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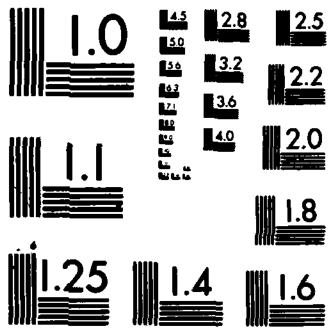

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USER NEED SATISFACTION AS
A BASIS FOR TACTICAL
AIRLIFT SCHEDULING

THESIS

Joseph C. Bryant Captain, USAF
Stephen R. Gordon Captain, USAF

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Specific classes of supply established by the U.S. Army are considered, with the degree to which user needs are met in each class defining the term "user need satisfaction." A detailed tactical airlift resupply network using SLAM (Simulation Language for Alternative Modeling) is developed for testing the effect of varying different airlift scheduling heuristics and sets of supply class weights used to determine scheduling priorities. A modified worth assessment technique is used to determine numerical values for each supply class, reflecting the relative worth of each class to the Army. These values are used to obtain a score reflecting the effectiveness of the resupply effort, based on average supply levels maintained at each base over a thirty-day period.

The combination of two scheduling heuristics, each at two levels, and scheduling weight, at three levels, produce a total of twelve policies, and ten replications for each policy are accomplished. Both a multiple ranking procedure and analysis of variance are employed to compare the mean scores for each policy.

Analysis of results shows that proper combinations of heuristics and weight set can be used in scheduling airlift sorties to reflect the needs and desires of Army theater commanders, according to how they value each supply class. The study concludes with recommendations for further sensitivity analysis using different scenarios, and the application of Multiattribute Utility Theory to assess utility curves from Army decision makers for each supply class.

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USER NEED SATISFACTION AS A BASIS FOR TACTICAL AIRLIFT SCHEDULING

THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Operations Research

Joseph C. Bryant, B.S.
Captain, USAF

Stephen R. Gordon, B.A.
Captain, USAF

March 1984

Preface

This thesis studies the feasibility of using a new measure of effectiveness for tactical airlift. We first became interested in pursuing this topic after considerable discussion of our mutual belief that the traditional measures of effectiveness used by the Military Airlift Command--departure reliability, aircraft utilization rate, and total cargo tonnage delivered--were inappropriate for tactical airlift. Because the purpose of tactical airlift in the resupply role is to support troops in combat, we felt that the needs of the Army in specific categories of supply should be the driving force in tactical airlift scheduling. We also held the opinion that the effectiveness of an airlift resupply effort should be measured by how well the Army's needs are met. Our discovery that previous work on this particular subject was practically nonexistent motivated us in our attempt to make a positive contribution by doing original research in this area.

We wish to express our appreciation to our advisors in the Department of Operational Sciences, Maj James R. Coakley and Lt Col Gerald R. Armstrong. Their enthusiastic support, encouragement, constructive criticism, and timely suggestions contributed significantly to the success of our efforts.

Mere words are insufficient to express the debt of gratitude we owe our wives, Barbara Bryant and Ruthie Gordon, and our children, Leslie and Lauren Bryant and Sarah Gordon. Their constant love, understanding, and great sacrifice throughout the past year were very important to the ultimate completion of this project.

Joseph C. Bryant

Stephen R. Gordon

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Abstract

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USER NEED SATISFACTION AS A BASIS FOR TACTICAL AIRLIFT SCHEDULING

I. Background

Introduction

Since the end of World War II, the United States has assumed major responsibility for the security of the free world. In accepting this responsibility, the U.S. has made commitments to protect the vital interests of its allies, including the direct involvement of American military forces if those interests are threatened by an aggressor. If American involvement becomes necessary, the means must exist to rapidly deploy forces in significant numbers to counter the threat. The Military Airlift Command (MAC) gives the U.S. the ability to deploy ". . . forces to any part of the world and support them there. Airlift embodies a key facet of a fundamental Air Force capability--rapid, long range mobility [10:3]."

MAC is divided into two major areas which together make its long-range deployment capability possible--intertheater and intratheater airlift. Intertheater airlift, also known as strategic airlift, involves long-range transportation between theaters of operations. Intratheater or tactical airlift involves the movement of personnel, supplies and equipment between points within a particular theater (18:i). MAC operates 77

C-5 and 268 C-141B aircraft, designed to perform the strategic airlift mission, and 258 C-130 aircraft devoted to tactical airlift (33:9). An example best illustrates why both categories of aircraft are required to accomplish the MAC mission, and points out differences between the two.

The airlift mission to Khe Sanh, South Vietnam, was one of the best known airlift missions of the Vietnam War. A 6,000 man Marine force was surrounded by enemy forces numbering more than 20,000, and could be resupplied only by air. The runway was suitable only for C-130 operations because it required an aircraft with a short field landing capability. The C-141 aircraft had the size and long range necessary to transport large quantities of supplies and equipment from the United States to Da Nang, a major aerial port only thirty minutes by air from Khe Sanh. That thirty-minute sortie flown by the C-130 was every bit as important as the thousands of miles flown by the larger C-141 (19:13).

> In other words, getting loads 99.9 percent of the distance from the West Coast of the United States to Khe Sanh accomplished nothing until intra-theater airlifters brought the munitions and supplies to the battle. During the last two weeks of February 1968, C-130s delivered by airdrop and extraction 148 tons of critical supplies daily (90 percent of everything reaching Khe Sanh). Khe Sanh would have fallen without such support [19:13].

In addition to the different capabilities of the aircraft used in strategic and tactical airlift, a significant difference between the two airlift types was demonstrated in

Vietnam. The C-141s delivered materiel to only the major aerial ports such as Saigon, Cam Ranh Bay, and Da Nang, from which the C-130s and other tactical airlift aircraft resupplied the ground forces throughout the country. The flow of C-141s was steady, regardless of specific ground operations being carried out at a particular time. The scheduling of strategic airlift missions was very predictable since it was based generally on the total amount of materiel required to support the overall war effort.

