .3200e+04 +                             +                   a         +
    .3840e+04 +                             +                          a  +
    .4480e+04 +                             +                       a     +
    .5120e+04 +                             +                          a  +
    .5760e+04 +                             +                             a
    .6400e+04 +                             +                             a
    .7040e+04 +                             +                             a
    .7680e+04 +                             +                          a  +
    .8320e+04 +                             +                          a  +
    .8960e+04 +                             +                   a         +
    .9600e+04 +                             +                   a         +
    .1024e+05 +                             +                             a
    .1088e+05 +                             +                             a
    .1152e+05 +                             +                       a     +
    .1216e+05 +                             +                             a
    .1280e+05 +                             +                          a  +
    .1344e+05 +                             +                       a     +
    .1408e+05 +                             +                   a         +
    .1472e+05 +                             +                             a
    .1536e+05 +                             +                   a         +
    .1600e+05 +                             +                       a     +
    .1664e+05 +                             +                a            +
    .1728e+05 +                             +                a            +
    .1792e+05 +                             +                             a
    .1856e+05 +                             +                   a         +
    .1920e+05 +                             +                       a     +
    .1984e+05 +                             +                             a
              0     10    20    30    40    50    60    70    80    90    100
time

                                  minimum  .7500e+00
                                  maximum  .1000e+01
```

THIS IS A SAMPLE OF THE "CSRLALL" OUTPUT FILE

TNOW	AVAIL	# OBS	TOTAL	#MF	L#	TNOW	# GEN	GENTIM	#OBS	TOTAL
.0000.0000										
733.	.813	1.	.813							
864.	.375	2.	1.688							
				.0	2.	980.	1.	8.2	0	.0
				.0	12.	985.	2.	13.4	0	.0
				.0	4.	987.	3.	15.7	0	.0
				.0	13.	988.	4.	16.4	0	.0
				.0	14.	991.	5.	19.4	0	.0
				.0	3.	994.	6.	22.0	0	.0
				.0	8.	998.	7.	26.1	0	.0
				.0	15.	998.	8.	26.3	0	.0
				1.0	1.	1000.	9.	27.9	0	.0
				.0	9.	1001.	10.	29.3	0	.0
				2.0	16.	1004.	11.	32.2	1	32.2
2135.	.375	3.	2.563							
2767.	.813	4.	3.375							
				2.0	6.	3046.	1.	14.7	1	32.2
				.0	1.	3047.	2.	16.0	1	32.2
				.0	7.	3056.	3.	24.5	1	32.2
				.0	8.	3060.	4.	28.6	1	32.2
				.0	9.	3062.	5.	31.3	1	32.2
				.0	4.	3064.	6.	32.6	1	32.2
				2.0	10.	3066.	7.	34.5	1	32.2
				3.0	5.	3070.	8.	38.7	1	32.2
				1.0	12.	3071.	9.	40.2	1	32.2
				7.0	11.	3073.	10.	42.2	1	32.2
				2.0	16.	3077.	11.	46.2	2	73.4
3925.	.938	5.	4.313							
				.0	12.	4313.	1.	13.3	2	73.4
				.0	10.	4316.	2.	15.9	2	73.4
				.0	9.	4316.	3.	16.1	2	73.4
				.0	11.	4317.	4.	16.3	2	73.4
				.0	6.	4326.	5.	26.3	2	73.4
				.0	16.	4326.	6.	26.5	2	73.4
				.0	7.	4332.	7.	31.7	2	73.4
				2.0	14.	4332.	8.	32.3	2	73.4
				.0	8.	4333.	9.	32.7	2	73.4
				1.0	13.	4333.	10.	33.6	2	73.4
				2.0	15.	4333.	11.	37.8	3	115.2
4513.	.375	6.	5.138							

THIS IS THE "CSRLAVG" OUTPUT FILE

# OBS	RUN	CODE	AVGEN	AVAVL
.010	.0000	.0000	39.48	.9021

Appendix C

Input Data

This appendix lists the input data and data sources used in the model. The data has been separated into three parts; MTBF rates for the seven launcher subsystems, activity duration, and decision structures. Table C.1 lists the MTBF rates, Table C.2 lists the types of activities and duration of the activities, and Table C.3 lists the conditions used for routing launchers through the network.

Table C.1

MTBF by Subsystem

Subsystem	Predicted	Allocated
Structure	120,232	50,000
Power Drive Unit (PDU)	23,090	2,820
PDU Controller	10,000	5,000
Electrical/Electronic		
Missile Interface Unit (MIU)	48,015	21,753
Relay Assembler	33,744	37,938
Other Electronic/Electrical	41,971	41,971
Environmental Control System	23,034	5,120

The activities table lists the events and the duration of the events that the launchers go through in the network. The data and data sources are displayed in Table C.2 by activity number in the order in which it occurs in the network. This table also lists the distribution used for the data, gives a code for the type of event that is being processed, and gives a brief description of the event. The codes used for the type of event are:

G - generation exercise
A - launcher inspection
R - repair
T - trailer activity

The following are the sources for the data used in the model:

D056 - repair times for the SRAM launcher from the AFLC data base (1 Oct 83 - 31 Mar 84); used triangular distribution.

Boeing - estimates from Boeing Document No. D405-10350-1, Reliability/Maintainability, Allocations, Assessment and Analysis Report - CSRL.

SAC - expert opinion from maintenance personnel familiar with the SRAM launcher; used triangular distribution with pessimistic, most likely and optimistic time estimates.

WAG - educated guess from maintenance personnel.

