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AN ANALYSIS OF AIRCREW RATIOS IN STRATEGIC AIRLIFT -- A SLAM SIMULATION

THESIS

Brian L. Sutter
Captain, USAF

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IN STRATEGIC AIRLIFT --
A SLAM SIMULATION

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
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Master of Science in Operations Research

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Preface

The purpose of this study was to develop a simulation model for helping Air Force decision makers to choose optimal ratios of aircrews to aircraft. The immediate need for this model is in evaluating crew ratios for MAC's new airlifter, the C-17; but the approach should be valid for any strategic airlift aircraft.

The model primarily measured four attributes: aircraft utilization rate, average monthly flying time, average work month, and average time away from home station. Second order regression equations were also derived as estimators of the first three of these measures.

Sensitivity analysis was performed on various crew ratios, target utilization rates, flying time limits, and staging policies. The results seemed plausible, but analysis should continue. The study could be of significant value to planners at HQ MAC and the Air Staff.

In performing the modeling, experimentation, and writing of this thesis, I had a great deal of help from others. I am deeply indebted to my faculty advisor, Lt Col Charles Ebeling, for his continuing patience and assistance. His high standards and insistence on an operationally useful model has set an ideal for future studies. I also wish to thank Capt David Tate at Studies and Analysis and Maj Wayne Stanberry and Maj Glen Moses at HQ MAC for assistance.
throughout the project. Finally, I wish to thank my wife, Linda, and daughters for their understanding and concern during the entire eighteen months at AFIT.

Brian L. Sutter
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Abstract

This investigation examined the C-17's mission capability in terms of each aircraft's utilization and that utilization's effect on the aircrew. Specifically, average monthly flying times and average work months, as well as aircraft utilization, were found to be affected by changes in flying time limits, staging policies, target utilization rates, the number of crews, and the launch reliabilities.

The analysis was accomplished through a SLAM simulation of a portion of the MAC airlift system. A single homestation and two homestations were modeled; however, only the single homestation model was analyzed. The output of the simulation was regressed to yield an estimating equation for achieved utilization, average monthly flying time, and average work month for both a NATO and a SWA scenario.

Parameters varied in the sensitivity analysis were crew ratios, target utilization, monthly and quarterly flying limits, and staging policies. Results pointed toward 4.8 crews per C-17 without considering the cost tradeoffs. Staging one crew at an enroute base for every forty-five planned mission transits seemed to be optimal. The results also showed a significant benefit in the sustained phase when the 30/90 day limits were raised to 150/450 hours.
I. Introduction

General Issue

The Air Force doctrine states that the United States Air Force "must be able to surge and expand to any part of the globe within hours" (8:5). In order to accomplish this mission, Military Airlift Command (MAC) plays a vital role -- that of transporting the troops and equipment. If this mission can be accomplished with one less crew per aircraft, MAC can save approximately $1.526 billion (17). This, in fact, was the justification in the 1985 budget process for funding a 4.0 crew ratio for the new C-17 as opposed to the proposed 5.0.

HQ MAC and Air Force Studies and Analysis need a model for determining mission capability given the number of authorized crews and the impact of changing that number. They need a model that is capable of answering such "What if?" questions as: What is the impact on aircraft utilization if monthly and quarterly flying time limits are raised?

Objectives

The purpose of this research is twofold: 1) to provide a prediction equation that will give decision makers a quick answer as to the utilization rates of their aircraft that can be expected given certain system characteristics, and 2) to provide a model that can show, in a dynamic manner,
results when parameters are varied and is flexible enough to be applied to various aircraft and/or scenarios.

Air Staff and HQ MAC planners do not currently have an adequate, portable (capable of being used at more than a single location) methodology for assessing mission capability. This study will address the capability of MAC to accomplish its mission given a specific scenario and associated aircrew, aircraft, and system characteristics.

In order to make this determination, the following subsidiary questions must be answered:

1. How does an aircraft flow through the airlift system?
2. How does an aircrew flow through the airlift system?
3. What input parameters need to be considered in determining aircrew ratios?

**Scope and Limitations**

This study will address MAC's intertheater (between theater) airlift. The specific aircraft referenced will be the C-17, although it could be any aircraft currently in the Air Force inventory or a future acquisition, assuming its characteristics are known.

MAC plans for two different types of contingencies, surge and sustained, each lasting forty-five days. Typically, sustained operation has driven the crew ratios because of the high utilization rates, maintenance "catch up" from surge, and tired aircrews. Recently, concern has also been increasing over peacetime capability and transition into
surge. This study will model forty-five days of both surge and sustained as well as forty-five days of peacetime operation.

To maintain a manageable model, only major factories will be addressed. Air refueling will not be addressed to reduce scenario complexity and because SAC support is uncertain at this time. Secondly, degradation due to chemical warfare will not be addressed. Third, local, test, and ferry flights will not be included for simplicity and also because they did not affect results of a previous study (11:44). Finally, integral crews will be maintained to avoid a complex scheduling algorithm on the front end of the model. Integral crews and additional assumptions associated with the input data will be discussed in Chapter II.

**Historical Background**

Making credible minimum cost estimates of the productivity of the airlift force demands having the minimum number of aircrews per aircraft (aircrew ratio) that still allows the mission to be accomplished.

The primary reason for minimizing aircrew requirements is money. A Government Accounting Office report to Congress illustrates this fact:

A reduction of the aircrew ratio of 3.25:1 to 3:1 crews per aircraft for the C-5, and 4:1 to 3:1 aboard the C-141 would trim AF funding requirements by as much as $105 million for the airlift forces if only active duty crews were cut and $66 million if only reserve personnel were cut. (3:4)
Aircrew ratios are used not only in the budgeting process, but also in evaluating wartime requirements, squadron Manning, crew welfare, tolerable workloads, and mission effectiveness.

An Air Force-wide conference was held at the Pentagon 18-20 March 1985 to discuss the uses of aircrew ratios, the multitudes of approaches for determining these ratios, and command responsibilities. The conference concluded that the aircrew process is a MAJCOM responsibility. They recommended a detailed analysis of both wartime and peacetime mission taskings as a start. Then, with whatever methodology is appropriate, the commands should justify the aircrew ratios, new or revised, in a Program Decision Package. Once approved, if the validated ratio is to satisfy a wartime need, the data is incorporated into the Wartime Requirements Model which studies a total force engagement. The funded ratios are then used to update peacetime rated requirements, Manning levels, and budgets. They are published in AFR 173-13, US Air Force Cost and Planning Factors (4).

In 1967, General Estes, Commander Military Airlift Command, motivated MAC to formally study its aircrew Manning for the first time when he stated that he did not want the future C-5’s capability to be limited by aircrews (10). It was then necessary to determine the minimum crew force required to maximize the C-5’s productivity. Many studies have been completed since that time.
Lockheed Corporation offered to accomplish this study for the yet unreceived C-5 at a cost of 2.5 to 6.5 million dollars. Opting for a cheaper alternative, a joint MAC / System Program Office study was begun in April 1967. The School of Aerospace Medicine (USAFSAM) became consultants on the human factors aspects in May and ultimately were given the entire project in September (10). Among their goals was to optimize the crew manning ratio, crew composition, and crew management.

The first simulation model was completed in 1969 and modified in 1974 to include isochronal (calendar based) maintenance, multiple routes, and 1973 Yom-Kippur War data.

In 1979, The General Accounting Office (GAO) had numerous criticisms. Among those were surging longer than required, unduly restricting flying hours, ignoring attrition, assuming staff duties during wartime, and not modeling transition between phases. The accusation was that "unrealistic information was fed into the model" (3). Many improvements have been incorporated since that time, but a few deficiencies still exist: transition between peace and surge and between surge and sustained has not been modeled; alert crews have not been utilized; and enroute maintenance has not been modeled. In addition, since the USAFSAM model has been revised so many times, the documentation is incomplete in some cases and voluminous in others. In fact, in June 1985, Studies and Analysis was unsuccessful in attempts to
fully understand and use the USAFSAM model in-house at the Pentagon (24).

Other studies have been completed. The "TAC Flier" model (TAC's counterpart in crew ratio determination) is under revision at this time. However, because of the divergence of missions between TAC and MAC, it is unusable. For instance, in TAC all sorties return to the launching base, and in MAC the aircraft may not return for two to three weeks. The obvious place to look for a workable model is the commercial airlines whose missions are somewhat akin to MAC's. Unfortunately, the airlines contacted were reluctant to divulge proprietary information.

Analytic studies have been accomplished. Robert L. Stowell published an analytic method in 1980 that depends heavily on simulation output (23). The Center for Cybernetic Studies at the University of Texas attacked the mission planning and scheduling problems. Their algorithm starts with a solution to a linear programming problem of scheduling aircraft and then uses Bender's decomposition technique for the assignment of crews to the Flight legs (1:7,13). They also showed the relationship between minimizing total completion time and its dual, a transshipment problem, that can be solved as a network (1:9). In 1966, a MAC crew ratio (MACRO) study group was formed to determine the appropriate aircrew ratios for MAC airlift. The end result was a set of regression equations with two
independent variables each depending on the known quantities. The equations are still in use today for aircrew activity planning (13:44). Another result of this study group was Eq (1) for a quick guess crew ratio. It is still in use at HQ MAC plans.

\[
CR = \frac{(45 \text{ days} \times \text{surge PUR}) + (45 \text{ days} \times \text{sustained PUR})}{(\text{avg. 90 day flying time}) \times (\text{percent available})} \quad (1)
\]

The results of the Cybernetic study were accurate for small problems, and the MACRO equation gives a lower bound on the crew ratio. However, practical airlift problems have given rise to a "mixed integer programming problem with about 32000 constraints, 35000 linear variables (including logicals) and 10000 zero-one variables" (1:6). Because of the dynamic nature of the airlift system and the extremely large dimensions of an analytic model, simulation will be the general technique applied in this study.

Overview

The remainder of this thesis consists of four chapters. Chapter II describes the simulation model, its input data, and inherent assumptions. Chapter III contains the methodology. The experimental design, major factors, factor screening, measures of effectiveness, scenarios, and verification/validation are discussed. Chapter IV describes the results. Included are the statistical results of Analysis of Variance, regression results, and sensitivity analysis.
The final chapter, Chapter V, discusses the conclusions reached during the course of this research and recommendations for future analysis.
II. Model

The purpose of this chapter is to explain how aircraft and aircrews are modeled as they flow through the airlift system. The first section of the chapter briefly describes the SLAM simulation language. The second section gives a narrative description of the model and describes the interaction of the FORTRAN and SLAM network sections of the model. The third section discusses the input data, its sources, and the assumptions made when applying it. The final section then describes the output of the model.

SLAM Background

Rather than presenting a detailed description of SLAM, this section provides a simplified description of the language that is necessary for understanding the development of the crew ratio model. Further detail on SLAM can be found in Pritsker (20) and Banks and Carson (2).

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

The event scheduling orientation concentrates on events and how they affect the states of the system. It uses a FORTRAN model to schedule events to occur at predetermined times.
The process-interaction approach concentrates on entities and the sequence of events and activities they undergo as they flow through the system. The processes are represented by the nodes and branches of a network.

The interaction of the FORTRAN and network models allows events to alter the flow of entities in the network and also allows entities in the network to initiate events in the FORTRAN model.

Narrative Description

The model developed in this research is a discrete-event network simulation employing both orientations (event-scheduling and process-interaction) to model a portion of the MAC airlift system. Fig. 2.1 shows the basic flow through the network as well as how the crews, missions, and aircraft are integrated.

The SLAM network consists of eight major sections: initialization, mission generation, crew rest, preflight, mission sortie, enroute stop, postmission, and scheduled maintenance. In addition, some events are more conveniently handled with FORTRAN interaction. Examples of these events include contingency phase changes from peace to surge and surge to sustained, alert crew regeneration, and mission cancellation. Appendix A shows a more detailed flow of crews and missions (entities) and aircraft (resources) through the system. Appendices B and C contain the SLAM and FORTRAN code respectively. Each subsection is described
Fig. 2.1. Model Flow
below followed by a description of the input data and inherent assumptions. The time increment in the model is hours.

**SLAM Network.**

**Initialization.** In the initialization section of the SLAM model, the user defines:

1. Staging policy
2. 30/90 day flying time limits
3. Launch reliabilities
4. Percent of assigned crews that are mission capable and available
5. Ratio of crews to aircraft
6. Number of crews initially available
7. Peacetime maximum ramp time before reentering crew rest
8. Length of time within which a crew may be alerted without requiring additional crew rest
9. Number of hours after which a scheduled mission is cancelled if no crew or aircraft is available

These parameters will be described in detail later in this chapter.

Scenario data is input through an external file, "ROUTE". This file encompasses routing, scheduled flight times, scheduled ground times, whether a base is a staging location, and target utilization rates for peace, surge, and sustained operations. Appendix D shows the format for this data file.

After the scenario is established, the aircraft are created, the crews are created, and identification numbers are assigned to each crew. One crew is put in BRAVO alert status (i.e. on telephone alert and capable of launch in three hours). Incidentally, MAC's utilization of BRAVO
crews is uncertain for contingency operations. Quite possibly all crews will be on telephone alert, but using one crew here is sufficient to model the effect desired. Accrued flying time is then tested and if a crew is within twenty hours of its monthly or quarterly flying time limits, it is delayed twelve hours and placed at the end of the crew pool. If a crew has exceeded either of these two limits, it is delayed twenty-four hours. These rules do not force low time crews to be scheduled first, but it does preempt high time crews.

**Mission Generation.** Missions are generated at a rate commensurate with the target utilization rate. For example, if the peacetime target rate is 3.5 and the expected flying time for a mission is 19.1672 hours (from the scenario), a mission would be generated every 4.381 hours as shown in Eq (2).

\[
\frac{3150 \text{ hrs.}}{\text{mo.}} \div \frac{19.1672 \text{ hrs.}}{\text{msn.}} = 164.343 \text{ msns./mo.}
\]

\[
\frac{164.343 \text{ msns.}}{720 \text{ hrs.}} = \frac{1 \text{ msn.}}{X \text{ hrs.}}
\]

\[X = 4.381 \text{ hrs.}\]

These missions are assigned a mission number and are either passed to a mission pool to wait for a crew or cancelled if there are no aircraft on station or projected inbound.

**Crew Rest.** When a crew and mission are matched, the crew enters predeparture crew rest and waits for an aircraft. Predeparture crew rest is normally twenty-four
hours waiverable to twelve. Since schedulers usually have enough notice to put the crew into crew rest earlier, this model will observe only the inviolate twelve hours. The crew is allowed one hour travel time to the base once the crew, aircraft, and mission are matched together.

Preflight. Preflight (ground) time (normally 2.3 hours) is distributed as depicted in TABLE 2.2 and will be discussed later in this chapter. Probabilities of an on-time launch, delayed launch or rescheduled launch (launch reliabilities) are as specified in the initialization section of the model.

Mission Sortie. During the flight portion, the next leg is looked at to ensure duty day limits will not be broken. If the basic sixteen hour duty day would be exceeded, the crew reenters crew rest and subroutine ‘Cancel’ is initiated (the FORTRAN subroutines will be defined later). The actual flying time is distributed with a triangular distribution from one-half hour early to one hour late. This variation will account for wind changes, traffic control delays, diversions, etc. At the end of each sortie, flying time is updated and the average achieved utilization rate over that phase of the conflict is computed.

Enroute Stops. At an enroute stop, unless it is a scheduled staging location, a throughflight is accomplished taking approximately 2.3 hours, and the flying phase is entered again. If the mission is at a staging location,
duty day and interarrival statistics are compiled and the mission is routed to the appropriate stage base subprogram. An identical (except for statement labels and queue numbers) subprogram exists for each enroute stop in the model. The aircraft and mission are assigned to the next available crew, and the previous crew enters crew rest and subsequently enters the available pool. If a crew exceeds its 30/90 day flying time limits, that crew is transported (deadheaded) home (after a minimum crew rest) taking approximately twenty-four hours. Enroute station preflight times and launch reliabilities are obtained in a similar manner as those at home station.

**Postmission.** If the next station is the home base, statistics are collected on mission lengths, time away from station, average work month, and average monthly flying hours. Unscheduled maintenance is performed (normally distributed with a mean of six hours) and if scheduled maintenance is not required, the aircraft is freed for the next mission.

**Scheduled Maintenance.** Scheduled maintenance for the C-17 will include two days down every sixty days for a homestation check, ten days down every eighteen months for refurbishment, and thirty days down every thirty-six months for an Analytic Condition Inspection (A.C.I.) (21:3). MAC has stated that A.C.I. and refurbishment will not be accomplished during surge.
The aircraft are removed for scheduled maintenance only at home station at the completion of a mission. The frequency at which an aircraft is removed is dependent on the number of aircraft:

Homestation: 60 days x 24 hrs/NACFT
Refurbishment: 547.92 hrs (18 mos) x 24 hrs/NACFT
A.C.I.: 1095.84 hrs (36 mos) x 24 hrs/NACFT

FORTRAN Events.

Bravo. Anytime a mission is being rescheduled at home station, a check is made to see if a BRAVO crew is available. If so, the new crew is matched with the mission and 'Upbrav' is called to regenerate the alert crew.

Cancel. Every hour the mission pool is checked. If a mission has been scheduled for more than twelve hours (specified by user) and is still lacking a crew or aircraft, that mission is removed from the pool and cancelled.

Midup. Every twenty-four hours, the index is incremented for accumulating flying time. Since the model is concerned with quarterly flying time, the index resets to one after ninety-one. Additionally, if no flying time is flown in a particular day, the previous day's total is carried forward.

Mission. When a mission is generated, it is assigned a mission number based on its frequency of usage during the particular phase of conflict.
Next. 'Next' determines a new sortie's destination, scheduled air time, scheduled ground time, and whether the next stop is a staging location.

Stagecr. At the beginning of each phase (peace, surge, and sustained), stage crews are either positioned to or removed from staging locations. These crews are used to pick up an aircraft and mission when they transit that base allowing the previous crew to enter crew rest. The total number at each base is based on the number of missions projected to transit that location in a month. It is equal to:

\[ \sum \left( \text{Route freq.} \times \frac{\text{hrs per mo}}{\text{man exp. fly time}} \div \text{stage factor} \right) \]  

Once again, MAC does not have a definite staging "policy" (17). This technique (based on mission transits) was used in the USAFSAM model and appears adequate.

Surge. As surge is entered, missions are generated at a higher rate and the remainder of the reserve complement is added. MAC assumes that a full reserve complement (crew ratio equal to that of active duty) will be available during surge and sustained operations whereas only half is available during peacetime. (24) In addition, scheduled maintenance is cancelled and crew work rules are changed. Specifically, maximum ramp times and alert windows are extended to twelve hours, and post mission crew rest is reduced to twelve hours.
Sustain. After forty-five days of surge, normal work rules and scheduled maintenance are resumed. Mission frequency is also updated based on the utilization rates desired for the next forty-five days.

Upbray. Every forty-eight hours, or when a BRAVO crew is utilized, a new BRAVO crew must be generated. If no crews are available, the next available crew assumes the duty after twelve hours of crew rest.

Upolim. At the end of each duty day, monthly and quarterly flying times are updated.

Warmup. The simulation is assumed to reach steady-state after 600 hours. At that time, flying time, duty time, and time away from station are reinitiated to zero to force the statistics to apply only to the current phase of conflict. Warmup is discussed further in Chapter III.

Window. Every hour, all crew pools (at home and enroute) are checked for the length of time they have been legal for alert. If this user specified limit is exceeded, the crew reenters crew rest and the mission goes to the next available crew.

Input Data and Assumptions

Previous models of this type have become so complicated that they are virtually unintelligible. To help reduce the complexity of this model, many assumptions have been made at the outset. Factors shown previously to be of little importance are omitted or aggregated. Historical C-141
experience was used with adjustments for a C-17 contingency environment. Note, however, that the computer code can be modified if future analysis suggests revision. In other words, initiating the model with different input values is easy in the initiation section of the SLAM portion, whereas a change in logic would require computer code revision.

A major assumption has to do with diversions. All missions will start and terminate at their home bases. Diversions and their subsequent rescheduling are difficult to plan for and model accurately. Their effect overall (except possibly some inefficiency) should average out as the cargo has the same ultimate destination.

Another parameter, attrition, will not be modeled. Traditionally, it has not been modeled in MAC studies because it is assumed that it will only affect Backup Inventory Aircraft (BIA) and not impact the Primary Assigned Aircraft (PAA). In addition, losing a PAA aircraft improves the crew ratio unless replaced with a BIA. The system would then have more aircrews per aircraft to accomplish the same mission. Thus, the assumption is a conservative one.

Augmented crews (additional crewmembers added to a crew for air refueling or to lengthen the crew duty day) will not be considered. This is necessary in order to maintain an integral crew as an entity. Integral crews are not used in MAC, but treating them that way allows for easier
bookkeeping and a way to aggregate many schedule related parameters such as illnesses and emergency leave (incorporated in percent of crews available). This assumption should have little effect as augmented crews put an additional resource requirement on schedulers, and this extra burden would be offset with the added scheduling flexibility of non-integral crews. It is also a reasonable assumption since crews are generally not split up once they leave homestation, and quite often crews are rescheduled together during heavy flying activity.

In this model, peacetime is treated the same as wartime in many respects. MACR 28-2 states that no formal training will be conducted during contingencies (7:12), and ordinary leave will be suspended at least through the third month of a general war (7:33). Obviously, during peacetime these two factors play a role but the benefits gained by adding the scheduling algorithm alluded to early in this chapter are not worth the costs of the additional run time. Also, thus far at the Air Staff, peacetime capability is not as important as the transition from peacetime to surge. The important thing is that the drivers of MAC's capability (surge and sustained) are not affected by the peacetime simplification.

HQ MAC and MAC Numbered Air Forces have waiver authority over many aircrew restrictions such as length of crew rest, flying time limits, duty day limits, etc. (6:4-1).
This model will be capable of addressing these waivers, but the only ones that will specifically be addressed in the analyses are the 30 and 90 day flying time limits.

Engine running on/offloads (ERO's) will not be considered directly. Their reduced ground times would definitely impact the model output, but a definite MAC policy does not exist for their utilization. Scheduled ground time will be varied in the model which will measure the effect of the reduced ground time.

All missions are assumed to have the same priority. In peacetime, this is definitely not the case. For instance, nuclear airlift missions and exercise missions have priority over static displays. But during wartime, it is realistic to assume approximately equal priority for all missions.

Input data carries with it many of these assumptions. It falls into two categories, crew related and system related. Some are stochastic, and others are set by policy. TABLES 2.1 and 2.2 below summarize the data and its origin (excluding the experimental factors which will be covered in detail in the next chapter). Lack of a source indicates that the value is based on personal experience.

Output

Appendix E contains excerpts of the output generated by this simulation. Four measures of effectiveness will be discussed in the next chapter: achieved aircraft utilization, average work month, average monthly flying hours, and

2-13
### TABLE 2.1

Crew Related Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alert Window</td>
<td>Peace: 6 hrs.</td>
<td>MACR 55-1</td>
</tr>
<tr>
<td></td>
<td>Surge &amp; sustained: 12 hrs.</td>
<td></td>
</tr>
<tr>
<td>Predeparture Rest</td>
<td>12 hrs. inviolate</td>
<td>MACR 55-141</td>
</tr>
<tr>
<td>Enroute Rest</td>
<td>UNFRM(13,14) 12 hrs. min.--------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ 1 hr. tvl + post msn duties</td>
<td></td>
</tr>
<tr>
<td>Post mission Rest</td>
<td>12 hrs. if gone &lt; 36</td>
<td>MACR 55-141</td>
</tr>
<tr>
<td></td>
<td>Time gone ≥ 3 &lt; 72</td>
<td></td>
</tr>
<tr>
<td>Crew Duty Day</td>
<td>16 hrs.</td>
<td>MACR 55-141</td>
</tr>
<tr>
<td>Max Ramp (before crew rest)</td>
<td>Peace: 6 hrs. (4 by reg. MACR 55-1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>+ 2 ground time</td>
<td></td>
</tr>
<tr>
<td>Deadhead Time (back home)</td>
<td>RNORM(24,3)</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 2.2

System Related Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sched. Maintenance</td>
<td>H.S.C.: RNORM(48,1)</td>
<td>C-17 Ute Rate</td>
</tr>
<tr>
<td></td>
<td>Refurb: RNORM(240,5)</td>
<td>Staff Study</td>
</tr>
<tr>
<td></td>
<td>A.C.I.: RNORM(720,10)</td>
<td></td>
</tr>
<tr>
<td>Max. Resched. Delay</td>
<td>12 hrs.</td>
<td>USAF/SAGM</td>
</tr>
<tr>
<td>Ground Time (on-time)</td>
<td>UNFRM(2.0,2.3)</td>
<td>HQMAC/LG</td>
</tr>
<tr>
<td>Ground Time (delay)</td>
<td>UNFRM(2.3,Max ramp)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(29 mos C-141)</td>
<td></td>
</tr>
<tr>
<td>Ground Time (2nd crew)</td>
<td>EXPON(3.3) incl. travel</td>
<td></td>
</tr>
<tr>
<td>Enroute Gnd (on-time)</td>
<td>UNFRM(Sched-.5,Sched+.2)</td>
<td></td>
</tr>
<tr>
<td>Enroute Gnd (delay)</td>
<td>UNFRM(Sched+.2,Max ramp)</td>
<td></td>
</tr>
<tr>
<td>Ground Time (resched)</td>
<td>TRIAG(Max ramp-2,Max. ramp)</td>
<td></td>
</tr>
<tr>
<td>MX After Cancel</td>
<td>UNFRM(3,12)</td>
<td></td>
</tr>
<tr>
<td>Number Aircraft</td>
<td>30</td>
<td>USAF/SA</td>
</tr>
</tbody>
</table>

2-14
time away from station. In table and graphical format, these measures are compiled every five days for the peacetime, surge, and sustained phases. This makes trend analysis very easy.