In sharp contrast to strategic airlift scheduling was the scheduling of tactical airlift missions. While there was certainly a large amount of routine resupply to units within the country, certain combat situations required rapid resupply on short notice. In such situations, troop commanders requested tactical airlift based on the needs of the moment. In short, the airlift user dictated the scheduling of a large number of sorties. "The primary objective of tactical airlift was responsiveness, and accomplishment of the mission determined the generation of flying hours [46:9]." In the aftermath of Vietnam, General William Momyer, former commander of Tactical Air Command, stated that while strategic airlift could ultimately be handled by commercial carriers, the tactical airlift mission was inseparable from combat, and required emphasis on entirely different factors (5:10).

The Issue

Despite the fact that the strategic and tactical airlift missions are radically different, MAC uses the same basic criteria to measure their effectiveness (46:11). Traditionally, these criteria include tons of cargo moved within a certain time period, average aircraft flying time per day (utilization or ute rate), departure reliability (percentage of on-time takeoffs) and hours flown to hours programmed. Because of the predictable nature of strategic airlift requirements in wartime, these criteria are all appropriate measures of its effectiveness (24:4). Tactical airlift requirements, as previously noted, are generated to a large degree by the user. Because combat situations are constantly changing, tactical resupply of the units affected by these changing conditions is often more important than the need to maintain an efficient schedule (46:9). Despite this lesson supposedly learned in Vietnam, the same criteria of tons moved, ute rate, departure reliability and hours flown are still used as the primary measures of tactical airlift effectiveness (46:11).

Even for routine resupply missions in Vietnam, criteria such as total tons of [illegible]rgo moved resulted in the inefficient use of tactical air[illegible] [illegible]-130 crew members during this period became suspicious when [illegible] in palletized cargo began to look familiar. The crew members made a point to mark these loads in inconspicuous places to determine if they were ever taken off the pallets. After proving to themselves that this was indeed the case, the crew members reported they repeatedly carried the same loads from base to base, the markings undisturbed, over periods of weeks or months. They were convinced the loads were continuously scheduled for airlift because total cargo tonnage was a major measure of effectiveness (2).

A different measure of effectiveness (MOE) for tactical airlift is needed for several reasons. The fact that tactical requirements are often determined by the user as a result of changing combat situations makes response to these requests more important than the need to efficiently use the aircraft. Current MOEs do not consider different supply categories important to the user nor do they take into account shortages in particular categories which might give one base priority over another in mission scheduling. Finally, meeting the user's needs--that is, whether the user got the supplies he needed when he needed them--is not considered as a measure of effectiveness.

Problem Statement. The measures of effectiveness applied to strategic airlift are inappropriately applied to tactical airlift. The MOEs currently used are measurements made from the point of view of the airlift supplier rather than from that of the user. They make efficient use of aircraft and gross tonnages of cargo delivered more important than satisfying the particular supply needs of the user. Consequently, these MOEs do not drive the scheduling process toward meeting the tactical airlift user's needs.

Literature Review

Most of the work done in the area of airlift scheduling has been oriented toward strategic airlift. Holck and Ticknor developed a model to simulate the wartime capability of MAC in a European scenario. The model considered only two bases, one in the United States and one in Europe. One of the conclusions of the study was that tons of cargo delivered should be used as the primary measure of airlift effectiveness instead of ute rate (24:78). As previously discussed, neither of these is a suitable MOE for tactical airlift. In another study, Hamilton and Poe developed and tested a method for simulating strategic airlift using classical scheduling techniques. Although this study also addressed strategic airlift, it did prioritize cargo by employing job shop scheduling rules. However, the cargo was prioritized in categories according to its physical size--bulk, oversized, and outsized--rather than by specific categories, or classes, of supply. Also, the purpose of the cargo prioritization in this study was to increase the flow through the strategic airlift system to reach a single point of debarkation in the theater (21:118).

The M-14 model developed and currently used by MAC is designed to identify and resolve strategic airlift choke points at the air base level during wartime surge situations. It includes a 422 air base network for studying strategic problems on a worldwide basis (37:465). Although the possibility of extending the model to consider tactical airlift is under consideration, the model at its current stage of development is extremely large and complex. For this reason, an extension to model tactical airlift scenarios is not expected for some time (28).

The Model for Intertheater Deployment by Air and Sea (MIDAS) is another deployment model, used by the Office of the Secretary of Defense. Its very name states that it is an intertheater or strategic model. MIDAS uses heuristic scheduling algorithms to accomplish the deployment scheduling problem but considers only those aircraft which have strategic capabilities. It considers neither the intratheater deployment of units and their equipment from the offload point in the theater of operations nor the resupply of those units (26).

The strategic airlift models are concerned only with the initial deployment of forces to an aerial port of debarkation (APOD) in the theater of operations. They are not designed to model further movement of those forces from the APOD or their resupply. A few airlift models have been developed to consider the tactical situation, but only one of the four models of this type which were examined is currently in use.

A simulation model developed by Bowers deals with the scheduling of tactical airlift, but for a major deployment of Army forces specifically within the Alaskan theater, rather than for an extended resupply operation. The MOE for this model is closure time of the force deployment from origin to destination, and different factors are varied to determine their effect on this time (4:23). This model is similar to the strategic airlift models in that it deals with the deployment phase of an operation rather than the airlift required to sustain forces in the theater. Cargo in this model is prioritized, but the priorities are based on the requirements of the force deployment. The model is not appropriate for scheduling airlift resupply sorties prioritized on the basis of user needs.

A tactical airlift model used by the Mobility Division, Air Force Studies and Analysis (HQ USAF/SAGM), is the Tactical Airlift System Simulation Model (TASSM). Last used in 1979, TASSM is a deterministic model concerned with the movement of forces from the initial source to their final destination. The force movement requirements are satisfied by solving a transportation problem, using Vogel's transportation solution procedure which minimizes the distances from source to destination (45:p. 1-5). TASSM, like Bowers' Alaskan theater model, is concerned primarily with the movement of forces. It does not consider different classes of supply to establish mission priorities.