Table C.2

Activities Table

Act/Code	Duration	Description	Source
13/22T	unfrm(1.25,1.5,4)	Transport time back to IMF	SAC
14G	triag(6.0,8.0,10.0)	Download and upload missiles	SAC
15R	triag(1.9,2.4,2.9)	repair structure	D056
16R	triag(3.5,4.5,6.0)	repair of PDU	D056
17/18R	triag(3.5,4.5,6.0)	repair of PDU controller	D056
20/26R	triag(3.0,6.0,9.0)	r/r missiles for access	SAC
21R	triag(1.0,1.5,2.0)	r/r MIU	WAG
23R	triag(3.0,6.0,9.0)	r/r missiles	SAC
24/27R	triag(1.0,1.5,2.0)	r/r relay assembler	WAG
28/31T	unfrm(1.25,1.5)	transport time back to IMF	SAC
29/32R	triag(3.0,6.0,9.0)	r/r missiles	SAC
30R	triag(1.5,2.0,3.0)	r/r relay assembler	WAG
33R	triag(10.8,13.8,16.8)	repair electrical	D056
34T	unfrm(1.25,1.5)	transport time back to IMF	SAC
35R	triag(3.0,6.0,9.0)	r/r missiles	SAC
36R	triag(3.5,4.5,6.0)	repair ECS	D056
40R	triag(2.0,2.5,3.5)	time to exchange 1 missile	SAC
44T	unfrm(1.25,1.5)	transport time to IMF	SAC
45R	triag(2.5,3.0,3.5)	exchg 1 missle	SAC
47G	triag(1.0,2.0,4.0)	waiting for B-52	SAC
48G	triag(.75,1.0,1.25)	upload launcher	SAC
50/53T	unfrm(1.25,1.5)	delay for MLT	SAC
51/54G	triag(1.0,1.25,1.5)	upload pylon	SAC
56T	unfrm(1.25,1.5)	delay for MLT	SAC
57G	1.5	SIT test	AFOTEC
58G	triag(.75,1.0,1.5)	postload work	SAC
67G	84.0	Dummy, delay other work in IMF	SAC
71A	triag(.75,1.0,1.25)	upload to ests	SAC
72A	triag(6.0,8.0,10.0)	download missiles	SAC
73A	triag(12.0,12.5,13.0)	empty test	Boeing
76A	triag(1.9,2.4,3.4)	repair structure	D056
77A	triag(3.5,4.5,6.0)	repair PDU controller	D056
78A	triag(3.5,4.5,6.0)	repair PDU	D056
79A	triag(6.4,7.4,8.9)	repair MIU	D056
80A	triag(5.2,6.2,7.7)	repair relay assembler	D056
81A	triag(10.8,13.8,16.8)	repr other electronic/electrical	D056
82A	triag(3.5,4.5,6.0)	repair ECS	D056
85A	triag(6.0,8.0,10.0)	upload and SST	SAC
86A	triag(2.5,3.0,3.5)	loaded test	Boeing
87A	triag(6.0,8.0,10.0)	load warheads	SAC
88A	triag(2.0,2.5,3.0)	download & postload inspection	SAC
92A	xx(24)	shift off or ests down	SAC
93G	0.0	no shift down time during GEN	SAC
94A	xx(23)	time shift and ests working	SAC

Table C.3

Condition Table

Act/Code	Condition	Reason
1FG	atrib(14).lt.tnow	structure failure
2FG	atrib(15).lt.tnow	PDU controller failure
3FG	atrib(17).lt.tnow	MIU failure
4FG	atrib(18).lt.tnow	relay assembler failure
5FG	atrib(19).lt.tnow	electrical/electronic failure
6FG	atrib(20).lt.tnow	ECS failure
7FG	atrib(22).gt.0.0	missile failure(s)
9FG	atrib(16).lt.tnow	PDU failure
10F	atrib(5).eq.3.0	return launcher to ALT
11G	atrib(5).eq.5.0	return launcher to GEN
12S	atrib(5).eq.0.0	return launcher to STG
17FG	atrib(5).eq.0.0	repr PDU, return to STG
18FG		repr PDU, check for other failures
19/25FG	xx(6).ge.2.0	r/r missiles in IMF
26FG		r/r missiles on flight line
37G	xx(3).ge.8.0	leave failed missile
38G	xx(6).eq.1.0	exchg misl on flight line
39G	xx(6).eq.2.0	exchg misl in IMF
41/43/46G	atrib(22).gt.0.0	loop to exchg all misl failures
59G	xx(21).gt.xx(22)	ORI in progress
60G	xx(22).gt.xx(21)	QINSP in progress
65G	xx(3).le.10	exercise still in progress
66G	xx(3).gt.10	exercise is over, tie up ESTS
69/74/83G	nngat(shft).eq.1.0	work shift closed, wait
70/75/84G	nngat(shft).eq.0.0	work shift open continue work
76FG	atrib(14).lt.tnow	assign next structure failure
77FG	atrib(15).lt.tnow	assign next PDU failure
78FG	atrib(16).lt.tnow	assign next PDU controller fail
79FG	atrib(17).lt.tnow	assign next MIU failure
80FG	atrib(18).lt.tnow	assign next relay assmblr fail
81FG	atrib(19).lt.tnow	assign electrical/electronic
82FG	atrib(20).lt.tnow	assign next ECS failure
89/92FG	xx(12).eq.0.0	no GEN in progress, go to STG/ normal shifts
90/93FG	xx(12).eq.1.0	GEN in progress, go to GEN/ 24 hr shifts

Appendix D

Experimental Design

This Appendix contains the fractional factorial research design used in this research effort. The information was obtained from the National Bureau of Standard Applied Mathematics Series (13:22). The codes used for the one-fourth of a 2^8 factorial design are given in the table below:

Table D.1

Factors Used in Factorial Design

Factor	Code	Code Definition	Low	High
1	a	number of crew	8	12
2	b	number of MLTs	6	12
3	c	maintenance policy	3-level	2-level
4	d	inspection frequency	257 hrs	504 hrs
5	e	launcher load time*	.75,1.0,1.25	1.0,1.5,2.0
6	f	remove/replace missile*	2.0,2.5,3.5	2.5,3.0,4.0
7	g	remove/replace relay* assembler	1.0,1.5,2.0	1.5,2.0,3.0
8	h	failure rate	allocated	predicted

For example, ab means the high values are used for number of crews and number of MLTs, while holding all other factors at low values.

*The low, medium, and high values are given for the triangular distribution.

