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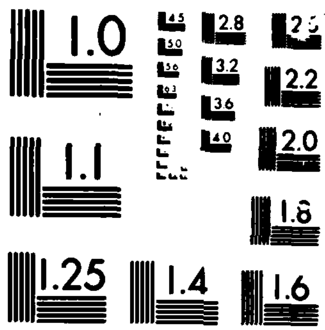


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# A SIMULATION MODEL FOR DETERMINING THE EFFECT OF RELIABILITY AND MAINTAINABILITY ON MAINTENANCE MANPOWER REQUIREMENTS AND MISSION CAPABILITIES

THESIS

Myron L. Lewellen
Captain, USAF

AFIT/GOR/OS/85D-13



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# A SIMULATION MODEL FOR DETERMINING THE EFFECT OF RELIABILITY AND MAINTAINABILITY ON MAINTENANCE MANPOWER REQUIREMENTS AND MISSION CAPABILITIES

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

Myron L. Lewellen, B.S.
Captain, USAF

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Improved reliability and maintainability of modern weapon systems has become the focus of top level Air Force leaders. To assist in R&M decisions, a simulation model specifically designed to address R&M questions must be developed. This research specifically addressed the problem of accurately predicting the impact of improved reliability and maintainability on maintenance manpower requirements, mission capable aircraft, and sortie rates. An additional question examined is the impact of Project Rivet Workforce on maintenance manpower requirements. Two scenerios were used with a peacetime scenerio used for the manpower analyses, and a wartime surge scenerio used for the mission effectiveness questions. The model developed is an aircraft maintenance model based on a generic squadron of twenty-four tactical fighters using current F-15 data and is written in Simulation Language for Alternative Modeling (SLAM). The analyses were performed with reliability levels at a baseline, a twofold improvement, and a fourfold improvement.

Maintainability was examined at a baseline, a 33% decrease, and a 67% decrease in mean repair times. A full factorial analysis of variance and regression analysis were used to address the mission effectiveness questions. A non-statistical analysis was performed for the manpower assessments using the capabilities of the model. The results of this research suggest that reliability, maintainability, and crew size have a significant effect on the average number of sorties that can be flown and the average number of mission capable aircraft available. The manpower analysis indicates that a twofold increase in reliability can reduce manpower requirements by 6% and a fourfold increase will result in a 22% reduction. The research also shows that for the work centers modeled, the specialty consolidations suggested by Project Rivet Workforce can result in manpower reductions of 4-13 percent.

## Preface

The purpose of this ~~research~~ was to analyze the effects of reliability and maintainability (R&M) on mission capable aircraft, sorties flown, and maintenance manpower. This was accomplished by developing a simulation model of the aircraft maintenance system for a generic tactical fighter squadron. The model can be used by AF/LE-R or other organizations that are required to make R&M decisions related to tactical aircraft or wish to gain additional insight into the relationship between R&M and aircraft performance. Care should be taken when using the manpower results of this study. The manpower impacts suggested are only applicable to the work centers and scenerios modeled and cannot be extrapolated to other areas of the maintenance complex. The study addresses the following questions:

1. What effect does reliability, maintainability, and crew size have on sortie generation capability and the average number of mission capable aircraft available?
2. What impact does improved system reliability have on maintenance manpower requirements?
3. What effect does specialty consolidation have on maintenance manpower requirements?

I wish to acknowledge those people who provided me the guidance and assistance that made this thesis possible. First, I want to thank my advisor, Lieutenant Colonel Charles E. Ebeling, for suggesting this topic area and for providing professional advice when necessary and a sense of humor when needed. I also want to thank Mr. Elliot Wunsh of ASD/ENSSC and Mr. Phil Stone and Capt Sam Pennartz of HQ TAC/XPMS for assisting me in obtaining the necessary data for this research. Finally, I wish to thank my wife, Linda, and my daughters, Angie and Missy, for their understanding and cooperation when studies were put ahead of good times.

Myron L. Lewellen

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## Abstract

Improved reliability and maintainability of modern weapon systems has become the focus of top level Air Force leaders. The assumption being made by these leaders is that improved R&M will reduce maintenance manpower requirements and improve mission effectiveness. To assist in R&M decisions, a simulation model specifically designed to address R&M questions must be developed. This research specifically addressed the problem of accurately predicting the impact of improved reliability and maintainability on maintenance manpower requirements, mission capable aircraft, and sortie rates. An additional question examined is the impact of Project Rivet Workforce on maintenance manpower requirements. Two scenerios were used with a peacetime scenerio used for the manpower analyses, and a wartime surge scenerio used for the mission effectiveness questions. The model developed is an aircraft maintenance model based on a generic squadron of twenty-four tactical fighters using current F-15 data and is written in Simulation Language for Alternative Modeling (SLAM). The analyses were performed with reliability levels at a baseline, a twofold improvement, and a fourfold improvement.

Maintainability was examined at a baseline, a 33% decrease, and a 67% decrease in mean repair times. Crew sizes were held at two levels, current minimum manpower requirements and with all maintenance tasks requiring only one person. A full factorial analysis of variance and regression analysis were used to address the mission effectiveness questions. A non-statistical analysis was performed for the manpower assessments using the capabilities of the model. The results of this research suggest that reliability, maintainability, and crew size have a significant effect on the average number of sorties that can be flown and the average number of mission capable aircraft available. The manpower analysis indicates that a twofold increase in reliability can reduce manpower requirements by 6% and a fourfold increase will result in a 22% reduction. These manpower results are only applicable to the work centers modeled and cannot be extrapolated across the maintenance complex. The research also shows that for the work centers modeled, the specialty consolidations suggested by Project Rivet Workforce can result in manpower reductions of 4-13 percent.

# A SIMULATION MODEL FOR DETERMINING THE EFFECT OF RELIABILITY AND MAINTAINABILITY ON MAINTENANCE MANPOWER REQUIREMENTS AND MISSION CAPABILITIES

## I. Introduction

### Background

Over the past ten years, improved reliability and maintainability of modern weapon systems has become the focus of top level management. As stated by General Charles A. Gabriel, Air Force Chief of Staff, "An effective R&M program can make our weapon systems more available, mobile, and durable, as well as reduce manpower and support costs".(4:transmittal letter). To support this commitment, the Air Force has established a Special Assistant for Reliability and Maintainability in the Air Staff and has published a detailed action plan, R&M 2000 (4), to ensure that R&M receives equal consideration with cost, schedule, and performance when weapon systems are evaluated.

The capability to quantify and minimize manpower requirements has always been a major objective of the Air Force and has become even more critical as Congressional constraints that limit manpower growth and in some instances greatly reduce stated manpower requirements are imposed. Managing manpower resources becomes even more critical as new programs are implemented and new weapon systems become operational. These programs are often implemented using current manpower strengths. To accomplish this, the Air Force must devise ways to reduce manpower requirements in existing programs. These reduction methods are often subjective and can result in optimistic estimates that become established goals or even hard commitments. The Air Force has had some success at reducing manpower requirements through productivity enhancement efforts and improved management concepts. A current enhancement initiative is Project Rivet Workforce which proposes consolidation of aircraft maintenance specialties. The impact of this project on maintenance manpower requirements is included as part of the analysis performed in this thesis.

The assumption made in the R&M 2000 action plan is that improved R&M will reduce current maintenance manpower requirements without reducing mission effectiveness. However, a need to quantify the effects that improved R&M has on maintenance manpower requirements is now required. When addressing this issue, misconceptions often occur where a reduction in manhours is assumed to translate into a reduction in manpower. These misconceptions are a result of not recognizing the impact that maintenance concepts and policies can have on manpower requirements. HQ TAC/XPMS conducted a study (5:1) that analyzed the effects of using manhours versus manpower and concluded that, "Study results indicate that predicted manpower reductions should not be based solely upon the reduction in man-hours caused by a doubling or quadrupling in subsystem reliability. Other factors such as minimum crew size, peak demands, and the interactions between subsystems have an effect upon manpower " (5:9).

Maintenance manpower currently includes 219,000 authorizations -- twenty-six percent of the 844,160 total Air Force authorizations. Studies have predicted a range of ten to twenty percent savings with a fourfold improvement in reliability. As an extreme, this ten percent difference could understate or overstate requirements by 21,900 authorizations.

Similiar predictions have been made concerning mission effectiveness such as the average number of mission capable aircraft available and the average daily sortie rate that can be flown. Predictions for sortie rates have suggested large increases in sorties can be achieved with twofold and fourfold improvements in reliability. Since these factors are critical elements of war and operational plans, understatement or overstatement could seriously affect our war-fighting capability.

Many of these estimates were derived from large scale simulation models that were not designed specifically for R&M assessment, rely on extremely large data bases, and require large amounts of computer time. To assist in the R&M decision process, a model must be developed that focuses on reliability and maintainability issues and thus provides accurate predictions from which Air Force level decisions can be made.

## Problem Statement

This thesis specifically addresses the problem of accurately predicting the impact of improved reliability and maintainability on maintenance manpower requirements, mission capable aircraft, and sortie rates. This thesis does not address the effects of R&M on other issues such as cost, spares, and mobility.

Prior to addressing specific objectives, it is necessary to define the terms reliability and maintainability as they are used in this thesis. "Reliability is the probability of a device performing its purpose adequately for the period of time intended under the operating conditions encountered." (1:1).

> Maintainability is a quality of the combined features and characteristics of equipment design which permits or enhances the accomplishment of maintenance by personnel of average skill under natural and enviromental conditions under which it will operate. As in the case of reliability, maintainability is a probability statistic. The basic difference between the two is that in the case of maintainability we are interested in the probability of restoring a device which has failed or is functioning abnormally to its full operating effectiveness within a period of time, whereas reliability is concerned with the probability of survival of an operating unit with respect to time (1:113-114).

Objectives

The objectives of this thesis can best be described by the following research questions.

1. How does improved reliability impact sortie generation capability?
2. How does improved system maintainability impact sortie generation capability?
3. How does improved system reliability coupled with improved maintainability impact sortie generation capability?
4. What effect does crew size have on sortie generation capability?
5. What effect does crew size in conjunction with improved reliability and/or maintainability have on sortie generation capability?
6. How does improved system reliability impact the number of mission capable aircraft?
7. How does improved system maintainability impact the number of mission capable aircraft?
8. How does improved system reliability coupled with improved maintainability impact the number of mission capable aircraft?
9. What effect does crew size have on the number of mission capable aircraft?
10. What effect does crew size in conjunction with improved reliability and/or maintainability have on the number of mission capable aircraft?

11. What impact does improved system reliability have on maintenance manpower requirements?

12. What effect does specialty consolidation have on maintenance manpower requirements?

## Overview

The remainder of this thesis contains four chapters. Chapter II provides a description of the aircraft maintenance system and identifies three measures of merit and two scenerios used in the research.

Chapter III describes the Slam model and identifies the four primary variables of interest included in the model. It also addresses the assumptions and limitations of the model and describes the methods of verification and validation used.

Chapter IV provides descriptions of the analyses performed and the results of each. Also included are tradeoff curves for reliability and maintainability that show the various combinations of reliability and maintainability levels required to achieve a set of desired sortie rates.

The final chapter discusses specific and general conclusions that can be reached based on the model developed and the analyses performed.

# II. Operational Concept

## System Definition

The aircraft maintenance system is a highly complex system of resources and activities that interact to maintain a pool of mission capable aircraft. The overall system can be broken into smaller modules--scheduled maintenance, unscheduled maintenance, and flying activities--and can be best understood by individually examining each of these modules as they were addressed in this study.

The scheduled maintenance areas include all maintenance actions that occur on a regular basis either prior to a mission or immediately following the mission. Prior to each mission, a preflight inspection is accomplished to ensure the aircraft is mechanically capable of flying the scheduled mission. If a system failure is detected during the preflight inspection, the aircraft is removed from the mission capable aircraft pool and sent to the unscheduled maintenance module. If no failures are detected, the aircraft is released to fly the mission. Immediately following a mission, a postflight or thruflight (depending on the remaining daily flying schedule) is accomplished. If system failures are discovered, the aircraft is removed from the mission capable pool and sent to the unscheduled maintenance module. In addition, following each mission a check is made to see if phase (preventive) maintenance is required. If phase is required, the aircraft is removed from the mission capable pool and the scheduled phase maintenance is performed. If no postflight failures are detected and phase maintenance is not scheduled, the aircraft remains in the mission capable pool and is sent to the flying module.

When an aircraft enters the unscheduled maintenance module, one of three possible actions can occur. 1) The defective component can be repaired on the aircraft and the aircraft released to the mission capable pool. 2) The failure cannot be duplicated and the aircraft is released. 3) The defective component is removed from the aircraft, replaced by a spare part, and the aircraft is released. If a remove and replace is accomplished, the removed component is sent to an in-shop repair facility where one of three possible actions can occur. 1) The component is repaired in-shop and used as a spare for future remove and replace actions. 2) The component cannot be repaired in-shop and is sent to depot. 3) The component is bench checked, no repair is required, and the component is released to the spares pool.

Once the aircraft has been released to the flying module, the flying module checks for daylight and weather conditions. If daylight and clear weather are present, the mission is flown.

The interaction of these three modules continue and together they make-up the aircraft maintenance system.

## Measures of Merit

The three primary measures of merit for this research are described below.

1. The first measure is the total number of sorties that can be flown for a designated period of time. In this thesis the analysis of sorties was based on a 30 day wartime surge period. This measure is significant because the primary mission of an aircraft maintenance system is the ability of the system to keep the aircraft flying.

2. The second measure of interest is the average number of mission capable aircraft available. While the number of sorties flown is dependent on available aircraft, sorties flown can also be influenced by factors such as daylight, weather, and other factors not directly controlled by the maintenance system. The number of mission capable aircraft provides a measure fully controlled by the aircraft maintenance system.

3. The third measure of merit is the number of maintenance manpower resources required to provide a desired sortie rate. This factor is a function of crew size, specialty structure, failure rates, and repair times. This measure is particularly important from a cost and resource availability standpoint.

Scenerio

There are two scenerios used for the analyses conducted in this thesis. A peacetime scenerio is used to address the manpower questions and a wartime surge scenerio is used in assessing mission capability impacts. Each of these scenerios are described as follows.

Peacetime. The peacetime scenerio is based on a generic squadron of 24 aircraft with a daily sortie rate of 1.0 (i.e. an average of one sortie per aircraft per day). Flying is restricted to daytime and clear weather must be present. Maintenance crews work two eight hour shifts per day except the crew chiefs, who work three eight hour shifts per day. The simulation model is based on twelve hours of daylight and bad weather occurs every 18 to 30 hours based on a uniform distribution and lasts for a duration of 1.5 to 2.5 hours also based on a uniform distribution. Two aircraft are considered non-mission capable due to awaiting supply, providing a 8.33 percent Non-mission Capable Supply (NMCS) rate. Therefore, 22 aircraft are available to fly if no unscheduled or phase maintenance is being performed.

Wartime Surge. A surge period of thirty days is modeled with the first seven days having no phase maintenance performed. There is no established daily sortie rate since during the surge period as many sorties as possible are desired. Maintenance crews work two twelve hour shifts per day for the entire thirty days. The number of aircraft modeled and the daytime and weather conditions are the same as the peacetime scenerio. Postflight time to taxi, park, and perform a post/thru flight inspection was reduced by .30 hours. The task time for phase maintenance was reduced from a uniform distribution from 24-36 hours for peacetime to a uniform distribution from 5-6 hours for the wartime surge.

A comparison of major factors for the two scenerios are summarized in Table I.

TABLE I

Comparison of Major Factors
For Peacetime and Wartime Surge Scenerios

| Factor | Peacetime Value | Surge Value |
|---|---|---|
| Sortie Rate | 24.00/day | 120.00/day |
| Number of Aircraft | 24.00 | 24.00 |
| Number of Work Centers | 24.00 | 24.00 |
| Daylight Hours | 12.00/day | 12.00/day |
| Average Sortie Length | 2.00 hours | 2.00 hours |
| Postflight Taxi and Park | .40 hours | .20 hours |
| Post/Thru Flight Inspection | .30 hours | .20 hours |
| Phase Length Day 1-7 | 24-36 hours | None |
| Phase Length Day 8 to End | 24-36 hours | 5-6 hours |
| Shift Lengths | 8.00 hours | 12.00 hours |
| Manhour Availability | 145.2 hrs/mo* | 309 hrs/mo** |
| Weather Conditions | Same For Both | |
| * 8 hrs/day, 5 days/wk | | ** 12 hrs/day, 6 days/wk |

# III. Model

## Model Structure

The model developed for this research is an aircraft maintenance model based on a generic squadron of twenty-four tactical aircraft. The model is written in Simulation Language for Alternative Modeling (SLAM) (8) and was developed on a Vax 11/785 VMS computer system. The model is a macro model with work unit codes (specific system identifications such as airframe, landing gear, etc.) aggregated to the two-digit level. Maintenance tasks are grouped into categories of scheduled maintenance (e.g. preflight, post/thru flight, and phase maintenance) and unscheduled maintenance and include repairs performed both on the aircraft and in-shop.

The model structure can be described as follows. A squadron of twenty-four aircraft are created. Each aircraft has twenty-one major systems and four scheduled phases associated with it. Failure clocks based on number of sorties flown for the twenty-one major systems and flying hours for the four phases are assigned as attributes of that specific aircraft. Once created the aircraft will enter the scheduled maintenance preflight activity. When the preflight is completed, the aircraft will be released to fly. Two conditions must be met before the sortie can be initiated. First, it must be daylight and second, there must be clear weather conditons (above minimums). If either or both of these conditions are not met, the aircraft is placed into a queue until both conditions are met. If these conditions are met, the aircraft proceeds through prelaunch activities and flies the sortie. Upon returning from the sortie, the failure clocks for the twenty-one major systems are decremented by one and the phase clocks are decremented by the length of the sortie. A check is made based on the value of the clocks after postsortie decrementing to determine if phase maintenance is required or if a system has failed and requires unscheduled maintenance. If neither has occurred, a thru/post flight is performed and if it is still daylight, the aircraft is released to fly. If daylight has expired, the aircraft is sent to preflight to prepare for the next day's flying.

If a system failure is detected and the aircraft is sent to the unscheduled maintenance network, it is declared non-mission capable and placed in a queue to await the availability of the required maintenance work center (resource). The model utilizes twenty-four maintenance work centers with a separate queue for each. Once the resource is available, the repair action is either completed on the aircraft or the failed component is removed and replaced with a spare part. The aircraft and resources are then released, the failure clock is reset, and a check is made to see if any more failures are present. If no more failures exist, the aircraft is designated mission capable and released for preflight. If a second failure is detected, the above process is repeated.

If a component was removed during the unscheduled maintenance action, an artificial entity (temporary component) is created and is routed to an in-shop repair network. This network has no impact on the availability of the aircraft and is therefore not significant in determining mission capable aircraft or number of sorties flown. However, it is significant for determining manpower resources. Once in the shop network, the entity awaits manpower resources and is sent through an activity where the component is either repaired and placed in the spares pool or sent to depot level maintenance. Once the shop repair is made, the resources are released and the artificial entity is terminated.

If phase maintenance is scheduled, the aircraft is declared non-mission capable and placed into the phase network for a specified period of time. Once this time period is over, the aircraft is released to the mission capable aircraft pool and sent to preflight.

Appendix B contains the SLAM and fortran code for the model as well as user information and sample model output.