Besides the primary MOE’s, statistics are gathered on the number of crews at home station, number of mission capable aircraft, duty days, mission lengths, overall flying times, cancellations, and enroute station interarrival times. In addition, statistics are generated for every queue (file), activity, and type of resource in the model.

Not all of these statistics are used in this analysis, but the advantage of having them all printed out is their availability for any “after the fact” analysis that may be requested by the users. They also serve a valuable purpose in model validation (discussed in Chapter III).
III. Methodology

This chapter discusses the tactics and strategy followed in running the simulation model. The objective is to answer the last of the research questions: What input parameters need to be considered in determining aircrew ratios? In answering this question the model validity will be established as well as its best use. Included in the chapter is a discussion of the warmup period, the experimental factors, the primary measures of effectiveness, model validation/verification, and the experimental design.

Warmup and Phase Transition

Pilot simulation runs indicated that it took approximately six hundred hours for the aircrew distribution, utilization rates, etc. to stabilize. Therefore, a warmup period of six hundred hours is added to the front end of the simulation to reach steady state.

Surge and sustained operations never reach steady state, which is typical of short real world conflicts. This transition period is a very complex issue.

The inherent variables pose questions such as: does warning time permit gradual buildup or require a prompt response; are we in a normal peacetime operation, standing down in preparation, or operating at a higher than normal level; are reserves mobilized at once or only after the situation worsens, and how many days does it take to make the decision to mobilize? (Response to GOA) (17)

The model developed in this research balances these issues. Stage crews are positioned instantaneously simulating
strategic warning and time to build up. Reserves are mobilized at the beginning of surge; and at the same time, activity rate is increased.

**Experimental Factors**

Anyone with knowledge of MAC's worldwide airlift system could list hundreds of factors that could influence the number of crews required to accomplish the mission. Reducing this list of factors to the most significant ones results in a simpler model. A simpler model is less expensive and allows for a more thorough analysis of the most significant factors. It requires fewer inputs, is easier to document and interpret, and facilitates transfer from one computer to another or incorporation into a larger system.

Based primarily on personal experience, eight factors are investigated in the experimental design. Other factors in the model are assumed either to be less subject to change or are such that changes in them would not significantly alter the final results. The eight factors are discussed below and summarized in TABLE 3.1.

a) **Staging Policy.** Staging policy is based upon the number of staging transits of a base. A MAC policy does not exist for staging its aircrews; however the USAFSAM study indicated that staging policy was a significant factor with the optimal near 45 (i.e., stage a crew for every 45 transits in a month).
TABLE 3.1
Experimental Factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Staging Policy</td>
<td>30 to 60</td>
</tr>
<tr>
<td>b) 30/90 Day Fly Limits</td>
<td>125/330 to 150/450</td>
</tr>
<tr>
<td>c) Target Util. Rates (peace/surge/sustained)</td>
<td>3.5/15.1/13.4 to 4.5/16.1/14.4</td>
</tr>
<tr>
<td>d) Percent of Crews Available</td>
<td>.80 to .90</td>
</tr>
<tr>
<td>e) Crew Ratio</td>
<td>4.0 to 5.0</td>
</tr>
<tr>
<td>f) Launch Reliability (on-time/delay/reschedule)</td>
<td>.948/.044/.008 to .955/.044/.001</td>
</tr>
<tr>
<td>g) Ground Time</td>
<td>2.1 to 2.3</td>
</tr>
<tr>
<td>h) Scenario</td>
<td>NATO to S.W. Asia</td>
</tr>
</tbody>
</table>

b) **Monthly and Quarterly Flying Time Limits.** During periods of heavy flying, the monthly and quarterly flying time limits are often scheduling limitations. USAF/SA is presently studying a proposed change to AFR 60-1, changing the present limits of 125/330 to 150/450 hours per month and quarter respectively (24).

c) **Target Aircraft Utilization Rates.** L.K. McSemann, II, Acting Assistant Secretary of the Air Force for Research, Development, and Logistics, has directed the Air Force to use the design utilization rates of 13.9 hours per day sustained and 15.6 hours per day surge for all systems comparisons (21:2). This study will vary these numbers by 0.5 hours on either side. The 4.0 peacetime rate was suggested by Studies and Analysis (24).
d) **Percent of Crews Available.** HQ MAC uses a .90 crew mission capable rate (per manpower directives) for most studies (22). Considering essential wartime additional duties and crew management inefficiencies, this value will be ranged between .80 and .90. It will take into account crewmembers in pipeline training, sick, on emergency leave, or committed to other duties.

e) **Crew Ratio.** The ratio of assigned crews to each aircraft will range from 4.0 to 5.0. 4.0 is the current ratio for C-141 crews. 5.0 is the proposed C-17 ratio needed to fill our airlift shortfall. Realistically, the required ratio will fall somewhere in-between.

f) **Launch Reliability.** Analyzing two years of C-141 data gives an average on-time (0.2 hrs. before scheduled to 0.3 hrs. after) departure reliability of 0.948 at home and 0.955 enroute, with the probabilities of having to be rescheduled equal to 0.008 and 0.001 respectively (12). These figures include local training flights which this model ignores. Also, even though maintenance reliability for the C-17 should be greater, supply, refueling, passenger processing, etc. will hold the rates down. It should be noted that a pilot run showed significance in this small range.

g) **Ground Time.** Scheduled ground time for C-141's and C-17's is 2.3 hours. Frequently, this time can be shortened in high threat areas with engine running on/offloads, etc. This screening will consider an average between 2.1 and 2.3.
h) **Scenarios.** Scenarios were suggested by USAF/SAGM. Pilot runs of multiple home base scenarios do not warrant using the expanded model for analysis. For the user's interest, Appendices F and G contain a workable multiple home base model. Asterisks indicate differences from the single base model. The screening will use two scenarios, one S.W. Asia and one NATO, each with a single home base (See Appendix H).

**Measures of Effectiveness**

Since the ratio of crews to aircraft is an input to the simulation, it would be nice to have the output portray a crew related statistic, a mission related statistic, and an aircraft related statistic. Achieved utilization rates (AUR) of aircraft, average flying hours per month, and mission cancellations are all useful, quantifiable measures.

Target utilization rates (TUR) are inputs to the model; so instead of analyzing just AUR, it must be analyzed with respect to the programmed target rates. Utilization rates will be measured at the end of each phase and will be the average of only that phase.

Average flying hours per month will also be measured for each phase. An alternative measure here could be the work hours per month since it is a common manpower measure.

The number of missions cancelled due to no aircraft or crew, to be consistent, will also be measured at the end of each phase.
Model Verification and Validation

Credibility is of utmost importance for a model to be considered for implementation. If the model's assumptions and logic are valid and the results have been verified, this credibility is guaranteed.

Validation will be somewhat difficult since the C-17 is not yet operational and wartime scenarios are not often tested operationally. However, the trends discovered during the analysis closely resemble the results of the USAFSAM study completed earlier this summer. For example, the peacetime achieved utilization rate (steady state) was within 0.2 hours of their results. The USAFSAM model measured steady state utilization rates between 11 and 15.5 hours during the surge phase and between 11 and 14 hours during the sustained phase. For the same target rates, this study found average rates of approximately 10 and 9 hours surge and sustained respectively. The lower rates are due to measuring an overall average for the phase rather than a steady state average, sacrificing some statistical robustness. An overall average seems more appropriate as real-world mission flow change during a phase and steady state is seldom reached. The lack of disparities between the models, in a sense, validates both models. In addition, Maj Wayne Stanberry, HQ MAC/XPSR, who has extensive experience both in SLAM simulations and modeling the MAC airlift system, critically reviewed the model, its assumptions, and results for face validity.
The logic has been verified primarily through periodic flow charting, concurrent debugging during the programming, pilot runs, and a SLAM TRACE option tracing missions, crews, and aircraft through the system. Assessing the reasonableness of output also helps verify the model. Partially mission capable (PMC) rate for the C-17 is guaranteed to be at least 82.5% (21). PMC in this simulation refers to any aircraft not in a preflight status or scheduled maintenance. The mean PMC rate through surge for the 64 initial screening runs was 78.223%. If the PMC aircraft in a preflight status were added, the numbers would be very close. Finally, consistency of the output was examined both over the ranges of interest and at extreme values to stress the system and check for reasonableness.

Design

The goal in the design phase is to investigate the relationships between the independent variables (factors) and the response (simulation output), determining, if possible, which factors exert the greatest effect on the response, and the extent of interaction between or among the factors. In the screening experiments, only two levels of each factor are investigated. These levels should be "far enough apart to measure anticipated effects, but not so far as to cause nonlinearities in the functional relationship to distort or mask significant effects (15:348)". This analysis will use the extreme values of the factors listed in TABLE 3.1.
TABLE 3.2

1/4 Replication of 8 Factors (9:22)

<table>
<thead>
<tr>
<th>(1)</th>
<th>cdgh</th>
<th>abcg</th>
<th>abdh</th>
<th>bdefh</th>
<th>bcefg</th>
<th>acdefgh</th>
<th>aef</th>
</tr>
</thead>
<tbody>
<tr>
<td>abcfgh</td>
<td>abdf</td>
<td>fh</td>
<td>cdfg</td>
<td>acdeg</td>
<td>aeh</td>
<td>bde</td>
<td>bcgh</td>
</tr>
<tr>
<td>bcdeg</td>
<td>beh</td>
<td>ade</td>
<td>acegh</td>
<td>cdfgh</td>
<td>df</td>
<td>abfh</td>
<td>abcdfg</td>
</tr>
<tr>
<td>adefh</td>
<td>acefg</td>
<td>bcdefgh</td>
<td>bef</td>
<td>ab</td>
<td>abcdgh</td>
<td>cg</td>
<td>dh</td>
</tr>
<tr>
<td>efg</td>
<td>cdef</td>
<td>abcefh</td>
<td>abdefg</td>
<td>bdg</td>
<td>bch</td>
<td>acd</td>
<td>agh</td>
</tr>
<tr>
<td>abce</td>
<td>abdegh</td>
<td>eg</td>
<td>cdeh</td>
<td>acdfh</td>
<td>afg</td>
<td>bdfgh</td>
<td>bcf</td>
</tr>
<tr>
<td>bcdfh</td>
<td>bfg</td>
<td>adfgh</td>
<td>acf</td>
<td>ca</td>
<td>degh</td>
<td>abeg</td>
<td>abcdah</td>
</tr>
<tr>
<td>adg</td>
<td>ach</td>
<td>bcd</td>
<td>bgd</td>
<td>abefgh</td>
<td>abcdreh</td>
<td>ce</td>
<td>fgh</td>
</tr>
</tbody>
</table>

It is difficult to account for aliases in a Resolution III or IV (some or all two factor interactions confounded) design because interactions that can be ignored are not obvious. Initial screening, therefore, will assume three factor and higher interactions to be negligible and will use a $2^{8-2}$ or 1/4 replication of a $2^8$ factorial to analyze all main factor effects and all two way interactions. This reduces the number of simulation runs from 256 for a full factorial to 64 with the fractional and also gives 27 degrees of freedom for error. The number of runs is reasonable since each run uses 2.5 minutes of C.P.U. time. The result is a Resolution V design in which no main effect or two factor interaction is aliased with any other main effect or two factor interaction.

The design chosen for screening is shown in TABLE 3.2. Small letters indicate a particular factor is at its high level. (1) indicates all factors are at their low levels. The defining contrast is $I = \overline{ABCEG-ABDFH-CDEFGH}$. For further
explanation, refer to Montgomery (14) or any Design of Experiments text.

In the second stage, the results of the initial screening were analyzed and the best set of subsequent runs chosen. It will be shown in the next chapter that two factors are insignificant and can be removed. This makes this fractional factorial design equivalent to a $2^6$ full factorial. By adding center points and axial points to the original design, orthogonality and uniform precision (variance) can be maintained. To keep all observations independent in the initial screening, a different set of random number seeds was used for each run. Also for the screening, measures of effectiveness were only evaluated during surge.
IV. Analysis and Results

The goal of this chapter is to give decision makers a tool to use in determining aircrew ratios. Results of the initial screening experiment will be discussed. Then the subsequent runs, setup, and results of the regression analyses will be described. Finally, sensitivity analysis on the major factors will be presented.

Initial Screening Results

Analyses of variance were accomplished for the fractional factorial design using the BMDP2V statistical package. The data and an example input program are included as Appendix I. Analyses for three measures of effectiveness (achieved utilization rate, average work month, and average flying hours) will be discussed separately. The small number of mission cancellations eliminated cancellations from consideration.

At the 95% confidence level, there are three main effects which significantly affect achieved utilization: staging policies, flying time limits, and scenarios. These and the significant two-factor interactions are shown in TABLE 4.1. Target utilization rates, crew ratios, and ground times are not significant at this level. However, since the crew ratio is as much a determinant of the number of crews as the percentage of crews available, it has
TABLE 4.1

Analysis of Variance -- AUR

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>SUM OF SQUARES</th>
<th>DEGREES OF FREEDOM</th>
<th>MEAN SQUARE</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAN</td>
<td>6230.07312</td>
<td>1</td>
<td>6230.07312</td>
<td>36550.70</td>
</tr>
<tr>
<td>STAGE</td>
<td>2.36165</td>
<td>1</td>
<td>2.36165</td>
<td>13.86*</td>
</tr>
<tr>
<td>FLYLMT</td>
<td>2.88767</td>
<td>1</td>
<td>2.88767</td>
<td>16.94*</td>
</tr>
<tr>
<td>TUR</td>
<td>.18953</td>
<td>1</td>
<td>.18953</td>
<td>1.11</td>
</tr>
<tr>
<td>PERCENT</td>
<td>.00396</td>
<td>1</td>
<td>.00396</td>
<td>.02</td>
</tr>
<tr>
<td>CR</td>
<td>.01747</td>
<td>1</td>
<td>.01747</td>
<td>.10</td>
</tr>
<tr>
<td>RELIAB</td>
<td>.00010</td>
<td>1</td>
<td>.00010</td>
<td>.00</td>
</tr>
<tr>
<td>GND</td>
<td>.08075</td>
<td>1</td>
<td>.08075</td>
<td>.47</td>
</tr>
<tr>
<td>LEGS(Scenario)</td>
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**=Significant at 99%

probably been masked by a higher level interaction and will not be omitted.
### TABLE 4.2

**Analysis of Variance -- AVGWORK**

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*Significant at 99%*
### TABLE 4.3
Analysis of Variance -- AVGFLY

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*Significant at 99%

At the same confidence level, average work month is significantly affected by five main factors: staging
policies, flying time limits, percent of crews available, crew ratios, and scenarios. These and significant interactions are indicated in TABLE 4.2. Again target utilization rates and ground times are not significant.

Factors and interactions affecting average monthly flying times are exactly the same as those affecting average work month; a somewhat intuitive result. TABLE 4.3 illustrates.

**Regression Analyses**

The fractional factorial design indicates that six potential independent variables explain achieved utilization rates, average work month, and average flying times. As target utilization rates and ground times are eliminated, all experimental combinations containing them are also eliminated. Thus, the $2^8-2$ fractional factorial becomes a $2^6$ full factorial (15:330). Since an objective of this study is to fit second order regression equations to the data, the next logical step is to perform additional runs at other levels in order to estimate the nonlinear relationships.

**Subsequent Runs.** Myers suggests thirty-six additional runs, twenty-four at center points and twelve at axial points with $\alpha = \pm 2.828$ (18:153). $\alpha$ is the multiplying factor used to set levels for the independent variables used in estimating nonlinear relationships. These are needed, not only to generate results at intermediate levels, but to
TABLE 4.4

Composite Levels

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maintain an approximately orthogonal and uniform precision design. Orthogonality will give enhanced meaning to the regression coefficients in the next section (i.e. uncorrelated estimates), and uniform precision (rotatability) ensures uniform variance in the responses. In addition, the replicated center points allow an evaluation of the appropriateness of the equations (18:153).

The factor levels for these subsequent runs are listed in TABLE 4.4. Five of the six main factors (all except scenario) have quantitative midpoints. To account for the sixth factor, twelve center points will be run for each of the two scenarios. The axial levels can be computed using Eq (4) with $\alpha = 2.828$.

$$e_i = \pm 2.828(.5)d_i + \bar{e}_1$$  \hspace{1cm} (4)

where $d_i$ = difference between high and low levels

$\bar{e}_1$ = midpoint between high and low levels

Additionally, levels for the deleted factors (ground times and target utilization rates) must be preset. Since
intuition suggests that target utilization rates should be significant, they were set at an intermediate level. Ground time was set at 2.1 hours arbitrarily.

Regression Results. The regression equations presented in this section will enable a decision maker to give initial capability estimates of the achieved utilization rates, average work months, or average monthly flying times given values for the input values.

A problem with including data from axial input values is the extreme responses (outliers) that sometimes arise, as is the case here. Referring to TABLE 4.4, staging policy and flying time limits are well outside the range of interest. For this reason, those observations will not be included in the regression analyses. Other potential outliers were investigated for accuracy but were not eliminated. The reason axial results were not eliminated completely was to maintain a higher degree of uniform precision and orthogonality. This study did conduct analyses without the axial points for comparison's sake; the results were better in some cases and worse in others (not included).

Stepwise regression analyses were performed with BMDPSR using adjusted squared multiple correlation ($R^2$). This method recognizes the tradeoff between additional degrees of freedom and the reduced variance associated with adding another variable. It is analogous to minimizing the residual mean square which enhances the predictive capability.
Separate regression analyses were performed for each scenario to study differences. Appendix J contains the axial and centerpoint data, an example input program, and output from BMDP9R. Analyses of residual plots, scatter plots, and correlation matrices did not show any marked deviations from the model assumptions. The coefficients in the equations on the following pages (TABLES 4.5-4.7) have been decoded to correspond to real data values as opposed to those coded for design matrix values of -1, 0, and 1 found in the appendix. Separate equations are shown for peace, surge, and sustained because of the changes in target utilization from one phase to another; but, they did come from the same regression model. Interactions, where one factor level is dependent on the level of a second factor, can be represented by a cross product term (i.e. multiplying the level of the first term by that of the second). TABLE 4.8 shows the allowable ranges for the parameters.

1Design matrix values are obtained from \( x_i = 2(e_i - \bar{e})/d_i \), where \( d_i \) is the difference between high and low levels and \( \bar{e} \) is the mean. The coefficients in Appendix J, \( C_i \), are in terms of \( x_i \). To translate: \( C_i \cdot x_i = C_i \cdot 2(1/d_i)(e_i - \bar{e}) + C_i \cdot (2/d_i) \bar{e} - C_i \cdot (2/d_i) \bar{e} \). 

\( C_i = C_i (2/d_i) \) and \( D_i = \bar{e} - \frac{1}{2} C_i (2/d_i) \bar{e} \).
TABLE 4.6
Regression Results -- Average Work Month

<table>
<thead>
<tr>
<th>Model</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peacetime AVGWORK (SWA)</td>
<td>258.75389 - 64725(STAGE) - 29.4086(CR) + 0.4679(FLYLMT) - 159.162(PERCENT) + 140.5539(PERCENT.RELIAB) + 0.406667(CR²) - 1.829122(TUR²)</td>
</tr>
<tr>
<td>Peacetime AVGWORK (NATO)</td>
<td>377.60666 - 674033(STAGE) - 29.1784(CR) - 151.7512(PERCENT) + 4.5602(PERCENT²) + 738177(CR²) - 1.7207(TUR²)</td>
</tr>
<tr>
<td>Surge AVGWORK (SWA)</td>
<td>347.35135 - 647055(STAGE) - 29.4086(CR) + 0.4679(FLYLMT) - 115.262(PERCENT) + 140.5539(PERCENT.RELIAB) + 0.406667(CR²) - 1.629056(TUR²)</td>
</tr>
<tr>
<td>Surge AVGWORK (NATO)</td>
<td>392.41066 - 674033(STAGE) - 29.1784(CR) - 151.7512(PERCENT) + 4.5602(PERCENT²) + 738177(CR²) - 0.822487(TUR²)</td>
</tr>
<tr>
<td>Sustained AVGWORK (SWA)</td>
<td>330.84145 - 64725(STAGE) - 29.4086(CR) + 0.4679(FLYLMT) - 159.162(PERCENT) + 140.5539(PERCENT.RELIAB) + 0.406667(CR²) - 1.978622(TUR²)</td>
</tr>
<tr>
<td>Sustained AVGWORK (NATO)</td>
<td>390.12145 - 674033(STAGE) - 29.1784(CR) - 151.7512(PERCENT) + 4.5602(PERCENT²) + 738177(CR²) - 0.622046(TUR²)</td>
</tr>
</tbody>
</table>

### Statistics

<table>
<thead>
<tr>
<th>Statistics</th>
<th>SWA</th>
<th>NATO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squared Multiple Correlation</td>
<td>.50566</td>
<td>.57776</td>
</tr>
<tr>
<td>Multiple Correlation</td>
<td>.50566</td>
<td>.57776</td>
</tr>
<tr>
<td>Adjusted Squared Multi. Corr.</td>
<td>.51573</td>
<td>.83133</td>
</tr>
<tr>
<td>Residual Mean Square</td>
<td>75.40151</td>
<td>7.205111</td>
</tr>
<tr>
<td>Standard Error of Est.</td>
<td>8.34022</td>
<td>1.950126</td>
</tr>
<tr>
<td>R-Statistic</td>
<td>78.11</td>
<td>211.79</td>
</tr>
<tr>
<td>Numerator Degrees of Freedom</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Denominator Degrees of Freedom</td>
<td>40</td>
<td>41</td>
</tr>
<tr>
<td>Significance (Tail Prob.)</td>
<td>.0000</td>
<td>.0000</td>
</tr>
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</table>

4-9
# TABLE 4.6
Regression Results — Average Fly Time

<table>
<thead>
<tr>
<th>Type of Operation</th>
<th>SWA Formula</th>
<th>NATO Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peacetime AVFLTM</td>
<td>( 161.93 + 9.25F + 2.45G + 0.30H )</td>
<td>( 179.05 + 7.25F + 1.75G )</td>
</tr>
<tr>
<td>Surge AVFLTM</td>
<td>( 224.73 + 9.25F + 2.45G + 0.30H )</td>
<td>( 154.45 + 7.25F + 1.75G )</td>
</tr>
<tr>
<td>Sustained AVFLTM</td>
<td>( 234.72 + 9.25F + 2.45G + 0.30H )</td>
<td>( 150.19 + 7.25F + 1.75G )</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Statistics</th>
<th>SWA</th>
<th>NATO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squared Multiple Correlation</td>
<td>0.9975</td>
<td>0.9957</td>
</tr>
<tr>
<td>Multiple Correlation</td>
<td>0.9527</td>
<td>0.9508</td>
</tr>
<tr>
<td>Adjusted Squared Multi. Corr.</td>
<td>0.9212</td>
<td>0.9204</td>
</tr>
<tr>
<td>Residual Mean Square</td>
<td>16.8901</td>
<td>1.0571</td>
</tr>
<tr>
<td>Standard Error of Est.</td>
<td>4.15726</td>
<td>1.17943</td>
</tr>
<tr>
<td>F-Statistic</td>
<td>52.34</td>
<td>445.49</td>
</tr>
<tr>
<td>Numerator Degrees of Freedom</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Denominator Degrees of Freedom</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Significance (Tail Prob.)</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