Another model developed for HQ USAF/SAGM, but not currently used, is the Airlift Vehicle Allocation Program (AVAP). This model simulates daily intratheater airlift demand and allocates airlift resources until the demand is satisfied. All aircraft are then returned to their home stations. Two aircraft fleet modes are available--fixed fleet and force sizing. If the aircraft fleet is fixed, the model determines how much cargo can be airlifted for that force size. The force sizing mode determines how many additional aircraft are required to satisfy demand (1:p. C-3). While this model actually considers the resupply problem, it does not consider base scheduling problems, different types of cargo, or aircraft maintenance problems (1:p. C-3). These limitations make it unsuitable for scheduling tactical airlift based on the user's need for each class of supply.

One theater airlift model currently in use is the Tactical Airlift System Comparative Analysis Model (TASCAM). TASCAM is designed to represent an intratheater airlift logistics system and is applicable to any theater (12:p. 2-1). The model is very detailed in that it considers maintenance problems, available ramp space, on/offload times, and scheduled airlift based on priorities. It also includes fighter aircraft activities and simulates competition at the PODs between strategic and tactical airlift aircraft (12:pp. 2-11 to 2-12). The major limitation of this model is that it uses scheduling priorities based on whether cargo is bulk, oversized or outsized. Different classes of supply are not considered, and the MOE is total tons of cargo delivered (12:p. A2-13).

Limitations of the models investigated make them inappropriate for scheduling tactical airlift to satisfy user needs in different supply classes. The MOEs of these models--ute rate, closure time and total cargo tonnage--are meaningless to the Army commander whose forces are engaged in battle. User priorities and requirements should play a much larger role in tactical airlift scheduling.

> A battalion commander engaged in an intense fire fight and seriously low on ammunition is interested only in the responsiveness and reliability of the aircraft delivering his supplies. He is not the least concerned with the efficient utilization of the airframe [46:9].

Total cargo tons delivered cannot be a measure of effectiveness unless they are the "tons" the commander most needs at the time. Only if the forces under his command are resupplied with the required classes of supply in sufficient quantities such that they can continue to fight will the airlift operation be considered effective. The tactical airlift user will suffer the consequences of an ineffective resupply effort. If his needs are used to prioritize the scheduling of resupply sorties, a direct measure of effectiveness is the degree to which those needs are met.

Research Objectives

Existing models do not consider as a measure of effectiveness the ability of tactical airlift to satisfy specific user needs in a resupply scenario. The objectives of this research effort are, therefore, threefold:

1. Develop a measure of effectiveness for tactical airlift scheduling based on the satisfaction of the user's needs. User needs in different supply categories should be the primary determinants of scheduling priorities.

2. Develop a model of a specific tactical airlift scenario. This model will be used to demonstrate the feasibility of this MOE as a basis for tactical airlift scheduling.

3. Experiment with this model to determine the impact, if any, on the level of user need satisfaction attained:

a. By the application of different airlift scheduling heuristics.

b. By weighting certain supply classes more heavily than others in the determination of scheduling priorities.

Summary

This chapter establishes the significant differences existing between the strategic and tactical airlift missions. Strategic airlift provides the long-range capability required to project forces between theaters, while tactical airlift operates within a theater of operations to provide for direct resupply of deployed forces engaged in combat operations. Despite these differences, the same measures of effectiveness--utilization rate, closure time and cargo tons delivered--are applied to both strategic and tactical airlift.

The ability of tactical airlift to satisfy the needs of the user is the MOE which should be applied to tactical airlift. Existing models, including the MAC M-14 model, the Model for Intertheater Deployment by Air and Sea (MIDAS), the Tactical Airlift System Simulation Model (TASSM), the Airlift Vehicle Allocation Program (AVAP), and the Tactical Airlift System Comparative Analysis Model (TASCAM), are all shown to be inadequate for studying the feasibility of this MOE as a means to determine tactical airlift scheduling priorities. As a result of existing model limitations, research objectives are outlined to develop and experiment with a new model for this purpose.

II. Methodology

Introduction

In order to meet the research objectives outlined in Chapter I, a particular approach must be followed. This chapter discusses, in general terms, the appropriate justification for the methodologies selected to accomplish the objectives.

Satisfaction of User Needs

Developing a measure of effectiveness based on satisfaction of user needs includes the requirement that the term "cargo" be broken down into sub-categories more specific than bulk, oversized, and outsized. To account for supplies and to aid in the calculation of supply requirements, the Department of the Army categorizes supplies into nine classes listed in Table I (35:p. 5-27). A certain desired quantity of supplies must be established by the user for these classes, and the degree to which the needs of the user in each class are met measures the effectiveness of the tactical resupply effort and defines the term "satisfaction of user needs."

Although all nine classes of supply are important, the Army considers classes III, V, and IX (POL, Ammunition, and Repair Parts) to be critical supplies, or ". . . those supplies vital to the support of operations [13:p. 5-1]." Army doctrine states that adequate fuel for force movement, adequate ammunition to engage enemy targets, and repair capability to keep

TABLE I

Supply Classes (15:p. 3-2)

Class I	Subsistence
Class II	Individual Equipment--Clothing, etc.
Class III	POL--Petroleum, Oil, and Lubricants
Class IV	Construction Materials
Class V	Ammunition--All Types
Class VI	Personal Demand Items
Class VII	Major End Items--Combinations of Products Ready for Intended Use Such as Tanks and Vehicles
Class VIII	Medical Materials
Class IX	Repair Parts and Components--Required for Maintenance Support

weapons systems operating are the essentials which provide the force with its fighting capability and must have priority over other classes of supply (13:p. 3-21, p. 5-2).

To consider only these three classes, however, would be to neglect special needs represented by other classes (subsistence, for example). Neglecting these other classes in a model of a resupply system would reduce its credibility. A relative ranking of all supply classes must be determined in order to quantify the level of need satisfaction attained by the resupply system.

A methodology which can be used to assign realistic numerical values to the supply classes, based on their relative value to the Army, is worth assessment. Worth assessment provides a formal methodology to establish an ordinal preference relationship between factors not quantifiable in terms of money (39:355). In the case of the supply classes, there are multiple objectives, i.e., the desire to maintain optimal or near optimal levels in each. By using a modified version of this technique, the assessments of Army officers with experience in combat arms will be used to determine their individual rankings of all supply categories from most to least valuable. Their individual assessments will be combined to obtain a single ranking of the relative supply class values. The consensus ranking of the officers will be used to represent the worth to the Army of each supply class considered in the system model. The values associated with the worth of each class will be used to quantify, in terms of a numerical score, the ability of the resupply effort to satisfy user needs. Details of the worth assessment session with the Army officers are discussed in Chapter III.