## Model Parameters

There are four primary variables of interest included in the model. Deterministic variables are resource levels for each maintenance work center and crew sizes for each repair task. Stochastic variables used in the model are times between failures (TBF) and times to repair (TTR). The distributions for each of these variables are based on the distributions used by the Logistics Composite Modeling (LCOM) model (3:3-30 to 3-31). The failure rates for unscheduled maintenance actions for the twenty-one major systems are based on an exponential distribution. The mean (u) of the distribution for each system is based on HQ TAC provided F-15 LCOM computer data dated 12 June 1985 and is an aggregation of subsystem failure rates into a total system (two-digit) failure rate by use of reciprocals. For example, as shown in Table II, the reciprocals of the sorties/failure are computed for each subsystem. These are summed to calculate the number of failures per sortie for the entire system. The reciprocal of this sum is then taken to compute the the number of sorties to failure for the entire system. Thus, the failure rate for system 11, airframe, in the model will be based on an exponential distribution with a mean of 3.31 sorties. Appendix A contains the failure rates for each system modeled.

The other stochastic variable, repair time, is based on a lognormal distribution with parameters mean and variance. The mean time to repair was computed by using HQ TAC provided F-15 LCOM computer data dated 12 June 1985.

TABLE II

Example Reliability Rate Computation

| Subsystem | Sorties/ Failures | Failures/ Sortie |
|---|---|---|
| 11A | 30 | 1/30 = .033 |
| 11D | 11 | 1/11 = .091 |
| 11G | 13 | 1/13 = .077 |
| 11K | 13 | 1/13 = .077 |
| 11P | 42 | 1/42 = .024 |
| Total Failures/ Sortie For System 11 | | .302 |
| Mean Sorties/Failure For System 11 | 1/.302 = 3.31 | |

To aggregate this data to the system level, the task repair time for each subsystem was weighted based on the frequency that the subsystem failed per sortie. These weighted subsystem repair times were summed to obtain a mean time to repair for the overall system. An example of this computation is shown in Table III. In the example, the frequency that each subsystem failed per sortie is shown in column four. These are summed to compute a total frequency for the overall system (.0273). Column five contains the percent of the overall frequency that is attributable to each subsystem (e.g. .0040 / .0273 = .15). The subsystem task repair times (column one) are weighted by these percentages (column two) to obtain a weighted task repair time for each subsystem (column three). These are summed to obtain a system mean time to repair (1.839).

TABLE III

Example Computation of Mean Time To Repair

| TASK REPAIR TIME | WEIGHT | WEIGHTED TIME | FREQUENCY PER SORTIE | % OF TOTAL FREQUENCY PER SORTIE |
|---|---|---|---|---|
| 1.3 | .15 | .195 | .0040 | 15 |
| 2.2 | .37 | .814 | .0102 | 37 |
| 1.8 | .31 | .558 | .0085 | 31 |
| 1.6 | .17 | .272 | .0046 | 17 |
| | | 1.839 system mean time to repair | .0273 total frequency per sortie | |

In addition to workload associated with a direct failure, work centers are often required to perform work unrelated to a particular system failure and therefore this time is not included in any subsystem repair time. However, this workload is essential for computing manpower requirements for each work center. To account for this workload, the time expended by a work center that could not be attributed to a particular failure was computed from the LCOM data for each system and work center and was applied to the system task time as a percentage of the mean time to repair. For the above example, if the time unassociated with a particular failure was 20 percent of the computed system mean time to repair, the system mean time to repair (1.839) was increased by .368 hours ( 1.839 X .20) and this value (2.207) was used as the mean for the lognormal distribution used to generate repair times.

The variance for the distribution is based on 29 percent of the mean. Historically, the 29 percent has been used in the LCOM model and does not appear to be well documented. Due to the scope of this model and time constraints, this value was accepted based on the success and AF acceptance of the LCOM model. However, an analysis of the significance of changes in repair time variability on mission capability is included in Chapter IV of this thesis. For the above example, the variance would be (2.207)(.29) = .640 hours. Therefore, the task time for the example task would be based on a lognormal distribution with mean of 2.207 (i.e. 1.839 + .368) hours and variance of .640 hours.

## Assumptions

The following assumptions were made in the development of the simulation model. Any analysis performed using this model should take these assumptions into consideration.

1. Sorties are only flown during daylight.
2. The model does not simulate the spare parts available or used during a repair action. The model assumes that spares are available when needed. To account for NMCS time, two aircraft are removed from the system. This equates to a (2/24) X 100 percent NMCS rate.

3. Unscheduled maintenance and phase actions are modeled to occur sequentially. Many systems and subsystems cannot be repaired in parallel due to safety. For example, to preclude potential fire hazards, some on-aircraft repairs cannot be made in conjunction with repairs to the fuel tanks. The aircraft maintenance system is modeled at the two-digit work unit code (system) level. When modeling at the 2-digit level, the parallel failures that occur within a subsystem are handled in the aggregated failure rate. In addition, many repairs that could be accomplished in parallel cannot be performed due to non-availability of the required work center. This is supported by the simulation output as, even when modeled in sequence, waiting for repair occurs due to nonavailability of manpower.
4. The statistical distributions used in the LCOM model are assumed valid and accurate in describing the random behavior of the reliability and maintainability factors in the aircraft maintenance system.

Limitations

The purpose of this model is to evaluate the effects of R&M. The model should not be used to determine total manpower requirements for specific squadrons. Some secondary workload is not modeled (e.g. corrosion control) since only specific maintenance work centers were of interest. Therefore, the total resource requirements indicated by the model are applicable only to those work centers modeled and do not reflect a total squadron requirement. The LCOM model should be used for manpower determination.

Any analysis performed using this model are scenerio and aircraft specific. For example, although the data used in this model is primarily F-15 data, the scenerio is very general due to the reduced number of maintenance actions and maintenance work centers modeled. Therefore, the output related to this thesis can be considered applicable to a generic tactical fighter used in the scenerios previously outlined. Any predictions for a specific aircraft would require the input of reliability and maintainability levels specific to that aircraft. In addition, the unscheduled maintenance network may require addition or deletion of system networks.

## Verification and Validation

**Verification.** The model was designed to permit verification by maintaining statistics on critical model activities. For example, the number of aircraft requiring a remove and replace action for a system are collected and reported in the output statistics. The number of aircraft going to the shop network is also collected and should equal the number of aircraft requiring a remove and replace action. Another example is that all aircraft flying a sortie receive a thru/post flight inspection. Therefore, the number of sorties flown should equal the number of aircraft that receive a thru/post flight inspection. Similiar checks exist throughout the model and provided the primary means of verifying that the unscheduled maintenance system was operating properly.

The next step was to verify that the model variables were functioning as designed. This was accomplished by changing these variables and observing the changes to output statistics dependent on these variables. For example, when the reliability rate was improved, the number of sorties flown increased from 1331 to 1553. When the mean repair times were decreased, the average turntime for an aircraft dropped from 6.498 hours in a surge to 5.00 hours. When a 1.0 sortie rate was set, 6048 sorties were flown in one year (24 sorties per day 21 days a month).

Validation. Validation was conducted by comparing the model output with historical LCOM results for tactical aircraft in a peacetime scenerio for the statistics collected. Output results such as turntime, mission capable aircraft, sorties, and manpower resource requirements were compared to the outputs of the LCOM model. Since all maintenance workload was not modeled, it was expected that the manpower requirements for the model should be slightly less than LCOM, but should not be higher. Table IV contains these statistics with the expected range for a tactical aircraft and the model results. Based on the designed verification procedures and the similarity of the model output to the LCOM output, the model is verified and validated as accurately modeling the aircraft maintenance system of a tactical aircraft.

TABLE IV

Validation Comparison Between
LCOM and Developed Model

| Factor | Expected Value | Model Value |
|---|---|---|
| Turntime | 7-9 hours | 8.693 hours |
| Mission Capable Aircraft | 14-19 | 15.77 |
| Sorties/day | 24.00 | 24.00 |
| Manpower | 310.00 | 293.00 |

# IV. Analyses and Results

## Overview

To answer the twelve research questions previously stated, three experiments were required. In addition, a fourth experiment was performed on the significance of the variance used for the lognormal distributions in determining the times to repair. The first experiment addressed the effect of percent change in maintenance manpower requirements due to changes in levels of reliability in a peacetime scenerio. The second experiment examined the percent change in the average number of sorties that can be flown and the percent change in the average number of mission capable aircraft available based on various levels of reliability, maintainability, and crew size in a wartime surge scenerio. The last two experiments were not related to the effects of R&M. The third is pertinent to a current Air Force initiative and analyzed the impact of Project Rivet Workforce (6) on aircraft maintenance manpower requirements. The fourth experiment concerning the variance was described above. The design and results for each of these experiments as well as the approach used to establish a manpower baseline will be detailed separately in this chapter.

## Manpower Baseline

Prior to any analysis, a manpower (resource) baseline had to be established for each of the twenty-four maintenance work centers modeled in the simulation. The baseline was established to support one sortie per aircraft per day (1.0 sortie rate). Initially the model was run with unlimited resources (200) for each work center, resulting in no waiting time for manpower. The number of positions required in the model for each center was then determined by multiplying the SLAM provided average utilization of each resource times the number of simulated hours (6288) minus a warm-up period of 240 hours. This calculation provided the total yearly manhours expended by each resource. This figure was then divided by twelve to obtain total monthly manhours. Using a monthly manhour factor of 168 hours for one unit of the resource (21 workdays X 8 hours per day), the total monthly manhours were divided by 168 to obtain a monthly model manpower requirement for each resource. If this value was less than minimum crew increments, then it was rounded up to the next minimum crew increment. For example, when run with unlimited resources, the average utilization for work center A326X8 was .3327 or 33.27 percent. This resulted in a yearly requirement of 2012.17 manhours (.3327 X 6048) or monthly manhours of 167.68 (2012.17/12). The monthly model manpower requirements were then calculated at .9981

(167.68/168) or 1.0 position. However, the minimum crew size for this work center is 2.0 and, therefore, the model requirements were established at 2.0 positions.

This procedure was repeated for each work center and these resource levels were entered into the model. The model was then run to see if the desired 1.0 sortie rate could be achieved. If the sortie rate was met, these resource levels were considered the minimum resource levels and were retained in the model. However, if the desired sortie rate was not met, resource levels were increased for selected work centers based on longest waiting time and longest queue length. The model was then rerun to see if the sortie rate was met. This procedure continued until the desired sortie rate was achieved and these resource levels were used as the baseline model resource requirements.

This baseline was used for both scenerios since the manpower conversion factor for wartime surge requirements is essentially the same as the peacetime factor due to an increase in available hours per resource and longer shift lengths. For example, when computing peacetime manpower requirements a factor of 1.157 is used to account for nonavailable time such as leave, sickness, etc. This is computed by dividing the 168 monthly available manhours by the Air Force peacetime manhour availability factor of 145.2 hours per month (2: Sec I, 3). During a wartime surge, one unit of a resource is available 360 hours a month (12 hours/day X 30 days). Using the Air Force wartime surge manhour availability factor of 309 hours per month (2: Sec I, 3), the wartime surge factor is 1.165. The small difference between these factors is insignificant and the same manpower requirement can be used for both scenerios. This baseline is contained in Table V on page 27 and was used in all four experiments as referenced in the descriptions that follow.

Experiment One -- Reliability Impacts on Manpower

Approach. While the baseline resource levels established above were based on the baseline mean failure rates and mean repair times from the previously referenced data sources, they do not represent the actual manpower requirements of a typical squadron since the model does not account for the nonavailable time referenced above. To establish the actual manpower requirement, the model resource levels were multiplied by the 1.157 factor developed above to account for nonavailable time.

The reliability rates were then increased by a multiple of two and the procedure previously described for determining manpower requirements were repeated to establish manpower levels for the new reliability criteria while maintaining the same desired 1.0 sortie rate. These manpower levels were compared to the baseline manpower requirements and the percent of change was computed. The baseline reliability rates were then increased by a multiple of four and the same procedure was repeated. Once again, these manpower levels were compared to the baseline manpower requirements and the percent of change was computed. The results of this experiment are detailed below and answer research question number eleven.

Results. The baseline manhour requirement was established at 293 manpower authorizations. A twofold increase in reliability resulted in a manpower requirement of 274 manpower authorizations. Therefore, a twofold increase in reliability requires 6% less manpower to maintain the same 1.0 sortie rate. A fourfold increase in reliability required 229 manpower authorizations to maintain a 1.0 sortie rate. Thus, a fourfold increase in reliability requires 22% less manpower to maintain the same sortie rate. These results are similar to predictions made in an unpublished contracted report and estimates made by HQ TAC. Detailed results of this analysis is contained in Table V. These requirement levels and potential decreases in manpower requirements are only applicable to the work centers modeled and these percentages cannot be extrapolated across the entire maintenance complex.

## Experiment Two -- R&M Impacts on Mission Capabilities

Approach. A full factorial (7:189-192) was performed with reliability and maintainability factors at three levels

TABLE V

Model/Manpower Requirements For Various R&M Levels

| Specialty Code | Baseline Requirement | Twofold Increase | Fourfold Increase |
|---|---|---|---|
| 326X6 | 8/9 | 8/9 | 8/9 |
| 326X7 | 6/7 | 6/7 | 4/5 |
| 326X8 | 8/9 | 6/7 | 4/5 |
| 326S3 | 8/9 | 6/7 | 4/5 |
| 326S4 | 10/11 | 8/9 | 8/9 |
| 326S5 | 8/9 | 6/7 | 4/5 |
| 404S1 | 4/5 | 4/5 | 4/5 |
| 423X0 | 8/9 | 6/7 | 6/7 |
| 423X1 | 4/5 | 4/5 | 4/5 |
| 423X4 | 8/9 | 8/9 | 4/5 |
| 423S0 | 4/5 | 4/5 | 4/5 |
| 423S1 | 2/3 | 2/3 | 2/3 |
| 423S2 | 4/5 | 4/5 | 4/5 |
| 423S3 | 8/9 | 8/9 | 4/5 |
| 423S4 | 5/6 | 4/5 | 4/5 |
| 426X2 | 24/27 | 24/27 | 18/20 |
| 426S2 | 24/27 | 24/27 | 18/20 |
| 426T2 | 8/9 | 8/9 | 8/9 |
| 427X5 | 8/9 | 8/9 | 4/5 |
| 427S5 | 2/3 | 2/3 | 2/3 |
| 431F1 | 54/62 | 54/62 | 54/62 |
| 431R1 | 8/9 | 8/9 | 4/5 |
| 462X0 | 21/24 | 18/20 | 12/13 |
| 462S0 | 12/13 | 8/9 | 8/9 |
| Total | 256/293 | 238/274 | 196/229 |
| Percent Decrease | | 6% | 22% |

and crew size and the random number stream at two levels. During recent briefings on R&M, reliability has been addressed at twofold and fourfold increases. Therefore, these levels plus the baseline reliabilty levels were used for this experiment. Maintainability is often discussed in conjunction with reliability, but no specific levels of interest have been identified. Thus, a subjective decision was made to set the levels of maintainability at current levels, a one third reduction, and a two third reduction in mean times to repair. Minimum crew sizes are currently established by maintenance policies such as those addressing safety. Two levels of crew size were therefore established--current levels based on current maintenance policies and at a crew size of one for each task, thus ignoring any minimum crew size requirements. The crew size of one was selected because it provided a comparison of the two extreme levels that can exist and any reductions implied would be the maximum that can be expected due to crew size. The two levels for the random number streams are based on a set of random number seeds and their antithetic values. The four factors and the levels used are summarized in Table VI.

TABLE VI

Levels of Factors Used in Factorial Design

| Factor | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| Reliability | Baseline | 2X increase | 4X increase |
| Maintainability | Baseline | 33% decrease | 67% decrease |
| Crew Size | Baseline | All one | ----- |
| Random Numbers | Initial | Antithetic | ----- |

This experiment is based on the wartime surge scenerio and is used to identify the main effects and interactions that are significant in predicting the average number of sorties flown and average number of mission capable aircraft. In order to conduct this experiment, the system had to be stressed for each R&M level. Therefore, the desired daily sortie rate was set at an unachievable 5.0 rate and the baseline reliability, maintainability, and manpower levels were used. Thirty-six runs with three replications each were made and the average number of sorties flown and the average number of mission capable aircraft available were collected for each run. A data file containing this information was compiled and was used as input to BMDP program 4V (9:388-412) and a full factorial analysis was conducted.

The BMDP input file and BMDP execution program are included in Appendix C. The ANOVA results are shown in Table VII through Table X where r = reliability, m = maintainability, c = crew size, and a = random number stream.

Antithetic sampling (8:506-508) was used as a variance reduction technique. The implication of this technique is that if the $Cov[X_i,X_j]$ can be made negative, then the variance of $X_I$ will be reduced. By setting $X_i = f(r_1,r_2,...r_q)$ then letting $X_j = f(1-r_1,1-r_2,...1-r_q)$ it is implied that a negative covariance will be induced between $X_i$ and $X_j$. Specifically, each of the eighteen possible factor combinations was run with the initial random number stream. Then each of these combinations was run again

TABLE VII

Analysis of Variance For Dependent Variable
Average Number Of Sorties Flown- Experiment One

| Source | Sum Of Squares | Degrees of Freedom | Mean Square | F | Tail Prob. |
|---|---|---|---|---|---|
| r | 6588150.00 | 2 | 3294070.00 | 7937.70 | .0000* |
| m | 3461470.00 | 2 | 1730730.00 | 4170.53 | .0000* |
| c | 3616.90 | 1 | 3616.90 | 8.72 | .0043* |
| a | 246.01 | 1 | 246.01 | .59 | .4439 |
| rm | 243524.00 | 4 | 60881.10 | 146.70 | .0000* |
| rc | 2301.46 | 2 | 1150.73 | 2.77 | .0692 |
| ra | 334.24 | 2 | 167.12 | .40 | .6700 |
| mc | 178.35 | 2 | 89.18 | .21 | .8071 |
| ma | 1012.35 | 2 | 506.18 | 1.22 | .3031 |
| ca | 173.79 | 1 | 173.79 | .42 | .5196 |
| rmc | 76.70 | 4 | 19.18 | .05 | .9959 |
| rma | 1964.15 | 4 | 491.04 | 1.18 | .3255 |
| rca | 611.24 | 2 | 305.62 | .74 | .4824 |
| mca | 545.02 | 2 | 272.509 | .66 | .5217 |
| rmca | 1488.04 | 4 | 372.01 | .90 | .4707 |
| error | 29879.33 | 72 | 414.99 | | |

* Significant at 1 percent

TABLE VIII

Analysis of Variance Of Contrasts For
Reliability and Maintainability
For Average Number of Sorties Flown

| Source | Levels Compared | Sum Of Squares | Deg. Of Freedom | Mean Square | F | Tail Prob. |
|---|---|---|---|---|---|---|
| r | 1 to 2 | 2146250.0 | 1 | 2146250.0 | 5171.79 | .00* |
| r | 1 to 3 | 6541950.0 | 1 | 6541950.0 | 15764.08 | .00* |
| m | 1 to 2 | 558448.0 | 1 | 558448.0 | 1345.69 | .00* |
| m | 1 to 3 | 3419550.0 | 1 | 3419550.0 | 8240.06 | .00* |

* Significant at 1 percent

TABLE IX

Analysis of Variance For Dependent Variable
Average Number Of Mission Capable Aircraft Available-
Experiment One

| Source | Sum Of Squares | Degrees of Freedom | Mean Square | F | Tail Prob. |
|---|---|---|---|---|---|
| r | 290.867 | 2 | 145.433 | 13997.67 | .0000* |
| m | 192.069 | 2 | 96.035 | 9243.14 | .0000* |
| c | 0.204538 | 1 | 0.204538 | 19.69 | .0000* |
| a | 0.000833 | 1 | 0.000833 | .08 | .7778 |
| rm | 19.225 | 4 | 4.806 | 462.58 | .0000* |
| rc | 0.143480 | 2 | 0.071740 | 2.77 | .0018* |
| ra | 0.007039 | 2 | 0.003519 | .34 | .7138 |
| mc | 0.102024 | 2 | 0.051012 | 4.91 | .0100 |
| ma | 0.028817 | 2 | 0.014409 | 1.39 | .2565 |
| ca | 0.010404 | 1 | 0.010404 | 1.00 | .3203 |
| rmc | 0.036026 | 4 | 0.009006 | .87 | .4881 |
| rma | 0.024345 | 4 | 0.006086 | .59 | .6739 |
| rca | 0.006746 | 2 | 0.003373 | .32 | .7238 |
| mca | 0.007013 | 2 | 0.003507 | .34 | .7147 |
| rmca | 0.042537 | 4 | 0.010634 | 1.02 | .4011 |
| error | 0.748067 | 72 | 0.010390 | | |

* Significant at 1 percent

TABLE X

Analysis of Variance Of Contrasts For
Reliability and Maintainability
For Average Number of Mission Capable Aircraft Available

| Source | Levels Compared | Sum Of Squares | Deg. Of Freedom | Mean Square | F | Tail Prob. |
|---|---|---|---|---|---|---|
| r | 1 to 2 | 100.347 | 1 | 100.347 | 9658.22 | .00* |
| r | 1 to 3 | 287.720 | 1 | 287.720 | 27692.49 | .00* |
| m | 1 to 2 | 38.296 | 1 | 38.296 | 3685.90 | .00* |
| m | 1 to 3 | 191.362 | 1 | 191.362 | 18418.21 | .00* |

* Significant at 1 percent

using the antithetic values of the initial random numbers and the results were averaged over the two levels of the random number stream.