Table D.2

Fractional Factorial Design

The following combinations of factors were used in the analysis of the CSRL:

(1)	cdgh	abcg	abdh	bdefh	bcefg	acdefgh	aef
abcfgh	abdf	fh	cdfg	acdeg	aeh	bde	bcegh
bcdeg	beh	ade	acegh	cfgh	df	abfh	abcdfg
adefh	acefg	bcdefgh	bef	ab	abcdgh	cg	dh
efgh	cdef	abcefh	abdefg	bdg	bch	acd	agh
abce	abdegh	eg	cdeh	acdfh	afg	bdfgh	bcf
bcdfh	bfg	adfgh	acf	ce	degh	abeg	abcdeh
adg	ach	bcd	bgh	abefgh	abcdef	cefh	defg

Appendix E

BMDP and SPSS Input/Output

This appendix lists the input data, input programs and relevant output for the two part statistical analysis. The order of presentation is given below:

1. SPSS Autocorrelation Analysis
2. BMDP Fractional Factorial Design
   a. ANOVA for Generation Time
   b. ANOVA for Availability
3. Regression Analysis
   a. Regression for Generation Time
   b. Regression for Availability

THIS IS THE SPSS INPUT PROGRAM, INPUT FILE AND OUTPUT USED TO CHECK

FOR AUTOCORRELATION AMONG THE AVAILABILITY OBSERVATIONS.

```
RUN NAME            AVAILABILITY
VARIABLE LIST       TNOW,AVAIL
INPUT FORMAT        FREEFIELD
INPUT MEDIUM        CARDS
N OF CASES          UNKNOWN
REGRESSION          METHOD=STEPWISE/VARIABLES=TNOW,AVAIL/
                    REGRESSION=AVAIL WITH TNOW/RESIDUALS
STATISTICS          ALL
OPTIONS             11,2
READ INPUT DATA
FINISH
```

THIS IS THE OUTPUT FOR AUTOCORRELATION WHEN THE OBSERVATIONS FOR

AVAILABILITY ARE TAKEN ON THE AVERAGE OF EVERY TWO WEEKS.

VARIABLE	MEAN	STANDARD DEV	CASES
TNOW	10376.3333	5479.1158	57
AVAIL	911.4386	77.3060	57

NUMBER OF CASES PLOTTED 57.

VON NEUMANN RATIO .94358 DURBIN-WATSON TEST .93193

THIS IS THE OUTPUT WHEN OBSERVATIONS ARE TAKEN ON THE AVERAGE OF

EVERY FOUR WEEKS.

VARIABLE	MEAN	STANDARD DEV	CASES
TNOW	10371.1379	5610.0433	29
AVAIL	916.2414	82.1634	29

NUMBER OF CASES PLOTTED 29.

VON NEUMANN RATIO 1.66252 DURBIN-WATSON TEST 1.60519

THIS IS THE INPUT DATA, BMDP INPUT PROGRAM AND OUTPUT TABLE FOR THE FRACTIONAL FACTORIAL ANALYSIS.

```
1 01 .0000.0000 44.79 .7610        3 01 .0111.1010 47.48 .7149
1 02 .0011.0011 38.40 .9189        3 02 .0100.1001 37.25 .9320
1 03 .0000.0101 37.59 .9298        3 03 .0111.1111 40.65 .9156
1 04 .0011.0110 48.35 .7231        3 04 .0100.1100 49.34 .7500
1 05 .0010.0111 39.47 .9276        3 05 .0101.1101 38.84 .9139
1 06 .0001.0100 46.28 .7456        3 06 .0110.1110 43.99 .7768
1 07 .0010.0010 48.26 .7390        3 07 .0101.1000 47.78 .7544
1 08 .0001.0001 37.25 .9232        3 08 .0110.1011 37.93 .9276
1 09 .0000.1111 38.14 .9232        3 09 .0111.0111 39.46 .9167
1 10 .0011.1100 51.73 .7059        3 10 .0100.0110 45.77 .7511
1 11 .0000.1010 45.19 .7336        3 11 .0111.0000 48.37 .7423
1 12 .0011.1001 40.16 .9211        3 12 .0100.0011 36.98 .9298
1 13 .0010.1000 47.03 .7500        3 13 .0101.0010 48.81 .7390
1 14 .0001.1011 39.40 .9243        3 14 .0110.0001 37.89 .9331
1 15 .0010.1101 39.17 .9254        3 15 .0101.0111 37.64 .9139
1 16 .0001.1110 47.10 .7434        3 16 .0110.0100 50.77 .7221
2 01 .1001.1101 37.15 .9265        4 01 .1110.0111 35.22 .9331
2 02 .1010.1110 41.67 .7193        4 02 .1101.0100 38.56 .7325
2 03 .1001.1000 41.93 .7512        4 03 .1110.0010 37.95 .7346
2 04 .1010.1011 36.39 .9364        4 04 .1101.0001 34.77 .9265
2 05 .1011.1010 38.56 .7336        4 05 .1100.0000 40.35 .7467
2 06 .1000.1001 36.48 .9320        4 06 .1111.0011 35.02 .9178
2 07 .1011.1111 36.56 .9298        4 07 .1100.0101 36.43 .9331
2 08 .1000.1100 40.46 .7544        4 08 .1111.0000 41.55 .7423
2 09 .1001.0010 38.03 .7412        4 09 .1110.1000 43.06 .7270
2 10 .1010.0001 35.36 .9237        4 10 .1101.1011 36.39 .9364
2 11 .1001.0111 34.84 .9254        4 11 .1110.1101 36.45 .9298
2 12 .1010.0100 41.20 .7599        4 12 .1101.1110 40.61 .7599
2 13 .1011.0101 35.10 .9336        4 13 .1100.1111 34.96 .9320
2 14 .1000.0110 41.52 .7138        4 14 .1111.1100 41.60 .7357
2 15 .1011.0000 43.90 .7412        4 15 .1100.1010 42.23 .7346
2 16 .1000.0011 36.07 .9331        4 16 .1111.1001 35.62 .9178
```

INPUT FILE FOR GENERATION TIME

```
/PROBLEM        TITLE IS 'THESIS'.
/INPUT          VARIABLES ARE 9.
                FORMAT IS '(7X,4F1.0,1X,4F1.0,1X,F5.2,6X)'.
                UNIT IS 1.
/VARIABLE       NAMES ARE A,B,C,D,E,F,G,H,GENTIM.
/DESIGN         FORM IS '8G,Y'.
                INCLUDED ARE 1,2,3,4,5,6,7,8,12,13,14,15,16,17,18,
                   23,24,25,26,27,28,34,35,36,37,38,45,46,47,48,
                   56,57,58,67,68,78.