Model Development

Because combat conditions change over time, supply consumption rates in certain classes change as well. A unit which defended a position for several days or weeks may launch an offensive, or another unit may come under siege in a different area of the theater, shifting emphasis to that particular area. In either case, the rates of supply consumption will increase or decrease with changing conditions. To model these changing conditions, the method selected must take into account the overall situation at the end of a given time period and predict the situation which will exist at the beginning of the following time period.

Shannon defines a model as

> . . . a representation of an object, system, or idea in some form other than that of the entity itself. Its purpose is usually to aid, as in explaining, understanding, or improving a system [41:4].

Among the benefits of modeling are its use to predict and to aid in experimentation (41:5). In the case of tactical airlift scheduling, a model can be used to predict base supply levels under different consumption conditions, and as an aid to experiment with different scheduling heuristics and sets of weights to determine mission scheduling priorities.

One portion of the model will require the calculation of daily supply levels at each base in each class. Consumption in certain classes depends heavily on combat conditions and, in the real world, while the type and length of combat situations might be predicted, they cannot be known with certainty. The methodology most applicable to the dynamic and complex nature of an airlift scenario with changing combat conditions over a period of time is simulation.

A realistic scenario involving a network of bases will be developed and computerized as a simulation model. Development of the scenario, justification of parameters used, and assumptions are discussed in Chapter III. Details of the simulation model itself, both in conceptual and specific terms, are discussed in Chapter IV.

Verification and Validation

Verification and validation are two important areas which must be given careful consideration in the development and use of a simulation model. Verification is defined as ". . . determining whether a simulation model performs as intended," while validation is ". . . determining whether a simulation model (as opposed to a computer program) is an accurate representation of the real world system under study [29:333-334]." The process followed to verify and validate the simulation model of the tactical airlift resupply system are discussed in Chapter V.

Experimental Design and Analysis

Once the model is developed, verified, and validated, experimentation to determine the effect of changing scheduling heuristics, and of changing the weights of the different supply classes in the determination of scheduling priorities, can be conducted. An experiment will be designed to show the effects on the level of user need satisfaction attained (in terms of the score) for each combination of heuristic and weighting methods considered. Statistical analysis of these results will be conducted to determine if one combination gives significantly better results than the others. The experimental design, including the specific heuristics and weighting combinations, sample size determination, procedures used in testing for significance and results of experimentation are given in Chapter VI.

Summary

This chapter discusses the approach to be followed to meet the research objectives stated in Chapter I. The term "satisfaction of user needs" is defined by considering cargo in nine classes of supply, corresponding to the supply classes considered by the Department of the Army, and the level of supplies in each category maintained by a tactical airlift resupply effort. In an attempt to determine how the Army values each supply class, a modified worth assessment procedure will be used to assess the opinions of Army officers with operational experience. Justification for the use of a simulation model is given, as well as the importance of verification and validation in its development. Once the model is developed, an experiment will be conducted to study the effects on the level of user need satisfaction attained by varying scheduling heuristics and scheduling priority determinations. Results of the experiment will be tested to determine if any particular combination gives significantly better results.

III. Conceptualization

Introduction

In order to study the feasibility of employing a measure of effectiveness based on the satisfaction of user needs as the driving force in tactical airlift scheduling, and to experiment with different scheduling heuristics and sets of supply class weights to obtain "good" solutions to the problem, a specific airlift resupply scenario is required. Each tactical airlift situation is unique, requiring that specific problems be overcome, such as distances between bases in the system and different resupply requirements of the ground forces. Unlike the use of strategic airlift in a force deployment, tactical airlift must respond to daily or even hourly changes in the theater of operations. Such changes result in varying combat intensities which directly influence consumption rates. The emphasis of the resupply effort may shift from one base to another which, because of a change in the battlefield situation, is now consuming certain classes of supply at a higher rate. As the consumption rates change at each base, airlift scheduling must be flexible enough to respond in a timely manner. Simulating the resupply of a network of deployed Army units should be based on a realistic battlefield situation which is itself scenario specific.

Scenario Justification and Geography

The scenario used in this study is situated in Southwest Asia, specifically Iran, and is selected for three reasons. First, the United States has vowed to protect the flow of energy resources from this region to the west. President Carter stated in 1980 that

> . . . any attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force [7].

It was this statement, in the aftermath of the Soviet invasion of Afghanistan in 1979 which led to the formation of the Rapid Deployment Force. Secondly, there is a high likelihood that U.S. determination to defend its interests might be tested. The Soviet Union is well aware of the critical importance of the region to the United States. A move by the Soviets to take control of the oil fields and the strategic Persian Gulf is well within the realm of possibility, given their close proximity to Iran and the precedent established by the invasion of Afghanistan. The USSR is also expected to become a major competitor for worldwide energy resources before the year 2000 (38:6). Thirdly, the scenario is situated in Iran because the combination of a limited surface transportation system and rugged, mountainous terrain makes any U.S. force in the country heavily dependent on aerial resupply (34).

The battlefield situation for the tactical airlift scenario is based on an invasion of Iran by Soviet forces from the northeast. Intelligence reports of an impending Soviet invasion and a deteriorating diplomatic situation precipitated introduction by the U.S. of a force of three divisions into Iran. In their initial advance, the Soviets captured the capital city of Tehran before being met northeast of the Zagros mountain range by U.S. forces. A battle front has been established along the northeastern edge of the mountains, and the American divisions are headquartered adjacent to three Iranian airfields--Arak, Khatami, and Yazd (Figure 1). These airfields are also accessible by major roads. The U.S. forces are composed of one armored and two mechanized divisions, each with a strength of approximately 16,000 men. This force structure was chosen based on the anticipated use by the Soviets of mechanized and heavily armored forces, and because the terrain in northeastern Iran is suited for these types of units. The division bases are approximately twenty-five kilometers behind the forward edge of the battle area (FEBA) and are in reasonable locations based on the direction of the Soviet attack (34).