Results. At the 99% confidence level, reliability, maintainability, crew size, and the interaction between reliability and maintainability have a significant effect on the average number of sorties that can be flown. In addition, reliability, maintainability, crew size, and the interactions reliability/maintainability and reliability/crew size have a significant effect on the average number of mission capable aircraft available. Table XI contains the cell statistics from BMDP 4V which are the values for sorties and mission capable aircraft averaged over the three replications. In addition, these factors were further averaged over the two random number streams to obtain the average number of sorties flown and the average number of mission capable aircraft available for each factor level combination.

Using this data, the percent increases in the dependent variables for each treatment combination of R&M were computed and are summarized in Table XII. While crew size was statistically significant, the percentage of change on the dependent variables was relatively low (i.e. 2 percent) in comparison to the reliability and maintainability factors and are not summarized. The data in Table XI can be used to make similiar predictions for the impact of crew size if desired.

TABLE XI

Values of Sorties and Mission Capable Aircraft
For Each Treatment Combination

| TREATMENT LEVEL* | | | AVERAGE VALUE** | |
|---|---|---|---|---|
| Rel | Maint | Crew | Mission Capable Aircraft | Sorties |
| 1 | 1 | 1 | 12.80 | 1331 |
| 2 | 1 | 1 | 15.88 | 1758 |
| 3 | 1 | 1 | 18.11 | 2065 |
| 1 | 2 | 1 | 14.81 | 1553 |
| 2 | 2 | 1 | 17.39 | 1924 |
| 3 | 2 | 1 | 19.04 | 2198 |
| 1 | 3 | 1 | 17.48 | 1910 |
| 2 | 3 | 1 | 19.12 | 2180 |
| 3 | 3 | 1 | 20.18 | 2364 |
| 1 | 1 | 2 | 13.10 | 1355 |
| 2 | 1 | 2 | 15.78 | 1755 |
| 3 | 1 | 2 | 18.16 | 2069 |
| 1 | 2 | 2 | 15.03 | 1577 |
| 2 | 2 | 2 | 17.44 | 1930 |
| 3 | 2 | 2 | 19.07 | 2208 |
| 1 | 3 | 2 | 17.52 | 1935 |
| 2 | 3 | 2 | 19.11 | 2186 |
| 3 | 3 | 2 | 20.17 | 2373 |

* Rel level 1 = baseline
Rel level 2 = 2X increase
Rel level 3 = 4X increase
Maint level 1 = baseline
Maint level 2 = .33 decrease
Maint level 3 = .67 decrease
Crew level 1 = baseline
Crew level 2 = no minimum crew sizes

** Averaged over the two random number streams.

TABLE XII

Percent Change In Sorties and Mission Capable Aircraft For Each Treatment Combination

| Treatment Level | | Dependent Variable | | | |
|---|---|---|---|---|---|
| Rel | Maint | Mission Capable Aircraft | Percent Change | Sorties | Percent Change |
| 1 | 1 | 12.80 | | 1331 | |
| 2 | 1 | 15.88 | 24 | 1758 | 32 |
| 3 | 1 | 18.11 | 41 | 2065 | 55 |
| 1 | 2 | 14.81 | 16 | 1553 | 17 |
| 2 | 2 | 17.39 | 36 | 1924 | 45 |
| 3 | 2 | 19.04 | 49 | 2198 | 65 |
| 1 | 3 | 17.48 | 37 | 1910 | 44 |
| 2 | 3 | 19.12 | 49 | 2180 | 64 |
| 3 | 3 | 20.18 | 58 | 2364 | 78 |

Rel level 1 = baseline
Rel level 2 = 2X increase
Rel level 3 = 4X increase
Maint level 1 = baseline
Maint level 2 = .33 decrease
Maint level 3 = .67 decrease

## Regression

Based on the results of the analysis of variance, the following regression equation was also developed using BMDP program 9R (9:264-277). Significant regression statistics are contained in Tables XIII and XIV.

$$Y = 1161.39 + 234.616X_1 + 958.922X_2 - 131.919X_1X_2 \quad (1)$$

where

$Y$ = Average number of sorties flown

$X_1$ = Multiple increase in reliability

$X_2$ = Percent decrease in maintainability

Using equation (1), sorties were fixed at various levels and tradeoff curves for reliability and maintainability were developed. These curves are shown in Figure 1 and can be used by decision makers to determine the possible combinations of reliability and maintainability rates that can be used to achieve a desired sortie rate. These curves are only applicable to the generic tactical model developed and could vary from actual curves designed with aircraft specific data. For example, if a 3.0 sortie rate is desired and the maximum improvement in reliability that can be achieved is a fourfold improvement, then a 14 percent decrease in maintainability must also be achieved.

TABLE XIII

Significant Regression Statistics

| Variable | Regression Coefficient | Standard Error | Contribution To R Squared |
|---|---|---|---|
| Intercept | 1161.39 | 24.1351 | |
| Reliability | 234.616 | 9.1222 | .36005 |
| Maintainability | 958.922 | 55.9719 | .15976 |
| Reliability/ Maintainability | -131.919 | 21.1554 | .02117 |

TABLE XIV

Statistics For Best Subset

| | |
|---|---|
| Mallows' CP | 4.00000 |
| Squared Multiple Correlation | .94339 |
| Multiple Correlation | .97128 |
| Adjusted Squared Multiple Correlation | .94176 |
| Residual Mean Square | 5625.778421 |
| Standard Error of Estimate | 75.005189 |
| F-Statistic | 577.73 |
| Numerator Degrees of Freedom | 3.0 |
| Denominator Degrees of Freedom | 104.0 |
| Significance (Tail Prob.) | .0000 |

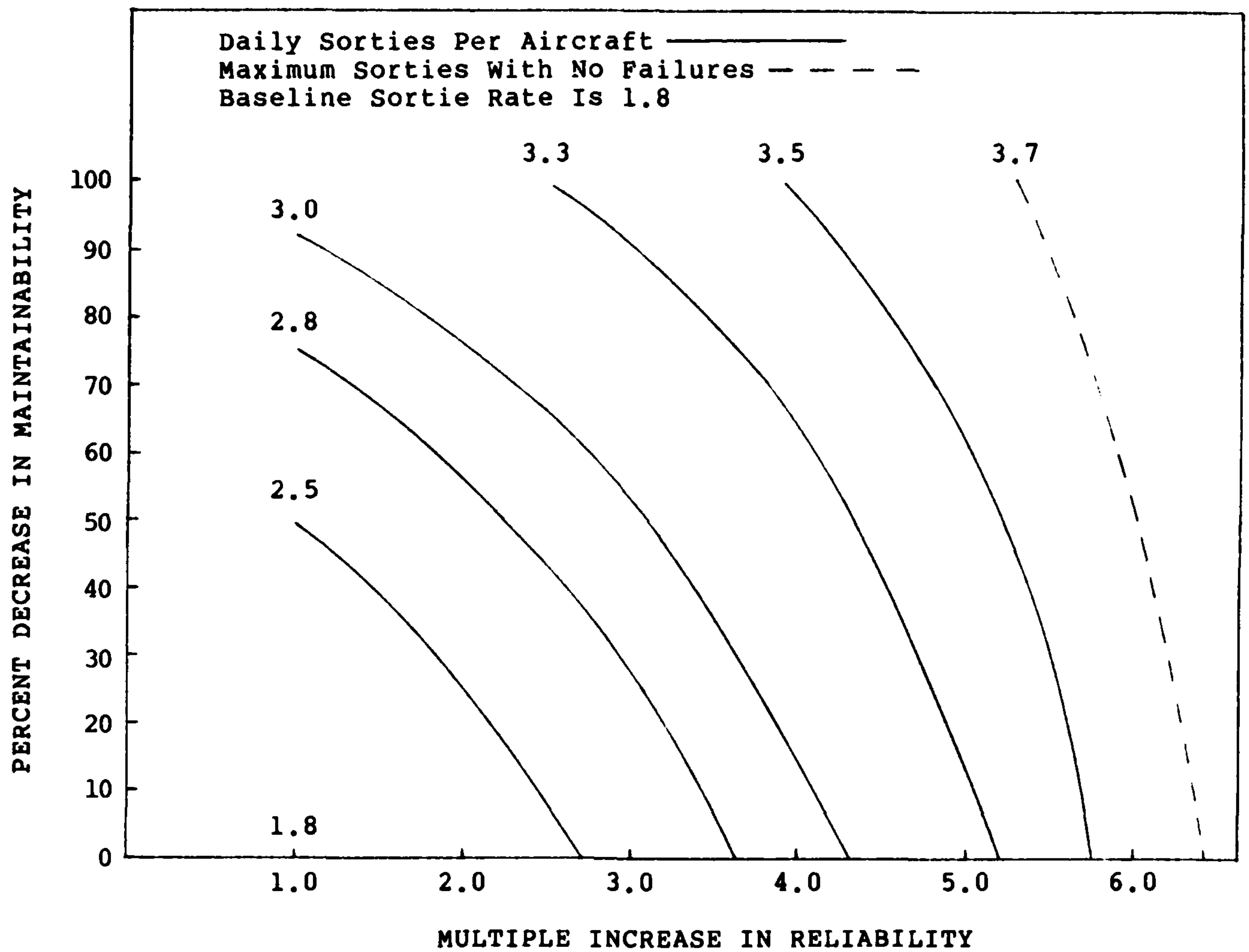



Figure 1. R&M Tradeoff Curves

## Experiment Three -- Project Rivet Workforce Impacts

Background. Project Rivet Workforce is a current Air Force initiative with an overall objective to "Create a more flexible, mobile, and survivable workforce which meets future employment concepts and maximizes training and utilization." (6:Section 18). One of the specific objectives is to "Combine similiar technology career fields where prudent, focus on on-equipment tasks and technologies." (6:Section 18). To achieve this objective several aircraft maintenance specialties have been recommended for consolidation. One of the goals of the Manpower Tiger Team of the Rivet Workforce project is to "address the potential manpower impacts" (6:Section 13B) of the proposed restructured specialties. This analysis will address the specialties as they apply to the work centers modeled and will examine the manpower impacts of consolidating these specialties, thus answering research question twelve. This experiment does not address all the proposed consolidations of Project Rivet Workforce since some of the specialties being considered are not contained in the simulation model.

Approach. Three incremental analyses were conducted with each addressing various levels of consolidation. The first analysis examined the impact of consolidating the flightline integrated avionics specialties 326X6, 326X7, and 326X8 into a single specialty

326XX and the shop integrated avionics specialties 326S3,326S4, and 326S5 into a single specialty 326SX. The second analysis addressed the effect of consolidating the flightline 423XX specialties--electrical, environmental, and pneudraulic--and the flightline 426XX, jet engine, into a single specialty 423XX and consolidating the shop 423XX and shop jet engine specialties into a single specialty 423SX. The third analysis consisted of combining the consolidations of analyses one and two.

To conduct each of these analyses, the peacetime scenerio was used with the resources modified as described above throughout the model. The baseline reliability and maintainability levels were used and the procedures used in experiment one were repeated. Once again manpower requirements, not model requirements, were compared to the manpower baseline and the percent change in manpower requirements based on the effects of Project Rivet Workforce were computed.

Results. The consolidations made in the first analysis resulted in a 4% decrease in total manpower requirements. The second analysis resulted in a 9% decrease and the third analysis resulted in a 13% reduction in total manpower requirements. As with experiment one, these decreases only apply to the model and can not be extrapolated across the entire maintenance complex. The results of these analyses are contained in Table XV.

TABLE XV

Rivet Workforce Experiment Results

| Specialty | Manpower | | | |
|---|---|---|---|---|
| | Baseline | 326XX/ 326SX Combined | 423XX/ 423SX Combined | 326XX/326SX/ 423XX/423SX Combined |
| 326XX | -- | 20 | -- | 20 |
| 326SX | -- | 23 | -- | 23 |
| 326X6 | 9 | -- | 9 | -- |
| 326X7 | 7 | -- | 7 | -- |
| 326X8 | 9 | -- | 9 | -- |
| 326S3 | 9 | -- | 9 | -- |
| 326S4 | 11 | -- | 11 | -- |
| 326S5 | 9 | -- | 9 | -- |
| 404S1 | 5 | 5 | 5 | 5 |
| 423XX | -- | -- | 32 | 32 |
| 423SX | -- | -- | 32 | 32 |
| 423X0 | 9 | 9 | -- | -- |
| 423X1 | 5 | 5 | -- | -- |
| 423X4 | 9 | 9 | -- | -- |
| 423S0 | 5 | 5 | -- | -- |
| 423S1 | 3 | 3 | -- | -- |
| 423S2 | 5 | 5 | 5 | 5 |
| 423S3 | 9 | 9 | 9 | 9 |
| 423S4 | 6 | 6 | -- | -- |
| 426X2 | 27 | 27 | -- | -- |
| 426S2 | 27 | 27 | -- | -- |
| 426T2 | 9 | 9 | 9 | 9 |
| 427X5 | 9 | 9 | 9 | 9 |
| 427S5 | 3 | 3 | 3 | 3 |
| 431F1 | 62 | 62 | 62 | 62 |
| 431R1 | 9 | 9 | 9 | 9 |
| 462X0 | 24 | 24 | 24 | 24 |
| 462S0 | 13 | 13 | 13 | 13 |
| TOTAL | 293 | 282 | 266 | 255 |
| Percent Decrease | -- | 4% | 9% | 13% |

## Experiment Four -- Variance Effect on Time To Repair

Background. The LCOM model primarily uses twenty-nine percent of the mean as the variance in the lognormal distributions used for repair times. The derivation of this factor is not well documented. The purpose of this experiment is to examine the effects of varying the level of the variance and determine if the level of the variance has a significant effect on the output of the model.

Approach. An analysis of variance was performed with the variance examined a five levels -- ten, twenty-nine, fifty, seventy-five, and ninety percent of the mean. As with experiment two the random number stream at two levels was used as a second factor and antithetic values were used as a variance reduction technique. In order to examine the system under stress, the wartime surge scenerio was used with the baseline manpower, reliability, and maintainability levels. Ten runs were made with three replications each and the values of mission capable aircraft and sorties was collected for each factor level combination. This data was placed into a data file and was used as input to BMDP program 4V and an ANOVA was performed.

Results. At the 99% confidence level, the variance level used for the lognormal distribution for times to repair does not have a significant effect on the average number of sorties that can be flown or the average number of mission capable aircraft available. However, at the 95%

confidence level, the variance level does have a significant effect on the average number of mission capable aircraft available. Pairwise comparisons were performed to determine which treatment levels actually cause the effect. Specifically, pairwise comparisons were performed to determine if a significant effect occurred when the variance was increased or decreased in small increments from the 29 percent modeled. Comparisons were made between the 10 percent and 29 percent treatment levels and the 29 percent and 50 percent levels and neither effect was significant. A third pairwise comparison was made between the extreme levels (i.e. 10 percent and 90 percent). This comparison was significant and suggests that the larger the change in the variance level, the more significant the effect on the average number of mission capable aircraft. The BMDP data file and BMDP execution file are contained in Appendix D. The analysis of variance results are shown in Table XVI through Table XVIII where v = variance and r = random number stream.

TABLE XVI

Analysis of Variance for the Dependent Variable Average Number of Mission Capable Aircraft Available- Experiment Four

| Source | Sum Of Squares | Degrees Of Freedom | Mean Square | F | Tail Prob. |
|---|---|---|---|---|---|
| v | 0.306613 | 4 | 0.0766533 | 4.21 | .0124* |
| r | 0.067123 | 1 | 0.067123 | 3.69 | .0692 |
| vr | 0.141787 | 4 | 0.035447 | 1.94 | .1422 |
| Error | 0.364533 | 20 | 0.018227 | | |

* Significant at 5 percent

TABLE XVII

Analysis of Variance for the Dependent Variable Average Number of Sorties Flown- Experiment Four

| Source* | Sum Of Squares | Degrees Of Freedom | Mean Square | F | Tail Prob. |
|---|---|---|---|---|---|
| v | 1884.20 | 4 | 471.05 | 1.12 | .3731 |
| r | 1717.63 | 1 | 1717.63 | 4.10 | .0564 |
| vr | 2490.20 | 4 | 622.55 | 1.49 | .2440 |
| Error | 8379.33 | 20 | 418.97 | | |

TABLE XVIII

Pairwise Comparison Analysis of Variance for the Dependent Variable Average Number of Mission Capable Aircraft

| Source | Variance Levels Compared | Sum Of Square | Deg. Of Freedom | Mean Square | F | Tail Prob. |
|---|---|---|---|---|---|---|
| v | 10% to 29% | .02803 | 1 | .02803 | 1.54 | .2293 |
| v | 29% to 50% | .00021 | 1 | .00021 | .01 | .9159 |
| v | 10% to 90% | .09363 | 1 | .09363 | 5.14 | .0347* |

* Significant at 5 percent

# V. Conclusions

## Overview

The research questions posed in Chapter I were answered by the analyses detailed in Chapter IV and specific conclusions can be drawn by summarizing these results. In addition, some general conclusions can be stated regarding the model, Rivet Workforce, and R&M.

## Research Questions

1. How does improved reliability impact sortie generation capability? Reliability has a significant effect on the average number of sorties that can be flown. A 32% increase in sorties can be expected from a twofold increase in reliability and a 55% improvement with a fourfold increase.
2. How does improved system maintainability impact sortie generation capability? Maintainability is significant in predicting the average number of sorties that can be flown. A 33% reduction in the mean time to repair will increase the average number of sorties by 17% and a 67% reduction will result in a 44% increase.
3. How does improved system reliability coupled with improved maintainability impact sortie generation capability? The interaction between reliability

and maintainability has a significant effect on the average number of sorties that can be flown. The conclusions pertaining to these factors are shown in Table XIX.

TABLE XIX

Reliabilty and Maintainability Interaction Impact on Sorties

| Reliability Increase | Percent Decrease In Maintainability | Percent Increase In Sorties |
|---|---|---|
| 2X | 33 | 45 |
| 2X | 67 | 64 |
| 4X | 33 | 65 |
| 4X | 67 | 78 |

4. What effect does crew size have on sortie generation capability? Crew size was determined to be statistically significant in predicting the number of sorties that can be flown, however, from a percent of change viewpoint the effect is relatively small when compared to reliability and maintainability impacts. The percent of change in the average number of sorties when ignoring minimum crew size requirements is 2 percent.

5. What effect does crew size in conjunction with improved reliability and/or maintainability have on sortie generation capability? The interactions of crew size with reliability and/or maintainability were not statistically significant in predicting the average number of sorties that can be flown.