4-10
### Regression Results -- Achieved Utilization Rates

<table>
<thead>
<tr>
<th>Regression Equation</th>
<th>SWA</th>
<th>NATO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Peacetime AUR (SWA)</strong></td>
<td>$AUIR = 2.5130045 - 0.0157561 \times \text{STAGE} + 0.0347014 \times \text{PLM} + 0.449596 \times \text{TUR} + 0.007181 \times \text{PERCENT} + 0.008662 \times \text{CF}$</td>
<td>$AUIR = 1.2719897 - 0.79809 \times \text{PERCENT} - 0.005962 \times \text{CF}$</td>
</tr>
<tr>
<td><strong>Peacetime AUR (NATO)</strong></td>
<td>$AUIR = 1.6142029 - 0.79009 \times \text{PERCENT} - 0.005962 \times \text{CF}$</td>
<td>$AUIR = 2.874514 \times \text{RELIAB} - 0.078974 \times \text{TUR}$</td>
</tr>
<tr>
<td><strong>Surge AUR (SWA)</strong></td>
<td>$AUIR = 1.6142029 - 0.79009 \times \text{PERCENT} - 0.005962 \times \text{CF}$</td>
<td>$AUIR = 2.874514 \times \text{RELIAB} - 0.078974 \times \text{TUR}$</td>
</tr>
<tr>
<td><strong>Surge AUR (NATO)</strong></td>
<td>$AUIR = 1.6142029 - 0.79009 \times \text{PERCENT} - 0.005962 \times \text{CF}$</td>
<td>$AUIR = 2.874514 \times \text{RELIAB} - 0.078974 \times \text{TUR}$</td>
</tr>
<tr>
<td><strong>Sustained AUR (SWA)</strong></td>
<td>$AUIR = 1.5747584 - 0.167551 \times \text{STAGE} + 0.0347014 \times \text{PLM} + 0.449596 \times \text{TUR} + 0.007181 \times \text{PERCENT} + 0.008662 \times \text{CF}$</td>
<td>$AUIR = 1.476098 - 0.75618 \times \text{PERCENT} - 0.005962 \times \text{CF}$</td>
</tr>
<tr>
<td><strong>Sustained AUR (NATO)</strong></td>
<td>$AUIR = 1.476098 - 0.75618 \times \text{PERCENT} - 0.005962 \times \text{CF}$</td>
<td>$AUIR = 2.874514 \times \text{RELIAB} - 0.078974 \times \text{TUR}$</td>
</tr>
</tbody>
</table>

#### Statistics

<table>
<thead>
<tr>
<th>Statistics</th>
<th>SWA</th>
<th>NATO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squared Multiple Correlation</td>
<td>.99397</td>
<td>.99100</td>
</tr>
<tr>
<td>Multiple Correlation</td>
<td>.99397</td>
<td>.99100</td>
</tr>
<tr>
<td>Adjusted Squared Mult. Corr.</td>
<td>.99478</td>
<td>.99248</td>
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<tr>
<td>Residual Mean Square</td>
<td>.064302</td>
<td>.064302</td>
</tr>
<tr>
<td>Standard Error of Est.</td>
<td>.254875</td>
<td>.10357</td>
</tr>
<tr>
<td>F-Statistic</td>
<td>9.27</td>
<td>1.12</td>
</tr>
<tr>
<td>Numerator Degrees of Freedom</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Denominator Degrees of Freedom</td>
<td>34</td>
<td>41</td>
</tr>
<tr>
<td>Significance (Tail Prob.)</td>
<td>.00000</td>
<td>.00000</td>
</tr>
</tbody>
</table>

4-11
TABLE 4.8
Variable Ranges for Regressions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAGE</td>
<td>1 crew prepositioned for every ?? transits</td>
<td>30 to 60</td>
</tr>
<tr>
<td>FLYLMT</td>
<td>30/90 day fly limits</td>
<td>125 /330 to 150 /450</td>
</tr>
<tr>
<td>PERCENT</td>
<td>Percent of crews avail</td>
<td>.80 to .90</td>
</tr>
<tr>
<td>RELIAB</td>
<td>Prob. of on-time, delayed or cancelled takeoff</td>
<td>.948 / .044 / .008 to .955 / .044 / .001</td>
</tr>
<tr>
<td>TUR</td>
<td>Peace, surge, &amp; sustained target ute rates</td>
<td>3.5/15.1/13.4 to 4.5/16.1/14.4</td>
</tr>
<tr>
<td>CR</td>
<td>Crew ratio</td>
<td>4.0 to 5.0</td>
</tr>
</tbody>
</table>

* = Value to enter regression equation with.

The quadratic response functions for average work month and average flying time for the NATO scenario resulted in a $R^2 > .98$ and a standard error of the estimate (MSE$^{1/2}$) < 1.96. For the SWA scenario, $R^2$ was still over .90, but the standard error was larger (5.95 and 4.11 for average work month and flying time respectively). Thus, the predictive capability could be somewhat impaired. See TABLES 4.5 and 4.6.

$R^2$ for achieved utilization rates were lower (.54700 and .76544 for NATO and SWA scenarios respectively), but the standard error was less than .44 in both cases (See Appendix J). To further investigate the fit of these response functions, the center point replications were used to estimate pure error, thereby splitting the sums of squares into components. The results are shown in Fig. 4.1. This analysis indicates that the NATO regression is adequate and the SWA regression is not. In other words, the SWA numerator
SWA Scenario

\[ \sum (Y_i - \bar{Y})^2 = 0.68468 \]

\[ \text{df} = 12 - 1 = 11 \]

\[ \text{MSPE} = 0.04976 \quad \text{SSE} = 44(1.1911) = 8.41624 \]

\[ \text{SSE} = 8.41624 - 0.574667 = 7.841573 \quad \text{df} = 44 - 11 = 33 \]

\[ \text{MSLF} = 0.2366 \]

\[ F = \frac{\text{MSLF}}{\text{MSPE}} = 4.297846 \]

\[ F(0.05;11,33) = 2.12 \]

Reject hypothesis of good fit.

NATO Scenario

\[ \sum (Y_i - Y)^2 = 0.7825 \]

\[ \text{df} = 12 - 1 = 11 \]

\[ \text{MSPE} = 0.049243 \quad \text{SSE} = 41(1.1911) = 49.9243 \]

\[ \text{SSE} = 49.9243 - 0.167467 = 49.75687 \quad \text{df} = 41 - 11 = 30 \]

\[ \text{MSLF} = 0.046538 \]

\[ F = \frac{\text{MSLF}}{\text{MSPE}} = 0.68468 \]

\[ F(0.05;11,30) = 2.11 \]

Cannot reject hypothesis of good fit.

Fig. 4.1. Lack of Fit Analysis for AUR Response Functions

Mean square is estimating something which is in excess of \( \sigma^2 \), the experimental error variance. This could possibly be due to higher order terms that are not included or, more likely, the small number of degrees of freedom for pure error associated with only twelve center point replications.

Further analysis of the residuals for this case (Appendix J) showed three potential outliers, cases 15, 37, and 50. Upon investigation of the simulation output, ten cases...
SWA Scenario

\[ Y = 10.85667 \]
\[ \sum (Y_i - \bar{Y})^2 = .5364667 \]
\[ df = 12 - 1 = 11 \]
\[ MSFE = .0513334 \]
\[ SSE = 34(.064839) = 2.204492 \]
\[ SSLF = 2.204492 - .5364667 = 1.6680253 \]
\[ df = 34 - 11 = 23 \]
\[ MSLF = .0725228 \]
\[ F = MSLF/MSFE = 1.4870471 \]
\[ F(.05;11,23) = 2.24 \]

Cannot reject hypothesis of good fit.

Fig. 4.2. Lack of Fit -- AUR Revised

were found where achieved utilization rate in surge had peaked out earlier in the phase and were on a downward trend when measured; the difference between the peak average and overall average was significant in eight cases. Incidentally, in the NATO scenario, three cases peaked early but only by a very small amount. Deleting these cases (3, 13, 24, 28, 37, 41, 50, and 82) resulted in an adequate regression. See Fig. 4.4 for the lack of fit analysis and Appendix J for revised residual plots.

Since the equations are scenario dependent, they should only be used to approximate capability, work month, and monthly flying time. Users should keep in mind that the work month and flying time figures do not include duties or training missions at home station.
**Confidence Limits.** A confidence region is hard to visualize on surfaces such as these but limits could easily be placed on individual input combinations. Boundaries for a Working-Hotelling confidence region over all input combinations, $X_h$, are indicated in Eq (5).

$$\hat{Y}_h \pm Ws(\hat{Y}_h)$$

where $W^2 = pf(1-\alpha; p, n-p)$ (19:244)

The standard error of the predicted value, $s(\hat{Y}_h)$, is available from BMDP for combinations in the experimental design. Unfortunately, the interval obtained is only valid at that particular input combination. For example, if one were interested in an estimate of achieved utilization rate for a SWA scenario at input values matching Case 1 where all eight variables are at their high level, $s(\hat{Y}_h) = .1065$, the number of parameters ($p$) = 8, and $F(.95; 8, 34) = 2.23$. It follows that:

$$W^2 = 8(2.23)$$

$$\hat{Y}_h \pm Ws(\hat{Y}_h) = 10.9670 \pm 4.2237(.1065)$$

$$= 10.9670 \pm .4498$$

$$= (10.517, 11.4168) \text{ with 95% confidence}$$

One can readily see here that in spite of the relatively low $R^2$, the predictive capability is acceptable.
Sensitivity Analysis

Analysts at HQ MAC and Studies and Analysis are interested in the effect of changing one main factor. The coefficients of the regression equations approximate a unit change in the input parameters, assuming a high degree of orthogonality has been maintained. Most decision makers, however, would prefer a graphical analysis. This section will present graphical comparisons holding all variables constant except one. The variables varied are crew ratio, staging policy, target utilization rates, and flying time limits. The effect of these changes on achieved utilization rates, average work month, average monthly flying times, and time away from station for the NATO scenario will be shown. Appendix K shows the results of three replications for each factor. The variables held constant will take on the center point values from TABLE 4.4.

Crew Ratio Sensitivity. The crew ratio was given values 4.0, 4.2, 4.4, 4.6, 4.8, and 5.0. The impact of these changes is shown in Figs. 4.3-4.7. There seems to be no AUR benefit in increasing the crew ratio to 5.0 as it peaks at 4.8. 4.8 also results in the least amount of time away from home. Another factor in the system is apparently restraining increased benefit. There is an anomaly in the results for a crew ratio of 4.0 that is partially explainable. The crews at homestation were depleted quite early and the number of cancellations due to either no aircraft or
Fig. 4. Effect of CR(4.0, 4.2, 4.4) on AUR (NATO)
Fig. 4.4. Effect of CR (4.6, 4.8, 5.0) on AOR (NATO)
Fig. 4.5. Effect of CR on Avg Work Month (NATO)
no crews available was an order of magnitude higher than other cases. Apparently, 4.0 crews per aircraft is simply not enough to maintain the desired utilization with the associated values of the other factors. The significant drop in work month, flying time, and achieved utilization going from surge to sustained when CR = 4.0 could be a result of flying time limits.

**Staging Policy Sensitivity.** Staging policy was given values 30, 45, and 60. There is apparently no benefit in staging more crews than one every 45 transits (See Figs. 4.8 -4.10). However, staging a crew for every 30 transits rather than 45 significantly reduces aircraft utilization in the sustained phase by approximately two hours a day.
Fig. 5.3. Effect of Staging Policy on Work Month (NATO)

160 -
140 -
120 -
100 -
80 -
60 -
40 -
20 -
0 -

Peace Surge Sustain

Fig. 5.4. Effect of Staging Policy on Avg Mtf Fly Time (NATO)

100 -
80 -
60 -
40 -
20 -
0 -

Peace Surge Sustain
Target Utilization Rate Sensitivity. Peace, surge, and sustained TUR's were given values 3.5/15.1/13.4, 4.0/15.6/13.9, and 4.5/16.1/14.4. Increasing TUR beyond 4.0/15.6/13.9 reduces utilization rate, work month, and flying time in the sustained phase. This is quite possibly an indication that the sustained phase is the primary driver in restricting capability. It also indicates that the C-17 cannot be flown above the 13.9 projected utilization rate during a sustained conflict. Figs. 4.11-4.13 illustrate.
Fig. 4.12. Effect of Target Ute Rate on Work Month (NATO)

Fig. 4.13. Effect of Target Ute Rate on Avg Mo Fly Time (NATO)
**Fly Time Limit Sensitivity.** Fly time limits were evaluated at 125/330 and 150/450. Raising the limits had a positive impact in both peacetime and sustained operations whereas surge characteristics were unaffected (See Figs. 4.14-4.16). Aircraft utilization was increased by almost four hours a day in peacetime and almost three hours a day in sustained operations. This increased utilization obviously increases monthly flying time and the crew's work month; therefore, the length of conflict plays a definite role. These results indicate that the proposed increase in AFR 60-1 to 150/450 should definitely be considered.
Fig. 4.15. Effect of 30/90 Day Limits on Work Month (NATO)

Fig. 4.16. Effect of 30/90 Day Limits on Avg Mo Fly Time (NATO)
Observations and Recommendations

Observations

This study examined the C-17's mission capability in terms of each aircraft's utilization and that utilization's effect on the aircrew. Specifically, average monthly flying times and average work months, as well as aircraft utilization, were found to be affected by changes in flying time limits, aging policies, target utilization rates, the number of crews, and the launch reliabilities.

The equations in the previous chapter show the relationships between these factors and responses for various levels of these parameters. The simulation then can accurately measure the dynamic effects of those changes. The simulation also gives the capability to vary work rules, change scenarios, analyze parameter values outside the ranges of the regressions, and answer many other "What if?" questions.

The sensitivity analysis yielded the following conclusions:

1. There is no benefit in staging more than one crew for every forty-five planned mission transits. Capability is significantly reduced, however, if thirty missions are used for the basis instead of forty-five.

2. Sustained capability is degraded if target utilization rates are increased above 4.0, 15.6, and 13.9
hours per day for peacetime, surge, and sustained respectively. These surge and sustained values were directed by the SECOEF for C-17 planning.

3. Monthly and quarterly flying time limits are a major restricting factor in both peacetime and sustained operations. Surge operations are only slightly affected.

4. 4.8 crews per aircraft yield the highest payoffs in utilization and crew workloads. 4.0 crews per aircraft are not enough. In-between these values, tradeoffs must be considered between the number of crews and the associated cost.

Future Studies

The value of this study lies in future research. As it exists now, valuable insights can be gained on the factor effects; but the model was not designed to produce optimal answers.

Costs need to be included in the analysis in order to weigh the effects of crew ratio changes. To say that 4.8 crews per aircraft yields the highest utilization is one thing; but is the extra $305 million worth increasing the ratio from 4.6?

MAC does not have a staging policy for its contingencies. Major Charles Dillard, USAF/SAGM, has developed an analytic solution assuming exponential interarrival rates. This needs to be verified and expanded into a usable policy, as it is doubtful that (during a contingency) accurate
estimates of the number of mission transits or interarrival times can be made.

This simulation model could be an integral component of a decision support system. The system could mesh a multitude of attributes (cost, utilization, work month, etc.) and help decision makers to choose optimal crew ratios and optimal staging policies, not only to maximize aircraft utilization, but to maximize overall mission effectiveness.
Appendix A

Model Flow Charts

This appendix illustrates the flow of missions, crews, and aircraft through the SLAM model. It gives a pictorial representation of the interactions of the model segments.
Fig. A.1: Generation
Fig. A.2. Crew Rest & Preflight
Fig. A.4. Termination
Appendix B

SLAM Network Code

GEN.EDIT, THESIS.P/4/85, 28, 72;
LIMITS, 26, 28, 400;
TIMT, NNO (2), CREWS AT HOME, 20/9/75;
TIMT, NND (11), CREWS AT CYPR;
TIMT, NND (2), CREWS AT ESXX;
TIMT, NND (4), CREWS AT CYY;
TIMT, XX (1), MISSIONS CANCEL;
TIMT, XX (50), BURNOUT;
TIMT, XX (19), AFT PMC;
RECORD, TIME=PR, S, 120; EVERY FIVE DAYS
VAR, XX (1), A, AVE WORK MONTH;
VAR, XX (1), B, AVE FLY HRS;
VAR, XX (1), C, AVE TIME AWAY;
PRIORITY, HVF (20), 11, HVF (20), 12, HVF (20), 13, HVF (20), 14, HVF (20), 15, HVF (20), 16;
HVF (20), 17, HVF (20); GIVES PRIORITY TO A CREW THAT HAS BEEN MECH. STAGED
**************************************************************
INITIALIZATION
**************************************************************
**************************************************************
INTL, XX (1) = 0; STAGING POLICY
INTL, XX (1) = 12; 10 DAY FLYING TIME LIMIT
INTL, XX (1) = 20; 90 DAY FLYING TIME LIMIT
INTL, XX (1) = 30; 6 MONTH RELIABILITY
INTL, XX (1) = 40; DELAY RELIABILITY
INTL, XX (1) = 50; PROB OF RESCHEDULING
NOTE: XX (20) = XX (30) = XX (1) = 1
INTL, XX (1) = 20; PERCENT AVAILABLE
INTL, XX (3) = A; OPEN RATE
INSERT SCENARIO, TIMES, AND TARGET JET. RATES INTO FILE "ROUTE;"
INSERT INITIAL NUMBER OF CREWS INTO FIRST CREATE STATEMENT & ASSIGN TO XX (47)
# CREWS AVAILABLE=10, PLANET 10, CREWS=10, PERCENT AVAILABLE=100
INTL, XX (1) = 1; CREWS AVAILABLE INITIALLY
INTL, XX (1) = 2; RESCHEDULE RATE PERIOD
INTL, XX (1) = 3; RESCHEDULE ALERT WINDOW
INTL, XX (1) = 4; MISSIONS AFTER WHICH A SCHED. MISSION IS CANCELLED IF NO CREW OF AC
**************************************************************

NETWORK:

RESOURCE SCENARIO, A;
CREATE, 10, 4, AIRCRAFT

CREATE, 10, 20, CREWS
ENTRY;
ASSIGN, XX (1) = XX (30) = XX (1) = 1, ATPB (18) = XX (11), ATPB (5) = 1,
ATPB (10) = 10, ATPB (5) = ATPB (18) = ATPB (11) = ATPB (5) = ATPB (10) = 10;
ATPB (5) = 0
EXIT;
ENTRY;
ACT, ATPB (18) = 14, EQUIP, JUEE;
POSITIONS FIRST BASE CREW

9-1
A

ACT:

START: 

ATRIB(5) = 1, ATRIB(11) = 16, ATRIB(17) = 1,

ATRIB(2) = 0, ATRIB(3) = 10: INIT BASIC CREW, PRESENT BASE, STAGE,

MISSION, SOFTIE FLY TIME, NEXT BASE

ATRIB(1) = 1, ATRIB(2) = 11 - 20, SE(1), PET: APPROACHING TO LIMIT

ATRIB(2) = 1, ATRIB(12) = 20, SE(3), PET: APPROACHING FLY TIME LIMIT

ACT:

RET: EVENT(10, 1)

ACT...START;

QUEUE(10): 

ACT/11, 12;

QUEUE(10): 

BRAVO CREW REST

QUEUE(3): 

BRAVO CREW FILE

QUEUE(2), MAT1:

AWAIT MISSION

;******************************************************************************************

;CREATE MISSIONS!!!

;******************************************************************************************

CREATE: RNDF(XX(15), 1, 3), 0;

MSN: EVENT(1, 1)

ACT(10):

COUNT MISSIONS

ATRIB(2) = 10, ATRIB(3) = 0, ATRIB(4) = 1, ATRIB(5) = 1: INITILIZE TO MATCH CREW

MAT(10) = MAT(10) + 1:

MAT(10): ACFT INBOUND, ACFT AVAILABLE

ACT:

MAT(11) = 1:

CANCEL DUE TO NO ACFT

MAT:

MATCH, GUEST: GUEST, DUE / REST

QUEUE(11): ATRIB(11) = RNDF(XX(17));

AVAIL:

QUEUE(11): ATRIB(11) = RNDF(XX(17));

MAT: MISSION QUEUE

MATCH, GUEST: GUEST, DUE / REST

QUEUE(11): ATRIB(11) = RNDF(XX(17));

ACT...queue:

;******************************************************************************************

;CREW REST!!!

;******************************************************************************************

ACT:

SOON: ATRIB(1) = 0, ATRIB(11) = 0, ATRIB(17) = 0:

MISSION NUMBER, FLY TIME & TIME AWAY INIT=0

ACT/1, 12:

ATRIB(16) = RNDF(XX(17));

AWAIT(4), ACFT;

ATRIB(11) = RNDF(XX(17));

SOON:

ACT...
****CREW SHOWS AT SCHEDULED TIME********

QUES QUEUE(1),.,,MATZ;
CREW

*****PREFLIGHT*****

QUES QUEUE(6),.,.,MATZ;
MISSION

MATZ MATCH-9, QUES/ACC, QUES/ACC;

ACC ACCUM, 2, LAST;

ATTACHES MSN TO CREW, RETAINS MSN ATTRIB
ASSIGN, ATRIB(17)=0, ATRIB(6)=TNOW, ATRIB(6)=TNOW;
LEE NUMBER INIT=0
ASSIGN, XX (18)=XX (18)-1;

SOM, 1;

ACT, EXPON(3) , ATRIB (17) ., NE ., FLY;

BRAVO CREW FLYING 'ADD 1 HR TUL' ACT:22;
ASSIGN, XX (19) = (X (10) + C.
SOM, 1;

ACT, UNFORM(2) . C. C. C. C. C. C. FLY;

ON TIME

ACT, UNFORM(2) , (X(10) , D. XX(6) , FLY;

PREFLIGHT < MAX RAMP

ACT/7, TRIG (XX (19) , XX (10) , XX (10) , XX (10) , XX (6) , XX;
RAMP EXCEEDED, RESCHEDULE

-----------------------------------------------------------------------

*****MISSION SORTIE*****

-----------------------------------------------------------------------

FLY1 ASSIGN, ATRIB(17)=0;

BRAVO UTILIZED

FLY SOM, 1;

EVENT, S. I;

COMPUTE NEXT LEG & FLY TIME
SOM, 1;

ACT, 19 , TNOW+ATRIB(3) - ATRIB (6) , GT, 15, MECH;

WILL EXCEED DUTY DAY ON NEXT LEG

ACT C. . .

ASSIGN, XX (19) = ATRIB (17) - E. (X (10) = ATRIB (17) + 1.