Tactical resupply of the American forces is carried out by surface and aerial transportation from the sea and aerial ports of debarkation (PODs). Sealift is received at the port of Bushehr, while strategic airlift is received at the Shiraz airport. All supplies enter the theater at these two PODs and

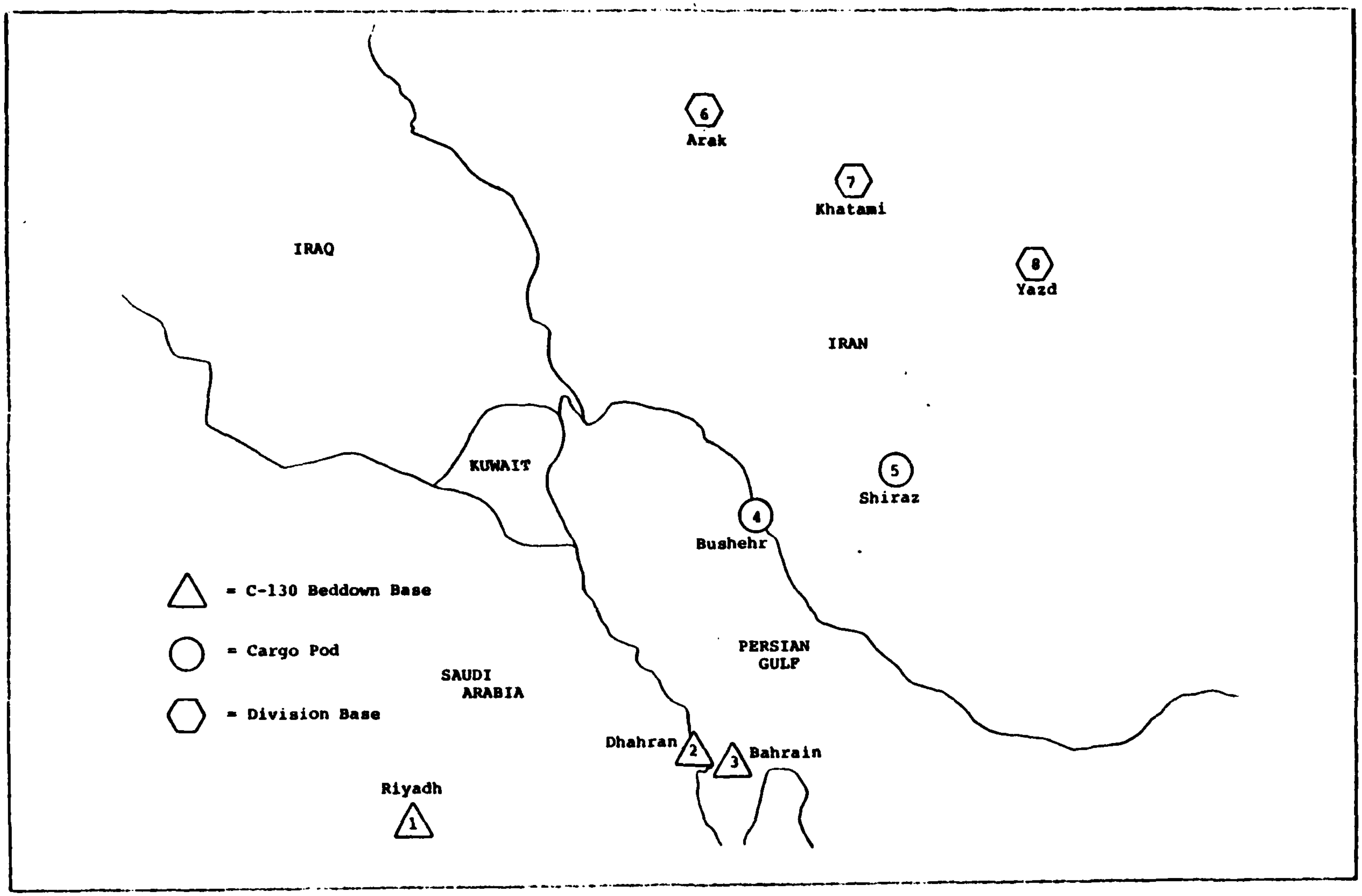

Figure 1. Geographical Situation

are delivered to the division bases predominantly by air, using the C-130 aircraft. Surface transportation is severely limited by long distances (Table II) between the PODs and division bases, and by the desolate, mountainous terrain. This mode of transport is used only for the resupply of wheeled and tracked vehicles, many of which are outsized items not capable of movement by C-130. In addition to resupply, the airlift of casualties from the division bases to Shiraz for evacuation from the theater is considered in the scenario.

The C-130 aircraft used in the scenario include both the E and H models of the aircraft currently in service. Because the two models of the aircraft are identical in terms of their cargo carrying capability, they will be considered identical for purposes of this scenario. The following performance and capability data apply:

True airspeed	290 knots
Maximum gross weight	155,000 pounds
Fuel capacity	62,900 pounds
Maximum 463L pallets	6 pallets

The airspeed used is an approved true airspeed option specified by MAC (11:p. 6-7). The gross weight and fuel capacity are actual limitations of the aircraft, and the maximum pallet load is known from years of operational airlift experience (17:p. 5-19, p. 1-52). The aircraft used in the scenario are based at two locations in Saudi Arabia, Riyadh and Dhahran, and at the

TABLE II

Matrix of Distances Between Bases
(Nautical Miles)

	Base 1	Base 2	Base 3	Base 4	Base 5	Base 6	Base 7	Base 8
Base 1 (Riyadh)	-	210	230	335	430	590	540	590
Base 2 (Dhahran)	210	-	25	165	230	470	400	405
Base 3 (Bahrain)	230	25	-	165	225	475	395	390
Base 4 (Bushehr)	335	165	165	-	100	320	230	250
Base 5 (Shiraz)	430	230	225	100	-	315	200	165
Base 6 (Arak)	590	470	475	320	315	-	135	270
Base 7 (Khatami)	540	400	395	230	200	135	-	130
Base 8 (Yazd)	590	405	390	250	165	270	130	-

international airport on Bahrain (Figure 1). The aircraft are organized in squadrons of sixteen aircraft with the standard ratio of two aircrews per aircraft. Up to nine squadrons (active duty) can be deployed to the region, based on the available ramp space at the basing locations (16). The decision was made to base the tactical airlift forces at locations separate from the PODs because the ramp space and servicing required would restrict the capability of the PODs to handle strategic airlift aircraft arriving in the theater. Basing the C-130s in Saudi Arabia and Bahrain also provides better security and makes use of existing facilities (ramp space and refueling capabilities).