6. How does improved system reliability impact the number of mission capable aircraft? Reliability has a significant effect on the average number of mission capable aircraft available. A twofold increase in reliability resulted in a 24% increase in the average number of mission capable aircraft and a fourfold increase translated into a 41% increase.
7. How does improved system maintainability impact the number of mission capable aircraft? Maintainability has a significant impact on the average number of mission capable aircraft. A 33% decrease in maintainability resulted in a 16% increase in mission capable aircraft. A 67% decrease resulted in a 37% increase.
8. How does improved system reliability coupled with improved maintainability impact the number of mission capable aircraft? The interaction between these two factors has a significant effect on the average number of mission capable aircraft available. The conclusions pertaining to these factors are summarized in Table XX.
9. What effect does crew size have on the number of mission capable aircraft? As with sorties, crew size is statistically significant but has a small impact on the percent of change in the average

TABLE XX

Reliability and Maintainability Interaction Impact on Mission Capable Aircraft

| Reliability Increase | Percent Decrease Maintainability | Percent Increase Mission Capable Aircraft |
|---|---|---|
| 2X | 33 | 36 |
| 2X | 67 | 49 |
| 4X | 33 | 49 |
| 4X | 67 | 58 |

number of mission capable aircraft. By ignoring minimum crew requirements, the average number of mission capable aircraft increased by 2 percent.

10. What effect does crew size in conjunction with improved reliability and/or maintainability have on the number of mission capable aircraft? The interaction of crew size with reliability was statistically significant. The interaction of crew size with maintainability and the three way interaction of crew size, reliability, and maintainability do not have a significant effect on the average number of mission capable aircraft available. A twofold increase in reliability while ignoring minimum crew requirements resulted in a 23% increase in the average number of mission capable aircraft available. A fourfold increase in reliability while ignoring minimum crew sizes resulted in a 42% increase.

11. What impact does improved system reliability have on maintenance manpower requirements? A twofold increase in reliability resulted in a 6% decrease in manpower requirements. A fourfold improvement resulted in a 22% reduction in manpower requirements.

12. What effect does specialty consolidation have on maintenance manpower requirements? Depending on the amount of consolidation, the reduction in manpower requirements ranged from 4%-13% for the specialties in the work centers modeled.

## General Conclusions

Model. Based on the capability of the model to answer the research questions, it can be concluded that the simulation model developed is an accurate macro level planning tool for making decisions related to R&M and can also be used to evaluate other aircraft maintenance initiatives related to the model structure.

Rivet Workforce. The analysis indicates that Project Rivet Workforce has the potential to reduce manpower requirements at a level similar to improved R&M. If the reductions derived for the work centers this research addressed are representative of the other maintenance work centers, reductions in aircraft maintenance manpower can be achieved now for current fighter aircraft at current levels of reliability and maintainability. Further research could be performed using the developed model to evaluate the manpower impacts of combining the objectives of Rivet Workforce with improved reliability and maintainability.

Reliability and Maintainability. The results of this research suggests that the payoff in improved R&M is greater for improving mission capabilities then reducing manpower. As indicated above, while R&M does have a significant effect on manpower, similiar results can be achieved through productivity enhancements such as Rivet Workforce. However, the improvements in mission capabilities shown in this research by improving R&M can have a significant impact on our war-fighting capability and should be considered a critical factor in weapon system acquisition. While reliability is spoken of most often and appears to be receiving the primary emphasis in R&M initiatives, this analysis indicates that maintainability can be highly influential on mission capabilities. For example, a twofold improvement in reliability coupled with a 67 percent reduction in maintainability can have the same effect on the increase in mission capable aircraft as a fourfold increase in reliability and a 33 percent reduction in maintainability. Also, a 33 percent decrease in maintainability combined with a twofold improvement in reliability can achieve a 36 percent improvement in mission capable aircraft compared to an only slightly better improvement of 41 percent with a fourfold increase in reliability. In summary, while reliability has been shown to be the most significant factor, improved maintainability can also be used to achieve desired results and can be an alternative to unachievable reliability improvements.

## Appendix A

## Input Data

This appendix contains the input data used in the model for reliability and maintainability factors. Table A.1 contains the parameters of the lognormal distributions used to compute unscheduled maintenance repair times for each system subdivided into on-aircraft repairs, remove and replace actions, and in-shop repairs. Table A.2 contains the parameters of the exponential distributions used to compute the failure rates for each system. The following codes are used in the tables.

OA = On-aircraft Repair
RR = Remove and Replace Action
SR = In-shop Repair
UM11 = Airframe
UM12 = Crew Station System
UM13 = Landing Gear
UM14 = Flight Control System
UM23 = Turbo Fan Power Plant
UM24 = Aux Power Plant
UM41 = Enviromental Control System
UM42 = Electric Power System
UM44 = Lighting System
UM45 = Hydraulic and Pneudraulic System
UM46 = Fuel System
UM47 = Oxygen System
UM49 = Miscellaneous Utilities
UM51 = Flight Instruments
UM55 = Malfunction Analysis Rec.
UM63 = UHF Communications
UM65 = IFF Communications
UM71 = Radio Navigation
UM74 = Fire Control System
UM75 = Weapons Delivery
UM76 = Penetration Aids

Table A.1

Unscheduled Maintenance Repair Times

| System Code | Type of Repair | Lognormal Distribution Mean | Variance |
|---|---|---|---|
| UM11 | OA | 2.366 | .686 |
| | RR | 3.915 | 1.135 |
| | SR | 8.537 | 2.476 |
| UM12 | OA | 4.278 | 1.241 |
| | RR | 2.556 | .741 |
| | SR | 2.640 | .766 |
| UM13 | OA | 2.829 | .820 |
| | RR | 4.907 | 1.423 |
| | SR | 4.410 | 1.279 |
| UM14 | OA | 2.521 | .731 |
| | RR | 4.415 | 1.280 |
| | SR | 4.890 | 1.418 |
| UM23 | OA | 2.649 | .768 |
| | RR | 6.964 | 2.020 |
| | SR | 93.840 | 27.214 |
| UM24 | OA | 2.453 | .711 |
| | RR | 11.060 | 3.207 |
| | SR | 16.000 | 4.640 |
| UM41 | OA | 2.172 | .630 |
| | RR | 3.077 | .892 |
| | SR | 1.700 | .493 |
| UM42 | OA | 4.221 | 1.224 |
| | RR | 3.976 | 1.153 |
| | SR | 14.524 | 4.212 |
| UM44 | OA | 4.690 | 1.360 |
| | RR | 6.097 | 1.768 |
| | SR | 13.778 | 3.996 |
| UM45 | OA | 1.846 | .535 |
| | RR | 2.940 | .853 |
| | SR | 1.882 | .546 |
| UM46 | OA | 3.850 | 1.117 |
| | RR | 5.337 | 1.548 |
| | SR | 3.774 | 1.094 |
| UM47 | OA | 3.036 | .880 |
| | RR | 2.534 | .735 |
| | SR | 2.662 | .772 |
| UM49 | OA | 6.566 | 1.904 |
| | RR | 15.149 | 4.393 |
| | SR | 2.359 | .684 |
| UM51 | OA | 3.850 | 1.117 |
| | RR | 3.153 | .914 |
| | SR | 4.068 | 1.180 |
| UM55 | OA | 3.850 | 1.117 |

| | | | |
|---|---|---|---|
| | RR | 3.080 | .893 |
| | SR | 9.272 | 2.689 |
| UM63 | OA | 1.800 | .522 |
| | RR | 1.680 | .487 |
| | SR | 8.698 | 2.522 |
| UM65 | OA | 1.457 | .423 |
| | RR | 1.800 | .522 |
| | SR | 8.888 | 2.578 |
| UM71 | OA | 5.225 | 1.515 |
| | RR | 3.300 | .957 |
| | SR | 11.064 | 3.209 |
| UM74 | OA | 2.476 | .718 |
| | RR | 2.504 | .726 |
| | SR | 7.705 | 2.234 |
| UM75 | OA | 2.844 | .825 |
| | RR | 3.162 | .917 |
| | SR | 6.293 | 1.825 |
| UM76 | OA | 1.757 | .510 |
| | RR | 2.040 | .592 |
| | SR | 10.858 | 3.149 |

Table A.2

MTBF in Sorties

| System Code | Exponential Distribution Mean |
|---|---|
| UM11 | 3.31 |
| UM12 | 25.83 |
| UM13 | 11.99 |
| UM14 | 13.63 |
| UM23 | 10.00 |
| UM24 | 41.38 |
| UM41 | 30.40 |
| UM42 | 39.86 |
| UM44 | 29.75 |
| UM45 | 18.63 |
| UM46 | 21.17 |
| UM47 | 155.00 |
| UM49 | 178.00 |
| UM51 | 37.38 |
| UM55 | 74.42 |
| UM63 | 17.65 |
| UM65 | 10.10 |
| UM71 | 19.56 |
| UM74 | 5.23 |
| UM75 | 5.65 |
| UM76 | 3.79 |

## Appendix B

## Simulation Model Code

This appendix contains the simulation model developed for this research. General user information is provided along with the SLAM and fortran code that makes-up the model. In addition, a sample extract of the output file is provided to give the user an idea of what information is available from the model.

### User Information

The model is written to represent a one year simulation with a ten day warm-up period. There are six variables that can be changed to accommodate changes in the scenerio and the input parameters. The first variable is designated XX(1) and represents the number of sorties that have been flown at the start of the simulation. For the analysis performed in this research, XX(1) was set at zero. The second variable is designated XX(25) and is used to change the mean time between failures. The use of this variable is extremely useful for any R&M analysis. To increase reliability by a given amount, XX(25) should be set to the multiple increase desired. In this research, the variable was set at one, two, and four to represent the baseline, twofold increase, and fourfold increase, respectively. Without the capabilility provided by this variable, the user would have to change the failure rates each place they occur in the model.

The third variable is designated XX(26) and is used to change the mean of the lognormal distributions used for the repair times (maintainability data) by any given factor. To decrease the mean time to repair, XX(26) should be set at 1-R where R represents the percent of decrease. In the analysis performed in Chapter IV, XX(26) was set at 1-.33 and 1-.67, with 1-.33 representing a 33% decrease in repair times and 1-.67 a 67% decrease. Once again, without the capability provided by this variable, the user would have to enter the model and change each repair time individually. The next variable is XX(27) and represents the percent of the mean that is used for the variance in the lognormal distributions used for the repair times. For these analyses, XX(27) was set at .29 for all repair times.

The variable XX(94) is used to set the desired daily sortie rate for the scenerio being used. This factor is changed by the model during the simulation based on whether the desired daily sortie rate is met. For the peacetime scenerio used in this research, XX(94) was set at 24 to represent 24 sorties per day or a 1.0 sortie rate based on one sortie per day per aircraft for 24 aircraft. For the wartime surge scenerio, XX(94) was set equal to 120 to represent a 5.0 sortie rate of five sorties per day per aircraft for 24 aircraft. The last variable is XX(95) and represents the number of mission capable aircraft available at the intialization of the model. This variable is also changed by the model as aircraft enter the unscheduled and phase maintenance networks. For this research, XX(95) was set equal to 22 to represent a 24 aircraft squadron with two aircraft down awaiting supply and therefore not mission capable.

Any other changes desired by the user will require entering the model and making the changes where the factor being changed appears. For example if the user desires to change the crew size for a task, the factor would have to be changed in the particular unscheduled maintenance network at the await node and the free node. The variables described above can be changed by a user with limited knowledge of SLAM. However, for any other changes, the user should have a working knowledge of SLAM to preclude inadvertent changes to the process being simulated.