/END
```

ANALYSIS OF VARIANCE FOR 1-ST
DEPENDENT VARIABLE - GENTIM

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
MEAN	104042.17048	1	104042.17048	59503.82	0.0000
A	378.65041	1	378.65041	216.58	.0000
B	.02089	1	.02089	.01	.9138
C	12.02975	1	12.02975	6.88	.0142
D	.26900	1	.26900	.15	.6980
E	10.11813	1	10.11813	5.79	.0233
F	2.79629	1	2.79629	1.60	.2163
G	6.47581	1	6.47581	3.70	.0649
H	774.11732	1	774.11732	442.77	0.0000
AB	2.72967	1	2.72967	1.56	.2222
AC	9.33618	1	9.33618	5.34	.0287
BC	1.89538	1	1.89538	1.08	.3070
AD	8.03558	1	8.03558	4.60	.0412
BD	.69305	1	.69305	.40	.5342
CD	.03499	1	.03499	.02	.8886
AE	.64135	1	.64135	.37	.5493
BE	.42491	1	.42491	.24	.6260
CE	1.09357	1	1.09357	.63	.4359
DE	1.37245	1	1.37245	.78	.3834
AF	5.98473	1	5.98473	3.42	.0753
BF	.20365	1	.20365	.12	.7355
CF	2.00677	1	2.00677	1.15	.2935
DF	2.27440	1	2.27440	1.30	.2641
EF	.84771	1	.84771	.48	.4922
AG	1.67575	1	1.67575	.96	.3363
BG	.32683	1	.32683	.19	.6689
CG	4.16399	1	4.16399	2.38	.1344
DG	.40285	1	.40285	.23	.6351
EG	.10106	1	.10106	.06	.8113
FG	.00004	1	.00004	.00	.9961
AH	78.94154	1	78.94154	45.15	.0000
BH	1.78508	1	1.78508	1.02	.3213
CH	1.13677	1	1.13677	.65	.4271
DH	.69345	1	.69345	.40	.5341
EH	.00231	1	.00231	.00	.9713
FH	.01336	1	.01336	.01	.9310
GH	4.80611	1	4.80611	2.75	.1089
ERROR	47.20541	27	1.74835		

INPUT FILE FOR AVAILABILITY

```
/PROBLEM        TITLE IS 'THESIS'.
/INPUT          VARIABLES ARE 9.
                FORMAT IS '(7X,4F1.0,1X,4F1.0,7X,F5.4)'.
                UNIT IS 1.
/VARIABLE       NAMES ARE A,B,C,D,E,F,G,H,AVAIL.
/DESIGN         FORM IS '8G,Y'.
                INCLUDED ARE 1,2,3,4,5,6,7,8,12,13,14,15,16,17,18,
                   23,24,25,26,27,28,34,35,36,37,38,45,46,47,48,
                   56,57,58,67,68,78.
```

ANALYSIS OF VARIANCE FOR 1-ST
DEPENDENT VARIABLE - AVAIL

SOURCE	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE	F	TAIL PROB.
MEAN	43.54855	1	43.54855	291045.12	0.0000
A	.00009	1	.00009	.60	.4440
B	.00000	1	.00000	.00	.9570
C	.00050	1	.00050	3.33	.0790
D	.00053	1	.00053	3.57	.0698
E	.00000	1	.00000	.02	.9005
F	.00003	1	.00003	.21	.6526
G	.00007	1	.00007	.50	.4370
H	.53491	1	.53491	3574.92	0.0000
AB	.00004	1	.00004	.28	.6026
AC	.00009	1	.00009	.57	.4569
BC	.00006	1	.00006	.42	.5224
AD	.00063	1	.00063	4.21	.0499
BD	.00004	1	.00004	.24	.6293
CD	.00030	1	.00030	2.03	.1656
AE	.00000	1	.00000	.00	.9910
BE	.00016	1	.00016	1.07	.3092
CE	.00015	1	.00015	1.02	.3220
DE	.00000	1	.00000	.00	.9732
AF	.00008	1	.00008	.55	.4643
BF	.00015	1	.00015	.97	.3322
CF	.00002	1	.00002	.13	.7223
DF	.00004	1	.00004	.25	.6215
EF	.00011	1	.00011	.72	.4022
AG	.00007	1	.00007	.49	.4399
BG	.00046	1	.00046	3.06	.0917
CG	.00011	1	.00011	.71	.4067
DG	.00007	1	.00007	.45	.5083
EG	.00012	1	.00012	.79	.3818
FG	.00025	1	.00025	1.66	.2081
AH	.00027	1	.00027	1.83	.1869
BH	.00010	1	.00010	.70	.4099
CH	.00014	1	.00014	.94	.3406
DH	.00006	1	.00006	.41	.5293
EH	.00000	1	.00000	.00	.9510

FH	.00000	1	.00000	.02	.8992
GH	.00016	1	.00016	1.05	.3151
ERROR	.00404	27	.00015		

THIS IS THE INPUT DATA, THE SPSS INPUT PROGRAM, THE SCATTERGRAM INPUT PROGRAM, AND THE RELEVANT OUTPUT FOR THE REGRESSION.