Scenario Rationale

The scenario as outlined is intended to create a realistic experimental situation. It is not meant to reflect any particular U.S. war plan, nor need it necessarily be plausible in its sequence of events. The key point is that this scenario is intended to provide a challenging test environment for use in experimentation with a new tactical airlift measure of effectiveness--satisfaction of user needs.

Airlift Scheduling Process

The scheduling of a large number of airlift missions during a sustained resupply scenario requires considerable planning and coordination. Although some short notice missions are expected, the majority will be accomplished on the basis of a published schedule for a given time period. Published schedules provide maintenance organizations with information as to the number of aircraft which must be generated during the scheduling period and the required configurations. Responsible individuals at onload and offload points can plan the proper number of servicing crews based on the number of arrivals expected during the period. Individual unit aircrew schedulers also use the published information to schedule properly rested crews against each mission. In short, a well-planned schedule of operations should facilitate the accomplishment of the airlift mission--to provide the soldiers in the field with sufficient quantities in all supply classes.

In this scenario, an airlift schedule, or air tasking order (ATO) is published every twelve hours, and execution of this ATO begins three hours after its publication. The three-hour time lag provides the various organizations involved sufficient time for the preparation of aircraft, crews, and equipment before the first mission is scheduled to depart. The missions for each twelve-hour period are scheduled based on priorities established at the three division bases, according to the quantities on hand in each supply class. Those missions with the highest priority are scheduled to depart first. The missions are assigned to the three aircraft bases, and departures and arrivals throughout the scheduling period are "flowed" to avoid over saturation of the on/offload capabilities of any one base at any one time. As each aircraft is offloaded at a division base, the status of each appropriate supply class is updated. At the end of each period, the status in all supply classes is updated for the unit's consumption according to the combat intensity experienced by the division during that time. The current status at the end of the period is then used to determine the mission priorities for the next schedule. This process is repeated at twelve-hour intervals throughout the scenario duration.

Typical Mission

All airlift missions originate from and terminate at the aircraft home bases. From its home base, each aircraft on a resupply mission flies to either Bushehr or Shiraz to onload cargo or fuel. From the POD, the aircraft proceeds to one of the three division bases for offload. After this offload, the aircraft returns to one of the PODs to onload for another sortie. Following the second resupply sortie, the aircraft recovers at its home base where the crew enters crew rest (for a minimum of twelve hours) and the aircraft maintenance status is assessed. The required maintenance and servicing functions are performed on the aircraft and another crew is alerted to fly the next mission. The sequence of events for an aeromedical evacuation (air evac) mission differs slightly from that of a resupply mission. For this mission, an aircraft departs from its home base and proceeds directly to one of the three division bases to onload patients. After flying to Shiraz to offload the patients, the aircraft flies another air evacuation sortie from Shiraz to a division base and back to Shiraz before returning to its home base.

The amount of crew duty time remaining after each sortie determines whether or not the aircraft continues its mission. The normal maximum crew duty time specified in MAC Regulation 55-130 is sixteen hours (11:p. 3-4). The aircrew can accept an extension of crew duty day, if approved by the theater Commander of Airlift Forces, but eighteen hours is the absolute maximum crew duty period (11:p. 3-4). Although each mission is planned to include two resupply or air evac sorties, certain conditions may preclude mission completion. Maintenance delays or delays for onloading or offloading due to saturation of service capabilities contribute to this problem. The check of remaining crew duty time is made after each sortie in an effort to keep crew duty time below eighteen hours. If a long delay will result in the aircrew exceeding the maximum crew duty length, it remains overnight at the point where the delay occurs.

Scenario Parameters

Aircraft Configurations and Onload/Offload Times. For each mission, an aircraft can have one of three configurations--

cargo, POL, or air evac. Maximum capacities for these configurations are determined based on available planning factor data:

1. Cargo configured missions involve the airlift of all but one of the supply classes considered (specifically POL). The eight "cargo" supply classes supplied by airlift in the scenario are given in Table III. Planning factors based on historical figures and given in Air Force Regulation 76-2 specify that the average weight of a standard 463L pallet is 2.3 tons for all cargo classes except ammunition. Ammunition pallets have an estimated average weight of 3.3 tons per pallet (32). Although the C-130 aircraft is limited to a maximum of six cargo pallets per sortie, the weight of ammunition pallets restricts their number to five due to weight limitations of the aircraft cargo ramp (the location of the sixth pallet) (6:p. 2-19). An aircraft loaded with five ammunition pallets can carry a nonammunition pallet in the sixth pallet position.

2. POL configured missions are those which deliver bulk fuel to the divisions in aircraft configured with a special collapsible bladder (14:p. 3-15). While experts agree that airlift is the most inefficient way of transporting fuel, they also agree that in a scenario such as Iran, where distances between bases are great, roads are scarce and susceptible to interdiction, and pipelines are not available, airlift of POL may be the only viable alternative (9; 34). For planning

TABLE III

Classes of Supply Transported by
Cargo Configured Aircraft

Class	Description
I	Subsistence
II	Clothing and Equipment
IV	Construction Materials
V	Ammunition
VI	Personal Demand Items
VIII	Medical Supplies
IX	Repair Parts and Components

purposes, a bladder configured aircraft is capable of a maximum load of 6,500 gallons (9). At 6.5 pounds per gallon, the total weight of 42,250 pounds is within the capabilities of the aircraft in terms of weight.

3. Aeromedical evacuation configured C-130 aircraft are capable of transporting up to seventy-four litter patients per sortie (17:p. 4-236). However, a typical configuration includes a mix of approximately 50 percent litter and 50 percent ambulatory patients, and is the configuration used in the scenario (44).