## Slam Code

```
GEN,LEWELLEN,MANPOWER MODEL,5/15/85,,NO;
LIMITS,40,98,200; INTLC,XX(1)=0.0;     NUMBER OF SORTIES
FLOWN INTLC,XX(25)=1.0;    RELIABILITY FACTOR
INTLC,XX(26)=1.0;    MAINTAINABILITY FACTOR
INTLC,XX(27)=0.29;   VARIANCE PERCENTAGE OF MEAN
INTLC,XX(94)=24.0;   DAILY SORTIE RATE DESIRED
INTLC,XX(95)=22.0;   NUMBER OF MISSION CAPABLE ACFT
TIMST,XX(95),MSN CAP ACFT,22/0/1;
;
;
;
;     TIME UNIT IS HOUR
NETWORK;
      RESOURCE/A326X6(4),7;         TAC CONTROL
      RESOURCE/A326X7(3),8,31;      AUTO PILOT
      RESOURCE/A326X8(4),9;         COMM NAV
      RESOURCE/A326S3(4),10;        ECM TEST STATION
      RESOURCE/A326S4(5),11;        AUTO TEST STATION
      RESOURCE/A326S5(4),12;        MANUAL TEST STATION
      RESOURCE/A404S1(2),13;        PHOTO
      RESOURCE/A423X0(4),14,32;     ELECT
      RESOURCE/A423X1(2),15;        ENVIRO
      RESOURCE/A423X4(4),16;        PNEU
      RESOURCE/A423S0(2),17;        SHOP ELECT
      RESOURCE/A423S1(1),18;        SHOP ENVIRO
      RESOURCE/A423S2(2),19;        SHOP EGRESS
      RESOURCE/A423S3(4),20;        FUEL
      RESOURCE/A423S4(3),21;        SHOP PNEU
      RESOURCE/A426X2(12),22,31,32,34;  JET ENGINES
      RESOURCE/A426S2(12),23;       SHOP JET ENGINES
      RESOURCE/A426T2(4),6;         ENGINE TEST CELL
      RESOURCE/A427X5(4),25,34;     STRUCTURE REPAIR
      RESOURCE/A427S5(2),26;        SHOP STRUCTURE REPAIR
      RESOURCE/A431F1(18),27;       CREW CHIEF
      RESOURCE/A431R1(4),28;        CREW CHIEF REPAIR AND REC
      RESOURCE/A462X0(12),29;       MUNITIONS
      RESOURCE/A462S0(6),30;        SHOP MUNITIONS
      GATE/DAY,OPEN,2;              STARTING WITH DAY SHIFT
      GATE/STORM,OPEN,3;
;
;       MODEL SEGMENT I      ***SORTIE GENERATION***
;
;
;
;                            ***MAIN NETWORK***
;
;
      CREATE,0,,,22;             CREATES 22 OF 24 ACFT WITH
;                                REMAINING 2 AIRCRAFT
;                                AWAITING SUPPLIES
;
;
```

```
;
;
;               THE FOLLOWING SET OF ASSIGN STATEMENTS
;               ASSIGN MEAN FAILURE RATES TO THE DESIGNATED
;               SYSTEM. THE GLOBAL VARIABLE PROVIDES
;               A MEANS TO VARY THE RATE. FOR EXAMPLE,
;               IF WE WANT TO IMPROVE THE RELIABILITY
;               (FAILURE RATE) BY TWOFOLD, THE
;               VARIABLE XX(25) WOULD BE SET EQUAL TO
;               2 IN THE INTIALIZATION STATEMENT ABOVE.
;
;                    XX(3)= AIRFRAME-UM11
;                    XX(4)= CREW STATION SYSTEM-UM12
;                    XX(5)= LANDING GEAR-UM13
;                    XX(6)= FLIGHT CONTROL SYSTEM-UM14
;                    XX(7)= TURBO FAN POWER PLANT-UM23
;                    XX(8)= AUX POWER PLANT-UM24
;                    XX(9)= ENVIRO CONTROL SYSTEM-UM41
;                    XX(10)= ELECT POWER SYSTEM-UM42
;                    XX(11)= LIGHTING SYSTEM-UM44
;                    XX(12)= HYDRAULIC AND PNEU SYSTEM-UM45
;                    XX(13)= FUEL SYSTEM-UM46
;                    XX(14)= OXYGEN SYSTEM-UM47
;                    XX(15)= MISC UTILITIES-UM49
;                    XX(16)= FLIGHT INSTRUMENTS-UM51
;                    XX(17)= MALFUNCTION ANALYSIS REC.-UM55
;                    XX(18)= UHF COMMUNICATIONS-UM63
;                    XX(19)= IFF SYSTEM-UM65
;                    XX(20)= RADIO NAVIGATION-UM71
;                    XX(21)= FIRE CONTROL SYSTEM-UM74
;                    XX(22)= WEAPONS DELIVERY-UM75
;                    XX(23)= PENETRATION AIDS-UM76
;                    XX(24)= EXPLOSIVE DEVICES
;
;
;
     ASSIGN,XX(3)=3.31*XX(25),
            XX(4)=25.83*XX(25),
            XX(5)=11.99*XX(25),
            XX(6)=13.63*XX(25),
            XX(7)=10.00*XX(25),
            XX(8)=41.38*XX(25),
            XX(9)=30.40*XX(25),
            XX(10)=39.86*XX(25),
            XX(11)=29.75*XX(25);
     ASSIGN,XX(12)=18.63*XX(25),
            XX(13)=21.17*XX(25),
            XX(14)=155.0*XX(25),
            XX(15)=178.0*XX(25),
            XX(16)=37.38*XX(25),
            XX(17)=74.42*XX(25),
            XX(18)=17.65*XX(25);
     ASSIGN,XX(19)=10.10*XX(25),
            XX(20)=19.56*XX(25),
```

```
          XX(21)=5.23*XX(25),
          XX(22)=5.65*XX(25),
          XX(23)=3.79*XX(25),
          XX(24)=1136*XX(25);
;
;
;                   THE FOLLOWING STATEMENTS ASSIGN
;                   THE MEAN AND VARIANCE TO THE REPAIR
;                   TIMES FOR THE UNSCHEDULED MAINTENANCE
;                   TASKS. THE GLOBAL VARIABLE XX(26)
;                   PROVIDES A MEANS TO CHANGE THE
;                   MAINTAINABILITY OF THE SYSTEMS.
;                   FOR EXAMPLE, IF WE WANTED TO DECREASE
;                   THE AMOUNT OF TIME IT TAKES TO REPAIR
;                   A SYSTEM BY 20 PER CENT, XX(26) WOULD
;                   BE SET TO .80 IN THE INTIALIZATION
;                   STATEMENT.
;
;
;
     ASSIGN,XX(31)=2.366*XX(26),ATRIB(31)=XX(31)*XX(27),
            XX(32)=3.915*XX(26),ATRIB(32)=XX(32)*XX(27),
            XX(33)=8.537*XX(26),ATRIB(33)=XX(33)*XX(27);
     ASSIGN,XX(34)=4.278*XX(26),ATRIB(34)=XX(34)*XX(27),
            XX(35)=2.556*XX(26),ATRIB(35)=XX(35)*XX(27),
            XX(36)=2.640*XX(26),ATRIB(36)=XX(36)*XX(27);
     ASSIGN,XX(37)=2.829*XX(26),ATRIB(37)=XX(37)*XX(27),
            XX(38)=4.907*XX(26),ATRIB(38)=XX(38)*XX(27),
            XX(39)=4.410*XX(26),ATRIB(39)=XX(39)*XX(27);
     ASSIGN,XX(40)=2.521*XX(26),ATRIB(40)=XX(40)*XX(27),
            XX(41)=4.415*XX(26),ATRIB(41)=XX(41)*XX(27),
            XX(42)=4.890*XX(26),ATRIB(42)=XX(42)*XX(27);
     ASSIGN,XX(43)=2.649*XX(26),ATRIB(43)=XX(43)*XX(27),
            XX(44)=6.964*XX(26),ATRIB(44)=XX(44)*XX(27),
            XX(45)=93.840*XX(26),ATRIB(45)=XX(45)*XX(27);
     ASSIGN,XX(46)=2.453*XX(26),ATRIB(46)=XX(46)*XX(27),
            XX(47)=11.060*XX(26),ATRIB(47)=XX(47)*XX(27),
            XX(48)=16.00*XX(26),ATRIB(48)=XX(48)*XX(27);
     ASSIGN,XX(49)=2.172*XX(26),ATRIB(49)=XX(49)*XX(27),
            XX(50)=3.077*XX(26),ATRIB(50)=XX(50)*XX(27),
            XX(51)=1.700*XX(26),ATRIB(51)=XX(51)*XX(27);
     ASSIGN,XX(52)=4.221*XX(26),ATRIB(52)=XX(52)*XX(27),
            XX(53)=3.976*XX(26),ATRIB(53)=XX(53)*XX(27),
            XX(54)=14.524*XX(26),ATRIB(54)=XX(54)*XX(27);
     ASSIGN,XX(55)=4.690*XX(26),ATRIB(55)=XX(55)*XX(27),
            XX(56)=6.097*XX(26),ATRIB(56)=XX(56)*XX(27),
            XX(57)=13.778*XX(26),ATRIB(57)=XX(57)*XX(27);
     ASSIGN,XX(58)=1.846*XX(26),ATRIB(58)=XX(58)*XX(27),
            XX(59)=2.940*XX(26),ATRIB(59)=XX(59)*XX(27),
            XX(60)=1.882*XX(26),ATRIB(60)=XX(60)*XX(27);
     ASSIGN,XX(61)=3.850*XX(26),ATRIB(61)=XX(61)*XX(27),
            XX(62)=5.337*XX(26),ATRIB(62)=XX(62)*XX(27),
            XX(63)=3.774*XX(26),ATRIB(63)=XX(63)*XX(27);
     ASSIGN,XX(64)=3.036*XX(26),ATRIB(64)=XX(64)*XX(27),
```

```
         XX(65)=2.534*XX(26),ATRIB(65)=XX(65)*XX(27),
         XX(66)=2.662*XX(26),ATRIB(66)=XX(66)*XX(27);
  ASSIGN,XX(67)=6.566*XX(26),ATRIB(67)=XX(67)*XX(27),
         XX(68)=15.149*XX(26),ATRIB(68)=XX(68)*XX(27),
         XX(69)=2.359*XX(26),ATRIB(69)=XX(69)*XX(27);
  ASSIGN,XX(70)=3.850*XX(26),ATRIB(70)=XX(70)*XX(27),
         XX(71)=3.153*XX(26),ATRIB(71)=XX(71)*XX(27),
         XX(72)=4.068*XX(26),ATRIB(72)=XX(72)*XX(27);
  ASSIGN,XX(73)=3.850*XX(26),ATRIB(73)=XX(73)*XX(27),
         XX(74)=3.080*XX(26),ATRIB(74)=XX(74)*XX(27),
         XX(75)=9.272*XX(26),ATRIB(75)=XX(75)*XX(27);
  ASSIGN,XX(76)=1.800*XX(26),ATRIB(76)=XX(76)*XX(27),
         XX(77)=1.680*XX(26),ATRIB(77)=XX(77)*XX(27),
         XX(78)=8.698*XX(26),ATRIB(78)=XX(78)*XX(27);
  ASSIGN,XX(79)=1.457*XX(26),ATRIB(79)=XX(79)*XX(27),
         XX(80)=1.800*XX(26),ATRIB(80)=XX(80)*XX(27),
         XX(81)=8.888*XX(26),ATRIB(81)=XX(81)*XX(27);
  ASSIGN,XX(82)=5.225*XX(26),ATRIB(82)=XX(82)*XX(27),
         XX(83)=3.300*XX(26),ATRIB(83)=XX(83)*XX(27),
         XX(84)=11.064*XX(26),ATRIB(84)=XX(84)*XX(27);
  ASSIGN,XX(85)=2.476*XX(26),ATRIB(85)=XX(85)*XX(27),
         XX(86)=2.504*XX(26),ATRIB(86)=XX(86)*XX(27),
         XX(87)=7.705*XX(26),ATRIB(87)=XX(87)*XX(27);
  ASSIGN,XX(88)=2.844*XX(26),ATRIB(88)=XX(88)*XX(27),
         XX(89)=3.162*XX(26),ATRIB(89)=XX(89)*XX(27),
         XX(90)=6.293*XX(26),ATRIB(90)=XX(90)*XX(27);
  ASSIGN,XX(91)=1.757*XX(26),ATRIB(91)=XX(91)*XX(27),
         XX(92)=2.040*XX(26),ATRIB(92)=XX(92)*XX(27);
  ASSIGN,XX(93)=10.858*XX(26),ATRIB(93)=XX(93)*XX(27),
         XX(96)=4.600*XX(26),ATRIB(96)=XX(96)*XX(27),
         ATRIB(94)=0,ATRIB(95)=0;
;
;
;                    THE FOLLOWING STATEMENTS ASSIGN THE
;                    FAILURE RATES OF THE SYSTEMS AS
;                    ATTRIBUTES OF THE ENTITY
;
  ASSIGN,ATRIB(1)=EXPON(XX(3),1),
         ATRIB(2)=EXPON(XX(4),1),
         ATRIB(3)=EXPON(XX(5),1),
         ATRIB(4)=EXPON(XX(6),1),
         ATRIB(5)=EXPON(XX(7),1),
         ATRIB(6)=EXPON(XX(8),1),
         ATRIB(7)=EXPON(XX(9),1),
         ATRIB(8)=EXPON(XX(10),1);
  ASSIGN,ATRIB(9)=EXPON(XX(11),1),
         ATRIB(10)=EXPON(XX(12),1),
         ATRIB(11)=EXPON(XX(13),1),
         ATRIB(12)=EXPON(XX(14),1),
         ATRIB(13)=EXPON(XX(15),1),
         ATRIB(14)=EXPON(XX(16),1),
         ATRIB(15)=EXPON(XX(17),1),
         ATRIB(16)=EXPON(XX(18),1);
  ASSIGN,ATRIB(17)=EXPON(XX(19),1),
```

```
              ATRIB(18)=EXPON(XX(20),1),
              ATRIB(19)=EXPON(XX(21),1),
              ATRIB(20)=EXPON(XX(22),1),
              ATRIB(21)=EXPON(XX(23),1),
              ATRIB(22)=EXPON(XX(24),1),
              ATRIB(23)=UNFRM(0,50),
              ATRIB(24)=UNFRM(51,100);
       ASSIGN,ATRIB(25)=UNFRM(101,150),
              ATRIB(26)=UNFRM(151,200),
              ATRIB(27)=UNFRM(201,250),
              ATRIB(28)=UNFRM(251,300),
              ATRIB(30)=UNFRM(351,400);
;
;
;                    *******FLIGHT LINE NETWORK*******
;
;
PRE    AWAIT(27),A431F1/4;              WAIT FOR CREW CHIEFS
       ACT/1,RLOGN(1.8,.52,2);          PERFORM PRE-FLIGHT
       FREE,A431F1/4;                   RELEASE CREW CHIEFS
       GOON,1;
       ACT,,ATRIB(95).EQ.1,GG1;         CHECK TO SEE IF
;                                       RETURNING FROM PHASE
       ACT,,ATRIB(95).EQ.0;             IF NOT RETURNING FROM
;                                       PHASE, COLLECT
;                                       TURN TIME.
FLY    COLCT,INT(94),TURN TIME;         COLLECT STATISTIC ON
;                                       AIRCRAFT TURN TIME
GG1    ASSIGN,ATRIB(95)=0;
RTRN   AWAIT(2),DAY;                    WAIT FOR DAYLIGHT
       AWAIT(3),STORM;                  WAIT FOR CLEAR WEATHER
       GOON,1;
       ACT,,NNGAT(DAY).EQ.1,RTRN;       IF WEATHER CLEARS
;                                       BUT IT IS NIGHT,
;                                       RETURNS TO WAIT FOR
;                                       DAYLIGHT
       ACT,,NNGAT(DAY).EQ.0;            IF WEATHER IS CLEAR
;                                       AND IT IS DAYLIGHT
;                                       ACFT FLIES.
       ASSIGN,XX(1)=XX(1)+1;            INCREASE NUMBER OF
;                                       DAILY SORTIES FLOWN
;                                       BY ONE.
       ACT,,,SORT;                      SENDS TO FLY SORTIE
       ACT;                             CREATES DUMMY ENTITY
;                                       TO CHECK IF DAILY
;                                       SORTIE RATE HAS BEEN MET.
       GOON,1;
       ACT/79,,XX(1).EQ.XX(94),DAY1;    CHECKS DAILY SORTIES
;                                       FLOWN AGAINST SCHEDULE
       ACT,,,TER1;                      TERMINATES DUMMY ACTIVITY
SORT   GOON;
       ACT,.8;                          DELAY FOR VARIOUS
;                                       PRE-LAUNCH TASKS
       ASSIGN,XX(2)=RNORM(2,.5,2);      ASSIGN SORTIE LENGTH
```

```
          ACT/5,XX(2);                      FLY SORTIE
          ASSIGN,ATRIB(94)=TNOW;            INITIATE TURN TIME CLOCK
;
;
;
;                       THE FOLLOWING STATEMENTS DECREMENT THE
;                       FAILURE CLOCKS FOR EACH SYSTEM
;
;
          ASSIGN,ATRIB(1)=ATRIB(1)-1,
                 ATRIB(2)=ATRIB(2)-1,
                 ATRIB(3)=ATRIB(3)-1,
                 ATRIB(4)=ATRIB(4)-1,
                 ATRIB(5)=ATRIB(5)-1,
                 ATRIB(6)=ATRIB(6)-1,
                 ATRIB(7)=ATRIB(7)-1,
                 ATRIB(8)=ATRIB(8)-1;
          ASSIGN,ATRIB(9)=ATRIB(9)-1,
                 ATRIB(10)=ATRIB(10)-1,
                 ATRIB(11)=ATRIB(11)-1,
                 ATRIB(12)=ATRIB(12)-1,
                 ATRIB(13)=ATRIB(13)-1,
                 ATRIB(14)=ATRIB(14)-1,
                 ATRIB(15)=ATRIB(15)-1,
                 ATRIB(16)=ATRIB(16)-1;
          ASSIGN,ATRIB(17)=ATRIB(17)-1,
                 ATRIB(18)=ATRIB(18)-1,
                 ATRIB(19)=ATRIB(19)-1;
          ASSIGN,ATRIB(20)=ATRIB(20)-1,
                 ATRIB(21)=ATRIB(21)-1,
                 ATRIB(22)=ATRIB(22)-1;
;                ATRIB(23)=ATRIB(23)-XX(2),
          ASSIGN,ATRIB(24)=ATRIB(24)-XX(2);
;         ASSIGN,ATRIB(25)=ATRIB(25)-XX(2),
          ASSIGN,ATRIB(26)=ATRIB(26)-XX(2);
;                ATRIB(27)=ATRIB(27)-XX(2),
          ASSIGN,ATRIB(28)=ATRIB(28)-XX(2);
;                ATRIB(29)=ATRIB(XX)-XX(2),
          ASSIGN,ATRIB(30)=ATRIB(30)-XX(2);
          GOON;
          ACT,.4;                     DELAY TIME TO TAXI AND PARK
          AWAIT(27),A431F1/4;             WAIT FOR CREW CHIEFS
          ACT/6,RLOGN(.30,.09,4);     PERFORM POST-FLIGHT
          FREE,A431F1/4;              MAKE CREW CHIEFS AVAILABLE
          ASSIGN,ATRIB(97)=TNOW,ATRIB(29)=TNOW;
;
;
;
;                         THE FOLLOWING SET OF ACTIVITIES
;                         CHECK THE FAILURE CLOCKS TO SEE
;                         IF UNSCHEDULED MAINTENANCE IS
;                         REQUIRED. IF UNSCHEDULED MAINTENANCE
;                         THE ENTITY TO THE PROPER MODULE
```

```
;
;
;
GN1   GOON,1;
      ACT/90,,ATRIB(1).LE.0,UM11;
      ACT/90,,ATRIB(2).LE.0,UM12;
      ACT/90,,ATRIB(3).LE.0,UM13;
      ACT/90,,ATRIB(4).LE.0,UM14;
      ACT/90,,ATRIB(5).LE.0,UM23;
      ACT/90,,ATRIB(6).LE.0,UM24;
      ACT/90,,ATRIB(7).LE.0,UM41;
      ACT/90,,ATRIB(8).LE.0,UM42;
      ACT/90,,ATRIB(9).LE.0,UM44;
      ACT/90,,ATRIB(10).LE.0,UM45;
      ACT/90,,ATRIB(11).LE.0,UM46;
      ACT/90,,ATRIB(12).LE.0,UM47;
      ACT/90,,ATRIB(13).LE.0,UM49;
      ACT/90,,ATRIB(14).LE.0,UM51;
      ACT/90,,ATRIB(15).LE.0,UM55;
      ACT/90,,ATRIB(16).LE.0,UM63;
      ACT/90,,ATRIB(17).LE.0,UM65;
      ACT/90,,ATRIB(18).LE.0,UM71;
      ACT/90,,ATRIB(19).LE.0,UM74;
      ACT/90,,ATRIB(20).LE.0,UM75;
      ACT/90,,ATRIB(21).LE.0,UM76;
;      ACT/90,,ATRIB(23).LE.0,PH1;
      ACT/90,,ATRIB(24).LE.0,PH2;
;      ACT/90,,ATRIB(25).LE.0,PH3;
      ACT/90,,ATRIB(26).LE.0,PH4;
;      ACT/90,,ATRIB(27).LE.0,PH5;
      ACT/90,,ATRIB(28).LE.0,PH6;
;      ACT/90,,ATRIB(29).LE.0,PH7;
      ACT/90,,ATRIB(30).LE.0,PH8;
;     ACT,,NNGAT(DAY).EQ.0,FLY;         NODE ONLY USED FOR
;                                       SURGE MODELING
      ACT;
COL   COLCT,INT(97),MAINT TIME;         COLLECT TIME IN
;                                       UNSCHEDULED AND PHASE
;                                       MAINTENANCE
;
;
      ACT,,,PRE;                        IF NO UNSCHEDULED OR
;                                       PHASE MAINTENANCE IS
;                                       REQUIRED
;                                       THE ENTITY IS SENT TO
;                                       PRE-FLIGHT
;
;
;     MODEL SEGMENT II        ***WEATHER***
;
      CREATE,UNFRM(18,30),,,1;     THIS MODULE CREATES BAD
;                                  WEATHER EVERY 18 - 30
```

```
CLS    CLOSE,STORM;                   HOURS AND THE BAD WEATHER
;                                     LASTS FOR 1.5 - 2.5 HOURS
       ACT/7,UNFRM(1.5,2.5);
       OPEN,STORM;
       ACT,UNFRM(18,30),,CLS;
;
;      MODEL SEGMENT III        ***DAY/NIGHT ***
;
       CREATE,,12;                    THIS MODULE CREATES
;                                   DAYTIME EVERY 12 HOURS
BACK   CLOSE,DAY;
       ACT/96,,,DY1;                  CREATES DUMMY ENTITY TO
;                                     SEE IF DAILY
;                                     SORTIE RATE HAS BEEN MET.
       ACT/87,12;
       OPEN,DAY;
       ACT/88,12,,BACK;
DY1    GOON,1;
       ACT/91,,XX(1).LE.XX(94),DAY2;  COMPARES DAILY SORTIES
;                                     FLOWN AGAINST SCHEDULE
       ACT/92,,,TER1;                 TERMINATES DUMMY ENTITY
DAY1   ASSIGN,ATRIB(98)=99;
       ACT,,,DAY2;
CL1    CLOSE,DAY;                     CLOSES DAY GATE IF
;                                     DAILY SORTIE RATE
;                                     HAS BEEN MET.
       ASSIGN,XX(1)=0,XX(94)=24;      RESETS DAILY SORTIE
;                                     COUNTER AND SCHEDULE
TER1   TERM;
DAY2   GOON,1;
       ACT,,XX(1).EQ.0,TER1;
       ACT;
       COLCT,XX(1),SORTIES,40/20/1;    COLLECTS DATA ON
;                                      NUMBER SORTIES FLOWN
;                                      PER DAY.
       GOON,1;
       ACT,,ATRIB(98).EQ.99,CL1;
       ACT;
       GOON,1;
       ACT/93,,XX(1).EQ.0,TER1;        IF DAY GATE HAS BEEN
;                                      CLOSED DUE TO
;                                      MEETING DAILY SORTIE
;                                      RATE, NO ACTION
;                                      IS TAKEN
       ACT/94;
       ASSIGN,XX(94)=XX(94)-XX(1)+24;  IF DAILY SORTIE RATE
;                                      WAS NOT MET BEFORE
;                                      THE DAY GATE IS CLOSED,
;                                      THE SCHEDULED
;                                      SORTIES FOR NEXT DAY
;                                      IS INCREASED BY
;                                      THE NUMBER OF SORTIES
;                                      SHORT THE PREVIOUS
```

```
;                                           DAY
;
;
      ASSIGN,XX(1)=0;                       RESETS DAILY SORTIE
;                                           COUNTER TO ZERO
      ACT,,,TER1;
;
;
;                                     ***SHIFT CHANGES***
;
;
      CREATE;
      ACT,8;
;                                     THIS MODULE CHANGES THE
;                                     RESOURCE LEVELS AND CREATES
;                                     THREE 8 HOUR SHIFTS
SHFT  ALTER,A326X6/0;
      ALTER,A326X7/0;
      ALTER,A326X8/0;
      ALTER,A326S3/0;
      ALTER,A326S4/0;
      ALTER,A326S5/0;
      ALTER,A404S1/0;
      ALTER,A423X0/0;
      ALTER,A423X1/0;
      ALTER,A423X4/0;
      ALTER,A423S0/0;
      ALTER,A423S1/0;
      ALTER,A423S2/0;
      ALTER,A423S3/0;
      ALTER,A423S4/-1;
      ALTER,A426X2/0;
      ALTER,A426S2/0;
      ALTER,A426T2/0;
      ALTER,A427X5/0;
      ALTER,A427S5/-2;
      ALTER,A431F1/0;
      ALTER,A431R1/0;
      ALTER,A462X0/-3;
      ALTER,A462S0/0;
      ACT,8;
      ALTER,A326X6/-4;
      ALTER,A326X7/-3;
      ALTER,A326X8/-4;
      ALTER,A326S3/-4;
      ALTER,A326S4/-5;
      ALTER,A326S5/-4;
      ALTER,A404S1/-2;
      ALTER,A423X0/-4;
      ALTER,A423X1/-2;
      ALTER,A423X4/-4;
      ALTER,A423S0/-2;
      ALTER,A423S1/-1;
```

```
        ALTER,A423S2/-2;
        ALTER,A423S3/-4;
        ALTER,A423S4/-2;
        ALTER,A426X2/-12;
        ALTER,A426S2/-12;
        ALTER,A426T2/-4;
        ALTER,A427X5/-4;
        ALTER,A427S5/0;
        ALTER,A431F1/0;
        ALTER,A431R1/-4;
        ALTER,A462X0/-9;
        ALTER,A462S0/-6;
        ACT,8;
        ALTER,A326X6/4;
        ALTER,A326X7/3;
        ALTER,A326X8/4;
        ALTER,A326S3/4;
        ALTER,A326S4/5;
        ALTER,A326S5/4;
        ALTER,A404S1/2;
        ALTER,A423X0/4;
        ALTER,A423X1/2;
        ALTER,A423X4/4;
        ALTER,A423S0/2;
        ALTER,A423S1/1;
        ALTER,A423S2/2;
        ALTER,A423S3/4;
        ALTER,A423S4/3;
        ALTER,A426X2/12;
        ALTER,A426S2/12;
        ALTER,A426T2/4;
        ALTER,A427X5/4;
        ALTER,A427S5/2;
        ALTER,A431F1/0;
        ALTER,A431R1/4;
        ALTER,A462X0/12;
        ALTER,A462S0/6;
        ACT,8,,SHFT;
;
;       MODEL SEGMENT IV     ***UNSCHEDULED MAINTENANCE***
;
UM11    ASSIGN,XX(95)=XX(95)-1;
        GOON;
        ACT,,.05,RR11;
        ACT,,.95;
        GOON;
        ACT,,.01,A111;
        ACT,,.14,A112;
        ACT,,.77,A113;
        ACT,,.08;
        AWAIT(27),A431F1/1;
        ACT/8,RLOGN(XX(31),ATRIB(31),2);
        FREE,A431F1/1;
```

```
ASG1  ASSIGN,ATRIB(1)=EXPON(XX(3),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
A111  AWAIT(8),A326X7/2;
      ACT/8,RLOGN(XX(31),ATRIB(31),2);
      FREE,A326X7/2;
      ACT,,,ASG1;
A112  AWAIT(20),A423S3/2;
      ACT/8,RLOGN(XX(31),ATRIB(31),2);
      FREE,A423S3/2;
      ACT,,,ASG1;
A113  AWAIT(25),A427X5/1;
      ACT/8,RLOGN(XX(31),ATRIB(31),2);
      FREE,A427X5/1;
      ACT,,,ASG1;
RR11  GOON;
      ACT,,.79,A114;
      ACT,,.11,A115;
      ACT,,.10;
      AWAIT(27),A431F1/1;
      ACT/9,RLOGN(XX(32),ATRIB(32),2);
      FREE,A431F1/1;
ASG2  ASSIGN,ATRIB(1)=EXPON(XX(3),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
      ACT,,.53,S11;
      ACT,,.06,S111;
      ACT,,.41,S112;
A114  AWAIT(8),A326X7/2;
      ACT/9,RLOGN(XX(32),ATRIB(32),2);
      FREE,A326X7/2;
      ACT,,,ASG2;
A115  AWAIT(16),A423X4/2;
      ACT/9,RLOGN(XX(32),ATRIB(32),2);
      FREE,A423X4/2;
      ACT,,,ASG2;
S11   AWAIT(11),A326S4/1;
      ACT/10,RLOGN(XX(33),ATRIB(33),2);
      FREE,A326S4/1;
      ACT,,,COL2;
S111  AWAIT(21),A423S4/1;
      ACT/10,RLOGN(XX(33),ATRIB(33),2);
      FREE,A423S4/1;
      ACT,,,COL2;
S112  AWAIT(26),A427S5/2;
      ACT/10,RLOGN(XX(33),ATRIB(33),2);
      FREE,A427S5/2;
      ACT,,,COL2;
;
;
;
UM12  ASSIGN,XX(95)=XX(95)-1;
      GOON;
      ACT,,.25,RR12;
      ACT,,.75;
```

```
          AWAIT(19),A423S2/2;
          ACT/11,RLOGN(XX(34),ATRIB(34),2);
          FREE,A423S2/2;
          ASSIGN,ATRIB(2)=EXPON(XX(4),1),XX(95)=XX(95)+1;
          ACT,,,GN1;
RR12      GOON;
          AWAIT(16),A423X4/1;
          ACT/12,RLOGN(XX(35),ATRIB(35),2);
          FREE,A423X4/1;
          ASSIGN,ATRIB(2)=EXPON(XX(4),1),XX(95)=XX(95)+1;
          ACT,,,GN1;
          ACT;
          AWAIT(28),A431R1/2;
          ACT/13,RLOGN(XX(36),ATRIB(36),2);
          FREE,A431R1/2;
          ACT,,,COL2;
;
;
;
UM13      ASSIGN,XX(95)=XX(95)-1;
          GOON;
          ACT,,.59,RR13;
          ACT,,.41;
          GOON;
          ACT,,.23,A131;
          ACT,,.51,A132;
          ACT,,.26;
          AWAIT(28),A431R1/2;
          ACT/14,RLOGN(XX(37),ATRIB(37),2);
          FREE,A431R1/2;
ASG3      ASSIGN,ATRIB(3)=EXPON(XX(5),1),XX(95)=XX(95)+1;
          ACT,,,GN1;
A131      AWAIT(14),A423X0/2;
          ACT/14,RLOGN(XX(37),ATRIB(37),2);
          FREE,A423X0/2;
          ACT,,,ASG3;
A132      AWAIT(16),A423X4/2;
          ACT/14,RLOGN(XX(37),ATRIB(37),2);
          FREE,A423X4/2;
          ACT,,,ASG3;
RR13      GOON;
          ACT,,.11,A133;
          ACT,,.04,A134;
          ACT,,.09,A135;
          ACT,,.76;
          AWAIT(27),A431F1/2;
          ACT/15,RLOGN(XX(38),ATRIB(38),2);
          FREE,A431F1/2;
ASG4      ASSIGN,ATRIB(3)=EXPON(XX(5),1),XX(95)=XX(95)+1;
          ACT,,,GN1;
          ACT;
          AWAIT(21),A423S4/1;
          ACT/16,RLOGN(XX(39),ATRIB(39),2);
```

```
       FREE,A423S4/1;
       ACT,,,COL2;
A133   AWAIT(14),A423X0/2;
       ACT/15,RLOGN(XX(38),ATRIB(38),2);
       FREE,A423X0/2;
       ACT,,,ASG4;
A134   AWAIT(16),A423X4/2;
       ACT/15,RLOGN(XX(38),ATRIB(38),2);
       FREE,A423X4/2;
       ACT,,,ASG4;
A135   AWAIT(28),A431R1/2;
       ACT/15,RLOGN(XX(38),ATRIB(38),2);
       FREE,A431R1/2;
       ACT,,,ASG4;
;
;
;
UM14   ASSIGN,XX(95)=XX(95)-1;
       GOON;
       ACT,,.34,RR14;
       ACT,,.66;
       GOON;
       ACT,,.15,A142;
       ACT,,.85;
       AWAIT(28),A431R1/2;
       ACT/17,RLOGN(XX(40),ATRIB(40),2);
       FREE,A431R1/2;
ASG5   ASSIGN,ATRIB(4)=EXPON(XX(6),1),XX(95)=XX(95)+1;
       ACT,,,GN1;
A142   AWAIT(16),A423X4/1;
       ACT/17,RLOGN(XX(40),ATRIB(40),2);
       FREE,A423X4/1;
       ACT,,,ASG5;
RR14   GOON;
       ACT,,.82,A143;
       ACT,,.18;
       AWAIT(28),A431R1/2;
       ACT/18,RLOGN(XX(41),ATRIB(41),2);
       FREE,A431R1/2;
ASG6   ASSIGN,ATRIB(4)=EXPON(XX(6),1),XX(95)=XX(95)+1;
       ACT,,,GN1;
       ACT,,.28,S14;
       ACT,,.72,S141;
A143   AWAIT(16),A423X4/2;
       ACT/18,RLOGN(XX(41),ATRIB(41),2);
       FREE,A423X4/2;
       ACT,,,ASG6;
S14    AWAIT(12),A326S5/1;
       ACT/19,RLOGN(XX(42),ATRIB(42),2);
       FREE,A326S5/1;
       ACT,,,COL2;
S141   AWAIT(21),A423S4/1;
       ACT/19,RLOGN(XX(42),ATRIB(42),2);
```

```
      FREE,A423S4/1;
      ACT,,,COL2;
;
;
;
UM23  ASSIGN,XX(95)=XX(95)-1;
      GOON;
      ACT,,.28,RR23;
      ACT,,.72;
      GOON;
      ACT,,.02,A231;
      ACT,,.06,A232;
      ACT,,.51,A233;
      ACT,,.37,A235;
      ACT,,.04;
      AWAIT(28),A431R1/2;
      ACT/20,RLOGN(XX(43),ATRIB(43),2);
      FREE,A431R1/2;
ASG7  ASSIGN,ATRIB(5)=EXPON(XX(7),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
A231  AWAIT(31),ALLOC(1);
      ACT/20,RLOGN(XX(43),ATRIB(43),2);
      FREE,A326X7/2;
      FREE,A426X2/4;
      ACT,,,ASG7;
A232  AWAIT(32),ALLOC(2);
      ACT/20,RLOGN(XX(43),ATRIB(43),2);
      FREE,A423X0/2;
      FREE,A426X2/4;
      ACT,,,ASG7;
A233  AWAIT(22),A426X2/4;
      ACT/20,RLOGN(XX(43),ATRIB(43),2);
      FREE,A426X2/4;
      ACT,,,ASG7;
A235  AWAIT(34),ALLOC(3);
      ACT/20,RLOGN(XX(43),ATRIB(43),2);
      FREE,A427X5/2;
      FREE,A426X2/4;
      ACT,,,ASG7;
RR23  GOON;
      ACT,,.06,A236;
      ACT,,.94;
      AWAIT(22),A426X2/4;
      ACT/21,RLOGN(XX(44),ATRIB(44),2);
      FREE,A426X2/4;
ASG8  ASSIGN,ATRIB(5)=EXPON(XX(7),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
      ACT;
      AWAIT(23),A426S2/2;
      ACT/22,RLOGN(XX(45),ATRIB(45),2);
      FREE,A426S2/2;
      AWAIT(6),A426T2/4;
      ACT/81,RLOGN(XX(96),ATRIB(96),2);
```

```
        FREE,A426T2/4;
        ACT,,,COL2;
A236    AWAIT(14),A423X0/3;
        ACT/21,RLOGN(XX(44),ATRIB(44),2);
        FREE,A423X0/3;
        ACT,,,ASG8;
;
;
UM24    ASSIGN,XX(95)=XX(95)-1;
        GOON;
        ACT,,.32,RR24;
        ACT,,.68;
        AWAIT(16),A423X4/2;
        ACT/23,RLOGN(XX(46),ATRIB(46),2);
        FREE,A423X4/2;
ASG9    ASSIGN,ATRIB(6)=EXPON(XX(8),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
RR24    GOON;
        ACT,,.14,A242;
        ACT,,.86;
        AWAIT(16),A423X4/2;
        ACT/24,RLOGN(XX(47),ATRIB(47),2);
        FREE,A423X4/2;
AS10    ASSIGN,ATRIB(6)=EXPON(XX(8),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
        ACT;
        AWAIT(21),A423S4/2;
        ACT/25,RLOGN(XX(48),ATRIB(48),2);
        FREE,A423S4/2;
        ACT,,,COL2;
A242    AWAIT(14),A423X0/2;
        ACT/24,RLOGN(XX(47),ATRIB(47),2);
        FREE,A423X0/2;
        ACT,,,AS10;
;
;
UM41    ASSIGN,XX(95)=XX(95)-1;
        GOON;
        ACT,,.72,RR41;
        ACT,,.28;
        AWAIT(15),A423X1/1;
        ACT/26,RLOGN(XX(49),ATRIB(49),2);
        FREE,A423X1/1;
        ASSIGN,ATRIB(7)=EXPON(XX(9),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
RR41    GOON;
        AWAIT(15),A423X1/1;
        ACT/27,RLOGN(XX(50),ATRIB(50),2);
        FREE,A423X1/1;
        ASSIGN,ATRIB(7)=EXPON(XX(9),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
        ACT;
        AWAIT(18),A423S1/1;
```

```
      ACT/28,RLOGN(XX(51),ATRIB(51),2);
      FREE,A423S1/1;
      ACT,,,COL2;
;
;
;
UM42  ASSIGN,XX(95)=XX(95)-1;
      GOON;
      ACT,,.44,RR42;
      ACT,,.56;
      AWAIT(14),A423X0/2;
      ACT/29,RLOGN(XX(52),ATRIB(52),2);
      FREE,A423X0/2;
      ASSIGN,ATRIB(8)=EXPON(XX(10),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
RR42  AWAIT(16),A423X4/1;
      ACT/30,RLOGN(XX(53),ATRIB(53),2);
      FREE,A423X4/1;
      ASSIGN,ATRIB(8)=EXPON(XX(10),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
      ACT,,.55,S42;
      ACT,,.07,S421;
      ACT,,.38;
      AWAIT(11),A326S4/2;
      ACT/31,RLOGN(XX(54),ATRIB(54),2);
      FREE,A326S4/2;
      ACT,,,COL2;
S42   AWAIT(17),A423S0/2;
      ACT/31,RLOGN(XX(54),ATRIB(54),2);
      FREE,A423S0/2;
      ACT,,,COL2;
S421  AWAIT(21),A423S4/2;
      ACT/31,RLOGN(XX(54),ATRIB(54),2);
      FREE,A423S4/2;
      ACT,,,COL2;
;
;
;
UM44  ASSIGN,XX(95)=XX(95)-1;
      GOON;
      ACT,,.77,RR44;
      ACT,,.23;
      AWAIT(14),A423X0/2;
      ACT/32,RLOGN(XX(55),ATRIB(55),2);
      FREE,A423X0/2;
      ASSIGN,ATRIB(9)=EXPON(XX(11),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
RR44  GOON;
      AWAIT(14),A423X0/1;
      ACT/33,RLOGN(XX(56),ATRIB(56),2);
      FREE,A423X0/1;
      ASSIGN,ATRIB(9)=EXPON(XX(11),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
```

```
        ACT,,.75,S44;
        ACT,,.25;
        AWAIT(17),A423S0/1;
        ACT/34,RLOGN(XX(57),ATRIB(57),2);
        FREE,A423S0/1;
        ACT,,,COL2;
S44     AWAIT(12),A326S5/1;
        ACT/34,RLOGN(XX(57),ATRIB(57),2);
        FREE,A326S5/1;
        ACT,,,COL2;
;
;
;
;
UM45    ASSIGN,XX(95)=XX(95)-1;
        AWAIT(16),A423X4/2;
        ACT,,.32,RR45;
        ACT/35,RLOGN(XX(58),ATRIB(58),2),.68;
        FREE,A423X4/2;
        ASSIGN,ATRIB(10)=EXPON(XX(12),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
RR45    GOON;
        ACT/36,RLOGN(XX(59),ATRIB(59),2);
        FREE,A423X4/2;
        ASSIGN,ATRIB(10)=EXPON(XX(12),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
        ACT;
        AWAIT(21),A423S4/1;
        ACT/37,RLOGN(XX(60),ATRIB(60),2);
        FREE,A423S4/1;
        ACT,,,COL2;
;
;
;
;
UM46    ASSIGN,XX(95)=XX(95)-1;
        GOON;
        ACT,,.85,RR46;
        ACT,,.15;
        AWAIT(8),A326X7/1;
        ACT/38,RLOGN(XX(61),ATRIB(61),2);
        FREE,A326X7/1;
AS11    ASSIGN,ATRIB(11)=EXPON(XX(13),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
RR46    GOON;
        ACT,,.30,A462;
        ACT,,.70;
        AWAIT(20),A423S3/2;
        ACT/39,RLOGN(XX(62),ATRIB(62),2);
        FREE,A423S3/2;
AS12    ASSIGN,ATRIB(11)=EXPON(XX(13),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
        ACT,,,S46;
```

```
A462  AWAIT(8),A326X7/1;
      ACT/39,RLOGN(XX(62),ATRIB(62),2);
      FREE,A326X7/1;
      ACT,,,AS12;
S46   AWAIT(12),A326S5/1;
      ACT/40,RLOGN(XX(63),ATRIB(63),2);
      FREE,A326S5/1;
      ACT,,,COL2;
;
;
;
;
UM47  ASSIGN,XX(95)=XX(95)-1;
      AWAIT(15),A423X1/2;
      ACT,,.52,RR47;
      ACT/41,RLOGN(XX(64),ATRIB(64),2),.48;
      FREE,A423X1/2;
      ASSIGN,ATRIB(12)=EXPON(XX(14),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
RR47  GOON;
      ACT/42,RLOGN(XX(65),ATRIB(65),2);
      FREE,A423X1/2;
      ASSIGN,ATRIB(12)=EXPON(XX(14),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
      ACT;
      AWAIT(18),A423S1/1;
      ACT/43,RLOGN(XX(66),ATRIB(66),2);
      FREE,A423S1/1;
      ACT,,,COL2;
;
;
;
;
UM49  ASSIGN,XX(95)=XX(95)-1;
      AWAIT(14),A423X0/1;
      ACT,,.86,RR49;
      ACT/44,RLOGN(XX(67),ATRIB(67),2),.14;
      FREE,A423X0/1;
      ASSIGN,ATRIB(13)=EXPON(XX(15),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
RR49  GOON;
      ACT/45,RLOGN(XX(68),ATRIB(68),2);
      FREE,A423X0/1;
      ASSIGN,ATRIB(13)=EXPON(XX(15),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
      ACT,,.60,S49;
      ACT,,.20,S491;
      ACT,,.20;
      AWAIT(18),A423S1/1;
      ACT/46,RLOGN(XX(69),ATRIB(69),2);
      FREE,A423S1/1;
      ACT,,,COL2;
S49   AWAIT(12),A326S5/1;
```

```
        ACT/46,RLOGN(XX(69),ATRIB(69),2);
        FREE,A326S5/1;
        ACT,,,COL2;
S491    AWAIT(17),A423S0/1;
        ACT/46,RLOGN(XX(69),ATRIB(69),2);
        FREE,A423S0/1;
        ACT,,,COL2;
;
;
;
;
UM51    ASSIGN,XX(95)=XX(95)-1;
        AWAIT(8),A326X7/1;
        ACT,,.79,RR51;
        ACT/47,RLOGN(XX(70),ATRIB(70),2),.21;
        FREE,A326X7/1;
        ASSIGN,ATRIB(14)=EXPON(XX(16),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
RR51    GOON;
        ACT/48,RLOGN(XX(71),ATRIB(71),2);
        FREE,A326X7/1;
        ASSIGN,ATRIB(14)=EXPON(XX(16),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
        ACT;
        AWAIT(11),A326S4/1;
        ACT/49,RLOGN(XX(72),ATRIB(72),2);
        FREE,A326S4/1;
        ACT,,,COL2;
;
;
;
;
UM55    ASSIGN,XX(95)=XX(95)-1;
        AWAIT(8),A326X7/1;
        ACT,,.39,RR55;
        ACT/50,RLOGN(XX(73),ATRIB(73),2),.61;
        FREE,A326X7/1;
        ASSIGN,ATRIB(15)=EXPON(XX(17),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
RR55    GOON;
        ACT/51,RLOGN(XX(74),ATRIB(74),2);
        FREE,A326X7/1;
        ASSIGN,ATRIB(15)=EXPON(XX(17),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
        ACT,,.63,S55;
        ACT,,.37;
        AWAIT(12),A326S5/1;
        ACT/52,RLOGN(XX(75),ATRIB(75),2);
        FREE,A326S5/1;
        ACT,,,COL2;
S55     AWAIT(11),A326S4/1;
        ACT/52,RLOGN(XX(75),ATRIB(75),2);
        FREE,A326S4/1;
```

```
      ACT,,,COL2;
;
;
;
;
UM63  ASSIGN,XX(95)=XX(95)-1;
      AWAIT(9),A326X8/1;
      ACT,,.49,RR63;
      ACT/53,RLOGN(XX(76),ATRIB(76),2),.51;
      FREE,A326X8/1;
      ASSIGN,ATRIB(16)=EXPON(XX(18),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
RR63  GOON;
      ACT/54,RLOGN(XX(77),ATRIB(77),2);
      FREE,A326X8/1;
      ASSIGN,ATRIB(16)=EXPON(XX(18),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
      ACT;
      AWAIT(12),A326S5/1;
      ACT/55,RLOGN(XX(78),ATRIB(78),2);
      FREE,A326S5/1;
      ACT,,,COL2;
;
;
;
;
UM65  ASSIGN,XX(95)=XX(95)-1;
      AWAIT(9),A326X8/1;
      ACT,,.13,RR65;
      ACT/56,RLOGN(XX(79),ATRIB(79),2),.87;
      FREE,A326X8/1;
      ASSIGN,ATRIB(17)=EXPON(XX(19),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
RR65  GOON;
      ACT/57,RLOGN(XX(80),ATRIB(80),2);
      FREE,A326X8/1;
      ASSIGN,ATRIB(17)=EXPON(XX(19),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
      ACT,,.15,S65;
      ACT,,.85;
      AWAIT(12),A326S5/1;
      ACT/58,RLOGN(XX(81),ATRIB(81),2);
      FREE,A326S5/1;
      ACT,,,COL2;
S65   AWAIT(11),A326S4/1;
      ACT/58,RLOGN(XX(81),ATRIB(81),2);
      FREE,A326S4/1;
      ACT,,,COL2;
;
;
;
;
```

```
UM71  ASSIGN,XX(95)=XX(95)-1;
      GOON;
      ACT,,.18,A711;
      ACT,,.82,RR71;
A711  GOON;
      AWAIT(8),A326X7/2;
      ACT/59,RLOGN(XX(82),ATRIB(82),2);
      FREE,A326X7/2;
      ASSIGN,ATRIB(18)=EXPON(XX(20),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
RR71  GOON;
      AWAIT(8),A326X7/1;
      ACT/60,RLOGN(XX(83),ATRIB(83),2);
      FREE,A326X7/1;
      ASSIGN,ATRIB(18)=EXPON(XX(20),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
      ACT,,.89,S71;
      ACT,,.11;
      AWAIT(12),A326S5/1;
      ACT/61,RLOGN(XX(84),ATRIB(84),2);
      FREE,A326S5/1;
      ACT,,,COL2;
S71   AWAIT(11),A326S4/1;
      ACT/61,RLOGN(XX(84),ATRIB(84),2);
      FREE,A326S4/1;
      ACT,,,COL2;
;
;
;
;
UM74  ASSIGN,XX(95)=XX(95)-1;
      GOON;
      ACT,,.48,RR74;
      ACT,,.52;
      AWAIT(7),A326X6/2;
      ACT/62,RLOGN(XX(85),ATRIB(85),2);
      FREE,A326X6/2;
      ASSIGN,ATRIB(19)=EXPON(XX(21),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
RR74  GOON;
      ACT,,.74,A741;
      ACT,,.26;
      AWAIT(13),A404S1/2;
      ACT/63,RLOGN(XX(86),ATRIB(86),2);
      FREE,A404S1/2;
AS13  ASSIGN,ATRIB(19)=EXPON(XX(21),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
      ACT,,.58,S74;
      ACT,,.34,S741;
      ACT,,.08,S742;
A741  AWAIT(7),A326X6/2;
      ACT/63,RLOGN(XX(86),ATRIB(86),2);
      FREE,A326X6/2;
```

```
        ACT,,,AS13;
S74     AWAIT(11),A326S4/1;
        ACT/64,RLOGN(XX(87),ATRIB(87),2);
        FREE,A326S4/1;
        ACT,,,COL2;
S741    AWAIT(12),A326S5/1;
        ACT/64,RLOGN(XX(87),ATRIB(87),2);
        FREE,A326S5/1;
        ACT,,,COL2;
S742    AWAIT(13),A404S1/2;
        ACT/64,RLOGN(XX(87),ATRIB(87),2);
        FREE,A404S1/2;
        ACT,,,COL2;
;
;
;
;
UM75    ASSIGN,XX(95)=XX(95)-1;
        AWAIT(29),A462X0/3;
        ACT,,.67,RR75;
        ACT/65,RLOGN(XX(88),ATRIB(88),2),.33;
        FREE,A462X0/3;
        ASSIGN,ATRIB(20)=EXPON(XX(22),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
RR75    GOON;
        ACT/66,RLOGN(XX(89),ATRIB(89),2);
        FREE,A462X0/3;
        ASSIGN,ATRIB(20)=EXPON(XX(22),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
        ACT,,.31,S75;
        ACT,,.69;
        AWAIT(30),A462S0/2;
        ACT/67,RLOGN(XX(90),ATRIB(90),2);
        FREE,A462S0/2;
        ACT,,,COL2;
S75     AWAIT(11),A326S4/1;
        ACT/67,RLOGN(XX(90),ATRIB(90),2);
        FREE,A326S4/1;
        ACT,,,COL2;
;
;
;
;
UM76    ASSIGN,XX(95)=XX(95)-1;
        AWAIT(9),A326X8/1;
        ACT,,.41,RR76;
        ACT/68,RLOGN(XX(91),ATRIB(91),2),.59;
        FREE,A326X8/1;
        ASSIGN,ATRIB(21)=EXPON(XX(23),1),XX(95)=XX(95)+1;
        ACT,,,GN1;
RR76    GOON;
        ACT/69,RLOGN(XX(92),ATRIB(92),2);
        FREE,A326X8/1;
```

```
      ASSIGN,ATRIB(21)=EXPON(XX(23),1),XX(95)=XX(95)+1;
      ACT,,,GN1;
      ACT;
      AWAIT(10),A326S3/1;
      ACT/70,RLOGN(XX(93),ATRIB(93),2);
      FREE,A326S3/1;
COL2  COLCT,INT(29),RPR CYCLE TIME;
      TERM;
;
;
;
;
;      MODEL SEGMENT V        ***PHASE MAINTENANCE***
;
;PH1   ASSIGN,XX(95)=XX(95)-1;
;      ACT/71,24.00;
;      ASSIGN,ATRIB(23)=50,ATRIB(95)=1,XX(95)=XX(95)+1;
;      ACT,,,COL;
PH2   ASSIGN,XX(95)=XX(95)-1;
      ACT/72,UNFRM(24.0,36.0);
      ASSIGN,ATRIB(24)=100,ATRIB(95)=1,XX(95)=XX(95)+1;
      ACT,,,COL;
;PH3   ASSIGN,XX(95)=XX(95)-1;
;      ACT/73,24.00;
;      ASSIGN,ATRIB(25)=150,ATRIB(95)=1,XX(95)=XX(95)+1;
;      ACT,,,COL;
PH4   ASSIGN,XX(95)=XX(95)-1;
      ACT/74,UNFRM(24.0,36.0);
      ASSIGN,ATRIB(26)=200,ATRIB(95)=1,XX(95)=XX(95)+1;
      ACT,,,COL;
;PH5   ASSIGN,XX(95)=XX(95)-1;
;      ACT/75,24.00;
;      ASSIGN,ATRIB(27)=250,ATRIB(95)=1,XX(95)=XX(95)+1;
;      ACT,,,COL;
PH6   ASSIGN,XX(95)=XX(95)-1;
      ACT/76,UNFRM(24.0,36.0);
      ASSIGN,ATRIB(28)=300,ATRIB(95)=1,XX(95)=XX(95)+1;
      ACT,,,COL;
;PH7   ASSIGN,XX(95)=XX(95)-1;
;      ACT/77,48.00;
;      ASSIGN,ATRIB(29)=350,ATRIB(95)=1,XX(95)=XX(95)+1;
;      ACT,,,COL;
PH8   ASSIGN,XX(95)=XX(95)-1;
      ACT/78,UNFRM(24.0,36.0);
      ASSIGN,ATRIB(30)=400,ATRIB(95)=1,XX(95)=XX(95)+1;
      ACT,,,COL;
;
;
;
      ENDNETWORK;
TIMST,NRUSE(1),A326X6,8/0/1;
TIMST,NRUSE(2),A326X7,4/0/1;
TIMST,NRUSE(3),A326X8,7/0/1;
```

```
TIMST,NRUSE(4),A326S3,5/0/1;
TIMST,NRUSE(5),A326S4,6/0/1;
TIMST,NRUSE(6),A326S5,5/0/1;
TIMST,NRUSE(7),A404S1,4/0/1;
TIMST,NRUSE(8),A423X0,6/0/1;
TIMST,NRUSE(9),A423X1,2/0/1;
TIMST,NRUSE(10),A423X4,4/0/1;
TIMST,NRUSE(11),A423S0,4/0/1;
TIMST,NRUSE(12),A423S1,2/0/1;
TIMST,NRUSE(13),A423S2,4/0/1;
TIMST,NRUSE(14),A423S3,4/0/1;
TIMST,NRUSE(15),A423S4,4/0/1;
TIMST,NRUSE(16),A426X2,12/0/1;
TIMST,NRUSE(17),A426S2,12/0/1;
TIMST,NRUSE(18),A426T2,4/0/1;
TIMST,NRUSE(19),A427X5,4/0/1;
TIMST,NRUSE(20),A427S5,2/0/1;
TIMST,NRUSE(21),A431F1,16/0/1;
TIMST,NRUSE(22),A431R1,4/0/1;
TIMST,NRUSE(23),A462X0,18/0/1;
TIMST,NRUSE(24),A462S0,6/0/1;
INIT,0,6288;
MONITOR,CLEAR,240;
FIN;
```