ASSIGN, XX (21) = TRIG 19(X (19) , ATRIB (2) , XX (20) , 4);

ASSIGN, ATRIB (17) = ATRIB (17) + 4 (X (21));

ASSIGN, ATRIB (15) = ATRIB (15) - XX (21);

ASSIGN, XX (18) = XX (19) + 1;

SOM, 1;

ACT, 5, XX (21) , ATRIB (17) ., XX (22) , HOME, NEXT HOME
ACT, 5, XX (21) ;

ASSIGN, XX (18) = XX (18) + 1;

ASSIGN, XX (27) = TNOW - XX (24) , XX (27) = (X (12) - X (27);

ASSIGN, XX (28) = XX (28) (XX (21) + 14 , XX (28) = XX (28) - ATRIB (2) - XX 28);

COMPUTE ACHIEVED JET RATE

-----------------------------------------------------------------------

LOSEC PLOT STORES

-----------------------------------------------------------------------

SOM, 1;

ACT C. ATRIB(4) ., SQ, , , STAGE;

STAGE CREW

ACT;

SOM;

ASSIGN, ATRIB(2) = ATRIB(2);

ACT SQNOW = SQ, XX (21) , FLY;

SCHEDULED ONE TIME
DUTY DAY EXCEEDED - MECHANICAL STAGE

ASSIGN, ATRIB(1) = ATRIB(1), ATRIB(17) = ATRIB(17) - 1;
ACT,, STAGE;

STAGE

ASSIGN, XX(30) = XX(30) + TNOW - ATRIB(6);
ASSIGN, XX(18) = XX(18) + 1;
EVENT, 10, 1;
COLC, INT(6), DUTY DAY,, 1;
ACT, 26, ATRIB(2).EQ.10, XCLD;
ACT, ATRIB(2).EQ.11, CYR;
ACT, ATRIB(2).EQ.12, EX;
ACT, ATRIB(2).EQ.13, KR;
ACT, ATRIB(2).EQ.14, CYX;
ACT, ATRIB(2).EQ.15, ED;
ACT, ATRIB(2).EQ.16, EN;
ACT, ATRIB(2).EQ.17, KT;
CREATE, 0, 1; DUMMY TO INIT QUEUE;
ACT;

QUEUE

QUEUE(9);
ACT;
GOON, 1;
ACT, ATRIB(2).EQ.10, QUE2;
ACT, ATRIB(2).EQ.11, CY;
ACT, ATRIB(2).EQ.12, EX;
ACT, ATRIB(2).EQ.13, KR;
ACT, ATRIB(2).EQ.14, CYX;
ACT, ATRIB(2).EQ.15, ED;
ACT, ATRIB(2).EQ.16, EN;
ACT, ATRIB(2).EQ.17, KT;
ACT;
TERM;

CYR STAGE

GOON, 1;
ACT, ATRIB(11) = ATRIB(21), MEI:
ACT;
COLC, REF, INT, AT CYR, MEI;
MEI:
GOON, 1;
ACT... GJ:
ACT;
GOON, 1;
ACT CYR, XIFOR(2A, 2B, 2C, 2D, 2F, 2T, 2E, 2G, 2H), DEAD;
: CHECK TO/PD TIME & DEADHEAD HOME IF EXCEEDED
ACT;
CY
GOON;
ACT, UNFP(17, 1A, 1C):
ASSIGN, ATRIB(18) = TNOW;
ACT..3112;
Q111 QUEUE(1),...,MAT3;
Q112 QUEUE(11),...,MAT3;
MAT3 MATCH.S,3111/4X1,3111/ACI;

AXI G6ON;
ASSIGN,XX(31)=ATRIB(1),XX(32)=ATRIB(2),XX(33)=ATRIB(3),
XX(34)=ATRIB(4),XX(35)=ATRIB(9),XX(36)=ATRIB(13),
XX(37)=ATRIB(19);
ACI ACCUM,2.2,LAST;
ASSIGN,ATRIB(1)=XX(31),ATRIB(2)=XX(32),ATRIB(3)=XX(33),
ATRIB(4)=XX(34),ATRIB(9)=XX(35),ATRIB(13)=XX(36),
ATRIB(19)=XX(37),ATRIB(20)=0;
ACT...,CONT;

EGXX STAGE

EGXX G6ON.1;
ACT.,ATRIB(1)=XG,ATRIB(2)=ME12;
ACT;
COLCT,BET,INTER AT EGXX..1;

WE12 G6ON.2;
ACT..,0121;
ACT;
G6ON.1;
ACT/21,ANDR/M25.,3..3,ATRIB(11).GE.X2(.3).OR.ATRIB(12).GE.XX(3).DEAD;
ACT;
EG G6ON;
ACT..UNFEM(13..14..5);
ASSIGN,ATRIB(1)=XG;
ACT...,Q122;
G111 QUEUE(32),...,MAT4: ACFT
G112 QUEUE(12),...,MAT4: CREWS AVAIL
MAT4 MATCH.S.3111/4X1,3112/AC2;

AX2 G6ON;
ASSIGN,XX(31)=ATRIB(1),XX(32)=ATRIB(2),XX(33)=ATRIB(3),
XX(34)=ATRIB(4),XX(35)=ATRIB(9),XX(36)=ATRIB(13),
XX(37)=ATRIB(19);
ACI ACCUM,2.2,LAST;
ASSIGN,ATRIB(1)=XX(31),ATRIB(2)=XX(32),ATRIB(3)=XX(33),
ATRIB(4)=XX(34),ATRIB(9)=XX(35),ATRIB(13)=XX(36),
ATRIB(19)=XX(37),ATRIB(20)=0;
ACT...,CONT;

KPYX STAGE

KPYX G6ON.1;
ACT.,ATRIB(1)=XG,ATRIB(2)=ME12;
ACT;
COLCT,BET,INTER AT KPYX..1;

WE11 G6ON.2;
ACT..,0111;
ACT;
G6ON.:
ACT;
KF
600N;
ACT,UNFRM(13,14,3);
ASSIGN,ATRIB(16)=TNOW;
ACT,,Q132;
Q131 QUEUE(23),,.,MAT5, ACFT
Q132 QUEUE(13),,.,MAT5; CREWS AVAIL W/2
MAT5 MATCH,S,Q131/Q132,1312/Q3;
AX3 600N;
ASSIGN.XX(30)=ATRIB(1),XX(32)=ATRIB(2),XX(33)=ATRIB(3),
XX(34)=ATRIB(4),XX(35)=ATRIB(9),XX(36)=ATRIB(13),
XX(37)=ATRIB(14);
ACT
ACCUM,,0,LAST;
ASSIGN,ATRIB(11)=XX(31),ATRIB(2)=XX(32),ATRIB(3)=XX(33),
ATRIB(4)=XX(34),ATRIB(9)=XX(35),ATRIB(13)=XX(36),
ATRIB(14)=XX(37),ATRIB(20)=0;
ACT,,CONT;

CYXX 500N,1;
ACT,,ATRIB(1).EQ.ATRIB(2),ME(4);
ACT;
COLCT.BET,INTER AT CYXX,,1;
ME14 500N,2;
ACT,,Q141;
4CT;
600N,1;
ACT;
CYXX 500N;
ACT,UNFRM(13,14,3);
ASSIGN,ATRIB(16)=TNOW;
ACT,,Q142;
Q141 QUEUE(24),,.,MAT5, ACFT
Q142 QUEUE(14),,.,MAT5; CREWS AVAIL
MAT5 MATCH,,Q141/Q142,142/Q4;
AX4 600N;
ASSIGN.XX(31)=ATRIB(1),XX(32)=ATRIB(2),XX(33)=ATRIB(3),
XX(34)=ATRIB(4),XX(35)=ATRIB(9),XX(36)=ATRIB(13),
XX(37)=ATRIB(14);
AC4 ACCUM,,0,LAST;
ASSIGN,ATRIB(11)=XX(31),ATRIB(2)=XX(32),ATRIB(3)=XX(33),
ATRIB(4)=XX(34),ATRIB(9)=XX(35),ATRIB(13)=XX(36),
ATRIB(14)=XX(37),ATRIB(20)=0;
ACT,,CONT;

EDXX 500N,1;
ACT,,ATRIB(1).EQ.ATRIB(2),ME(5);
ACT;
COLCT, BET, INTER AT ENIX,,1;

ME15  GOOD, 2;  
      ACT,,Q151;  
      ACT;  
      GOOD, 1;  
      ACT/21, ATRIB(11).GE.XX(2).OR.ATRIB(12).GE.XX(3), DEAD;  
      ACT;  
      ED  GOOD;  
      ACT, UNFRM(13,.14,.3);  
      ASSIGN, ATRIB(16)=TNOW;  
      ACT,,Q152;  
      Q151 QUEUE(25)...., MAT7; ACFT  
      Q152 QUEUE(15)...., MATF; CREWS AVAIL

MAT7 MATCH,5, Q151, Q152/AC5;  
AXE  ASSIGN, XX(21)=ATRIB(1), XX(22)=ATRIB(2), XX(23)=ATRIB(3), XX(24)=ATRIB(4), XX(25)=ATRIB(9), XX(36)=ATRIB(13), XX(37)=ATRIB(19);  
ACE  ACCUM,2, LAST;  
      ASSIGN, ATRIB(11)=XX(21), ATRIB(1)=XX(22), ATRIB(2)=XX(23), ATRIB(4)=XX(24), ATRIB(9)=XX(25), ATRIB(13)=XX(36), ATRIB(19)=XX(37);  
      ACT,, CONT;  

ENIX  GOOD, 1;  
      ACT,,ATRIB(11).EQ.ATRIB(2), ME16;  
      ACT;  
      COLCT, BET, INTER AT ENIX,,1;  

ME16  GOOD, 2;  
      ACT,,Q161;  
      ACT;  
      GOOD, 1;  
      ACT/21, ATRIB(12), ATRIB(11).GE.XX(2).OR.ATRIB(12).GE.XX(3), DEAD;  
      ACT;  
      EN  GOOD;  
      ACT, UNFRM(13,.14,.3);  
      ASSIGN, ATRIB(16)=TNOW;  
      ACT,,Q162;  
      Q161 QUEUE(26)...., MAT8; ACFT  
      Q162 QUEUE(16)...., MAT8; CREWS AVAIL

MAT8 MATCH, 6, Q161, Q162/AC6;  
AXE  ASSIGN, XX(21)=ATRIB(1), XX(22)=ATRIB(2), XX(23)=ATRIB(3), XX(24)=ATRIB(4), XX(25)=ATRIB(9), XX(36)=ATRIB(13), XX(37)=ATRIB(19);  
ACE  ACCUM,2,LAST;  
      ASSIGN, ATRIB(11)=XX(21), ATRIB(1)=XX(22), ATRIB(2)=XX(23), ATRIB(4)=XX(24), ATRIB(9)=XX(25), ATRIB(13)=XX(36), ATRIB(19)=XX(37);  
      ACT,, CONT;  

KTK
GCDN.1;
ACT.,ATRIB(11).EQ.ATRIB(2).,ME17;
ACT;
COLCT,SET,INTER AT KTIK.,1;
ME17 
GCDN.2;
ACT.,0171;
ACT;
GCDN.1:
ACT/21,ANORM(24.,3.,31).,ATRIB(11).SE.XX(2).,OR.ATRIB(12).,SE.XX(17).,DEAD;
ACT;
KT 
GCDN;
ACT.UFRM(13.,14.,3);
ASSIGN,ATRIB(16)=STNOW;
ACT.,0172;
G171 QUEUE(27),,.,MAT9; ACT;
G172 QUEUE(17),.,.,MAT9; CREWS AVAIL
MAT9 MATCH,5,0172/AC7; 
AX7 ASSIGN,XX(31)=ATRIB(11),XX(32)=ATRIB(2),XX(33)=ATRIB(3), 
XX(34)=ATRIB(4),XX(35)=ATRIB(9),XX(36)=ATRIB(13), 
XX(37)=ATRIB(19);
AX7 ACCUM,2,2,LAST;
ASSIGN,ATRIB(1)=XX(31),ATRIB(2)=XX(32),ATRIB(3)=XX(33), 
ATRIB(4)=XX(34),ATRIB(9)=XX(35),ATRIB(13)=XX(36), 
ATRIB(19)=XX(37),ATRIB(20)=0;
ACT.,,CONT;
;
MISSION CONTINUATION###

MISSION CONTINUATION###

CONT 
GCDN;
ACT/23; 
ENROUTE DEPARTURES
ASSIGN,XX(19)=ATRIB(19)-.5,XX(20)=ATRIB(19)+.5,XX(31)=XX(10)-2;
ASSIGN,XX(19)=XX(19)-1;
ASSIGN,ATRIB(1)=ATRIB(2),ATRIB(6)=STNOW,; PRESENT NODE=ATRIB(2)
ACT/4,UNFRM,XX(19),XX(20),XX(14),FLY; 
NO MAJOR MNX
ACT/23,UNFRM,XX(20),XX(10),XX(5),FLY; 
DELAY
ACT/6,TRAS(XX(31),XX(10),XX(10),X1,XX(5),STAGE; RAMP EXCEEDED
MISSION CONTINUATION###

MISSION CONTINUATION###

HOME 
GCDN;
EVENT,10,1; 
UPDATE 30/90 TIME
COLCT.INT(8),MISSION LENGTH;
TRACK MSN LENGTHS
COLCT.INT(8),LAST DUTY DAY;
TRACK FINAL DUTY DAY

;
ASSIGN, ATRIB(10) = ATRIB(10) + TNOW - ATRIB(8); TRACK TIME AWAY

GOOD:
ASSIGN, XX(18) = XX(18) - 1;

IMMEDIATE CHANGES:
ASSIGN, XX(26) = XX(26) + ATRIB(7), ATRIB(7) = 0; ACCUMULATE FLYING TIME
ASSIGN, XX(25) = XX(25) - XX(27); FLY TIME THIS PHASE
ASSIGN, XX(30) = XX(30) + TNOW - ATRIB(6); ACCUM. DUTY TIME
ASSIGN, XX(30) = TNOW - XX(24), XX(30) - XX(30) - XX(40); DUTY TIME THIS PHASE
ASSIGN, XX(41) = XX(9) * XX(23) / 730.56, XX(41) = XX(39) / XX(41); AVG WORK MONTH
ASSIGN, XX(42) = XX(9) * XX(23) / 730.56, XX(42) = XX(25) / XX(42); AVG FLY HRS
ASSIGN, XX(43) = XX(43) + TNOW - ATRIB(8); CUM. TIME AWAY
ASSIGN, XX(44) = XX(47) - XX(45); TIME AWAY THIS PHASE
ASSIGN, XX(46) = XX(9) * XX(23) / 730.56, XX(46) = XX(44) / XX(46); AVG TIME AWAY
ASSIGN, XX(17) = XX(17) + 1;

COCT, XX(25) FLY TIME, 2; FLY TIME THIS PHASE
ACT, USERF(7), START; CREW AVAILABLE
ACT, USERF(7), ACFT INBOUND
FREE, ACFT/1;

ASSIGN, XX(17) = XX(17) - 1; RESET COUNTER, ACFT INBOUND
ASSIGN, XX(18) = XX(18) + 1;

TERM:

******************************************************************************
*** UNSUCCESSFUL HOMESTATION PREFLIGHT ****
******************************************************************************

YCL GOOD:

ASSIGN, XX(30) = XX(30) + TNOW - ATRIB(6); ADD DUTY TIME
ASSIGN, XX(18) = XX(18) + 1;

GOOD, 2:
ACT... START;
ACT... INFORM(7, 12, 2);
EVENT... 111;
ACT... ATRIB(17), NE. 0.252;
ACT;
GOOD, 2;
ACT... 210;
FREE, ACFT/1;
TERM;

XCLI GOOD:

ASSIGN, XX(30) = XX(30) + TNOW - ATRIB(6); DUTY DAY EXCEEDED AT HOME

GOOD, 2:
ACT... START;
ACT;
EVENT... 111;
ACT... ATRIB(17), NE. 0.252;
ACT;
GOOD, 2;
ACT... 310;
ACT;
FREE, ACFT/1;
TERM;

XCLA GOOD, 1:
ACT... 19;
COUNT MISSIONS CANCELLED DUE TO NO ACFT

B-9
TERM;

;*********************************************************************

***SCHEDULED MAINTENANCE***

;*********************************************************************

A.C.I AND REFURB NOT ACCOMPLISHED DURING SURGE

HOMESTATION CHECK: 2 DAYS DOWN EACH 60 DAYS

CREATE.XX(47), 0;
AWAIT(1), ACFT;
ASSIGN.XX(19)=XX(19)-1;
ACT/CP. RANGM(48, 1, 3);
ASSIGN.XX(18)=XX(18)+1;
FREE, ACFT/1;
TERM;

CREATE.XX(48), 0;
SOCN.1;
ACT, XX/48, ELD.1, TERM;
ACT;
AWAIT(1), ACFT;
ASSIGN.XX(18)=XX(18)-1;
ACT/CP. RANGM(240, 5, 3);
ASSIGN.XX(19)=XX(19)+1;
FREE, ACFT/1;
TERM;

A.C.I. (REPLACING ISCH): 10 DAYS DOWN EACH 18 MOS

REFURBISHMENT: 10 DAYS DOWN EACH 18 MOS

CREATE.XX(50), 100;
SOCN.1;
ACT, XX/50, ELD.1, TERM;
ACT;
AWAIT(1), ACFT;
ASSIGN.XX(18)=XX(18)-1;
ACT/CP. RANGM(20, 10, 1);
ASSIGN.XX(19)=XX(19)+1;
FREE, ACFT/1;
TERM;

A.C.I. (REPLACING ISCH): 10 DAYS DOWN EACH 16 MOS

AFBITPARRLY START AT 100

CREATE.XX(51), 100;
SOCN.1;
ACT, XX/51, ELD.1, TERM;
ACT;
AWAIT(1), ACFT;
ASSIGN.XX(19)=XX(19)-1;
ACT/CP. RANGM(20, 10, 1);
ASSIGN.XX(18)=XX(18)+1;
FREE, ACFT/1;
TERM;

;*********************************************************************

***DEADHEAD HOME: EXCEEDED FLY TIME***

;*********************************************************************

DEAD DUEDE(7);
HOME STATION SCHEDULED MAINTENANCE
CREW PRIOR TO MISSION ASSIGNMENT
MISSION
AWAIT ACFT
CREW PRIOR TO MATCHING WITH MISSION (MAT2)
*SN PRIOR TO MATCHING WITH CREW (MAT2)
DEADHEAD TRANSITION
BRAVO CREW FILE
BRANCHING FOR WINDOW (FORTRAN)
ENTRY TO BRAVO IF CREW REST NEEDED
CREW ENROUTE
ACFT ENROUTE
CREW FED
STAGE
PREFLIGHT HOME STATION - ON TIME
PREFLIGHT MY AT STAGE
FLY
RAMP EXCEEDED ENROUTE
RAMP EXCEEDED AT HOME
QUICK TURN END TIME
AFTER (CL
NUMBER OF MISSION
BASE COUNT
CANCEL NO ACFT
DUTY CANCEL
EXCEEDS 90 LIMITS AT HOME
EXCEEDS 90 LIMITS IN SYSTEM
*SN CANCELLED PRIOR TO PREFLIGHT
ENROUTE MISSIONS
DEPARTURES
BRAVO FLIES
DUTY CANCEL AT HOME
PREFLIGHT HOME STATION - LATE DEPARTURE
PREFLIGHT ENROUTE - LATE DEPARTURE
HEC
RETURN
7) APPROACHING TO DAY LIMITS
8) APPROACHING 90 DAY LIMITS
9) REST FOR BRAVO

; USER FS
1) FLY TIME
2) HOME CREW REST
3) MX
4) CALC MISSION FREQ TO MEET "UR
5) STAGE

; ATTRIBUTES
1) PRESENT NODE
2) NEXT NODE
3) SORTIE FLY TIME
4) STAGE=1
5) BASIC=1
6) SHOW TIME FLY DAY
7) CUM. FLY TIME
8) SHOW TIME FOR MSN
9) ROUTE NUMBER
10) CUM. TIME AWAY FROM HOME
11) CUM. FLY TIME FOR 70 DAYS
12) CUM. FLY TIME FOR 90 DAYS
13) WHICH LEG NUMBER
14) CREW ID
15) DAILY CUM FLY TIME
16) START TIME MISC
17) MISSION FOR BRAVO CREW
18) EVENT NUMBER
19) ECHOED GROUND TIME

; SLAM
1) STAGING POLICY = 1 CREW FOR EVERY 20 ARRIVALS
2) TO DAY FLY TIME LIMIT
3) 90 DAY FLY TIME LIMIT
4) ON-TIME PROBABILITY
5) DELAY PROBABILITY
6) RESCHEDULE PROBABILITY
7) PRESENT AVAILABLE
8) CREW RATIO
9) # CREWS CREATED
10) MAX RAM TIME
11) SLEEP WINDOW
12) # OF HOURS AFTER WHICH MSN IS CANCELLED IF NO ACPT OF CREW
13) COUNTER FOR CREW ID
14) VACANCY
15) MISSION FREQUENCY
16) RESOURCE COUNT OF INBOUND ACPT
17) ACPT HOME SENDING MAINTENANCE
18) # ACPT
19) # MISC
20) MISC
I:

SC:

\[
\begin{align*}
\text{NUMBER OF LESS} & \quad \text{TIME SINCE PHASE CHANGE} \\
\text{TIME OF PHASE CHANGE} & \quad \text{FLY TIME SINCE PHASE CHANGE} \\
\text{FLY TIME AT PHASE CHANGE} & \quad \text{SYSTEM FLY TIME} \\
\text{FLY TIME AT PHASE CHANGE} & \quad \text{UTE RATE} \\
\text{& ACFT CREATED} & \quad \text{ACCUM. DUTY HOURS} \\
\text{SAVE ATTRIBUTES AT STAGE BASES} & \quad \text{MISC} \\
\text{DUTY TIME SINCE PHASE CHANGE} & \quad \text{FLY TIME AT PHASE CHANGE} \\
\text{DUTY TIME AT PHASE CHANGE} & \quad \text{AVG TIME MONTH} \\
\text{AVG # FLY HOURS} & \quad \text{TOTAL TIME FROM HOME} \\
\text{TIME AWAY SINCE PHASE CHANGE} & \quad \text{TIME AWAY AT PHASE CHANGE} \\
\text{TIME AWAY AT PHASE CHANGE} & \quad \text{AVG # TIME FROM HOME} \\
\text{FREQ OF HSC} & \quad \text{FREQ OF REFURBISHMENT} \\
\text{SUF/STG, 1=SURGE, 2=SUSTAINED} & \quad \text{FREQ OF ACFI} \\
\text{PENGES FROM RESCHEDULING} & \quad \text{STAGE CREW UTILIZED} \\
\text{INDEX FOR CREW REST (1=PEACE/PEACE, 2=SURGE, \text{\& SUSTAINED})} & \quad \text{FLY FLIGHT TIME} \\
\text{SUF/STG, 1=SURGE, 2=SUSTAINED} & \quad \text{FLY FLIGHT TIME} \\
\text{# EXTENDING ALET WINDOW} & \quad \\
\end{align*}
\]
SUBROUTINE EVENT(EVNT)
GO TO (1,2,3,4,5,6,7,8,9,10,11,12) JEVNT
1 CALL BRAVO
RETURN
2 CALL CANCEL
RETURN
3 CALL JUMP
RETURN
4 CALL MISSION
RETURN
5 CALL NEXT
RETURN
6 CALL STAGECR
RETURN
7 CALL SURGE
RETURN
8 CALL SUPPORT
RETURN
9 CALL SUPPORT
RETURN
10 CALL SUPPORT
RETURN
11 CALL WAGNER
RETURN
12 CALL WINDOW
RETURN
SUBROUTINE BRAVO

C *********************************************************************
C BRAVO CREW AVAILABLE
C *********************************************************************
COMMON/SCOM/A(1000),BDL(1000),TNOW(100),MFA,MSTOP,NCLR1,
NNDP,NPRNT,NNPUN,NSET,NTAPE,ELSE(1000),SSEL(1000),TNEXT,TNOW,A(1000)
COMMON OSET(40000)
DIMENSION NSET(4000),
EQUIVALENCE(NSET(1),OSET(1))
DIMENSION A(10)
I=20
IF (I.EQ.0) GO TO 20
CALL PMOVE(I,B,A)
A(19)=TRBL(I)
A(18)=TGW
A(17)=1
XX(12)=1
CALL FILEM(S,A)
TRBL(17)=1
RETURN
20 CALL UPBR
RETURN
END

SUBROUTINE CANCEL

C ****************************CANCEL IF IN SCHEDULED MSN QUEUE(C) FOR MORE THAN 12 HRS.
C COMMON/SCOM/A(1000),BDL(1000),TNOW(100),MFA,MSTOP,NCLR1,
NNDP,NPRNT,NNPUN,NSET,NTAPE,ELSE(1000),SSEL(1000),TNEXT,TNOW,A(1000)
COMMON OSET(40000)
DIMENSION NSET(4000),
EQUIVALENCE(NSET(1),OSET(1))
DIMENSION B(34)
RANK=1
VY=VNO(3)
9 IF (VY.RT.7) GO TO 9
CALL CMOV(RANK,7,B)
TT=TNOW-B/16
IF (TT.LE.XX(12)) GO TO 9
CALL CMOV(RANK,7,B)
VY=VY-1
XX(6)=XX(12)-1
XX(7)=XX(17)+1
GO TO 9
RETURN
END