Aircraft onload and offload times depend on the aircraft configuration. For cargo configured aircraft, Air Force planning factors specify 2 hours for onload and 1.5 hours for offload. However, these times are average figures which include servicing and possible delays for maintenance problems (32). Because maintenance delays and taxi times are considered separately, on and offload times are reduced accordingly. Cargo onload ranges from 0.5 to 1.5 hours, with 1 hour being the most likely. Offloads range from 0.5 to 1 hour, with 0.75 hour most likely.

POL configured aircraft (bladder birds) require an average of 2 hours for onload and offload of fuel (9). For variability of loading/offloading times, a range from 1.5 to 2.5 hours is used, with 2 hours being the most likely.

Aircraft configured for aeromedical evacuation differ in onload and offload times, given the previously mentioned mix of litter and ambulatory patients. Experience gained from training exercises indicate that onload can be accomplished in 0.5 to 0.75 hours, and offload in 0.75 to 1 hour (44). This variation is due to an assumption on the part of the medical crew that patients will be onloaded under possible hostile fire conditions requiring a rapid onload. A more stable environment is expected at the offload point permitting a slower offload of patients (44).

Maintenance Considerations. The assumption, in any airlift scenario, that all aircraft will be in commission at all times, and that no delays will be encountered due to maintenance or logistics, is totally lacking in credibility. Although the

C-130 is generally considered a very reliable aircraft, it is nevertheless subject to occasional mechanical breakdowns. In addition to unscheduled maintenance problems, the aircraft are periodically susceptible to programmed maintenance and the accomplishment of necessary inspections of critical components.

On a given day, a certain number of aircraft will be unavailable for mission tasking for various logistics-related reasons. An informal, unpublished analysis of aircraft generation exercises and Operational Readiness Inspections was conducted by the Headquarters MAC, Logistics Analysis Directorate to determine the average in-commission rate for the C-130. Results of the study showed an overall, steady-state, in-commission rate of approximately 82 percent of the available aircraft each day (40). In this scenario, an aircraft which is determined to be out of commission will be unavailable for scheduling for a period of twenty-four hours.

In addition to the in-commission rate, there is also a possibility at the aircraft home stations and at each enroute stop that the aircraft will experience departure delays. Maintenance problems are often discovered by the aircrew after the aircraft has been assigned a mission departure time at home station or prior to departing after onload or offload at an enroute location. These problems can result in minor delays ranging from less than an hour to considerably longer than twenty-four hours. To realistically represent the possibility of maintenance delays, data collected by the MAC Integrated Reporting System were obtained from HQ MAC/LGXA and applied to the Iranian airlift scenario. The data reflect all enroute and home station maintenance-related delays encountered by active duty MAC C-130s during calendar year 1983 (3). Table IV provides a breakdown of the delay times and the percentages for each category. Of some 44,400 C-130 departures during 1983 (based on an average of 3,700 per month), 1,971 departure delays were experienced, resulting in a late departure rate of 4.44 percent (3).

The 82 percent in-commission rate and the 4.44 percent delay rate are incorporated into the scenario through the use of probability distributions. Aircraft delayed at enroute locations in excess of the crew duty time required to return to home station remain at that location until the crew completes a normal crew rest period. Required maintenance action is assumed to be performed at the enroute base by maintenance personnel either in place at that base or brought in on the next available sortie. After the aircraft is repaired and crew rest is complete, the aircraft returns to its home station.

Airfield Capabilities. The maximum number of aircraft on the ground (MOG) at a base at any one time is a function of the available ramp space. MOG figures for six of the eight bases in the scenario were obtained from the MAC Operations Research Division (HQ MAC/XPSR):

TABLE IV

C-130 Departure Delays (CY 1983) (3)

Delay Time (Hours)	0-1	1-2	2-3	3-4	4-8	8-24	>24
Number of Late Departures	596	399	221	124	177	231	223
Percentage of Total	30%	20%	11%	6%	9%	12%	12%
Total Delays--1,971							

Base	Type	MOG
Riyadh	C-130 Home Base	42
Dhahran	C-130 Home Base	48
Bahrain	C-130 Home Base	39
Bushehr	Sea POD	12
Shiraz	Aerial POD	16
Khatami	Division Base	17

(23)

MOG figures for the remaining two division bases in the scenario, Arak and Yazd, were not available. Although in reality these bases may have a lower MOG than Khatami, for purposes of the scenario it is assumed that the MOG for these two bases has been made equal to that of Khatami (17) by using pierced steel planking (PSP). This material was used in Southeast Asia, and is present at some NATO bases to provide additional ramp space for aircraft in the C-130 gross weight category. In addition to indicating available ramp space, MOG figures imply the maximum number of aircraft which can be simultaneously serviced (loaded, offloaded, refueled, etc.) at a base (43).

Consumption. Although supply consumption rates in most supply classes are constant according to division type, consumption of supplies in classes III and V (POL and ammunition) is also a function of the intensity of combat experienced at any point in time. There are four levels of combat considered in this scenario--intense, moderate, light, and reserve. These levels are identical to those specified in planning factor data supplied by the U.S. Army Logistics Center for input to the Joint Strategic Capabilities Plan (42; 34).

Consumption data were obtained for a Middle East scenario from the Army Logistics Center in terms of tons per day for each supply class. The figures were then converted to equivalent pallets per day for each class using the expected pallet weights previously discussed (3.3 tons for ammunition and 2.3 tons otherwise), with two exceptions. Figures for Class III (POL) were converted into units of hundreds of gallons consumed per day, and figures for Class VII (major end items--armored vehicles, trucks, etc.) were not considered because Class VII resupply is not accomplished using airlift. Consumption rates for those supply classes with constant demand regardless of combat conditions are given in Table V. Consumption data were provided for classes III and V at the intense level of combat, and were scaled down to the other levels using the following ratios:

moderate level = 71% of intense
light level = 43% of intense
reserve level = 21% of intense (42)

POL and ammunition consumption figures calculated for mechanized and armored divisions are given in Table VI.