## FORTRAN CODE

```
 PROGRAM MAIN
      DIMENSION NSET(40000)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA
     1,MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100)
     1,SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET(40000)
      EQUIVALENCE(NSET(1),QSET(1))
      NNSET=40000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      NPLOT=2
      CALL SLAM
      STOP
      END
      SUBROUTINE EVENT(I)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA
     1,MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100)
     1,SSL(100),TNEXT,TNOW,XX(100)
      RETURN
      END
      SUBROUTINE INTLC
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA
     1,MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100)
```

```
     1,SSL(100),TNEXT,TNOW,XX(100)
      RETURN
      END
      SUBROUTINE OTPUT
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA
     1,MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100)
     1,SSL(100),TNEXT,TNOW,XX(100)
      DIMENSION X(24)
          DO 10 I=1,24
             X(I)=(RRAVG(I)*(TNOW-240))/12
             WRITE(NPRNT,20)I,X(I)
 20       FORMAT('  THE MONTHLY MANHOURS FOR RESOURCE',I2
     1,2X,'IS',F10.4)
 10       CONTINUE
      RETURN
      END
      SUBROUTINE ALLOC(I,IFLAG)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA
     1,MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100)
     1,SSL(100),TNEXT,TNOW,XX(100)
      IFLAG=0
      GO TO (1,2,3),I
 1    IF(NNRSC(16).LE.3.OR.NNRSC(2).LE.1) RETURN
      CALL SEIZE(16,4)
      CALL SEIZE(2,2)
      IFLAG=-1
      RETURN
 2    IF(NNRSC(16).LE.3.OR.NNRSC(8).LE.1) RETURN
      CALL SEIZE(16,4)
      CALL SEIZE(8,2)
      IFLAG=-1
      RETURN
 3    IF(NNRSC(16).LE.3.OR.NNRSC(19).LE.1) RETURN
      CALL SEIZE(16,4)
      CALL SEIZE(19,2)
      IFLAG=-1
      RETURN
      END
```