```
.01 8. 1.  257. 1.00 2.5 1.0 4350.0 36.28 .9331
    3. 1.  257. 1.00 2.5 1.0 2480.0 39.37 .8465
    3. 1.  257. 1.00 3.0 2.0 2480.0 43.24 .3377
    8. 2.  257. 1.00 3.5 1.5 2480.0 44.31 .8537
    3. 2.  504. 1.50 2.5 2.0 2480.0 43.36 .8542
    3. 2.  504. 1.50 3.0 1.5 2480.0 46.08 .3366
   10. 1.  257. 1.20 2.5 1.0 1302.0 40.32 .8103
   10. 1.  257. 1.20 3.0 2.0 1302.0 38.96 .3125
   10. 2.  257. 1.00 3.5 1.5 1802.0 43.38 .8037
   10. 2.  504. 1.00 2.5 2.0 1802.0 40.62 .7544
   10. 2.  504. 1.00 3.0 1.5 1302.0 42.92 .7577
   12. 1.  750. 1.00 2.5 1.0 2178.0 41.87 .3102
   12. 1.  750. 1.00 3.0 2.0 2173.0 41.13 .3194
   12. 2.  750. 1.00 3.5 1.5 2178.0 47.01 .8361
   12. 2.  504. 1.50 2.5 2.0 2173.0 39.38 .3432
   12. 2.  504. 1.50 3.0 1.5 2178.0 41.62 .3257
.02 8. 1.  257. 1.00 3.0 2.0 4350.0 36.75 .9342
.03 3. 1.  257. 1.00 3.5 1.5 4350.0 40.59 .9232
.04 8. 1.  504. 1.00 2.5 2.0 4350.0 37.60 .9309
.05 3. 1.  504. 1.50 3.0 1.5 4350.0 37.91 .9320
.06 8. 2.  504. 1.50 3.5 1.0 4350.0 39.35 .9134
.07 8. 2.  504. 1.50 4.0 1.5 4350.0 41.11 .9178
.08 8. 2. 1008. 1.50 2.5 2.0 4350.0 43.42 .9200
.09 8. 2. 1008. 1.25 3.0 2.5 4350.0 42.05 .9243
.10 8. 2. 1008. 1.25 3.5 3.0 4350.0 43.23 .9276
.11 8. 2.  750. 1.25 2.5 2.0 4350.0 43.39 .9375
.01 3. 1.  504. 1.00 2.5 1.0 3866.0 36.05 .3991
.02 8. 1.  504. 1.00 3.0 2.0 3866.0 36.23 .9046
.03 3. 1.  504. 1.00 3.5 1.5 3366.0 37.52 .9221
.04 8. 1.  257. 1.00 2.5 2.0 3866.0 39.59 .9101
.05 8. 2.  257. 1.00 3.0 1.5 3366.0 42.12 .9243
.06 8. 2.  257. 1.50 3.5 1.0 3866.0 40.52 .9276
.07 3. 2.  257. 1.50 4.0 1.5 3856.0 42.57 .9254
.08 8. 2. 1008. 1.50 2.5 2.0 3366.0 39.28 .3904
.09 8. 2. 1003. 1.50 3.0 2.5 3366.0 42.08 .3393
.10 8. 2. 1008. 1.00 3.5 3.0 3366.0 42.13 .3953
.11 3. 2. 1008. 1.00 2.5 2.0 3366.0 41.95 .3980
.01 8. 1. 1008. 1.50 2.5 1.0 3270.0 42.74 .3914
.02 3. 1. 1003. 1.50 3.0 2.0 3270.0 41.61 .9002
.03 8. 1. 1008. 1.00 3.5 1.5 3270.0 45.30 .8371
.04 3. 1.  504. 1.00 2.5 2.0 3270.0 37.36 .8958
.05 8. 2.  504. 1.00 3.0 1.5 3270.0 39.43 .3904
.06 3. 2.  504. 1.50 3.5 1.0 3270.0 41.71 .9013
.07 3. 2.  504. 1.50 4.0 1.5 3270.0 43.22 .8914
.08 3. 2.  257. 1.50 2.5 2.0 3270.0 42.03 .9123
```

.09	8.	2.	257.	1.25	3.0	2.5	3270.0	42.98	.8969
.10	8.	2.	257.	1.25	3.5	3.0	3270.0	42.17	.9024
.11	8.	2.	257.	1.25	4.0	1.5	3270.0	45.99	.9090
.01	8.	1.	257.	1.00	2.5	1.0	2527.0	39.74	.8596
.02	8.	1.	257.	1.00	3.0	2.0	2527.0	40.02	.8717
.03	8.	1.	257.	1.00	3.5	1.5	2527.0	43.64	.8454
.04	8.	1.	504.	1.00	2.5	2.0	2527.0	42.39	.8235
.05	8.	1.	504.	1.50	3.0	1.5	2527.0	42.87	.8224
.06	8.	1.	504.	1.50	3.5	1.0	2527.0	41.42	.8564
.07	8.	2.	504.	1.50	4.0	1.5	2527.0	50.17	.8553
.08	8.	2.	1008.	1.50	2.5	2.0	2527.0	47.23	.8202
.09	8.	2.	1008.	1.25	3.0	2.5	2527.0	47.39	.8136
.10	8.	2.	1008.	1.25	3.5	3.0	2527.0	50.54	.8231
.11	8.	2.	1008.	1.25	2.5	2.0	2527.0	47.82	.8311
.01	8.	2.	257.	1.20	2.5	1.0	1347.0	46.73	.7588
.02	8.	2.	257.	1.20	3.0	2.0	1347.0	48.04	.7588
.03	8.	2.	257.	1.00	3.5	1.5	1347.0	47.19	.7500
.04	8.	2.	504.	1.00	2.5	2.0	1347.0	48.43	.7390
.05	8.	1.	504.	1.00	3.0	1.5	1347.0	42.72	.7292
.06	8.	1.	504.	1.50	3.5	1.0	1347.0	49.98	.7193
.07	8.	1.	504.	1.50	4.0	1.5	1347.0	45.94	.7379
.08	8.	1.	1008.	1.50	2.5	2.0	1347.0	49.17	.6696
.09	8.	1.	1008.	1.50	3.0	2.5	1347.0	50.01	.6613
.10	8.	1.	1008.	1.50	3.5	3.0	1347.0	51.69	.6741
.11	8.	1.	1008.	1.25	3.0	1.5	1347.0	47.41	.7143
.01	10.	2.	257.	1.00	2.5	1.0	4350.0	36.53	.9287
.02	10.	2.	257.	1.00	3.0	2.0	4350.0	37.35	.9298
.03	10.	2.	257.	1.00	3.5	1.5	4350.0	37.52	.9112
.04	10.	2.	504.	1.00	2.5	2.0	4350.0	36.29	.9287
.05	10.	2.	504.	1.50	3.0	1.5	4350.0	38.21	.9276