SUBROUTINE MTFP

C ****************************CHANGE DAY FOR UPLIN
C AND CARRY FORWARD PREVIOUS SAME TIME IF NOT FLOWN TODAY
COMMON/SCOM/A(1000),BDL(1000),TNOW(100),MFA,MSTOP,NCLR1,
NNDP,NPRNT,NNPUN,NSET,NTAPE,ELSE(1000),SSEL(1000),TNEXT,TNOW,A(1000)
COMMON OSET(40000)
IMAN
C-2
IF "N.EQ.1" THEN
N=1
ELSE
N=N+1
ENDIF
DO TO L=1,160
IF (N.EQ.1.AND.ACFLTM(L,N).LT.ACFLTM(L,N+1)) THEN
ACFLTM(L,N)=ACFLTM(L,91)
ELSEIF (N.EQ.1.AND.ACFLTM(L,N).LT.ACFLTM(L,1)) THEN
ACFLTM(L,N)=ACFLTM(L,N-1)
ELSEIF (N.LT.90.AND.N.GT.1.AND.ACFLTM(L,N).LT.ACFLTM(L,N+1)) THEN
ACFLTM(L,N)=ACFLTM(L,N-1)
ENDIF
30 CONTINUE
CALL SCHDL(T..24,000=02,AATID)
RETURN
END
SUBROUTINE MISSION
******************************************************************************************
WHICH MISSION
COMMON/COMM/ATTRIB(100),DO(100),DO(100),STNOW,II,MFA,MSTOP,MCLNR
,NCORD,NPRT,NPUN,NSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XY(100)
COMMON/BRIAN/NUMATE,BASIC(100),NLEES(100),FREQ(100),TURP,TURGG
,ISTAGE(10,2101),STAGE(10,101),STAGE(10,101),STAGE(10,101),NSTAGE,ROUTE
,FREQ(100),FREQ(10),"TURG","BESMO","EXFLY",SB
E=SIGN(C)
SUM=0
P=1
DO 25 J=1,NUMATE
IF "X"(J).EQ."E" SUM=SUM+FREQ(J)
IF "X"(J).EQ."E" SUM=SUM+FREQ(J)
IF "X"(J).EQ."E" SUM=SUM+FREQ(J)
IF "X"(J).EQ."E" SUM=SUM+FREQ(J)
25 CONTINUE
"ATTRIB"=NBASE(P,01)
ATTRIB(P)=
RETURN
END
SUBROUTINE NEXT
******************************************************************************************
NEXT.LED
COMMON/COMM/ATTRIB(100),DO(100),DO(100),STNOW,II,MFA,MSTOP,MCLNR
,NCORD,NPRT,NPUN,NSET,NTAPE,LE(100),LE(100),TNEXT,TNOW,XY(100)
COMMON/BRIAN/NUMATE,BASIC(100),NLEES(100),FREQ(100),TURP,TURGG
,ISTAGE(10,2101),STAGE(10,101),STAGE(10,101),STAGE(10,101),NSTAGE,ROUTE
,FREQ(100),FREQ(10),"TURG","BESMO","EXFLY",SB
ATTRIB(10)=ATTRIB(10)
"ATTRIB"=NBASE(ATTRIB(10),ATTRIB(10))
ATTRIB(10)=STAGE(ATTRIB(10),ATTRIB(10))
SUBROUTINE STAGECR

C **********************************************************
C ************POSITION STAGE CREWS
C COMMON/COMN/ATFIB(100),CDL(100),CDL(100),STNOW,II,NMA,HSTO,INLR
1,NCRP,NRTM,INPAN,INSET,TAPE,SS(100),SS(100),TNEEXT,TNOW,XX(100)
C COMMON/BRIAN/NUMTE,BASIC(100),NLESS(100),FREDPC(100),TURPC,TURSS
1,NBASE(10,10),STAGE(10,10),GET(10,10),SAT(10,10),HACFT,ROUTE
1,FRESDU(10),FRESGG(10),TURPS,HASMO,EXFLY,SB

DIMENSION NETE(40000)
C COMMON NETE(40000)
C EQUIVALENCE (NETE(1),SET(1))

DIMENSION ACHM(10),NTOTT(17)
DO 10 I=1,17
NTOTT(I)=0
CONTINUE

DO 20 J=1,NUMATE
  DO 30 I=1,NLESS(I)-1
    IF (STAGE(J,J).ED.1) THEN
      SB=BASE(J,J)
      IF (XX(40).EQ.0) NTOTT(SB)=NTOTT(SB)+FREDPC(I)+HASMO/EXFLY
    CONTINUE
    IF (YY(40).EQ.0) NTOTT(SB)=NTOTT(SB)+FRESGG(I)+HASMO/EXFLY
  CONTINUE
ENDF
CONTINUE

DO 40 J=1,17
  IF (XX(40).EQ.0) WRITE(NPRINT,100),NTOTT(J)
  IF (YY(40).EQ.0) WRITE(NPRINT,100),VNTOT(J)
  IF (YY(40).EQ.0) WRITE(NPRINT,100),VNTOT(J)
CONTINUE

DO 50 K=1,17
  IF (NTOTT(K).LE.0) THEN
    CALL UNLINK(1)
    CALL LINK(1)
    GO TO 21
  ELSEIF (NTOTT(K).GT.NWKT) THEN
    IF (NWKT+1.EQ.5) 23 TO 22
    CALL MOVE(1,12,A)
    A=A+1
  ELSE
    CALL MISSION FOR STAGE CREWS ALLOWING FOR HEAD & FEET
    IF (VNTOT(K).GT.12) END
    CALL FILE(1,1)
    NTOTT(K)=NTOTT(K)
ENDF
CONTINUE
100 FORMAT/' PEACE STAGE CREWS AT ','12',' ',12'
101 FORMAT/' SURGE STAGE CREWS AT ','12',' ',12'
102 FORMAT/' SUSTAINED STAGE CREWS AT ','12',' ',12'
RETURN
END

SUBROUTINE SURGE
C **********************************************************************
C TRANSITION TO SURGE
C COMMON XCOM/STAGE, NTRANS/STAGE, NTRANS/STAGE, NTRANS/STAGE,
C NREPEAT/STAGE, NTRANS/STAGE, NTRANS/STAGE, NTRANS/STAGE,
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AN ANALYSIS OF AIRCREW RATIOS IN STRATEGIC AIRLIFT - A
SLAM SIMULATION(U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH SCHOOL OF ENGINEERING
UNCLASSIFIED B L SUTTER DEC 85 AFIT/ENS/GOR/85D-19 F/G 5/9
RETURN
END

SUBROUTINE UPBRAV

******************************************************************
CHANGE BRAVO CREW EVERY 48 HRS OR WHEN UTILIZED
COMMON/SCMK/ATRIB(100),SD(100),SSL(100),TNOW,II,MFA,STOP,NCLNR
I,NCRD,NPRT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,IX(100)
COMMON QSET(40000)
DIMENSION NSET(40000)
EQUIVALENCE (NSET(I),JSET(I))
DIMENSION A(30)
ATRIB(0)=0.
NQ=0
IF (IX(5) .NE. 0 .OR. NQ .NE. 0) GO TO 12
CALL LINK(1,8)
CALL LINK(12)
12: I(5)=0
NQ=0
IF (NQ .NE. 0) GO TO 11
CALL LINK(1,2)
IF (ATRIB(17) .EQ. 0) CALL LINK(8)
IF (ATRIB(17) .NE. 0) CALL LINK(10)
11: MRANK=MIND(1,NCLNR,19,9,9,0,0,0)
IF (MRANK .NE. 0) CALL RMOVE (MRANK,NCLNR,A)
ATRIB(12)=9,
CALL SCHRDL (. Conducts=0, ATRIB)
ATRIB(12)=0.
RETURN
END

SUBROUTINE USETLM

******************************************************************
UPDATE PO AND TO DAY TIME
COMMON SCMK: ATRIB (100), SD (100), SSL (100), TNOW, II, MFA, STOP, NCLNR
I, NCRC, NPNR, NNRUN, NNSET, NTAPE, SS (100), SSL (100), TNEXT, TNOW, IX (100)
COMMON QSET(10000), NN, N
IF (N .NE. 31) THEN
NP=1
ELSE
NP=NP+1
ENDIF
IF (N .NE. 31) THEN
NQ=N+1
ELSE
NQ=NP+1+N+10
ENDIF
ATRIB(13)=4CLMTM(0) ATRIB(14) .PLUS ATRIB(15) - ATRIB(14) .N0
ATRIB(14)=4CLMTM(0) ATRIB(14) .PLUS ATRIB(15) - ATRIB(14) .N0
AULMTM(0) ATRIB(14) .N0 = AULMTM(0) ATRIB(14) .N + ATRIB(15)
ATRIB(15)=0
XX(5)=ATRIB(11)
YY(55)=ATRIB(12)

C-6
RETURN
END

SUBROUTINE WARMUP

C **************************************************************
C **** REINITIATE STATISTICS AFTER WARMUP PERIOD ****
C C**************************************************************
C COMMON/SCOM/ATTRIB(100),DDL(100),JNOW,II,MFA,MSTOP,NCLNR
C 1,NCPDR,NFINT,NNMAX,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
C XX(24)=6.000E+03
C XX(27)=XX(26)
C XX(40)=XX(30)
C XX(45)=XX(43)
C RETURN
END

SUBROUTINE WINDOW

C **************************************************************
C **** ALERT WINDOW IN ALL QUEUES ****
C C**************************************************************
C COMMON/SCOM/ATTRIB(100),DDL(100),JNOW,II,MFA,MSTOP,NCLNR
C 1,NCPDR,NFINT,NNMAX,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
C COMMON JSET(40000)
C DIMENSION NNSET(40000)
INTEGER RANK,Z
C EQUIVALENCE(NSET(1),JSET(1))
C DIMENSION A(130), R(130)
C RANK=1
I=1
Z=NN=0
IF (RANK.GT.2) GO TO 11
CALL COPY(RANK,1,A)
IF (TNOW-A(161).LE.XX(114)) GO TO 11
CALL PMOVE(RANK,1,A)
IF (T.EQ.0) THEN
XX(114)=XX(117)+1
Z=Z+1
IF (Z.GE.2) THEN
NMAX=MIND(11,1,XX(121))
K=CALL PMOVE(NMAX.3,4)
XX(121)=XX(125)+1
ENDIF
ENDIF
I=I+1
Z=Z+1
CALL FILEM(2,A)
XX(121)=XX(125)+1
GO TO 2
IF (T.EQ.4) THEN
I=I+1
ELSE
I=I+1
ENDIF
IF (I.LE.17) THEN
Z=NN=Z
GO TO 9
ENDIF
C - 7
SUBROUTINE INTLC

C **********************************************************
C **********INITIALIZE**********
C COMMON/SCOM/ATRIB(100), DD(100), DM(100), DTMOD, II, MFA, MSTOP, MCLNR
C 1, NCOR, NFNRT, NNPUN, NSET, NTAG, SS(100), SSL(100), NTEXT, TNOW, IX(100)
C COMMON/BRON/NUMRT, BASIC(100), NLEGS(100), FREOSG, TURPC, TURSG
C 1, NBASE(10,0:10), STAG(10,10), SET(10,10), SRT(10,10), NACFT, ROUTE
C 1, FRESU(10), FRESG(10), TURPS, HRSMO, EXFFLY, SB
C COMMON/FLY/ACFLTH(10,0:1), NAM,N
C CHARACTER*6 BASE(10,0:10)
C NUMRT=0
C WRITE(NPRNT,200)
200 FORMAT(' ROUTE DATA',/)
C OPEN (UNIT=12, FILE="ROUTE", STATUS="OLD")
C READ(12,*)ROUTE
10 IF (ROUTE.LE.9999) THEN
  READ(12,*)BASIC(ROUTE), NLEGS(ROUTE), FREOSG(ROUTE)
  1,FRESG(ROUTE), FRESU(ROUTE)
  READ(12,201)(BASE(ROUTE,J), J=0,NLEGS(ROUTE))
201 FORMAT(11A6)
  READ(12,*)STAG(ROUTE,J), J=1,NLEGS(ROUTE))
  READ(12,*)STAG(ROUTE,J), J=1,NLEGS(ROUTE))
  READ(12,*)SATG(ROUTE,J), J=1,NLEGS(ROUTE))
  WRITE(NPRNT,202)(ROUTE, BASIC(ROUTE), NLEGS(ROUTE))
202 FORMAT(' ROUTE ', 'FC -2', 'FRESU(ROUTE),FRESG(ROUTE)
  IF (ROUTE.LE.9999) THEN
  WRITE(NPRNT,203)(BASE(ROUTE,J), J=0,NLEGS(ROUTE))
  WRITE(NPRNT,204)(BASE, 'FRESU(ROUTE),FRESG(ROUTE),FRESU(ROUTE)
  IF (ROUTE.LE.9999) THEN
  WRITE(NPRNT,205)(BASE=11A6)
  WRITE(NPRNT,206)(STAG(ROUTE,J), J=1,NLEGS(ROUTE))
  WRITE(NPRNT,207)(STAG(ROUTE,J), J=1,NLEGS(ROUTE))
  WRITE(NPRNT,208)(SATG(ROUTE,J), J=1,NLEGS(ROUTE))
  WRITE(NPRNT,209)(SCHL SD TIME: ', 'FAC.1')
  WRITE(NPRNT,210)(SCHL AIR TIME: ', 'FAC.2')
  NUMRT=NUMRT+1
  READ(12,*)ROUTE
  GO TO 10
  ENDIF
  READ(12,*)NACFT, TURPS, TURSG, TURSU
  WRITE(NPRNT,207)(ROUTE, 'FRESU(ROUTE),FRESG(ROUTE)
  IF (ROUTE.LE.9999) THEN
  WRITE(NPRNT,208)(BASE(ROUTE,J), J=0,NLEGS(ROUTE))
  DO 10 ROUTE=1, NUMRT
  DO 10 J=1,NLEGS(ROUTE)
  C -8
IF (BASE(ROUTE,J),ED.'K48') NEASE(ROUTE,J)=10
IF (BASE(ROUTE,J),ED.'C48') NEASE(ROUTE,J)=11
IF (BASE(ROUTE,J),ED.'E48') NEASE(ROUTE,J)=12
IF (BASE(ROUTE,J),ED.'K48') NEASE(ROUTE,J)=13
IF (BASE(ROUTE,J),ED.'C48') NEASE(ROUTE,J)=14
IF (BASE(ROUTE,J),ED.'E48') NEASE(ROUTE,J)=15
IF (BASE(ROUTE,J),ED.'E54') NEASE(ROUTE,J)=16
IF (BASE(ROUTE,J),ED.'K54') NEASE(ROUTE,J)=17

CONTINUE

PEACETIME CREW REST POLICY
XX(45)=2
XX(47)=60*24/NACFT
XX(48)=547.22*24/NACFT
XX(50)=10*6.24*24/NACFT
XX(29)=NACFT
XX(31)=NACFT
N=91
20 TO 1=1.160
ACFLTM(0,1)=UNFRM(25,110,,2)
RC=ACFLTM(1,1)
IF (RC GE 125.) THEN
DC=UNFRM(0,125,,3)
ACFLTM(1,2)=RC-DC
ELSEIF (RC LT 125.) THEN
ACFLTM(1,2)=UNFRM(0,RC,,2)
ENDIF
SC=ACFLTM(1,2)
DO X=0,90
ACFLTM(1,1)=X
END

CONTINUE
ACFLTM(1,1)=0
DO X=0,90
ACFLTM(1,1)=ACFLTM(1,1)+ACFLTM(1,1)
END

CONTINUE

MISSION FREQUENCY
XX(15)=USEEF(1)$
AT15=15=0.
CALL CIBCL(1.24,E+IC.AT15)$
CALL CIBCL(1.44,14,E+IC.AT15)$
AT15=15=9.
CALL CIBCL(1.44,14,E+IC.AT15)$
AT15=15=18.
CALL CIBCL(1.44,14,E+IC.AT15)$
AT15=15=36.
CALL CIBCL(1.44,14,E+IC.AT15)$
AT15=15=36.
CALL CIBCL(1.44,14,E+IC.AT15)$
AT15=15=36.
RETURN
END
SUBROUTINE CPUT

 ***************OUTPUT
COMMON/COM1,ATTRIB(100),DB(100),SDL(100),TNOW,II,MFA,HSTOP,NCLNR
1,NCRD,NPRINT,NRUN,NSET,NTAPE,SB(100),SSEL(100),TNEXT,TNOW,XX(100)
COMMON/BRIAN,NUMRT,NSET,NTAPE,SB(100),SSEL(100),TNEXT,TNOW,XX(100)
COMMON/BRIAN,NUMRT,E BASIC(110),NLRESS(10),FREGPC(10),TURPC,TURSE
1,NBASE(10,0:10),STAGE(10,10),SET(10,10),SAT(10,10),MACFT,ROUTE
1,FREGS(10),FREGS(10),FREGS(10),FREGS(10),FREGS(10),FREGS(10),FREGS(10)
COMMON/FLY/ACFLTM(160,91),MAN,N
WRITE(NPRINT,102),XX(1)
102 FORMAT(' STAGE CREW FOR EVERY ',F7.2,' ARIVALS')
WRITE(NPRINT,103),XX(1)
103 FORMAT('9 & 90 DAY LIMITS: ',F5.0)
WRITE(NPRINT,104),XX(1)
104 FORMAT(' CREWS AVAILABLE: ',F4.0)
WRITE(NPRINT,105),XX(1)
105 FORMAT(' RELIABILITY FACTORS: ',F4.0)
RETURN
END

FUNCTION USEF(IFN)

 ***************USER FUNCTIONS
COMMON/COM1,ATTRIB(100),DB(100),SDL(100),TNOW,II,MFA,HSTOP,NCLNR
1,NCRD,NPRINT,NRUN,NSET,NTAPE,SB(100),SSEL(100),TNEXT,TNOW,XX(100)
COMMON/BRIAN,NUMRT,E BASIC(110),NLRESS(10),FREGPC(10),TURPC,TURSE
1,NBASE(10,0:10),STAGE(10,10),SET(10,10),SAT(10,10),MACFT,ROUTE
1,FREGS(10),FREGS(10),FREGS(10),FREGS(10),FREGS(10),FREGS(10),FREGS(10)
COMMON/FLY/ACFLTM(160,91),MAN,N
DIMENSION VAL(10)
GO TO (1,2,3,4,5) IFN
1 COMPUTE SCHED FLY TIME
RETURN

 ***************COMPUTE HOME STATION CREW REST
IF (TNOW-ATTRIB(3)+.15) USERF=12
IF (TNOW-ATTRIB(3)+.65) USERF=72
IF (TNOW-ATTRIB(3)+1.15) USERF=72
RETURN

 ***************HOME STATION ESTIMATED UNHELD MAINTENANCE
USERF=MCRE.12
RETURN
EkipY=0

 ***************COMPUTE SCHEDULING FREQUENCY FOR TARGET USE RATE
IF (HRESM+MACFT+TURPC=0.44)
IF (HRESM=MACFT+TURPC=0.44)
IF (MACFT=HRESM+TURPC=0.44)
DO IF J=1,NLESET
VAL(I)=0
DO 20 J=1,NLESET
VAL(I)=VAL(I)+SAT(I,J)
20 CONTINUE
C-10
IF (XX(4).EQ.1) EXPFLY=EXPFLY+(FREDPC(I)*VAL(I))
IF (XX(4).EQ.1) EXPFLY=EXPFLY+(FREDSS(I)*VAL(I))
IF (XX(4).EQ.1) EXPFLY=EXPFLY+(FREDSU(I)*VAL(I))
15 CONTINUE
USERF=770.56/(HRSD/EXPFLY)
RETURN

0 ****************************IS BASE STAGING LOCATION?
5 USERF=STAGE(ATRIB(9),ATRIB(13)-1)
RETURN
5 USERF=0
RETURN
END
Appendix D

Scenario Files

This appendix contains the scenario data files used for both single homebase models and the multiple homebase model. See Appendix H for scenario information.

"Route" for NATO Single Base

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D-1
For NATD Multi-homebase

1 7 11 0.0 0.88
KCWS KPXX EGXX KCHS
0 1 1
2.3 2.3 2.3
0.87 7.72 9.87

2
1 5 59 29 26
KCWS KPXX CYXX EDXX EGXX KCHS
0 1 0 1 1
2.3 2.3 2.3 2.3
0.87 7.27 5.87 1.21 9.87

3
1 5 6 0.0 0.0
KCWS KPXX CYXX ENXX EGXX KCHS
0 1 0 1 1
2.3 2.3 2.3 2.3
0.87 7.27 5.87 2.24 9.87

4
1 5 6 0.0 137 1.9
KCWS KPXX CYXX EDXX EGXX KCHS
0 1 0 1 1
2.3 2.3 2.3 2.3
2.67 4.79 5.87 1.21 7.81

5
1 5 5 177 2.5
WFRL 7550 CYXX EDXX EGXX WFRI
0 1 0 1 1
2.3 2.3 2.3 2.3

6
1 5 5 135 2.5
WFRL 7550 CYXX EDXX EGXX WFRI
0 1 0 1 1
2.3 2.3 2.3 2.3
2.67 4.79 5.87 1.21 7.81

D-2
"Route2" for SWA Single Homebox

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<td>50 4.0 15.8 13.9</td>
<td>50 4.0 15.8 13.9</td>
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Appendix E

Simulation Output

ROUTE DATA
PEACE USAGE: 0.220 SURGE USAGE: 0.000 SUSTAINED USAGE: 0.100
BASES: KCHS KPXX EGXX KCHS
STAGE: 0. 1. 1.
SCHED AND TIME: 2.1 2.1 2.1
SCHED AIR TIME: 0.97 7.72 8.97
PEACE USAGE: 0.780 SURGE USAGE: 0.720 SUSTAINED USAGE: 0.330
BASES: KCHS KPXX CYXX EGXX KCHS
STAGE: 0. 1. 0. 1.
SCHED AND TIME: 2.1 2.1 2.1 2.1
SCHED AIR TIME: 0.97 3.27 5.52 1.21 3.87
PEACE USAGE: 0.000 SURGE USAGE: 0.000 SUSTAINED USAGE: 0.000
BASES: KCHS KPXX CYXX EGXX KCHS
STAGE: 0. 1. 0. 1.
SCHED AND TIME: 2.1 2.1 2.1 2.1
SCHED AIR TIME: 0.97 3.27 5.07 2.64 8.87
PEACE USAGE: 0.000 SURGE USAGE: 0.530 SUSTAINED USAGE: 0.310
BASES: KCHS KTIX CYXX EGXX KCHS
STAGE: 0. 1. 0. 1.
SCHED AND TIME: 2.1 2.1 2.1 2.1
SCHED AIR TIME: 0.97 4.30 5.81 1.21 7.91
AIRCRAFT AT KCHS: 30 PEACE HUR: 7.54 SURGE HUR: 15.10 SUSTAINED HUR: 13.40

SLAM SUMMARY REPORT

SIMULATION PROJECT THERIS
BY SEUTTER

DATE 2/14/1985
RUN NUMBER 1 OF 1

CURRENT TIME 0.9761E-04
STATISTICAL ARRAYS CLEARED AT TIME 0.6500E-04
**STATISTICS FOR VARIABLES BASED ON OBSERVATION**

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<tr>
<th>Variable</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Minimum Value</th>
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**STATISTICS FOR TIME-PERSISTENT VARIABLES**

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**FILE STATISTICS**

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**REGULAR ACTIVITY STATISTICS**

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E-7
**RESOURCE STATISTICS**

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<th>CURRENT CAPACITY</th>
<th>AVERAGE UTIL</th>
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**TIME-PERSISTENT HISTOGRAM NUMBER 1**

CREWS AT HOME

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E-4
**STATISTICS FOR TIME-PERSISTENT VARIABLES**

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<tr>
<th>CREWS AT HOME</th>
<th>MEAN</th>
<th>STANDARD DEVIATION</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>TIME CURRENT INTERVAL</th>
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**TABLE NUMBER 1**

**RUN NUMBER 1**

<table>
<thead>
<tr>
<th>TIMEHRS</th>
<th>AUR</th>
<th>AVG WORK MONTH</th>
<th>AVG FLY HRSMO</th>
<th>AVG TIME AWAYMO</th>
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<tr>
<td>0.1800E+04</td>
<td>0.5047E+01</td>
<td>0.1216E+03</td>
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<td>0.1200E+04</td>
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**FLOT NUMBER 1**