<u>Sample Extract of Model Output</u>

**INTERMEDIATE RESULTS**

```
THE MONTHLY MANHOURS FOR RESOURCE 1 IS 197.7389
THE MONTHLY MANHOURS FOR RESOURCE 2 IS 151.9633
THE MONTHLY MANHOURS FOR RESOURCE 24 IS 238.3357
```

<u>SLAM SUMMARY REPORT</u>

```
          CURRENT TIME 0.6288+04
          STATISTICAL ARRAYS CLEARED AT TIME  0.2400E+03
```

**STATISTICS FOR VARIABLES BASED ON OBSERVATIONS**

| | MEAN VALUE | STANDARD DEVIATION | COEFF. OF VARIATION | NUMBER OF OBSERVATIONS |
|---|---|---|---|---|
| TURN TIME | 0.7324E+01 | 0.3690E+01 | 0.5038E+00 | ....5817 |
| MAINT TIME | 0.3676E+01 | 0.6672E+01 | 0.1815E+01 | ....6044 |
| SORTIE | 0.2400E+02 | 0.0000E+00 | 0.0000E+00 | .... 252 |
| RPR CYCLE TIME | 0.1707E+02 | 0.1916E+02 | 0.1122E+01 | ....1987 |

**STATISTICS FOR TIME-PERSISTENT VARIABLES**

| | MEAN VALUE | STANDARD DEVIATION | MINIMUM VALUE | CURRENT VALUE |
|---|---|---|---|---|
| MSN CAP ACFT | 0.1832E+02 | 0.3524E+01 | 0.4000E+01 | ....0.1800E+02 |
| A326X6 | 0.3923E+00 | 0.9395E+00 | 0.0000E+00 | ....0.0000E+00 |
| A326X7 | 0.3015E+00 | 0.6744E+00 | 0.0000E+00 | ....0.0000E+00 |
| A462S0 | 0.4729E+00 | 0.1010E+01 | 0.0000E+00 | ....0.0000E+00 |

**FILE STATISTICS**

| FILE NUMBER | ASSOCIATED NODE TYPE | AVERAGE LENGTH | STANDARD DEVIATION | MAX LENGTH | CURRENT LENGTH | AVERAGE WAITING TIME |
|---|---|---|---|---|---|---|
| 1 | | 0.0000 | 0.0000 | 0 | 0 | 0.0000 |
| 2 | AWAIT | 10.7224 | 8.6726 | 22 | 0 | 10.6818 |
| 3 | AWAIT | 0.0558 | 0.9996 | 22 | 0 | 0.0556 |
| 41 | CALENDAR | 15.3185 | 7.4136 | 34 | 30 | 0.5547 |

**REGULAR ACTIVITY STATISTICS**

| ACTIVITY INDEX | AVERAGE UTILIZATION | STANDARD DEVIATION | MAXIMUM UTILIZATION | CURRENT UTILIZATION | ENTITY COUNT |
|---|---|---|---|---|---|
| 1 | 1.7903 | 1.6842 | 4 | 1 | 6043 |
| 5 | 2.0080 | 5.2730 | 22 | 0 | 6048 |
| 6 | 0.3009 | 0.7370 | 4 | 0 | 6048 |
| 96 | 0.0000 | 0.0000 | 1 | 0 | 252 |

**RESOURCE STATISTICS**

| RESOURCE NUMBER | RESOURCE LABEL | CURRENT CAPACITY | AVERAGE UTIL. | STANDARD DEVIATION | MAXIMUM UTIL. | CURRENT UTIL. |
|---|---|---|---|---|---|---|
| 1 | A326X6 | 4 | 0.3923 | 0.9395 | 4 | 0 |
| 2 | A326X7 | 3 | 0.3015 | 0.6744 | 3 | 0 |
| 24 | A462S0 | 4 | 0.4729 | 1.0103 | 4 | 0 |

| RESOURCE NUMBER | RESOURCE LABEL | CURRENT AVAILABLE | AVERAGE AVAILABLE | MINIMUM AVAILABLE | MAXIMUM AVAILABLE |
|---|---|---|---|---|---|
| 1 | A326X6 | 4 | 2.2743 | -2 | 4 |
| 2 | A326X7 | 3 | 1.6985 | -2 | 3 |
| 24 | A462S0 | 4 | 2.1938 | -4 | 4 |

**GATE STATISTICS**

| GATE NUMBER | GATE LABEL | CURRENT STATUS | PCT. OF TIME OPEN |
|---|---|---|---|
| 1 | DAY | OPEN | 0.2453 |
| 2 | STORM | OPEN | 0.9229 |

## Appendix C

## Computer Files For Factorial and Regression Analyses

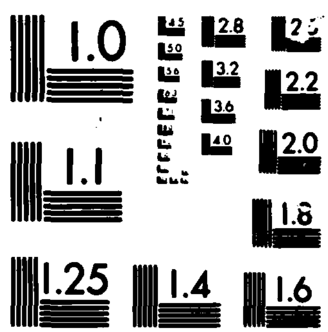
This appendix contains the BMDP files that were used for the factorial and regression analyses of the effect of R&M on mission capabilities.

### BMDP Execution File For Factorial Analysis

```
/PROBLEM  TITLE IS 'FACTORIAL'.
/INPUT    VARIABLE ARE 7.
          FORMAT IS FREE.
          FILE IS 'factorial.dat'.
/VARIABLE NAMES ARE ID,MC,SORT,REL,MAINT,CREW,RNNUM.
          LABEL IS ID.
/BETWEEN  FACTORS ARE REL,MAINT,CREW,RNNUM.
          CODES(1) ARE 1,2,3.
          NAMES(1) ARE BASE,TWOFOLD,FOURFOLD.
          CODES(2) ARE 1,2,3.
          NAMES(2) ARE BASE,ONETHIRD,TWOTHIRD.
          CODES(3) ARE 1,2.
          NAMES(3) ARE CURRENT,ALLONE.
          CODES(4) ARE 1,2.
          NAMES(4) ARE RNNUM1,RNNUM2.
/WEIGHTS  BETWEEN ARE EQUAL.
/PRINT    CELLS.
          MARGINALS = ALL.
/END
DESIGN    FACTOR = REL.
          TYPE = BETWEEN,CONTRAST.
          CODE= READ.
          VALUES = 1,-1,0.
          NAME   = REL12./
DESIGN    FACTOR = REL.
          VALUES = 1,0,-1.
          NAME   = REL13./
DESIGN    FACTOR = MAINT.
          VALUES = 1,-1,0.
          NAME   = MAINT12./
DESIGN    FACTOR = MAINT.
          VALUES = 1,0,-1.
          NAME   = MAINT13./
```

AD-A167 146 A SIMULATION MODEL FOR DETERMINING THE EFFECT OF RELIABILITY AND MAINTAIN..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGI.. M L LEWELLEN 2/2

UNCLASSIFIED DEC 85 AFIT/GOR/OS/85D-13 F/G 1/3 NL




MICROCOP'                CHART

```
DESIGN      FACTOR = CREW.
            VALUES = 1,-1.
            NAME   = CREW12./
PRINT       ALL./
ANALYSIS    ESTIMATES.
            PROCEDURE IS FACTORIAL./
```