.06	10.	1.	504.	1.50	3.5	1.0	4350.0	37.00	.9254
.07	10.	1.	504.	1.50	4.0	1.5	4350.0	37.60	.9243
.08	10.	1.	1008.	1.50	2.5	2.0	4350.0	37.99	.9178
.09	10.	1.	1008.	1.25	3.0	2.5	4350.0	38.06	.9173
.10	10.	1.	1008.	1.25	3.5	3.0	4350.0	38.41	.9178
.11	10.	1.	750.	1.25	2.5	2.0	4350.0	41.49	.9363
.01	10.	2.	504.	1.00	2.5	1.0	3866.0	35.09	.9090
.02	10.	2.	504.	1.00	3.0	2.0	3866.0	35.94	.9145
.03	10.	2.	504.	1.00	3.5	1.5	3866.0	36.65	.9145
.04	10.	2.	257.	1.00	2.5	2.0	3866.0	36.19	.9167
.05	10.	1.	257.	1.00	3.0	1.5	3866.0	36.53	.9156
.06	10.	1.	257.	1.50	3.5	1.0	3866.0	36.50	.9101
.07	10.	1.	750.	1.50	4.0	1.5	3866.0	46.02	.8762
.08	10.	1.	1008.	1.50	2.5	2.0	3866.0	36.31	.8958
.09	10.	1.	1008.	1.50	3.0	2.5	3866.0	37.12	.8991
.10	10.	1.	1008.	1.00	3.5	3.0	3866.0	36.85	.8860
.11	10.	1.	1008.	1.00	2.5	2.0	3866.0	34.95	.8969
.01	10.	2.	1008.	1.50	2.5	1.0	3270.0	41.04	.8860
.02	10.	2.	1008.	1.50	3.0	2.0	3270.0	41.67	.8838
.03	10.	2.	1008.	1.00	3.5	1.5	3270.0	43.14	.9057
.04	10.	2.	504.	1.00	2.5	2.0	3270.0	36.96	.8914
.05	10.	1.	504.	1.00	3.0	1.5	3270.0	33.28	.8772
.06	10.	1.	504.	1.50	3.5	1.0	3270.0	37.77	.8893
.07	10.	1.	750.	1.50	4.0	1.5	3270.0	48.13	.8785

.0810.	1.	257.	1.50	2.5	2.0	3270.0	37.22	.9189
.0910.	1.	257.	1.25	3.0	2.5	3270.0	38.62	.8936
.1010.	1.	257.	1.25	3.5	3.0	3270.0	37.71	.9287
.1110.	1.	257.	1.25	4.0	1.5	3270.0	39.44	.8969
.0110.	2.	1008.	1.50	2.5	1.0	3270.0	41.04	.8860
.0210.	2.	1008.	1.50	3.0	2.0	3270.0	41.67	.8838
.0310.	2.	1008.	1.00	3.5	1.5	3270.0	43.14	.9057
.0410.	2.	504.	1.00	2.5	2.0	3270.0	36.96	.8914
.0510.	1.	504.	1.00	3.0	1.5	3270.0	38.23	.8772
.0610.	1.	504.	1.50	3.5	1.0	3270.0	37.77	.8893
.0710.	1.	750.	1.50	4.0	1.5	3270.0	48.13	.8785
.0810.	1.	257.	1.50	2.5	2.0	3270.0	37.22	.9189
.0910.	1.	257.	1.25	3.0	2.5	3270.0	38.62	.8936
.1010.	1.	257.	1.25	3.5	3.0	3270.0	37.71	.9237
.1110.	1.	257.	1.25	4.0	1.5	3270.0	39.44	.8969
.0110.	1.	257.	1.20	2.5	1.0	1347.0	39.69	.7473
.0210.	1.	257.	1.20	3.0	2.0	1347.0	41.67	.7231
.0310.	1.	257.	1.00	3.5	1.5	1347.0	44.60	.7445
.0410.	1.	504.	1.00	2.5	2.0	1347.0	40.75	.7336
.0510.	2.	504.	1.00	3.0	1.5	1347.0	43.29	.7423
.0610.	2.	504.	1.50	3.5	1.0	1347.0	44.60	.7566
.0710.	2.	504.	1.50	4.0	1.5	1347.0	47.39	.7478
.0810.	2.	1008.	1.50	2.5	2.0	1347.0	51.98	.7377
.0910.	2.	1008.	1.50	3.0	2.5	1347.0	49.00	.7357
.1010.	2.	1008.	1.50	3.5	3.0	1347.0	44.55	.7204
.1110.	2.	1008.	1.25	3.0	1.5	1347.0	45.96	.7336
.0112.	2.	257.	1.00	2.5	1.0	4350.0	35.54	.9298
.0212.	2.	257.	1.00	3.0	2.0	4350.0	35.38	.9309
.0312.	2.	257.	1.00	3.5	1.5	4350.0	34.80	.9276
.0412.	2.	504.	1.00	2.5	2.0	4350.0	35.63	.9353
.0512.	2.	504.	1.50	3.0	1.5	4350.0	36.68	.9342
.0612.	1.	504.	1.50	3.5	1.0	4350.0	36.23	.9254
.0712.	1.	504.	1.50	4.0	1.5	4350.0	37.20	.9254
.0812.	1.	1008.	1.50	2.5	2.0	4350.0	36.21	.9167
.0912.	1.	1008.	1.25	3.0	2.5	4350.0	38.30	.9101
.1012.	1.	1008.	1.25	3.5	3.0	4350.0	37.68	.9167
.1112.	1.	750.	1.25	2.5	2.0	4350.0	33.83	.9421
.0112.	1.	504.	1.00	2.5	1.0	3866.0	34.36	.9068
.0212.	1.	504.	1.00	3.0	2.0	3866.0	35.16	.9063
.0312.	1.	504.	1.00	3.5	1.5	3866.0	34.15	.9211
.0412.	1.	257.	1.00	2.5	2.0	3866.0	34.95	.8991
.0512.	2.	257.	1.00	3.0	1.5	3866.0	35.35	.9178
.0612.	2.	257.	1.50	3.5	1.0	3866.0	37.35	.9200
.0712.	2.	257.	1.50	4.0	1.5	3866.0	37.01	.9090
.0812.	2.	1008.	1.50	2.5	2.0	3866.0	37.80	.8953
.0912.	2.	1008.	1.50	3.0	2.5	3866.0	39.55	.9032
.1012.	2.	1008.	1.00	3.5	3.0	3866.0	39.96	.8762
.1112.	2.	1008.	1.00	2.5	2.0	3866.0	39.07	.8737
.0112.	2.	1008.	1.50	2.5	1.0	3270.0	38.27	.9046
.0212.	2.	1008.	1.50	3.0	2.0	3270.0	39.73	.9013
.0312.	2.	1008.	1.00	3.5	1.5	3270.0	33.79	.8832
.0412.	2.	504.	1.00	2.5	2.0	3270.0	36.31	.8882