**RUN NUMBER 1**

**SCALES OF FLOT**

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<th>F=AUR</th>
<th>T=AUR</th>
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<td>0.505E-01</td>
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**TIMEHRS**

| 0.1900E+04 | U | + | + | UW | UF |
| 0.1200E+04 | + | - | - | UW | UF |
| 0.2040E-04 | - | - | - | U+W | UF |
| 0.2150E-04 | + | - | - | U+W | UF |
| 0.2280E-04 | + | - | - | U+W | UF |
| 0.2400E-04 | + | - | - | U+W | UF |
| 0.2520E-04 | + | - | - | U+W | UF |
| 0.2640E-04 | + | - | - | U+W | UF |
| 0.2760E-04 | + | - | - | U+W | UF |
Appendix E

Multi-Base SLAM Network Code

SEN.BUTCUM.THEIST.E(5/85, -5/88, . . . , 72);
LIMITS,1,1,0,800;
TIMST,NOW(2),CREWS AT HOME,(20/07/15)
TIMST,NOW(11),CREWS AT GVR;
TIMST,NOW(12),CREWS AT 66XX;
TIMST,NOW(14),CREWS AT GXX;
TIMST,XX(51),MISSIONS CANCEL;
TIMST,XX(56),BURNOUT;
TIMST,XX(19),# ACFT PMC
RECORD,NOW,TIMERS,5,6,120; EVERY FIVE DAYS
VAR,XX(58),1,1,H;H;
VAR,XX(41),X,AVE WORK MONTH;
VAR,XX(42),F,AVE FLY HOURS;
VAR,XX(43),T,AVE TIME AWAY;
PRIORITY(2,HUF/C(20),12,HUF/C(20),17,HUF/C(12),14,HUF/C(12),12,
HUF/C(17),HUF/C(20)); GIVE PRIORITY TO A CREW THAT HAS BEEN MECH. STAGED

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

USER INPUTS

INTL,XX(1)=5; STAGING POLICY
INTL,XX(2)=125; 30 DAY FLY LIMIT
INTL,XX(3)=30; 90 DAY FLY LIMIT
INTL,XX(4)=749; PROB. OF ON-TIME
INTL,XX(5)=344; PROB. OF DELAY
INTL,XX(6)=106; PROB OF RESCHEDULE
NOTE: XX(60)*XX(81)-XX(82) =1
INTL,XX(7)=30; PERCENT AVAILABLE
INTL,XX(8)=4; CREW RATIO

INSERT SCENARIO, TIMES, AND TARGET RTE FATES INTO FILE 'ROUTE.'
INSERT INITIAL NUMBER OF CREWS INTO FIRST CREATE STATEMENT & ASSIGN TO XX(9)
INTL,XX(9)=5; # CREWS AVAILABLE INITIALLY
INTL,XX(10)=1; MAY FLY PEACE
INTL,XX(11)=1; SELECT AUTHORITY
INTL,XX(12)=1; # CREWS AFTER WHICH A PEACED CREW IS CANCELLED IF NO CREW ON AC

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

NETWORK:

RESOURCE BIT FLIGHT;
CREATE 2: AIRCRAFT
CREATE 1: FLIGHT
CREATE 1: CREWS
CREATE 1: PEXT
CREATE 1: DROPP;
CREATE 1: ATatis(15)=X(15),ATatis(11)=X(11),ATatis(10)=0,ATatis(9)=1,
APRTIS(10),APRTIS(11),APRTIS(12),APRTIS(13),APRTIS(14),NOW,APRTIS(4),ATatis(13)=0;
APRTIS(14)=10;
BEND
ACT,APRTIS(14),EDC.LCD.; POSITING FIRST BROAD CREW
ACT,APRTIS(14),CDU.CHO.0; SECOND BROAD CREW
ACT;

F-1
GOOD;
ACT.1., QUES;
AMC1 AWAII.C1,BACFT;
ASSIGN.XX(CB)+XCI(5B)+1;
GOOD;
ACT.1;

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

***CREW SHOWS AT SQN***

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

QUEE, QUES(5),.,.,MAT:
CREW

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

QUEE, QUES(6),.,.,MAT:

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

MAT2, MATCH, PQ5, QUES, ACC, QUES, ACC;

ACC, ACHIEVE LAST:
ATTACHES MEN TO CREW, RETAINS MEN AT PIP
ASSIGN, ATRIB(1/0), ATRIB(4/1), NOW, ATRIB(9/1), NOW; 
Legal Number INIT=0
ASSIGN, XX(CB)+XX(18)+1;
GOOD;
ACT. EXPON(1,1), ATRIB(17), NE, 0, FLY;
FLY 22;
ASSIGN, XX(19)=XX(10)+1;
GOOD;
ACT.1, UNFRM(2,1, 2, 1, 3), XX(34), FLY;
ACT.27, UNFRM(8,1, XX(10), 21), XX(35), FLY;
PRELIGHT / MAX RAMP
ACT.7, TP64X(19), XX(10), XX(10), 4, XX, CL;
RAMP EXCEEDED, RESCHEDULE

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

***FLY***

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

FLY1 ASSIGN, ATRIB(17)=0;
FLY 20;
EVENT. 11;
COMPUTE NEXT LEG & FLY TIME
GOOD;
ACT.1F, NOW+ATRB(17)+ATRB(18)+ST, 18, MACH;

WILL EXCEED DUTY DAY ON NEXT LEG

ACT.24,;
ASSIGN, XX(18)+ATRB(17)+1, XX(20)+ATRB(17)+1;
ASSIGN, XX(21)+ATRB(17)+1, XX(19)+1;
ASSIGN, XX(22)+ATRB(17)+1, XX(18)+1;
ASSIGN, XX(23)+ATRB(17)+1, XX(17)+1;
GOOD;
ACT.1E, XX(21), ATRIB(17), ED, ATRIB(18), HOME;

NEXT HOME

ACT.1E, XX(21);
ASSIGN, XX(18)+XX(18)+1;
ASSIGN, XX(21)+NOW-XX(24)+XX(25)+XX(27)-XX(C19)+XX(C19)+ATRB(17)+XX(C19);
ME11 600N,2;
ACT.,.3111;
ACT;
600N,1;
ACT/21,ANDRM(4,3,3),ATTRIB(11).GE.XX(2),OR.ATTRIB(12).GE.XX(2),DEAD;
CHECK 30/90 TIME & DEADHEAD

ACT;
CY 600N;
ACT,UNFRM(13.,14.,3);
ASSIGN,ATTRIB(16)=TNOW;
ACT.,.Q112;
Q111 QUEUE(1),...,MAT3;
Q112 QUEUE(1),...,MAT3;
MAT3 MATCH,5,0111/AX(1),3112/AC1;
MATCH ACFT WITH CREW
AC1 ASSIGN,XX(31)=ATTRIB(11),XX(32)=ATTRIB(12),XX(33)=ATTRIB(13),
XX(34)=ATTRIB(4),XX(35)=ATTRIB(9),XX(36)=ATTRIB(10),
XX(37)=ATTRIB(19);
AC1 ACCUM,2,LAST;
ASSIGN,ATTRIB(11)=XX(31),ATTRIB(2)=XX(32),ATTRIB(3)=XX(33),
ATTRIB(4)=XX(34),ATTRIB(9)=XX(35),ATTRIB(10)=XX(36),
ATTRIB(19)=XX(37);
ACT,,CONT;

ME12 600N,1;
ACT,ATTRIB(11),EQ,ATTRIB(2),ME12;
ACT;
COLCT,GST.INTER AT EGXX,1;

ME13 600N,2;
ACT.,.3121;
ACT;
600N,1;
ACT/21,ANDRM(4,3,3),ATTRIB(11).GE.XX(2),OR,ATTRIB(12).GE.XX(2),DEAD;
ACT;

EG 600N;
ACT,UNFRM(13.,14.,3);
ASSIGN,ATTRIB(16)=TNOW;
ACT.,.Q112;
Q111 QUEUE(1),...,MAT4; ACFT
Q112 QUEUE(1),...,MAT4; CREWS AVAILABLE
ME14 MATCH,3,0111/AX(1),3112/AC1;
AX1 ASSIGN,XX(31)=ATTRIB(11),XX(32)=ATTRIB(12),XX(33)=ATTRIB(13),
XX(34)=ATTRIB(4),XX(35)=ATTRIB(9),XX(36)=ATTRIB(10),
XX(37)=ATTRIB(19);
AC1 ACCUM,2,LAST;
ASSIGN,ATTRIB(11)=XX(31),ATTRIB(2)=XX(32),ATTRIB(3)=XX(33),
ATTRIB(4)=XX(34),ATTRIB(9)=XX(35),ATTRIB(10)=XX(36),
ATTRIB(19)=XX(37);
ACT,,CONT;

XPX1 STAGE
VFXY 6001;
   ACT,,ATRIB(1),EQ,ATRIB(2),ME17;
   ACT;
   COLCT,SET,INTER AT VFXY,1;
ME13 6002;
   ACT,,Q131;
   ACT;
   6001;
   ACT/21,RNDM(24,...,3),ATRIB(11),SE,XX(2),OR,ATRIB(12),GE,XX(3),DEAD;
   ACT;
KP 6001;
   ACT,UNRMD(15,...,4),;
   ASSIGN,ATRIB(16)=TNOW+c1B
   ACT,,Q132;
Q121 QUEUE(23),,,,,,MATS;,ACFT
Q122 QUEUE(17),,,,,,MATS; CREWS AVAIL W/C
MATS MATCH,5,Q121/AXQ,0132/AC3;
AXJ ASSIGN,XX(21)=ATRIB(1),XX(22)=ATRIB(2),XX(33)=ATRIB(3),
   XX(34)=ATRIB(4),XX(35)=ATRIB(9),XX(36)=ATRIB(13),
   XX(37)=ATRIB(19);
AXJ ACCUM,2,.,LAST;
   ASSIGN,ATRIB(1)=XX(31),ATRIB(2)=XX(32),ATRIB(3)=XX(33),
   ATRIB(4)=XX(34),ATRIB(9)=XX(35),ATRIB(13)=XX(36),
   ATRIB(19)=XX(37);
   ACT,,CONT;
   CYXX STAGE

CYXX 6001;
   ACT,,ATRIB(1),EQ,ATRIB(2),ME14;
   ACT;
   COLCT,SET,INTER AT CYXX,1;
ME14 6002;
   ACT,,Q141;
   ACT;
   6001;
   ACT/21,RNDM(24,...,3),ATRIB(11),SE,XX(2),OR,ATRIB(12),GE,XX(3),DEAD;
   ACT;
CYX 6001;
   ACT,UNRMD(15,...,4),;
   ASSIGN,ATRIB(16)=TNOW;
   ACT,,Q142;
Q141 QUEUE(24),,,,,,MATS;,ACFT
Q142 QUEUE(14),,,,,,MATS; CREWS AVAIL
MATS MATCH,5,Q141/AXQ,0142/AC4;
AX4 ASSIGN,XX(31)=ATRIB(1),XX(32)=ATRIB(2),XX(33)=ATRIB(3),
   XX(34)=ATRIB(4),XX(35)=ATRIB(9),XX(36)=ATRIB(13),
   XX(37)=ATRIB(19);
AX4 ACCUM,2,.,LAST;
   ASSIGN,ATRIB(1)=XX(31),ATRIB(2)=XX(32),ATRIB(3)=XX(33),
   ATRIB(4)=XX(34),ATRIB(9)=XX(35),ATRIB(13)=XX(36),
   ATRIB(19)=XX(37);
ATRIB(4)=XX(34), ATRIB(9)=XX(15)=XX(36),
ATRIB(19)=XX(27);
ACT,, CONT;

KTIK 6001,
ACT,, ATRIB(1) EQ ATRIB(2), ME17;
ACT;
COLCT.BET.INTER AT KTIK,, 1;
ME17 6002,
ACT,, Q171;
ACT;
6001,
ACT/21, RNDM(24,, 3,, 3), ATRIB(11) EQ XX(12), OR ATRIB(12) EQ XX(3), DEAD;
ACT;
KT 6002,
ACT, UNFRM/13,, 14,, 3;
ASSIGN, ATRIB(16)=TNOW;
ACT,, Q172;
Q171 QUEUE(27),,,, MA10, ACFT
Q172 QUEUE(17),,,, MA10, CREWS AVAIL
MA10 MATCH, TQ171/A17, 172/AC7;
AX7 ASSIGN, XX(31)=ATRIB(1), XX(32)=ATRIB(2), XX(33)=ATRIB(3),
XX(34)=ATRIB(4), XX(35)=ATRIB(9), XX(36)=ATRIB(13),
XX(37)=ATRIB(19);
ACT7 ACCUM.2,, LAST;
ASSIGN, ATRIB(1)=XX(31), ATRIB(2)=XX(32), ATRIB(3)=XX(33),
ATRIB(4)=XX(34), ATRIB(9)=XX(35), ATRIB(13)=XX(36),
ATRIB(19)=XX(37);
ACT,, CONT;

KDOV STAGE

VDOV 6001,
ACT,, ATRIB(1) EQ ATRIB(2), ME18;
ACT;
COLCT.BET.INTER AT VDOV,, 1;
ME18 6002,
ACT,, Q191;
ACT;
6001,
ACT/21, RNDM(24,, 3,, 3), ATRIB(11) EQ XX(12), OR ATRIB(12) EQ XX(3), DEAD;
ACT;
KG 6002,
ACT, UNFRM/15,, 14,, 3;
ASSIGN, ATRIB(16)=TNOW;
ACT,, Q182;
Q182 QUEUE(18),,,, MA10, ACFT
Q182 QUEUE(18),,,, MA10, CREWS AVAIL
MA10 MATCH, TQ181/A18, 182/ACB;
AX8 ASSIGN, XX(31)=ATRIB(1), XX(32)=ATRIB(2), XX(33)=ATRIB(3),
XX(34)=ATRIB(4), XX(35)=ATRIB(9), XX(36)=ATRIB(13),
XX(37)=ATRIB(19);
ACT,, CONT;
ACS

ACLN2,2'.LAET;
ATRIB(Q)=XX(37);
ACT,,,CONT;

MISSION CONTINUATION

CONT GOON;

MISSION CONTINUATION

CREATE.1,1,3840;
EVENT.2;
EVENT.12;
TERM;

HOME

HOME

ACFT INBOUND

ACFT INBOUND
ASSIGN, XX(19) = XX(19) + 1;
TERM;

HM30 ASSIGN, XX(58) = XX(58) + 1;
C0LD, XX(58), SYS FLIGHT TIME, 2;
ACT, USERF(2), START;
ACT, USERF(3);
FREE, ACFT/1;
ASSIGN, XX(58) = XX(58) - 1;
ASSIGN, XX(18) = XX(18) + 1;
TERM;

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

### UNSUCCESSFUL HOMESTATION PREFLIGHT###

-----------------------------------------------

XCL; GOON;
ASSIGN, XX(30) = XX(30) + TNOW-ATRIB(6);
ASSIGN, XX(18) = XX(18) + 1;
GOON.2;
ACT., START;
ACT/2, UNFRMT(2, 1, 2);
EVENT.1, 1;
ACT/25, ATRIB(1), NE.0, QUE;
ACT;
GOON.2;
ACT., D10;
ACT., ATRIB(1). EQ. 30, FR1;
ACT., ATRIB(1). EQ. 10;
FREE, ACFT/1;
TERM;
FR1 FREE, ACFT/1;
TERM;

XCLD; GOON;
ASSIGN, XX(30) = XX(30) + TNOW-ATRIB(6);
GOON.2;
ACT., START;
ACT;
EVENT.1, 1;
ACT., ATRIB(1), NE.0, QUE;
ACT;
GOON.2;
ACT., D10;
ACT;
GOON.1;
ACT., ATRIB(1), EQ. 30, FR2;
ACT;
FREE, ACFT/1;
TERM;
FR2 FREE, ACFT/1;
TERM;

XCLA; GOON.1;
ACT.18;
COUNT MISSIONS CANCELLED DUE TO NO ACFT
TERM;

F-10
### SCHEDULED MAINTENANCE

---

**A.C.I AND REFURB NOT ACCOMPLISHED DURING SURGE HOME STATION CHECK: 2 DAYS DOWN EACH 60 DAYS**

- CREATE, XX(47), 0;
- 600N;
- ACT,, AM2O;
- ACT;
- AWAIT(1), ACFT;
- ASSIGN, XX(18) = XX(18) - 1;
- ACT/29, RNDM(48, 1, 3);
- ASSIGN, XX(18) = XX(18) + 1;
- FREE, ACFT/1;
- TERM;
- AMCD AWAIT(200), BACFT;
- ASSIGN, XX(19) = XX(19) - 1;
- ACT/29, RNDM(48, 1, 3);
- ASSIGN, XX(18) = XX(18) + 1;
- FREE, BACFT/1;
- TERM;

---

**REPURBSHMENT: 10 DAYS DOWN EACH 18 MOS**

- CREATE, XX(48), 0;
- 600N.1;
- ACT,, XX(49). EEG. 1. TERM;
- ACT;
- 600N;
- ACT,, AM2Z;
- ACT;
- AWAIT(1), ACFT;
- ASSIGN, XX(18) = XX(18) - 1;
- ACT/29, RNDM(240, 5, 3);
- ASSIGN, XX(18) = XX(18) + 1;
- FREE, ACFT/1;
- TERM;
- AMCD AWAIT(200), BACFT;
- ASSIGN, XX(19) = XX(19) - 1;
- ACT/29, RNDM(240, 5, 3);
- ASSIGN, XX(18) = XX(18) + 1;
- FREE, BACFT/1;
- TERM;

---

**A.C.I REPLACING ISOCH): 70 DAYS DOWN EACH 18 MOS**

- CREATE, XX(51), 100;
- 600N,;
- ACT,, XX(49). EEG. 1. TERM;
- ACT;
- 600N;
- ACT,, AM2Z;
- ACT;
- AWAIT(1), ACFT;
- ASSIGN, XX(19) = XX(19) - 1;

---

*NO INSPECTION IF SURGE POPULATION*
ACT;J1, ANDRM(700,10,3);  
ASSIGN,XX(I)=XX(I)+1;  
FREE,ACFT/1;  
TERM;  
AWIT,AWAIT (10), ACFT;  
ASSIGN,XX(I)=XX(I)-1;  
ACT; J1, ANDRM(700,10,3);  
ASSIGN,XX(I)=XX(I)+1;  
FREE,ACFT/1;  
TERM;  

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

********DEADHEAD HOME; EXCEEDED FLY TIME********

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

DEAD QUEUE(7);  
ACT;  
COLCT,INT(I), MISSION LENGTH;  
TRACK MISSION LENGTH  
ASSIGN, ATRIB(10)=ATRIB(10)+TANDM-ATRIB(9);  
TIME AWAY  
ASSIGN, XX(I)=XX(I)+UNF'HM(I,J,3), XX(I)=TANDM-IXX(21);  
ASSIGN, XX(16)=XX(16)+TANDM-ATRIB(2), XX(16)=TANDM-XX(43)-XX(45);  
AWAY  
ASSIGN, XX(I)=XX(I)+XX(55)-XX(40);  
ASSIGN, XX(I)=XX(I)+XX(23)+XX(55), XX(I)=XX(35)+XX(45);  
WORK  
SOON;  
ASSIGN, XX(I)=XX(I)+XX(23)+XX(55), XX(I)=ATRIB(7)=0;  
ACCUM FLY TIME  
ASSIGN, XX(I)=XX(I)+XX(23)-XX(27);  
ASSIGN, XX(I)=XX(I)+XX(23)+XX(27), XX(I)=XX(I)+XX(23)+XX(27), XX(I)=XX(I)+XX(23)+XX(27);  
FLY  
COLCT, XX(I), SYS FLY TIME,,2;  
ACT,USER, (2),START;  
CREW AVAIL.  
ACT;  
TERM;  
ENDNETWORK;  
SEEDS,SEED(1),NO,47835565(6);NO;  

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

**********DESCRIPTION OF COMPONENTS**********

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

QUEUES  
1) HOME SCHEDULED MAINTENANCE  
2) CREW PRIOR TO MISSION ASSIGNMENT  
3) MISSION  
4) AWAIT ACFT  
5) CREW PRIOR TO MISSION WITH MISSION (MATC)  
6) MISSION PRIOR TO MATCHING WITH CREW (MATC)  
7) DEADHEAD TRANSITION  
8) BRAVO CREW FILE  
9) BRANCHING FOR WINDOW (FORTRAN)  
10) 8 BRAVO  
11-19) CREW EXECUTE  
20-29) ACFT EXECUTE  
30) AWAIT INSPECTOR  
31) AWAIT BACFT  

ACTIVITIES

1) CREW REST
2) STAGE
3) PREFLIGHT HOME STATION - ON TIME
4) PREFLIGHT/MX AT STAGE
5) FLY
6) RAMP EXCEEDED ENROUTE
7) RAMP EXCEEDED AT HOME
8) QUICK TURN END TIME
9) MX AFTER XCL
10) NUMBER OF MISSIONS
11-17) BASE COUNT
18) CANCEL NO ACFT
19) DUTY DAY CANCEL
20) EXCEEDS 30/90 LIMITS AT HOME
21) EXCEEDS 30/90 LIMITS IN SYSTEM
22) # MSNS NOT CANCELLED PRIOR TO PREFLIGHT
23) # ENROUTE MISSIONS
24) DEPARTURES
25) BRAVO FLIES
26) DUTY DAY XCL AT HOME
27) PREFLIGHT HOME STATION - LATE DEPARTURE
28) PREFLIGHT ENROUTE - LATE DEPARTURE
29) HSC
30) REFURB
31) A.C.I.
32) APPROACHING 30 DAY LIMIT
33) APPROACHING 90 DAY LIMIT
34) CP FOR BRAVO

ATTRIBUTES

1) PRESENT NODE
2) NEXT NODE
3) FORM FLY TIME
4) STAGE=1
5) BASIC=1
6) SHOW TIME FOR DAY
7) CUM. FLY TIME
8) SHOW TIME FOR MEN
9) ROUTE NUMBER
10) CUM. TIME AWAY FROM HOME
11) CUM. FLY TIME FOR 30 DAYS
12) CUM. FLY TIME FOR 90 DAYS
13) WHICH LEG NUMBER
14) CREW ID
15) DAILY CUM FLY TIME
START TIME
MISSION FOR BRAVO CREW
EVENT NUMBER
SCHED GROUND TIME
NLEGS IN MISSION

STAGING POLICY - 1 CREW FOR EVERY 70 ARRIVALS
30 DAY FLY TIME LIMIT
90 DAY FLY TIME LIMIT
ON-TIME PROBABILITY
DELAY PROBABILITY
RESCHEDULE PROBABILITY
PERCENT AVAILABLE
CREW RATIO
CREws CREATED
MAX RAMP TIME
ALERT WINDOW
OF HOURS AFTER WHICH MSN IS CANCELLED IF NO ACFT OR CREW
COUNTER FOR CREW ID
WNG(Z)
MISSION FREQUENCY
RESOURCE COUNT OF INBOUND ACFT
ACFT HOME PENDING MAINTENANCE
PMC ACFT
MISC
MISC
MISC
NUMBER OF LEGS
TIME SINCE PHASE CHANGE
TIME OF PHASE CHANGE
FLY TIME SINCE PHASE CHANGE
SYSTEM FLY TIME
FLY TIME AT PHASE CHANGE
UTE RATE
ACFT CREATED
ACCM. DUTY HOURS
SAVE ATTRIBUTES AT STAGE BASES
MISC
DUTY TIME SINCE PHASE CHANGE
DUTY TIME AT PHASE CHANGE
AVG WORK MONTH
AVE NO FLY HOURS
TOTAL TIME FROM HOME
TIME AWAY SINCE PHASE CHANGE
TIME AWAY AT PHASE CHANGE
AVG NO TIME FROM HOME
FREQ OF HSC
FREQ OF REFURBISHMENT
FREQ OF PEACE. 1=Surge, 2=Sustained
FREQ OF ACI
NEESES FROM RESCHEDULING
52) STAGE CREW UTILIZED
53) INDEX FOR CREW REST (2=PEACE/SUSTAINED, 4=SURGE)
54) 20 DAY FLY TIME
55) 90 DAY FLY TIME
56) # EXCEEDING ALERT WINDOW
57) BACFT AVAIL + INBOUND
58) BACFT INBOUND
59) HOME STATION FOR MISSION