__BMDP Input Data File For Factorial Analysis__

| Case | M.C. Acft | Sorties | | Levels | | |
|---|---|---|---|---|---|---|
| 1 | 12.61 | 1329 | 1 | 1 | 1 | 1 |
| 2 | 12.82 | 1322 | 1 | 1 | 1 | 1 |
| 3 | 12.92 | 1346 | 1 | 1 | 1 | 1 |
| 4 | 14.90 | 1542 | 1 | 2 | 1 | 1 |
| 5 | 14.76 | 1579 | 1 | 2 | 1 | 1 |
| 6 | 14.79 | 1553 | 1 | 2 | 1 | 1 |
| 7 | 17.46 | 1934 | 1 | 3 | 1 | 1 |
| 8 | 17.58 | 1904 | 1 | 3 | 1 | 1 |
| 9 | 17.39 | 1903 | 1 | 3 | 1 | 1 |
| 10 | 15.88 | 1764 | 2 | 1 | 1 | 1 |
| 11 | 15.91 | 1748 | 2 | 1 | 1 | 1 |
| 12 | 15.66 | 1748 | 2 | 1 | 1 | 1 |
| 13 | 17.41 | 1903 | 2 | 2 | 1 | 1 |
| 14 | 17.43 | 1904 | 2 | 2 | 1 | 1 |
| 15 | 17.27 | 1955 | 2 | 2 | 1 | 1 |
| 16 | 19.14 | 2205 | 2 | 3 | 1 | 1 |
| 17 | 19.08 | 2176 | 2 | 3 | 1 | 1 |
| 18 | 19.12 | 2182 | 2 | 3 | 1 | 1 |
| 19 | 18.29 | 2076 | 3 | 1 | 1 | 1 |
| 20 | 18.00 | 2045 | 3 | 1 | 1 | 1 |
| 21 | 18.05 | 2087 | 3 | 1 | 1 | 1 |
| 22 | 19.08 | 2206 | 3 | 2 | 1 | 1 |
| 23 | 18.99 | 2194 | 3 | 2 | 1 | 1 |
| 24 | 19.08 | 2181 | 3 | 2 | 1 | 1 |
| 25 | 20.17 | 2394 | 3 | 3 | 1 | 1 |
| 26 | 20.06 | 2362 | 3 | 3 | 1 | 1 |
| 27 | 20.19 | 2375 | 3 | 3 | 1 | 1 |
| 28 | 13.11 | 1338 | 1 | 1 | 2 | 1 |
| 29 | 13.09 | 1330 | 1 | 1 | 2 | 1 |
| 30 | 13.32 | 1364 | 1 | 1 | 2 | 1 |
| 31 | 15.08 | 1563 | 1 | 2 | 2 | 1 |
| 32 | 15.18 | 1572 | 1 | 2 | 2 | 1 |
| 33 | 14.89 | 1571 | 1 | 2 | 2 | 1 |
| 34 | 17.54 | 1933 | 1 | 3 | 2 | 1 |
| 35 | 17.51 | 1970 | 1 | 3 | 2 | 1 |
| 36 | 17.42 | 1911 | 1 | 3 | 2 | 1 |
| 37 | 16.00 | 1768 | 2 | 1 | 2 | 1 |
| 38 | 15.99 | 1726 | 2 | 1 | 2 | 1 |
| 39 | 15.90 | 1777 | 2 | 1 | 2 | 1 |
| 40 | 17.59 | 1930 | 2 | 2 | 2 | 1 |
| 41 | 17.41 | 1925 | 2 | 2 | 2 | 1 |
| 42 | 17.49 | 1944 | 2 | 2 | 2 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 43 | 19.09 | 2215 | 2 | 3 | 2 | 1 |
| 44 | 19.00 | 2176 | 2 | 3 | 2 | 1 |
| 45 | 19.18 | 2175 | 2 | 3 | 2 | 1 |
| 46 | 18.34 | 2127 | 3 | 1 | 2 | 1 |
| 47 | 17.93 | 2079 | 3 | 1 | 2 | 1 |
| 48 | 18.04 | 2060 | 3 | 1 | 2 | 1 |
| 49 | 19.12 | 2210 | 3 | 2 | 2 | 1 |
| 50 | 19.12 | 2215 | 3 | 2 | 2 | 1 |
| 51 | 19.08 | 2171 | 3 | 2 | 2 | 1 |
| 52 | 20.18 | 2372 | 3 | 3 | 2 | 1 |
| 53 | 20.18 | 2352 | 3 | 3 | 2 | 1 |
| 54 | 20.14 | 2387 | 3 | 3 | 2 | 1 |
| 55 | 12.67 | 1347 | 1 | 1 | 1 | 2 |
| 56 | 12.84 | 1331 | 1 | 1 | 1 | 2 |
| 57 | 12.91 | 1310 | 1 | 1 | 1 | 2 |
| 58 | 14.81 | 1570 | 1 | 2 | 1 | 2 |
| 59 | 14.95 | 1536 | 1 | 2 | 1 | 2 |
| 60 | 14.65 | 1535 | 1 | 2 | 1 | 2 |
| 61 | 17.53 | 1913 | 1 | 3 | 1 | 2 |
| 62 | 17.42 | 1907 | 1 | 3 | 1 | 2 |
| 63 | 17.50 | 1896 | 1 | 3 | 1 | 2 |
| 64 | 15.98 | 1791 | 2 | 1 | 1 | 2 |
| 65 | 15.79 | 1768 | 2 | 1 | 1 | 2 |
| 66 | 16.01 | 1729 | 2 | 1 | 1 | 2 |
| 67 | 17.53 | 1949 | 2 | 2 | 1 | 2 |
| 68 | 17.31 | 1900 | 2 | 2 | 1 | 2 |
| 69 | 17.38 | 1928 | 2 | 2 | 1 | 2 |
| 70 | 19.21 | 2187 | 2 | 3 | 1 | 2 |
| 71 | 19.13 | 2193 | 2 | 3 | 1 | 2 |
| 72 | 19.06 | 2135 | 2 | 3 | 1 | 2 |
| 73 | 18.20 | 2057 | 3 | 1 | 1 | 2 |
| 74 | 18.03 | 2063 | 3 | 1 | 1 | 2 |
| 75 | 18.09 | 2061 | 3 | 1 | 1 | 2 |
| 76 | 19.15 | 2220 | 3 | 2 | 1 | 2 |
| 77 | 18.86 | 2185 | 3 | 2 | 1 | 2 |
| 78 | 19.06 | 2202 | 3 | 2 | 1 | 2 |
| 79 | 20.24 | 2372 | 3 | 3 | 1 | 2 |
| 80 | 20.20 | 2331 | 3 | 3 | 1 | 2 |
| 81 | 20.21 | 2351 | 3 | 3 | 1 | 2 |
| 82 | 13.01 | 1404 | 1 | 1 | 2 | 2 |
| 83 | 13.06 | 1346 | 1 | 1 | 2 | 2 |
| 84 | 13.02 | 1345 | 1 | 1 | 2 | 2 |
| 85 | 14.98 | 1587 | 1 | 2 | 2 | 2 |
| 86 | 15.13 | 1598 | 1 | 2 | 2 | 2 |
| 87 | 14.93 | 1569 | 1 | 2 | 2 | 2 |
| 88 | 17.62 | 1943 | 1 | 3 | 2 | 2 |
| 89 | 17.48 | 1943 | 1 | 3 | 2 | 2 |
| 90 | 17.55 | 1909 | 1 | 3 | 2 | 2 |
| 91 | 16.00 | 1762 | 2 | 1 | 2 | 2 |
| 92 | 15.99 | 1747 | 2 | 1 | 2 | 2 |
| 93 | 15.98 | 1748 | 2 | 1 | 2 | 2 |
| 94 | 17.48 | 1941 | 2 | 2 | 2 | 2 |
| 95 | 17.30 | 1921 | 2 | 2 | 2 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 96 | 17.33 | 1917 | 2 | 2 | 2 | 2 |
| 97 | 19.17 | 2198 | 2 | 3 | 2 | 2 |
| 98 | 19.11 | 2168 | 2 | 3 | 2 | 2 |
| 99 | 19.12 | 2181 | 2 | 3 | 2 | 2 |
| 100 | 18.29 | 2078 | 3 | 1 | 2 | 2 |
| 101 | 18.03 | 2026 | 3 | 1 | 2 | 2 |
| 102 | 18.35 | 2040 | 3 | 1 | 2 | 2 |
| 103 | 19.13 | 2221 | 3 | 2 | 2 | 2 |
| 104 | 18.99 | 2206 | 3 | 2 | 2 | 2 |
| 105 | 18.98 | 2225 | 3 | 2 | 2 | 2 |
| 106 | 20.21 | 2369 | 3 | 3 | 2 | 2 |
| 107 | 20.12 | 2366 | 3 | 3 | 2 | 2 |
| 108 | 20.18 | 2390 | 3 | 3 | 2 | 2 |

**BMDP Execution File For Regression Analysis**

```
/PROBLEM    TITLE IS 'THESIS REGESSION FOR R AND M'.
/INPUT      VARIABLES ARE 7.
            FORMAT IS FREE.
            FILE IS 'regress.dat'.
/VARIABLE   NAMES ARE ID,MC,SORT,REL,MAINT,CREW,RNNUM,RM.
            LABEL IS ID.
            ADD=1.
/TRAN       RM = REL*MAINT.
/PRINT      MATRICES ARE CORR,COVA,RREG,RESI.
/REGRESS    DEPENDENT IS SORT.
            INDEPENDENT ARE REL,MAINT,RM.
/PLOT       YVAR ARE SORT,SORT,SORT,RESIDUAL.
            XVAR ARE REL,MAINT,PREDICTD,PREDICTD.
            STAT.
            NORMAL.
/END
```

**BMDP Input Data File For Regression Analysis**

| Case | M.C. Acft | Sorties | | Levels | | |
|---|---|---|---|---|---|---|
| 1 | 12.61 | 1329 | 1 | 0 | 1 | 1 |
| 2 | 12.82 | 1322 | 1 | 0 | 1 | 1 |
| 3 | 12.92 | 1346 | 1 | 0 | 1 | 1 |
| 4 | 14.90 | 1542 | 1 | .33 | 1 | 1 |
| 5 | 14.76 | 1579 | 1 | .33 | 1 | 1 |
| 6 | 14.79 | 1553 | 1 | .33 | 1 | 1 |
| 7 | 17.46 | 1934 | 1 | .67 | 1 | 1 |
| 8 | 17.58 | 1904 | 1 | .67 | 1 | 1 |
| 9 | 17.39 | 1903 | 1 | .67 | 1 | 1 |
| 10 | 15.88 | 1764 | 2 | 0 | 1 | 1 |
| 11 | 15.91 | 1748 | 2 | 0 | 1 | 1 |
| 12 | 15.66 | 1748 | 2 | 0 | 1 | 1 |
| 13 | 17.41 | 1903 | 2 | .33 | 1 | 1 |
| 14 | 17.43 | 1904 | 2 | .33 | 1 | 1 |
| 15 | 17.27 | 1955 | 2 | .33 | 1 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 16 | 19.14 | 2205 | 2 | .67 | 1 | 1 |
| 17 | 19.08 | 2176 | 2 | .67 | 1 | 1 |
| 18 | 19.12 | 2182 | 2 | .67 | 1 | 1 |
| 19 | 18.29 | 2076 | 4 | 0 | 1 | 1 |
| 20 | 18.00 | 2045 | 4 | 0 | 1 | 1 |
| 21 | 18.05 | 2087 | 4 | 0 | 1 | 1 |
| 22 | 19.08 | 2206 | 4 | .33 | 1 | 1 |
| 23 | 18.99 | 2194 | 4 | .33 | 1 | 1 |
| 24 | 19.08 | 2181 | 4 | .33 | 1 | 1 |
| 25 | 20.17 | 2394 | 4 | .67 | 1 | 1 |
| 26 | 20.06 | 2362 | 4 | .67 | 1 | 1 |
| 27 | 20.19 | 2375 | 4 | .67 | 1 | 1 |
| 28 | 13.11 | 1338 | 1 | 0 | 2 | 1 |
| 29 | 13.09 | 1330 | 1 | 0 | 2 | 1 |
| 30 | 13.32 | 1364 | 1 | 0 | 2 | 1 |
| 31 | 15.08 | 1563 | 1 | .33 | 2 | 1 |
| 32 | 15.18 | 1572 | 1 | .33 | 2 | 1 |
| 33 | 14.89 | 1571 | 1 | .33 | 2 | 1 |
| 34 | 17.54 | 1933 | 1 | .67 | 2 | 1 |
| 35 | 17.51 | 1970 | 1 | .67 | 2 | 1 |
| 36 | 17.42 | 1911 | 1 | .67 | 2 | 1 |
| 37 | 16.00 | 1768 | 2 | 0 | 2 | 1 |
| 38 | 15.99 | 1726 | 2 | 0 | 2 | 1 |
| 39 | 15.90 | 1777 | 2 | 0 | 2 | 1 |
| 40 | 17.59 | 1930 | 2 | .33 | 2 | 1 |
| 41 | 17.41 | 1925 | 2 | .33 | 2 | 1 |
| 42 | 17.49 | 1944 | 2 | .33 | 2 | 1 |
| 43 | 19.09 | 2215 | 2 | .67 | 2 | 1 |
| 44 | 19.00 | 2176 | 2 | .67 | 2 | 1 |
| 45 | 19.18 | 2175 | 2 | .67 | 2 | 1 |
| 46 | 18.34 | 2127 | 4 | 0 | 2 | 1 |
| 47 | 17.93 | 2079 | 4 | 0 | 2 | 1 |
| 48 | 18.04 | 2060 | 4 | 0 | 2 | 1 |
| 49 | 19.12 | 2210 | 4 | .33 | 2 | 1 |
| 50 | 19.12 | 2215 | 4 | .33 | 2 | 1 |
| 51 | 19.08 | 2171 | 4 | .33 | 2 | 1 |
| 52 | 20.18 | 2372 | 4 | .67 | 2 | 1 |
| 53 | 20.18 | 2352 | 4 | .67 | 2 | 1 |
| 54 | 20.14 | 2387 | 4 | .67 | 2 | 1 |
| 55 | 12.67 | 1347 | 1 | 0 | 1 | 2 |
| 56 | 12.84 | 1331 | 1 | 0 | 1 | 2 |
| 57 | 12.91 | 1310 | 1 | 0 | 1 | 2 |
| 58 | 14.81 | 1570 | 1 | .33 | 1 | 2 |
| 59 | 14.95 | 1536 | 1 | .33 | 1 | 2 |
| 60 | 14.65 | 1535 | 1 | .33 | 1 | 2 |
| 61 | 17.53 | 1913 | 1 | .67 | 1 | 2 |
| 62 | 17.42 | 1907 | 1 | .67 | 1 | 2 |
| 63 | 17.50 | 1896 | 1 | .67 | 1 | 2 |
| 64 | 15.98 | 1791 | 2 | 0 | 1 | 2 |
| 65 | 15.79 | 1768 | 2 | 0 | 1 | 2 |
| 66 | 16.01 | 1729 | 2 | 0 | 1 | 2 |
| 67 | 17.53 | 1949 | 2 | .33 | 1 | 2 |
| 68 | 17.31 | 1900 | 2 | .33 | 1 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 69 | 17.38 | 1928 | 2 | .33 | 1 | 2 |
| 70 | 19.21 | 2187 | 2 | .67 | 1 | 2 |
| 71 | 19.13 | 2193 | 2 | .67 | 1 | 2 |
| 72 | 19.06 | 2135 | 2 | .67 | 1 | 2 |
| 73 | 18.20 | 2057 | 4 | 0 | 1 | 2 |
| 74 | 18.03 | 2063 | 4 | 0 | 1 | 2 |
| 75 | 18.09 | 2061 | 4 | 0 | 1 | 2 |
| 76 | 19.15 | 2220 | 4 | .33 | 1 | 2 |
| 77 | 18.86 | 2185 | 4 | .33 | 1 | 2 |
| 78 | 19.06 | 2202 | 4 | .33 | 1 | 2 |
| 79 | 20.24 | 2372 | 4 | .67 | 1 | 2 |
| 80 | 20.20 | 2331 | 4 | .67 | 1 | 2 |
| 81 | 20.21 | 2351 | 4 | .67 | 1 | 2 |
| 82 | 13.01 | 1404 | 1 | 0 | 2 | 2 |
| 83 | 13.06 | 1346 | 1 | 0 | 2 | 2 |
| 84 | 13.02 | 1345 | 1 | 0 | 2 | 2 |
| 85 | 14.98 | 1587 | 1 | .33 | 2 | 2 |
| 86 | 15.13 | 1598 | 1 | .33 | 2 | 2 |
| 87 | 14.93 | 1569 | 1 | .33 | 2 | 2 |
| 88 | 17.62 | 1943 | 1 | .67 | 2 | 2 |
| 89 | 17.48 | 1943 | 1 | .67 | 2 | 2 |
| 90 | 17.55 | 1909 | 1 | .67 | 2 | 2 |
| 91 | 16.00 | 1762 | 2 | 0 | 2 | 2 |
| 92 | 15.99 | 1747 | 2 | 0 | 2 | 2 |
| 93 | 15.98 | 1748 | 2 | 0 | 2 | 2 |
| 94 | 17.48 | 1941 | 2 | .33 | 2 | 2 |
| 95 | 17.30 | 1921 | 2 | .33 | 2 | 2 |
| 96 | 17.33 | 1917 | 2 | .33 | 2 | 2 |
| 97 | 19.17 | 2198 | 2 | .67 | 2 | 2 |
| 98 | 19.11 | 2168 | 2 | .67 | 2 | 2 |
| 99 | 19.12 | 2181 | 2 | .67 | 2 | 2 |
| 100 | 18.29 | 2078 | 4 | 0 | 2 | 2 |
| 101 | 18.03 | 2026 | 4 | 0 | 2 | 2 |
| 102 | 18.35 | 2040 | 4 | 0 | 2 | 2 |
| 103 | 19.13 | 2221 | 4 | .33 | 2 | 2 |
| 104 | 18.99 | 2206 | 4 | .33 | 2 | 2 |
| 105 | 18.98 | 2225 | 4 | .33 | 2 | 2 |
| 106 | 20.21 | 2369 | 4 | .67 | 2 | 2 |
| 107 | 20.12 | 2366 | 4 | .67 | 2 | 2 |
| 108 | 20.18 | 2390 | 4 | .67 | 2 | 2 |

# Appendix D

## Data Files For Analysis of Effect of Variance on Lognormal Distribution For Times To Repair

This appendix contains the BMDP execution and data files for the experiment that examines the effect of the variance in the lognormal distribution used for times to repair on the average number of mission capable aircraft available and the average number of sorties flown.

### BMDP Execution File

```
/PROBLEM     TITLE IS 'VARIANCE ANALYSIS'.
/INPUT       VARIABLE ARE 5.
             FORMAT IS FREE.
             FILE IS 'var.dat'.
/VARIABLE    NAMES ARE ID,MC,SORT,VAR,RNNUM.
             LABEL IS ID.
/BETWEEN     FACTORS ARE VAR,RNNUM.
             CODES(1) ARE 10,29,50,75,90.
             NAMES(1) ARE TEN,TWNTYNIN,FIFTY,SEVFIVE,NINETY.
             CODES(2) ARE 1,2.
             NAMES(2) ARE RNNUM1,RNNUM2.
/WEIGHTS     BETWEEN ARE EQUAL.
/PRINT       CELLS.
             MARGINALS = ALL.
/END
PRINT        ALL./
ANALYSIS     ESTIMATES.
             PROCEDURE IS FACTORIAL./
```

BMDP Data File

| Case Number | Mission Capable Aircraft | Sorties | Percent Of Mean | Random Number Steam |
|---|---|---|---|---|
| 1 | 12.62 | 1325 | 10 | 1 |
| 2 | 12.73 | 1335 | 10 | 1 |
| 3 | 12.87 | 1332 | 10 | 1 |
| 4 | 12.61 | 1329 | 29 | 1 |
| 5 | 12.82 | 1322 | 29 | 1 |
| 6 | 12.92 | 1346 | 29 | 1 |
| 7 | 12.68 | 1321 | 50 | 1 |
| 8 | 12.70 | 1341 | 50 | 1 |
| 9 | 12.86 | 1327 | 50 | 1 |
| 10 | 12.55 | 1349 | 75 | 1 |
| 11 | 12.83 | 1358 | 75 | 1 |
| 12 | 12.85 | 1359 | 75 | 1 |
| 13 | 12.83 | 1349 | 90 | 1 |
| 14 | 12.50 | 1334 | 90 | 1 |
| 15 | 12.67 | 1373 | 90 | 1 |
| 16 | 12.70 | 1322 | 10 | 2 |
| 17 | 12.74 | 1317 | 10 | 2 |
| 18 | 12.53 | 1283 | 10 | 2 |
| 19 | 12.67 | 1347 | 29 | 2 |
| 20 | 12.84 | 1331 | 29 | 2 |
| 21 | 12.91 | 1310 | 29 | 2 |
| 22 | 12.83 | 1386 | 50 | 2 |
| 23 | 12.94 | 1301 | 50 | 2 |
| 24 | 12.71 | 1334 | 50 | 2 |
| 25 | 12.65 | 1322 | 75 | 2 |
| 26 | 12.61 | 1308 | 75 | 2 |
| 27 | 12.36 | 1307 | 75 | 2 |
| 28 | 12.41 | 1362 | 90 | 2 |
| 29 | 12.46 | 1337 | 90 | 2 |
| 30 | 12.26 | 1306 | 90 | 2 |

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# VITA

Captain Myron L. Lewellen was born on 25 January 1950 in Zanesville, Ohio. He enlisted in the Air Force in 1968. He received a Bachelor of Science degree in Industrial Technology from Southern Illinois University at Carbondale in December 1979. He received a commission in the USAF through OTS in May 1980. His first assignment was to the Air Force Data Automation Management Engineering Team at Gunter AFS, AL. He was Chief of the Information Systems Branch which conducted Air Force-wide manpower studies of data automation activities. He was assigned to the Air Force Institute of Technology, Wright-Patterson AFB, OH in May 1984.

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