.0512.	1.	504.	1.00	3.0	1.5	3270.0	37.48	.8893
.0612.	1.	504.	1.50	3.5	1.0	3270.0	36.97	.8794

```
.0712. 1.  750. 1.50 4.0 1.5 3270.0 42.34 .8993
.0812. 1.  257. 1.50 2.5 2.0 3270.0 36.47 .9189
.0912. 1.  257. 1.25 3.0 2.5 3270.0 35.64 .9090
.1012. 1.  257. 1.25 3.5 3.0 3270.0 37.13 .9090
.1112. 1.  257. 1.25 4.0 1.5 3270.0 37.29 .8947
.0112. 1.  257. 1.00 2.5 1.0 2527.0 37.43 .8805
.0212. 1.  257. 1.00 3.0 2.0 2527.0 37.20 .8575
.0312. 1.  257. 1.00 3.5 1.5 2527.0 37.52 .8596
.0412. 1.  504. 1.00 2.5 2.0 2527.0 36.91 .8465
.0512. 1.  504. 1.50 3.0 1.5 2527.0 39.13 .8443
.0612. 1.  504. 1.50 3.5 1.0 2527.0 38.19 .8520
.0712. 2.  504. 1.50 4.0 1.5 2527.0 40.96 .8542
.0812. 2. 1008. 1.50 2.5 2.0 2527.0 43.25 .8279
.0912. 2. 1008. 1.25 3.0 2.5 2527.0 43.01 .8377
.1012. 2. 1008. 1.25 3.5 3.0 2527.0 41.92 .8257
.1112. 2. 1008. 1.25 2.5 2.0 2527.0 40.69 .8377
.0112. 1.  257. 1.20 2.5 1.0 1347.0 39.25 .7390
.0212. 1.  257. 1.20 3.0 2.0 1347.0 39.88 .7473
.0312. 1.  257. 1.00 3.5 1.5 1347.0 40.12 .7314
.0412. 1.  504. 1.00 2.5 2.0 1347.0 41.14 .7204
.0512. 2.  504. 1.00 3.0 1.5 1347.0 42.67 .7171
.0612. 2.  504. 1.50 3.5 1.0 1347.0 45.96 .7599
.0712. 2.  504. 1.50 4.0 1.5 1347.0 42.17 .7478
.0812. 2. 1008. 1.50 2.5 2.0 1347.0 43.39 .6941
.0912. 2. 1008. 1.50 3.0 2.5 1347.0 46.89 .6903
.1012. 2. 1008. 1.50 3.5 3.0 1347.0 42.94 .6645
.1112. 2. 1008. 1.25 3.0 1.5 1347.0 44.76 .6963
```

THIS IS THE SPSS REGRESSION INPUT FILE

```
RUN NAME          CSRL ANALYSIS
VARIABLE LIST     CREW,LEVEL,INSPT,LOAD,MISL,COMP,MTBF,GENTIM,AVAIL
INPUT FORMAT      (4X,F3.0,F3.0,F6.0,F5.2,2(1X,F3.1),1X,F6.1,F6.2,F6.4)
INPUT MEDIUM      CARDS .
N OF CASES        UNKNOWN
RECODE            LEVEL(1=3)
COMPUTE           INSP=547.5/INSPT
COMPUTE           MTBF=MTBF/3750.0
COMPUTE           CWXLEVL=CREW*LEVEL
COMPUTE           CWXINSP=CREW*INSP
COMPUTE           CWXMSL=CREW*MISL
COMPUTE           CWXMTBF=CREW*MTBF
COMPUTE           LGMTBF=LG10(MTBF)
REGRESSION        VARIABLES=CREW,LEVEL,LOAD,MTBF,CWXLEVL,CWXINSP,
                    CWXMSL,CWXMTBF,GENTIM/
                  REGRESSION=GENTIM WITH CREW TO CWXMTBF/RESIDUALS
STATISTICS        ALL
OPTIONS           2,3,3,11,22
SCATTERGRAM       AVAIL WITH LGMTBF
REGRESSION        VARIABLES=INSP,LGMTBF,AVAIL/
                   REGRESSION=AVAIL WITH LGMTBF,INSP/RESIDUALS
STATISTICS        ALL
OPTIONS           2,3,3,11,22
READ INPUT DATA
FINISH
```

```
RUN NAME          SCATTERGRAM OF RESIDUALS
VARIABLE LIST     Y,YHAT,RESIDUAL
INPUT FORMAT      FIXED(26X,2F13.7,F15.7)
N OF CASES        UNKNOWN
SCATTERGRAM       RESIDUAL WITH YHAT
SCATTERGRAM       YHAT WITH RESIDUAL
READ INPUT DATA
FINISH
```

VARIABLE	MEAN	STANDARD DEV	CASES
CREW	10.0000	1.6375	180
LEVEL	2.5000	.5014	180
LOAD	1.2478	.2229	180
MTBF	.3471	.1191	180
CWXLEVL	25.0111	5.5416	180
CWXINSP	12.3213	6.7405	180
CWXMSL	30.7500	7.1323	180
CWXMTBF	3.4694	1.3235	180
GENTIM	40.7539	4.0660	180

MULTIPLE R	.8670	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.7516	REGRESSION	8.	2224.305	278.038	64.588
STD DEV	2.0732	RESIDUAL	171.	734.935	4.293	SIG. .000
ADJ R SQUARE	.7400	COEFF OF VARIABILITY		5.1PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
CREW	-2.738	.573	23.689	.000	-1.12273	-.68398
LOAD	2.051	.756	7.353	.007	.11246	.06230
MTBF	-37.194	8.200	20.576	.000	-1.03935	-.31677
LEVEL	-5.317	1.945	7.471	.007	-.65566	-.32612
CWXINSP	-.171	.026	43.551	.000	-.28311	-.05163
CWXMSL	.143	.032	20.195	.000	.25075	.10784
CWXMTBF	1.529	.807	4.072	.045	.53239	.13870
CWXLEVL	.377	.193	3.818	.052	.60579	.23105
CONSTANT	74.919	5.974	157.300	.000		

COEFFICIENTS AND CONFIDENCE INTERVALS.

VARIABLE	B	95 PCT C.I.	