INIT: 0,3842; 3600  4.5 MOS + 600 HR WARM UP
MONTR, CLEAR, 600;
MONTR, SUMMARY, 1681, 1080;
SIMULATE;
FIN;

F-15
PROGRAM MAIN
DIMENSION NSET(40000)
COMMON/SCLI1/ATRIB(100), DB(100), DBL(100), DTNOW, II, MFA, MSTOP, NCLNP
1,NCPDR, NNPMT, NWRT, NSET, NTAPE, SS(100), SSL(100), TNEWT, TNOW, XX(1000)
COMMON/BRAIN/NUMTE, BASIC(10), LLESS(10), FREOPC(10), TURPC, TURSE
1,NBASE(10,0:10,1STAGE(10,10), SET(10,10), SAT(10,10), NACFT, ROUTE
1,FREPS(10), FREPS(10), TURPS, HASMO, EXPHLY
COMMON/FLY/ACFLTM(216, 911), MAN, N
COMMON GSET(40000)
EQUIVALENCE(NSET(1), GSET(1))
NSET=40000
NCPDR=5
NNPMT=5
NTAPE=7
NPLOT=2
CALL SLAM
STOP
END

SUBROUTINE EVENT(JEVNT)
COMMON/SCLI1/ATRIB(100), DB(100), DBL(100), DTNOW, II, MFA, MSTOP, NCLNP
1,NCPDR, NNPMT, NWRT, NSET, NTAPE, SS(100), SSL(100), TNEWT, TNOW, XX(1000)
COMMON/BRAIN/NUMTE, BASIC(10), LLESS(10), FREOPC(10), TURPC, TURSE
1,NBASE(10,0:10,1STAGE(10,10), SET(10,10), SAT(10,10), NACFT, ROUTE
1,FREPS(10), FREPS(10), TURPS, HASMO, EXPHLY
COMMON/FLY/ACFLTM(216, 911), MAN, N
DIMENSION NSET(40000)
COMMON GSET(40000)
EQUIVALENCE(NSET(1), GSET(1))
GO TO (11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23) JEVNT
1 CALL BRAVO
RETURN
2 CALL CANCEL
RETURN
3 CALL MIDUP
RETURN
4 CALL MISSION
RETURN
5 CALL NEXT
RETURN
6 CALL STAGEER
RETURN
7 CALL SURGE
RETURN
8 CALL SUSTAIN
RETURN
9 CALL USPRAV
RETURN

G-1
1) CALL UFLIM
   RETURN
2) CALL WARMUP
   RETURN
3) CALL WINDOW
   RETURN

C
4) CALL SPLIT
   RETURN
5) CALL UPBRAV(2)
   RETURN
END

SUBROUTINE BRAVO

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

PROGRAM BRAVO

CREW AVAILABLE

REWRITTEN FOR MULTI-BASE

C

COMMON: SCOM!/ATRIB(100), JD(100), JDX1(100), BTNDW, II, MFA, MSTOP, NLNR,
   NCPD, NFNT, NNRUN, NSET, NTAPE, SSL(100), TSHNT(100), THEIT, TNOW, XX(100)

COMMON: SET(40000)

DIMENSION NSET(40000)

EQUIVALENCE(INSET(1), JSET(1))

DIMENSION A1(4)

NNG=NNG(10)

NG10=NNG(11)

IF (ATRIB(1).EQ.10.AND. NGB.EQ.0) GO TO 12

IF (ATRIB(1).EQ.10.AND. NGB10.EQ.0) CALL RMOVE(1,10)

A(10)=ATRIB(1)

A(11)=ATRIB(11)

A(12)=ATRIB(12)

CALL FILEMIS(A)

C

AT history calls UPBRAS

IF (ATRIB(1).EQ.10.AND. NGB.EQ.0) CALL UPBRAS(1)

AT history calls UPBRAS

RETURN

END

SUBROUTINE CANCEL

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

PROGRAM CANCEL

CANCEL IF IN SCHEDULED MEN QUEUES 1 FOR MORE THAN 12 HRS.

C

COMMON: SCOM!/ATRIB(100), JD(100), JDX1(100), TNOW, II, MFA, MSTOP, NLNR,
   NCPD, NFNT, NNRUN, NSET, NTAPE, SSL(100), TSHNT(100), THEIT, TNOW, XX(100)

COMMON: SET(40000)

EQUIVALENCE(INSET(1), JSET(1))

DIMENSION B1(4)

INTEGER RANK

RANK=0

NY=NNG(11)

IF (FANG.YE.YE.0 TO 11

CALL COPY(FANG, J.B)

TT=TMOW-8(15)

IF (TT.LE.YY(11).5 TO 11

G-2
C

IF (B(1).EQ.10.) XX(17)=XX(17)+1
IF (B(1).EQ.30.) XX(58)=XX(58)+1
CALL PPOKE(RANK,J,6)
NY=NY-1
XX(51)=XX(51)+1
GO TO 9
11 RETURN
END

SUBROUTINE MIDUP

C***********************************************************************
CHANGE DAY FOR UPCFLTM
COMM:SCOM1/ATRIB100,DD100,DDL100,STNOW,IT,MFA,MSTOP,NCLMR
1,MCRP,VPNT,NMRUN,NNSET,NTAPE,SSL100,SSL100,TNEXT,TNOW,XX100
COMM:FLY/ACFLTM1216,N1,MAN,N
IF (N.EQ.91) THEN
  N=1
ELSE
  N=N+1
ENDIF
DO I=L,216
  IF (N.EQ.0.AND.ACFLT(N).LT.ACFLT(N+1)) THEN
    ACFLT(N)=ACFLTM(N+1)
  ELSEIF (N.EQ.91.AND.ACFLT(N).LT.ACFLT(N+1)) THEN
    ACFLT(N)=ACFLTM(N-1)
  ELSEIF (N.LE.90.AND.ACFLT(N+1).LT.ACFLT(N)) THEN
    ACFLT(N+1)=ACFLTM(N-1)
  ENDIF
ENDDO
CEND

SUBROUTINE MISSION

C***********************************************************************
WHICH MISSION
COMM:SCOM1/ATRIB100,DD100,DDL100,STNOW,IT,MFA,MSTOP,NCLMR
1,MCRP,VPNT,NMRUN,NNSET,NTAPE,SSL100,SSL100,TNEXT,TNOW,XX100
COMM:FLY/ACFLTM1216,N1,MAN,N
COMMON/FLY/ACFLTM1216,N1,MAN,N
IF (Y).NE.0 THEN
IF (Y).NE.91 THEN
  CONTINUE
ENDIF
CALL ATRIB100
AT(100)=0
RETURN
END
SUBROUTINE NEXT

COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),E'NOW,IT,MFA,MSTOP,NCLNR
1,NCPRO,NPRT,NRUN,NSET,NTAPE,SS(100),SSL(100),TNEW,TNOW,XX(100)
COMMON/BRIAN/HUMATE,BASIC(10),NLESS(10),FREQP(10),TURPC,TURSG
1,NBASE(10,2:10),STAGE(10,10),SST(10,10),SAT(10,10),NACFT,ROUTE
1,FREDS(10),FREQS(10),TURSU,HRSMO,EXPIFLY

ATRIB(12)=ATRIB(12)+1
ATRIB(2)=NBASE(1ATRIB(9),ATRIB(13))
ATRIB(3)=STG(1ATRIB(9),ATRIB(13))
ATRIB(5)=1
ATRIB(10)=STG(1ATRIB(9),ATRIB(17))
ATRIB(20)=NLESS(1ATRIB(9))
RETURN
END

SUBROUTINE SPLIT

COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),E'NOW,IT,MFA,MSTOP,NCLNR
1,NCPRO,NPRT,NRUN,NSET,NTAPE,SS(100),SSL(100),TNEW,TNOW,XX(100)
1,[ATRIB(14)
IF (MOD(11,2X,ED.0) THEN
ATRIB(1)=30,
ATRIB(2)=30.
ELSE
ATRIB(1)=10.
ATRIB(2)=11.
ENDIF
RETURN
END

SUBROUTINE STAGE5

COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),E'NOW,IT,MFA,MSTOP,NCLNR
1,NCPRO,NPRT,NRUN,NSET,NTAPE,SS(100),SSL(100),TNEW,TNOW,XX(100)
COMMON/BRIAN/HUMATE,BASIC(10),NLESS(10),FREQP(10),TURPC,TURSG
1,NBASE(11:10),STAGE(11,10),SST(11,10),SAT(11,10),NACFT,ROUTE
1,FREDS(11),FREQS(11),TURSU,HRSMO,EXPIFLY
DIMENSION NSET(11:999)
COMMON BST(4999)
EQUIVALENCE NSET(11,GEET/11)
DIMENSION AM(1:4),HNMT(18)
DO 1=1,19
HNMT(1)=0
CONTINUE
DO 15=1,14,HUMATE
DO 20 J=1,NLESS(I)-1
  IF ((STAGE(J).EQ.1) THEN
    NB=NBASE(J,J)
    IF (XX(49).EQ.0) NNTOT(NB)=NNTOT(NB)+FREDC(I)*HARSHMD/!
    EXPFY)/XX(1)
    IF (XX(49).EQ.1) NNTOT(NB)=NNTOT(NB)+FREDS(I)*HARSHMD/
    EXPFY)/XX(1)
    IF (XX(49).EQ.2) NNTOT(NB)=NNTOT(NB)+FRESS(I)*HARSHMD/
    EXPFY)/XX(1)
  ENDIF
20 CONTINUE
15 CONTINUE
DO 25 K=1,18
  IF (XX(49).EQ.0) WRITE(NPMMT,100)K,NNTOT(K)
  IF (XX(49).EQ.1) WRITE(NPMMT,101)K,NNTOT(K)
  IF (XX(49).EQ.2) WRITE(NPMMT,102)K,NNTOT(K)
25 CONTINUE
DO 22 X=1,18
  IF (NNTOT(K).LT.NNG(K)) THEN
    CALL UNLINK(1,X)
    CALL LINK(7)
    GO TO 21
  ELSEIF (NNTOT(K).ST.NNG(K)) THEN
    IF (NNG(2).EQ.0) SD TO 22
    CALL REMOVE(1,2,A)
    A(2)=K
    START MISSION FOR STAGE CREW ALLOWING FOR DEADHEAD & REST
    A(2)=TNDW-UNFRM(E,16,2)-12
    CALL FILE(1,A)
    NNTOT(K)=NNTOT(K)-1
    GO TO 21
    ENDIF
22 CONTINUE
100 FORMAT('PEACE STAGE CREWS AT ',12 completions
101 FORMAT('SURGE STAGE CREWS AT ',12 completions
102 FORMAT('SUSTAINED STAGE CREWS AT ',12 completions
RETURN
END
SUBROUTINE SURGE

******************************************************************************
** TRANSITION TO SURGE **
******************************************************************************
COMMON SCOM1-STRBP(100),LD(100),DL(100),D'MOW,11,HPA,HSDF,WSLR
L,WSDF,NNFMT,SPRUN,INSET,STAP,DS(100),BEI(100),TENET,TNOW,XX(100)
COMMON SFIAN,NUMATE,BASIC(10),NLESS(I),FREDC(I),TURC,TUR56
L,SSAGE(10),STAGE(10),DST(10),SST(10),KST(10),WAFET,ROUTE
L,FREDS(I),FRESS(I),TURS(11),HARSHMD,EXPFL
XX(49)=1
XX(16)=4
XX(15)=USEFF=4
XX(10)=12
XX(11)=12
XX(C1)=.1e30E+04
XX(27)=XX(26)
XX(40)=XX(30)
XX(45)=XX(43)
NCREW=(XX(9)*NACFT**2/4)*XX(7)
DO 10 I=1,NCREW
   CALL ENTER(1,A)
10  CONTINUE
XX(9)=XX(9)+NCREW
CALL STAGECR
RETURN
END

SUBROUTINE SUSTAIN
C
C **************************************** TRANSITION TO SUSTAINED
COMMON/SCOM:/ATRIB(100), DD(100), JDLL(100), DTNOW, II, MFA, MSTOP, NCLR
I, NACFF, NFANT, NAFUN, NFORE, 35(100), SSL(100), TNEXT, TNOW, XX(100)
COMMON/BRAIN, NUMFE, BASIC(100), MLESS(10), FREQC(10), TURP, TURR
I, NBASE(10,10), STAGE(10,10), SST(10,10), SAT(10,10), NACFT, ROUTE
I, FREQS(10), FREGS(10), RURPG, NRSHO, ERPFLY
XX(4)=2
XX(5)=2
XX(15)=USERF(4)
XX(10)=6
XX(11)=6
XX(24)=2760E+04
XX(27)=XX(26)
XX(40)=XX(50)
XX(45)=XX(43)
CALL STAGECR
RETURN
END

SUBROUTINE SUSTAIN
C
C **************************************** CHANGE BRAVO CREW EVERY 40 WFS OR WHEN UTILIZED
C
COMMON/SCOM:/ATRIB(100), DD(100), JDLL(100), DTNOW, II, MFA, MSTOP, NCLR
I, NACFF, NFANT, NAFUN, NFORE, 35(100), SSL(100), TNEXT, TNOW, XX(100)
COMMON/GSET(40000)
DIMENSION NGSET(40000)
EQUIVALENCE/NESET(1), GSET(1)
DIMENSION Z4C(4), B1(34)
ATRIB(5)=0,
Y0=FQ(9)
NO1=HMD(10)
GO TO 1.2
1 IF (XX(52), EQ, 10..9F33.WBS, EQ, 1) GO TO 12
   CALL MOVE(1,8,A)
   CALL FILEW(1, A)
12 NEXT=HME(2)
15 IF (NEXT.EQ, 0, OR, NACF, 11.EQ, 1) GO TO 11
   CALL COPF(-NEXT, 2, A)
   IF (A(11), EQ, 10.) GO TO 15
   NEXT=NSURF(NEXT)
G-6
CALL FMOVE(-NEXT,2,A)
IF (ATRIB(NEXT,9).EQ.0) CALL FILEM9,A)
IF (ATRIB(NEXT,9).NE.0) CALL FILEM(12,A)
GO TO 11
2 IF (XX(52).EQ.30 .OR. NO10.EQ.0) GO TO 17
CALL FMOVE(1,10,A)
CALL FILEM(2,A)
NEXT=MMFE(2)
14 IF (NEXT,EQ.0 .OR. NNACT(3A). Eq.1) GO TO 18
CALL COPY(-NEXT,1,A)
IF (A(NEXT.EQ.0) GO TO 16
NEXT=NSUCR(NEXT)
GO TO 14
15 CALL FMOVE(-NEXT,2,A)
IF (ATRIB(NEXT,9).EQ.0) CALL FILEM(10,A)
IF (ATRIB(NEXT,9).NE.0) CALL FILEM(2,A)
GO TO 19
16 IF (NFRANK.FEQ.0.1, NCLNR.JE.0) CALL FILEM(-NFRANK,NCLNR,B)
ATRIB(B)=.9.
CALL ECHDL(.4800E+02,.ATRIB)
ATRIB(B)=0.
IF (N.NEq.0) RETURN
18 IF (-NFRANK.FEQ.0.1, NCLNR.JE.0) CALL FILEM(-NFRANK,NCLNR,B)
ATRIB(B)=.1.
CALL ECHDL(.4800E+02,.ATRIB)
ATRIB(B)=0.
IF (N.NEq.0) RETURN
END
SUBROUTINE UFRTH
**********************************************************************
UPDATE 20 AND 70 DAY TIME
COMMON SECN,ATRIB(13),SE(100),DEL(100),TMONW,II,MPA,MSTIP,NCLNR
1,NISET,NSERT,NTRENT,NTAPE,SE(100),SE(100),NEXT,TMONW,XX(100)
COMMON AFAM,AFARTE,BASIC,100,MLEG(100),FREED(100),TURPC,TURSE
1,NBASE(10,100),STAGE(10,100),SAT(10,100),SAT(10,10),NACFT,ROUTE
1,FREED(10),TURPC(10),TURSE,NHMD,EXFLY
COMMON FL,ATRFL*CLE.P11,MAN,W
IF (N.LT.21) THEN
N=N+1
ELSE
N=N+1
ENDIF
IF (N.EQ.31) THEN
N=N+1
ELSE
N=N+1
ENDIF
AT3E (10) = ACFLN AT3E (14), N + ATRIB (15) - ACFLN AT3E (14), N90)
AT3E (11) = ACFLN AT3E (14), N + ATRIB (15) - ACFLN AT3E (14), N90)
AT3E (12) = ACFLN AT3E (14), N + ATRIB (15) - ACFLN AT3E (14), N90)
AT3E (13) = ATRIB (11)
AT3E (14) = ATRIB (11)
RETURN
END

SUBROUTINE WARMUP
COMMON ECOM, AT3E (10), ID (100), DBL (100), ITNOW, 11, MFA, MSDF, NCLNR
1, NCPDF, NFPNT, NNPUN, NINSET, NTAPE, SS (100), SSL (100), TGET, TNOW, X (100)
II: X = X E = 0
I : ID = (26)
II: ID = ID (70)
I: ID = ID (43)
RETURN
END

SUBROUTINE WINDOW

******************************************************************************
** ALERT WINDOW
******************************************************************************
COMMON ECOM, AT3E (10), ID (100), DBL (100), ITNOW, 11, MFA, MSDF, NCLNR
1, NCPDF, NFPNT, NNPUN, NINSET, NTAPE, SS (100), SSL (100), TGET, TNOW, X (100)
COMMON NSET (40000)
DIMENSION NSET (40000)
EQUIVALENCE NSET (1), NSET (1)
DIMENSION A (14), B (14)
INTEGER RANK, FILE
RANK = 1
FILE = 1
IF FAN (ST, 1) GO TO 11
CALL COPY (RANK, I, A)
IF TNOW - A (I) - E (11) 10 TO 11
CALL MOVE (RANK, I, A)
IF I (1, 4) THEN
II (1) = II (1) + 1
IF(00, 0)
NRANK = FIND (1, 0, 0, 0, 0, 0)
CALL MOVE (NRANK, 8, 8)
II (5) = II (5) + 1
ELSEIF I (1, 5) THEN
II (5) = II (5) + 1
IF(00, 0)
NRANK = FIND (1, 0, 0, 0, 0, 0)
CALL MOVE (NRANK, 8, 8)
II (5) = II (5) + 1
ENDIF
II = II - 1
4/20 = 1
CALL FILE (9, A)
II (15) = II (15) + 1
GO TO 3

G-S
IF (.LE.4) THEN
    I=1
ELSE IF (.LE.11) THEN
    I=11
ELSE
    I=I+1
ENDIF
IF (.LE.9) THEN
    J=NNQQ(1)
    GO TO 9
ENDIF
RETURN
END

SUBROUTINEIngredient

******************************************************************************INITIALIZE
COMMON SCMD, ASPI(100), LO(100), B(100), D(100), DNOW, 1, NFPA, NSUB, NCLASS
1, NEROF, NSMNT, NSET, NTAPE, S$1(100), S$2(100), T$1(100), T$2(100), XX(100)
COMMON BEAN(UMATE, BASIC(100), NLESS(100), FREQPC(100), TURPC, TURDS
1, NBASE(10, 100), STAGE(10, 100), SET(10, 100), SAT(10, 100), NACFT, ROUTE
1, FEED(100), FRED(100), TURDS, HREM1, EXPFLY
DIMENSION NSET(10000)
COMMON QSET(10000)
EQUIVALENCE INSET(1, QSET(1))
COMMON INFLM(216, 911, MAN, N
CHARACTER* BASE(10, 10)
NUM=0
WRITE (NPNT, 200)
200 FORMAT ('ROUTE DATA')
OPEN (UNIT=4, FILE='ROUTE1', STATUS='OLD')
REWIND (4)
READ 4, IC, ROUTE
IF (ROUTE.LE.9999) THEN
    READ 4, IC, BASIC(ROUTE), NLESS ROUTE, FREDPC(ROUTE)
1, FEED(ROUTE), FRED(ROUTE)
READ 4, IC, BASE(ROUTE), J=0, NLESS(ROUTE)
201 FORMAT (13A6)
READ 4, IC, STAGE(ROUTE), J=1, NLESS(ROUTE)
READ 4, IC, SET ROUTE, J=1, NLESS(ROUTE)
READ 4, IC, SAT ROUTE, J=1, NLESS(ROUTE)
WRITE(NPNT, 203) ROUTE, BASIC(ROUTE), NLESS(ROUTE)
202 FORMAT (ROUTE, ':FICT..,21X IF BASIC(I, FICT..21X, NUMBER OF
1, LESS(I, 12)
WRITE(NPNT, 203) FREDPC(ROUTE), FRED(ROUTE), FRED(ROUTE), FRED(ROUTE)
206 FORMAT (PBEG, USAGE 'FICT..', USAGE 'FICT..21X
1, SUSTAINED USAGE: 'FICT..21X
WRITE(NPNT, 206) BASE(ROUTE), J=0, NLESS(ROUTE)
207 FORMAT (BASES: 'I.X,11A6)
WRITE(NPNT, 204) STAGE(ROUTE), J=1, NLESS(ROUTE)
208 FORMAT (STAGE: 'I.X,11F6.3) (ROUTE, J=1, NLESS(ROUTE))
205 FORMAT (SCHED END TIME: 'I.MT,11F2.1)
WRITE(NPRT,205) (SAT(ROUTE,J),J=1,NLESS=ROUTE))

FORMAT(10,0,F2.2)
NUMTE=NUMTE+1
READ(I3,*)ROUTE
DO 10 M=1,NLESS(ROUTE)
IF (BASE(ROUTE,J),EQ.'XCYE' .AND. NBASE(ROUTE,J))=10
IF (BASE(ROUTE,J),EQ.'XCYE' .AND. NBASE(ROUTE,J))=11
IF (BASE(ROUTE,J),EQ.'XCYE' .AND. NBASE(ROUTE,J))=12
IF (BASE(ROUTE,J),EQ.'XCYE' .AND. NBASE(ROUTE,J))=13
READU(ROUTE,J)
WRITE(NPRT,207)NACFT,TURPC,TURSE,TURS
FORMAT(' TOTAL AIRCRAFT: ',F2.2,' PEACE TUR: ',F5.2,' SURGE TUR: ','F5.2',' SUSTAINED TUR: ','F5.2')
DO 50 ROUTE=1,NUMTE
DO 30 J=1,NLESS(ROUTE)

CONTINUE

C PEACETIME CDFSPEEST POLICY
**(EDIT)**
C CUMULATIVE DISTRIBUTION OF MISSIONS
**(EDIT)**
C ACFLT(1,1)=1.2
ACFLT(1,2)=12.116
ACFLT(1,3)=ACFLT(1,2)/ACFLT(1,1)
ELSEIF (FCD,J23,1) THEN
ACFLT(1,2)=ACFLT(1,1)
ENDIF
ACFLT(2,1)=ACFLT(2,1)/ACFLT(2,2)
ACFLT(2,2)=ACFLT(2,1)+ACFLT(1,1)*ACFLT(2,2)
END
ACFLT(3,1)=ACFLT(3,1)/ACFLT(3,2)
ACFLT(3,2)=ACFLT(3,1)+ACFLT(1,1)*ACFLT(3,2)
END
MISSION FREQUENCY

CALL SCHDL(1..,2400E+02,ATRIB)
CALL SCHDL(1..,681E+04,ATRIB)
ATRIB(18) = 0.
CALL SCHDL(9..,4800E+02,ATRIB)
ATRIB(18) = 0.
CALL SCHDL(6..,0100E+02,ATRIB)
ATRIB(18) = 0.
CALL SCHDL(2751E+04,ATRIB)
ATRIB(18) = 11.
CALL SCHDL(11..,6000E+02,ATRIB)
ATRIB(18) = 14.
CALL SCHDL(14..,4800E+02,ATRIB)
ATRIB(18) = 0.
RETURN
END

SUBROUTINE OUTPUT

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

COMMON/SCOM1/ATRIB(120),DD(100),DDL100),SNOW,11,MAST,01aNq
1.NCOMJ1NANPNT,NAVJN,NSIT,NTAPE,SS(100),SSL(100),TNET,0N0W,XX(100)
COMMON/BRJN/NUMATE,BASIC(10),NLE6S(10),FREQPC(10),TURPC,TURR6
1.NBASE(10,0)100),STAGE(10,10),SS(10,10),SAT(10,10),NACFT,ROUTE
1.FREQSU(10),FREQSE(10),TURSU,HRSMQ,EXFLY
COMMON:FLY:ACFLTIME(10),MAN.N
WRITE(NPANT,10111)XX(11)
101 FORMAT("STAGE CREW FOR EVERY 1.FL.")
WRITE(NPANT,1012)XX(12),XX(13)
102 FORMAT("# OF DAY LIMITS: ",ZF4.4)
WRITE(NPANT,1013)XX(9)
103 FORMAT("# CREWS AVAILABLE: ",ZF4.4)
WRITE(NPANT,1014)XX(14),XX(15),XX(16)
104 FORMAT("RELIABILITY FACTORS: ",ZF4.4,ZF4.4,ZF4.4,ZF4.4)
RETURN
END

FUNCTION USEEF(IFn)

COMMON/SCOM1/ATRIB(100),DD(100),DDL100),SNOW,11,MAST,01aNq
1.NCOMJ1NANPNT,NAVJN,NSIT,NTAPE,SS(100),SSL(100),TNET,0N0W,XX(100)
COMMON/BRJN/NUMATE,BASIC(10),NLE6S(10),FREQPC(10),TURPC,TURR6
1.NBASE(10,0)100),STAGE(10,10),SS(10,10),SAT(10,10),NACFT,ROUTE
1.FREQSU(10),FREQSE(10),TURSU,HRSMQ,EXFLY
COMMON:FLY:ACFLTIME(10),MAN.N
DIMENSION VAL(10)
RETURN
END

C COMPUTE SCHEDULED FLIGHT TIME

RETURN

C*****************************************************************************

G-11
IF (TNOW=ATRIB(8),37,215) USERF=72
RETURN
C ####################################################################################
7 USERF=FAIRM(6,12,3)
RETURN
4 EXPFLY=0
C ####################################################################################
C COMPUTE SCHEDULING FREQUENCY FOR TARGET UTE RATE
C HRS PER MO./EXP FLY TIME = $MSNS PER MO.
C
726 HRS IN A MO./MSNS PER MO. = FREQUENCY

IF (XX(49).EQ.0) HRSMO=NACFT>TURPC*30.44
IF (XX(49).EQ.1) HRSMO=NACFT>TURSS*30.44
IF (XX(49).EQ.2) HRSMO=NACFT>TURSU*30.44
DO 15 I=1,NUMRATE
   VAL(I)=0
   DO 20 J=1,NLEES(I)
      VAL(I)=VAL(I)+SAT(I,J)
20   CONTINUE
   IF (XX(49).EQ.0) EXPFLY=EXPFLY+(FREQPC(I)*VAL(I))
   IF (XX(49).EQ.1) EXPFLY=EXPFLY+(FREQSS(I)*VAL(I))
   IF (XX(49).EQ.2) EXPFLY=EXPFLY+(FREQSU(I)*VAL(I))
15   CONTINUE
C USERF=730.56/(HRSMO/EXPFLY)
RETURN
C ####################################################################################
C IS BASE A STAGING LOCATION?
5 USERF=STAGE(ATTRIB(9),ATTRIB(13)-1)
RETURN
5 USERF=0
RETURN
END
Appendix H

Scenario Exacts

This appendix contains the scenarios used for this study. They were provided by USAF/SAMM.