CREW	-2.7373	-3.9135	-1.6572
LOAD	2.0513	.5591	3.5436
MTBF	-37.1942	-53.3795	-21.0083
LEVEL	-5.3170	-9.1569	-1.4771
CWXINSP	-.1708	-.2219	-.1197
CWXMSL	.1429	.0802	.2057
CWXMTBF	1.5294	.0356	3.2233
CWXLEVL	.3765	-.0039	.7569
CONSTANT	74.9192	63.1279	86.7105

VARIABLE	MEAN	STANDARD DEV	CASES
INSP	1.2372	.6470	180
LGMTBF	-.4916	.1732	180
AVAIL	.8593	.0730	180

DEP. VAR... AVAIL

MULTIPLE R	.9744	ANOVA	DF	SUM SQUARES	MEAN SQ.	F
R SQUARE	.9494	REGRESSION	2.	.906	.453	1660.702
STD DEV	.0165	RESIDUAL	177.	.048	.000	SIG. .000
ADJ R SQUARE	.9488	COEFF OF VARIABILITY		1.9PCT		

VARIABLE	B	S.E. B	F	SIG.	BETA	ELASTICITY
INSP	.016	.002	66.208	.000	.13757	.02235
LGMTBF	.395	.007	3247.372	.000	.96349	-.22534
CONSTANT	1.034	.004	56832.663	0		

COEFFICIENTS AND CONFIDENCE INTERVALS.

VARIABLE	B	95 PCT C.I.	
INSP	.0155	.0113	.0193
LGMTBF	.3948	.3811	.4084
CONSTANT	1.0342	1.0256	1.0427

Bibliography

1. Air Force Operational Test and Evaluation Center (AFOTEC/LGMW). Second Draft of CSRL Test Plan, Annex 3: Operational Suitability. Kirtland AFB OH, 1 June 1984.

2. Banks, Jerry and John S. Carson, II. Discrete-Event System Simulation. New Jersey: Prentice-Hall, Inc., 1984.

3. Boeing Document No. D405-0347-1. CSRL Integrated Support Plan. 45. Boeing Military Airplane Company, Wichita, KS, 26 January 1983.

4. Boeing Document No. D405-10350-1. Reliability/Maintainability Allocations, Assessment and Analysis Report - CSRL. Boeing Military Airplane Company, Wichita, KS.

5. DeGovanni, Capt George and Maj Donald M. Douglas. Estimation of F-15 Peacetime Maintenance Manpower Requirements Using the Logistics Compostie Model. MS Thesis GOR/SM/76D-5. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, Dec 1976.

6. Department of the Air Force. Air Force Reliability and Maintainability Program. AFR 800-18. Washington: HQ USAF, 15 June 1982.

7. Department of the Air Force, Air Force Logisitics Command. D056 Data, WUC BA000. HQ AFLC: Wright-Patterson AFB OH, 1 Oct 1983 - 31 Mar 1984.

8. Hulem, Capt Frederick C., Logistics Evaluation Manager, Munitions. Personal Interviews. AFOTEC/LGMW, Kirtland AFB NM, 13 June through 2 November 1984.

9. McNichols, Charles W. "Applied Multivariate Statistics." Lecture materials distributed in SM 6.85, Applied Multivariate Analysis. School of Engineering, Air Force Institute of Technology (AFC), Wright-Patterson AFB OH, April 1984.

10. Melaragno, Lt Jeffrey J. Use of the Logistics Composite Model to Evaluate Avionics Availability, 1Jan 1980-1 Mar 1981. Report ASD-TR-81-5028, Aeronautical Systems Division (AFSC), Wright-Patterson AFB OH, July 1981 (AD A127 542).

11. Merrill, William C. and Karl A. Fox. Introduction to Economic Statistics. New York: John Wiley & Sons, Inc., 1973.

12. Neter, John and others. Applied Linear Regression Models. Homewood, IL: Richard D. Irwin, Inc., 1983.

13. Price, Capt Richard S., Jr. and Herb E. Morgan, Jr. Proposed Thesis Topic Correspondence. "An LCOM Simulation Model of the Common Strategic Rotary Launcher (CSRL) for Availability Projections."

AFOTEC/LG4A, Kirtland AFB NM, undated.

14. Pritsker, A. Alan, and Claude D. Pegden. Introduction to Simulation and SLAM. New York: John Wiley & Sons, Inc., 1979.

15. Smith, Palmer W. and Joseph M. Mellichamp. "Multidimensional Parametric Analysis Using Response Surface Methodology and Mathematical Programming as Applied to Military Problems." Proceedings of the Pacific Conference on Operations Research. 592-613. Military Operations Research Society of Korea, Seoul, Korea, 1979.

16. Tabachnick, Barbara B. and Linda S. Fidell. Using Multivariate Statistics. New York: Harper & Row Publishers, 1983.

17. United States Department of Commerce. Fractional Factorial Experiment Designs for Factors at Three Levels. National Bureau of Standards Applied Mathematics Series 54. Washington: Government Printing Office, 1959.

18. United States Department of Commerce. Fractional Factorial Experiment Designs for Factors at Two Levels. National Bureau of Standards Applied Mathematics Series 48. Washington: Government Printing Office, 1957.

VITA

Captain Sarah J. Gjerstad was born on 22 January 1956 in Marquette, Michigan. She attended the University of Minnesota from which she received a Bachelor of Arts degree in Mathematics, in December 1979. She received a commission in the USAF through OTS in June 1980. Her first assignment was to the Aeronautical Systems Division at Wright-Patterson AFB, OH. She worked as an Operations Research Analyst in the Life Cycle Cost Management Division until being reassigned to the Air Force Institute of Technology, WPAFB, OH in May 1983.

Permanent address: 1233 Trailwood South
Hopkins, MN 55343

VITA

First Lieutenant Roxann A. Oyler was born on 9 August 1959 in Stockton, California. She attended the University of Central Florida from which she received a Bachelor of Science degree in Applied Mathematics, in June 1981. Upon graduation, she received a commission in the USAF through the ROTC program and entered active duty in October 1981. Her first assignment was to the Deputy Chief of Staff Plans and Programs, Headquarters Air Force Logistics Command at Wright-Patterson AFB, OH. She worked as a Logistics Plans and Programs Staff Officer in the War and Logistics Plans Division and then as an Operations Research Analyst in the Management Science office until being reassigned to the Air Force Institute of Technology, WPAFB, OH in May 1983.

Permanent address: 1615 Idaho Ave
Orlando, FL 32809

END

FILMED

5-85

DTIC

END

FILMED

5-85

DTIC