TABLE H.1
NATO Single Homebase Scenario

<table>
<thead>
<tr>
<th>Route #</th>
<th>Deck</th>
<th>Deck</th>
<th>GT</th>
<th>FT</th>
<th>Stage</th>
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<tr>
<td>1</td>
<td>KCHS (10)</td>
<td>FXY (13)</td>
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<td>7.71</td>
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<td>7.71</td>
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<td>E Yard (12)</td>
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Route Frequency

<table>
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<tr>
<th>Route</th>
<th>Peak Percentage</th>
<th>Surge Percentage</th>
<th>Sustained Percentage</th>
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<tr>
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<td>75.0</td>
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H-1
### TABLE 4.2

**SWA Single Homebase Scenario**

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<th>Dest</th>
<th>GT</th>
<th>PT</th>
<th>Stage</th>
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<td>KDDV(11)</td>
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<td>ODXX(14)</td>
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### Route Frequency:

<table>
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<tr>
<th>Route #</th>
<th>Peace Percentage</th>
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<th>Sustained Percentage</th>
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H-2
### TABLE H.3

**NATO Multiple Homebase Scenario**

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<th>Stage</th>
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<td>KFMX(17)</td>
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<td>EGXX(12)</td>
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H-3
Appendix I

ANOVA

ANOVA Input Program

/PROBLEM
TITLE IS 'THESIS'.

/INPUT
VARIABLES ARE 17.
FORMAT IS FREE.
FILE IS 'anaoval.dat'.

/VARIABLE
NAMES ARE ID, STAGE, FLYLMT, TUR, PERCENT, CR, RELIAB, 
GND, LEGS, AURPUR, AVGWORK, AVGFLY, CANCEL, AUR, 
ADD=1.
LABEL IS ID.

/TRANSFORM
IF (TUR EQ -1) THEN AUR=AURP+15.1.
IF (TUR EQ 1) THEN AUR=AURP+10.1.
USE=ID LE 64.

/GROUP
CODES(2) ARE -1,1.
NAMES(2) ARE THIRTY, SIXTY.
CODES(3) ARE -1,1.
NAMES(3) ARE ONETWO, ONEFIVEZERO.
CODES(4) ARE -1,1.
NAMES(4) ARE THREEFIVE, FOURFIVE.
CODES(5) ARE -1,1.
NAMES(5) ARE EIGHTY, NINETY.
CODES(6) ARE -1,1.
NAMES(6) ARE FOUR, FIVE.
CODES(7) ARE -1,1.
NAMES(7) ARE NINEFOUR, NINEFIVEFIVE.
CODES(8) ARE -1,1.
NAMES(8) ARE TWOONE, TWOFOUR.
CODES(9) ARE -1,1.
NAMES(9) ARE NINTHRE, SWA.

/DESIGN
GROUPING ARE 2,3,4,5,6,7,8,9.
DEPENDENT IS 11.
INCLUDED ARE 1,2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18, 
19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44, 
45,46,47,48,49.

END
## Table 1.1

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| 20 | 1  | -1 | 1  | -1 | -1 | -1 | -1 | 1.1747 | 111.2 | 33.09 | 0 |
| 21 | -1 | -1 | 1  | 1  | -1 | -1 | -1 | 1.5972 | 105.1 | 85.58 | 0 |
| 22 | 1  | 1  | -1 | 1  | 1  | -1 | -1 | 1.7060 | 110.1 | 72.70 | 0 |
| 27 | -1 | 1  | -1 | -1 | 1  | 1  | 1  | 1.6695 | 150.0 | 77.05 | 0 |
| 54 | 1  | -1 | 1  | -1 | 1  | -1 | -1 | 1.5976 | 116.0 | 73.25 | 5 |
| 55 | -1 | -1 | 1  | 1  | -1 | 1  | -1 | 1.6857 | 147.6 | 92.95 | 31 |
| 56 | 1  | 1  | -1 | 1  | -1 | -1 | -1 | 1.6329 | 122.5 | 60.91 | 0 |
| 57 | -1 | 1  | 1  | -1 | -1 | 1  | -1 | 1.6760 | 142.9 | 36.51 | 48 |
| 58 | -1 | 1  | -1 | -1 | 1  | -1 | -1 | 1.5311 | 127.1 | 91.77 | 0 |
| 59 | -1 | -1 | -1 | 1  | 1  | -1 | -1 | 1.6695 | 129.0 | 75.73 | 6 |
| 60 | 1  | 1  | 1  | 1  | -1 | -1 | -1 | 1.6142 | 118.0 | 74.78 | 0 |
| 61 | 1  | 1  | 1  | 1  | 1  | -1 | -1 | 1.5984 | 104.4 | 65.76 | 60 |
| 62 | -1 | -1 | 1  | 1  | 1  | -1 | -1 | 1.6590 | 97.08 | 57.27 | 0 |
| 67 | -1 | -1 | -1 | -1 | 1  | -1 | -1 | 1.5789 | 148.3 | 91.28 | 312 |
| 54 | 1  | 1  | 1  | -1 | -1 | -1 | -1 | 1.7083 | 157.8 | 78.4 | 2 |
### Appendix J

#### Regression Analysis

**TABLE J.1**

**Center Point and Axial Data**

| 65 | 0 0 0 0 0 0 -1 -1 1.6968 136.2 97.08 0 |
| 66 | 0 0 0 0 0 0 -1 -1 1.6859 136.5 86.20 0 |
| 67 | 0 0 0 0 0 0 -1 -1 1.6897 137.2 96.08 0 |
| 68 | 0 0 0 0 0 0 -1 -1 1.7051 137.6 88.06 0 |
| 69 | 0 0 0 0 0 0 -1 -1 1.6840 136.6 85.24 0 |
| 70 | 0 0 0 0 0 0 -1 -1 1.6981 138.0 97.57 0 |
| 71 | 0 0 0 0 0 0 -1 -1 1.7141 137.3 89.24 0 |
| 72 | 0 0 0 0 0 0 -1 -1 1.7087 137.1 88.41 0 |
| 73 | 0 0 0 0 0 0 -1 -1 1.6867 131.1 82.50 0 |
| 74 | 0 0 0 0 0 0 -1 -1 1.7166 137.5 89.87 0 |
| 75 | 0 0 0 0 0 0 -1 -1 1.6872 134.9 85.84 0 |
| 76 | 0 0 0 0 0 0 -1 -1 1.6797 135.9 86.89 0 |
| 77 | 0 0 0 0 0 0 -1 -1 1.6506 129.0 81.30 0 |
| 78 | 0 0 0 0 0 0 -1 -1 1.6235 127.3 78.11 0 |
| 79 | 0 0 0 0 0 0 -1 -1 1.6508 123.6 78.92 0 |
| 80 | 0 0 0 0 0 0 -1 -1 1.6241 127.1 78.01 0 |
| 81 | 0 0 0 0 0 0 -1 -1 1.6276 123.4 77.39 0 |
| 82 | 0 0 0 0 0 0 -1 -1 1.6260 127.8 79.70 0 |
| 83 | 0 0 0 0 0 0 -1 -1 1.6242 127.4 77.43 0 |
| 84 | 0 0 0 0 0 0 -1 -1 1.6231 124.6 73.76 0 |
| 85 | 0 0 0 0 0 0 -1 -1 1.6210 127.0 77.70 0 |
| 86 | 0 0 0 0 0 0 -1 -1 1.6221 122.8 78.67 0 |
| 87 | 0 0 0 0 0 0 -1 -1 1.6245 122.9 78.03 0 |
| 88 | 0 0 0 0 0 0 -1 -1 1.6278 127.6 78.54 1 |
| 89 | 0 0 0 0 0 0 -1 -1 1.4829 117.5 61.41 513 |
| 90 | 0 0 0 0 0 0 -1 -1 1.5179 100.4 64.78 1 |
| 91 | 0 0 0 0 0 0 -1 -1 1.7230 50.07 41.71 5 |
| 92 | 0 0 0 0 0 0 -1 -1 1.5237 175.7 82.74 0 |
| 93 | 0 0 0 0 0 0 -1 -1 1.5237 176.7 82.74 0 |
| 94 | 0 0 0 0 0 0 -1 -1 1.5237 176.7 82.74 0 |
| 95 | 0 0 0 0 0 0 -1 -1 1.5237 176.7 82.74 0 |
| 96 | 0 0 0 0 0 0 -1 -1 1.5237 176.7 82.74 0 |
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| 98 | 0 0 0 0 0 0 -1 -1 1.5237 176.7 82.74 0 |
| 99 | 0 0 0 0 0 0 -1 -1 1.5237 176.7 82.74 0 |
| 100 | 0 0 0 0 0 0 -1 -1 1.5237 175.5 81.97 0 |
| 101 | 0 0 0 0 0 0 -1 -1 1.5237 175.5 81.97 0 |
| 102 | 0 0 0 0 0 0 -1 -1 1.5237 148.4 78.77 0 |
| 103 | 0 0 0 0 0 0 -1 -1 1.5237 148.4 78.77 0 |
| 104 | 0 0 0 0 0 0 -1 -1 1.5237 148.4 78.77 0 |
| 105 | 0 0 0 0 0 0 -1 -1 1.5237 148.4 78.77 0 |
| 106 | 0 0 0 0 0 0 -1 -1 1.5237 148.4 78.77 0 |
| 107 | 0 0 0 0 0 0 -1 -1 1.5237 148.4 78.77 0 |
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PROGRAM Regression Input for AUR

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TITLE IS 'AUR REGRESSION'.

'INPUT
VARIABLES ARE 17.
FORMAT IS FREE.
FILE IS 'anoval.dat'.

'VARIABLE
NAMES ARE ID, STAGE, FLYLMT, TUR, PERCENT, CR, RELIAB, GND, LEGS, AURFUR, AVGWCRK, AVGFLY, CANCEL, AUR, SF, PR, SL, FL, SSQ, PSQ, CSD, RSQ, CS, SC, ABEG, DEFG, TSG.
ADD=15.
LABEL IS ID.

'TRANFORM
IF (TUR EQ -1) THEN AUR=AURFUR*15.1.
IF (TUR EQ 1) THEN AUR=AURFUR*16.1.
IF (TUR EQ 0) THEN AUR=AURFUR*15.6.
SF=STAGE*FLYLMT.
PR=PERCENT*RELIAB.
SL=STAGE*LEGS.
FL=FLYLMT*LEGS.
SSQ=STAGE*STAGE.
FSQ=FLYLMT*FLYLMT.
PSQ=PERCENT*PERCENT.
CSQ=CR*CR.
PSQ=RELIAB*RELIAB.
CG=CR*GND.
SC=STAGE*CR.
ABEG=STAGE*FLYLMT*CR*GND.
DEFG=PERCENT*CR*RELIAB*GND.
TSG=TUR*TUR.
USE=LEGS EQ -1.
DELETE=99 TO 100.

'PROCEDURE
DEPENDENT IS AUR.
INDEPENDENT ARE STAGE, CR, FLYLMT, PERCENT, SF, PR, RELIAB, FSQ, SSQ, PSQ, SQ, SQ, SQ, SQ, TUR, TSG.
METHOD=NONE.
TOL=.01.

'PRINT
MATRICES ARE COVA, CORR, PREB, FREL.

'PLOT
YVAR ARE RESIDUAL, PREDICTD.
XVAR ARE PREDICTD, AVGWCRK.
NORMAL.
SIDE IS 40.25.

'END

J-2
### TABLE J.2

**EMDP Regression Results for AUF (SWA)**

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Accidental colliders

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</tbody>
</table>

**Fig. J-7. Residual Plot Continued**

*J-8*
Fig. 3.4. Normal Probability Plot. Residual
### Table J.4

**EMDP Regression Results for AUP (NATC)**

<table>
<thead>
<tr>
<th>STATISTICS FOR 'BEST' SUBSET</th>
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<tbody>
<tr>
<td>MALLOWS' CP</td>
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<tr>
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<tr>
<td>STANDARD ERROR OF EST.</td>
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<td>F-STATISTIC</td>
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<table>
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<th>VARIABLE</th>
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<th>STAND. T-VALUE</th>
<th>TOL. BIAS</th>
<th>SIG. BIAS</th>
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<td>0.0272224</td>
<td>7.05975</td>
<td>0.9900</td>
<td>0.0000</td>
</tr>
<tr>
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<td>-0.0228150</td>
<td>0.0100699</td>
<td>-2.12</td>
<td>0.0101</td>
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<td>-2.53</td>
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<td>0.0000</td>
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<tr>
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</table>

The contribution to R-squared for each variable is the amount by which R-squared would be reduced if that variable were removed from the regression equation.
### TABLE J.5

**PenQP Regression Results for AVGWCD: USWA**

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<td>MALLOWS' CP</td>
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<td>SQUARE MULTIPLE CORR.</td>
</tr>
<tr>
<td>MULTIPLE CORR.</td>
</tr>
<tr>
<td>ADJUSTED SQUARE MULT. CORR.</td>
</tr>
<tr>
<td>RESIDUAL MEAN SQUARE</td>
</tr>
<tr>
<td>STANDARD ERROR OF EST.</td>
</tr>
<tr>
<td>F-STATISTIC</td>
</tr>
<tr>
<td>NUMERATOR DEGREES OF FREEDOM</td>
</tr>
<tr>
<td>DENOMINATOR DEGREES OF FREEDOM</td>
</tr>
<tr>
<td>SIGNIFICANCE (TAIL PROB.)</td>
</tr>
</tbody>
</table>

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<th>VARIABLE</th>
<th>REGRESSION NO.</th>
<th>NAME</th>
<th>COEFFICIENT</th>
<th>STANDARD ERROR</th>
<th>COEFF.</th>
<th>T-STAT</th>
<th>STAND. TAIL TOL-BATION</th>
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<tr>
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<td></td>
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<td></td>
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<td>1.05181</td>
<td>-9.178</td>
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<tr>
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<td></td>
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<td>.92841</td>
<td>-15.162</td>
<td>-17.12</td>
<td>.000</td>
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<td>1.05181</td>
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<td>.92841</td>
<td>-.146</td>
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<tr>
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<td></td>
<td></td>
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<td>1.05191</td>
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<td>1.07</td>
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<td>.92841</td>
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</table>

The contribution to F-Sq is the amount by which F-Sq would be reduced if that variable were removed from the regression equation.
### TABLE J.6

**SUMMARY Regression Results for AVG-WORK (NATC)**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
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<td>Mallows' CP</td>
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<tr>
<td>Squared Multiple Correlation</td>
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<tr>
<td>Multiple Correlation</td>
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<tr>
<td>Adjusted Squared Multiple Correlation</td>
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<tr>
<td>Residual Mean Square</td>
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<tr>
<td>Standard Error of Estimate</td>
<td>1.993724</td>
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<tr>
<td>F-Statistic</td>
<td>413.70</td>
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</table>

**Statistics for 'Best' Subset**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression Coefficient</th>
<th>Standard Error</th>
<th>t-Stat</th>
<th>Significance (Tail Prob.)</th>
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<tr>
<td>Intercept</td>
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<tr>
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<td>-1.51</td>
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<tr>
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</table>

The contribution to R-squared for each variable is the amount by which R-squared would be reduced if that variable were removed from the regression equation.

---

**Note:**

- The table provides regression coefficients, standard errors, t-statistics, and significance levels for various variables.
- The significance level (p-value) for each variable indicates whether removing that variable would significantly reduce the explained variance in the regression model.
- Variables with p-values less than 0.05 are considered statistically significant at the 95% confidence level.

**Contribution to R-squared**

The contribution to R-squared for each variable is the amount by which R-squared would be reduced if that variable were removed from the regression equation.
### TABLE J.7

**SMOP Regression Results for AVFEL (SWA)**

<table>
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</thead>
<tbody>
<tr>
<td><strong>MALLOW'S CP</strong></td>
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<td><strong>SQUARED MULTIPLE CORRELATION</strong></td>
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<tr>
<td><strong>MULTIPLE CORRELATION</strong></td>
</tr>
<tr>
<td><strong>ADJUSTED SQUARED MULT. CORR.</strong></td>
</tr>
<tr>
<td><strong>RESIDUAL MEAN SQUARE</strong></td>
</tr>
<tr>
<td><strong>STANDARD ERROR OF EST.</strong></td>
</tr>
<tr>
<td><strong>F-STATISTIC</strong></td>
</tr>
<tr>
<td><strong>NUMERATOR DEGREES OF FREEDOM</strong></td>
</tr>
<tr>
<td><strong>DENOMINATOR DEGREES OF FREEDOM</strong></td>
</tr>
<tr>
<td><strong>SIGNIFICANCE (TAIL PROB.)</strong></td>
</tr>
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<table>
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<tr>
<th>VARIABLE</th>
<th>REGRESSION NO.</th>
<th>NAME</th>
<th>COEFFICIENT</th>
<th>STANDARD ERROR</th>
<th>STAND. T-</th>
<th>2TAIL TOL-</th>
<th>CONTRIBUTION</th>
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<td>.724</td>
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</table>

The contribution to the regression equation for each variable is the amount by which $R^2$ would be reduced if that variable were removed from the regression equation.

*significant at 5%
### STATISTICS FOR 'BEST' SUBSET

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### DENOMINATOR DEGREES OF FREEDOM

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### SIGNIFICANCE TAIL PROB.

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<tbody>
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### TABLE J.8

**BMDP Regression Results for AVGEL (NATO)**

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<th>COEFFICIENT</th>
<th>STANDARD ERROR</th>
<th>COEF. STAT.</th>
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<th>TOL.</th>
<th>B-ED CONS.</th>
<th>STAT. SIG.</th>
<th>EDENSE</th>
<th>R-ED</th>
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**Note:** The contribution to $R^2$-SQUARED for each variable is the amount by which $R^2$-SQUARED would be reduced if that variable were removed from the regression equation.

J-14
### Appendix E

#### Sensitivity Results

**TABLE K.1**

**Crew Ratio Sensitivity.**

<table>
<thead>
<tr>
<th>CR</th>
<th>Rep1</th>
<th>Rep2</th>
<th>Rep3</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>7.642</td>
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<td>7.704</td>
<td>7.647</td>
<td>7.608</td>
<td>7.653</td>
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</table>

**Crew Ratio Effect on AUR**

<table>
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<th>Rep2</th>
<th>Rep3</th>
<th>Avg.</th>
</tr>
</thead>
</table>

**Crew Ratio Effect on Avg. Work Month**

<table>
<thead>
<tr>
<th>CR</th>
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<th>Rep2</th>
<th>Rep3</th>
<th>Avg.</th>
</tr>
</thead>
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<tr>
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**Peace**

**Surge**

**Sustained**

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**Effect of Crew Ratio on Avg Fly Hours**

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**Effect of Crew Ratio on Time Away**

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- Peace

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- Sustained

### TUR Effect on Average Work Month

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- Peace

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- Sustained

### TUR Effect on Average Filling Time

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Effect of Fly Time Limits on Avg Work Month

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Effect of Fly Time Limits on Avg FLY Time

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### TABLE 4.5

**Staging Policy Sensitivity**

**Effect of Staging Policy on AUP**

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**Effect of Staging Policy on Avg Work Month**

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**Effect of Staging Policy on Avg Fix Time**

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Captain Brian L. Sutter was born on 7 March 1954 in Austin, Minnesota. Upon graduation from high school, he attended the United States Air Force Academy from which he received a Bachelor of Science degree in Mathematics in June 1976. He completed pilot training at Reese AFB, Texas in 1977, and remained there to instruct in the T-37 aircraft until February 1981. He transferred to McGuire AFB, New Jersey where he qualified and progressed to flight examiner in the C-141 aircraft. He entered the School of Engineering, Air Force Institute of Technology in 1984. In December 1985, he graduated and was assigned to the Analysis Branch, Air Force Military Personnel Center.

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Title: **AN ANALYSIS OF AIRCRAFT MAINTAINABILITY IN STRATEGIC AIRLIFT: A SLAM SIMULATION**

Thesis Advisor: Charles E. Buehler, Ph.D., Lieutenant Colonel, USAF Assistant Professor Department of Operational Sciences

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This investigation examined the C-17's mission capability in terms of each aircraft's utilization and that utilization's effect on the aircrew. Specifically, average monthly flying times and average work months, as well as aircraft utilization, were found to be affected by changes in flying time limits, staging policies, target utilization rates, the number of crews, and the launch reliabilities.

The analysis was accomplished through a SIMMOD simulation of a portion of the NAC airlift system. A single nonestation and two nonstation models were utilized; however, only the single nonestation model was analyzed. The output of the simulation was regressed to yield an estimating equation for achieved utilization, average monthly flying time, and average work month for both a NATO and a SWA scenario.

Parameters varied in the sensitivity analysis were crew ratios, target utilization, monthly in-quad flying limits, and staging policies. Results pointed toward 4.8 crews per C-17 without considering the cost trade-offs. Staging one crew at an enroute base for every forty-five planned mission transits seemed to be optimal. The results also showed a significant benefit in the sustained phase when the 30/90 day limits were raised to 150/450 hours.
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