Because combat conditions experienced by the three divisions change over time, their consumption rates in classes III and V will vary as well. Additionally, each of the three

TABLE V

Constant Demand Supply Classes (42)

(Daily Consumption in Pallets Per Day)

Supply Class	Mechanized Division (Strength = 16,597)	Armored Division (Strength = 16,295)
I	18	18
II	18	17
IV	30	30
VI	12	11
VIII	1	1
IX	18	17
Total	97	94

TABLE VI

Daily Consumption of Classes III and V (42)

Supply Class	Level of Combat			
	Intense	Moderate	Light	Reserve
Mechanized Division				
III (units of 100 gals/day)	1820	1300	780	390
V (pallets/day)	312	222	134	65
Armored Division				
III	1885	1365	845	390
V	305	217	131	64

divisions can be at a different level of combat on any given day depending on the battlefield situation. In this scenario, the variation in combat conditions is accomplished using a Markov process.

With each passing day, there is a probability that a division will remain at its current combat level, and there are probabilities it will transition to one of the other levels. A one-step transition matrix was developed to specify these probabilities. Although the specific probabilities in the matrix are not based on any historical data, they do yield steady state probabilities which reflect a moderate level of combat. According to expert opinion, the overall rate of consumption over the time period under consideration in this scenario is the rate associated with a moderate level of conflict (34). The one-step transition matrix and the steady state probabilities (the expected percentage of the time the divisions are at each level of combat) are given in Table VII.

As reflected in the matrix, the probability of transitioning by more than one increment of combat level steadily decreases. For example, a division at the intense level will transition to moderate with a probability of 0.5. It is less likely (probability of 0.1) to transition from intense to light, and there is no chance it will transition from intense to reserve in a period of only one day. The values for the

TABLE VII

One-Step Combat Level Transition Matrix

(With Steady-State Probabilities)

	Int	Mod	Lgt	Res
Int	0.4	0.5	0.1	0.0
Mod	0.2	0.5	0.2	0.1
Lgt	0.2	0.5	0.2	0.1
Res	0.0	0.5	0.4	0.1

Intense -- 0.231

Moderate -- 0.500

Light -- 0.192

Reserve -- 0.077

matrix were determined such that the steady state probabilities reflect a moderate level of combat and, therefore, consumption.

Airlift scheduling in this scenario is based on meeting the needs of the airlift user--the armored and mechanized divisions. This is accomplished through a priority system in which the base with the greatest need for resupply is ranked highest on the list of scheduling priorities. Priority is based on the importance of the supply class and also the level of supply in that class at each base. Stockpiled supply reserves serve as a "shock absorber" to allow uninterrupted operations in the theater in the event of perturbations in the supply system (35:p. 5-25). Therefore, up to a point, it is desirable to increase stockpiled supply levels. At some point, however, a level can be reached at which additional supplies are not productive, particularly in terms of accountability and storage space problems. The reserve level is determined by the supported commander in the theater of operations (35:p. 5-26). U.S. Army FM 10-67 specifies a fifteen-day supply for fuel in an undeveloped theater for planning purposes (14:p. 3-3). In the scenario, this fifteen-day level also applies to the other supply classes. These levels are computed at the moderate rate of consumption and are given for both division types in Table VIII.

The goal of the airlift resupply effort is to maintain supply levels at each base as near the desired fifteen-day level

TABLE VIII

Desired Supply Levels (32; 42)

Fifteen Days at Moderate Rate of Consumption
(Equivalent Pallets)*

Supply Class	Mechanized	Armored
I	270	270
II	270	255
III*	19,500	20,475
IV	450	450
V	3,330	3,255
VI	180	165
VIII	15	15
IX	270	255

*Class III (POL) measured in units of 100 gallons as possible. Mission priorities are basically determined using a percentage of the desired level currently on hand across all categories and all bases. If, for example, Base 7 (Khatami) has 65 percent of the desired level of ammunition and Base 8 (Yazd) has 75 percent, scheduling priority will be given to missions resupplying Base 7 with ammunition before ammunition missions are scheduled to Base 8. The same process applies to resupply of different categories at the same base.

Because some categories are considered more important than others, assigning priorities strictly based on a percentage of the desired level currently on hand may have to be augmented by weighting certain classes more heavily than others. For example, if ammunition is considered twice as important as food, ammunition sorties would be given scheduling priority if current supplies in both were at the same percentage level. Some balance of the scheduling weights must be achieved, however, because running out of any class of supply in a combat environment would most likely be disastrous. There is no advantage gained if having 100 percent of the desired level of ammunition is achieved at the expense of exhausting food supplies.

Evacuation of Casualties

The scenario includes the requirement that casualties be evacuated by air from the medical holding areas at each division base to Base 5 (Shiraz). From Shiraz, they are transported out of the theater by other airlift resources. Casualties include wounded and diseased/nonbattle injured personnel (DNBI), and are generated as a function of combat level. Although U.S. Army FM 101-10-1 provides casualty figures in different scenarios, these data are based on World War II and Korean War combat (15:p. 5-6). Given the greater destructive capability of modern weapons, casualty rates would probably be higher in a present or future scenario (34). Casualty data obtained from the U.S. Army Academy of Health Sciences give rates for a division at the intense combat level of 11.18 wounded and 2.78 DNBI per 1,000 personnel per day, for a total of fourteen per 1,000 per day (30). Because no casualty rates are specified at moderate, light, and reserve combat levels, it is reasonable to expect that casualty rates at these levels, in relation to the intense rate, can be calculated using the same ratios (71, 43, and 21 percent respectively) as for class III and V consumption rate conversions (30).

Another consideration in the evacuation of casualties is the evacuation policy in the theater of operations. The evacuation policy indicates the ". . . maximum number of days the patient may be hospitalized for a single period of illness or injury [15:p. 5-18]." In reality, many wounded or DNBI personnel would be able to return to combat duty after a relatively short period of time in a hospital at the division level. In this scenario, because detailed data are not available, it is assumed that all casualties are evacuated from the theater once they are hospitalized, an assumption representing a "worst case" situation. The evacuation policy for the scenario is that all casualties are to be evacuated within seven days after admission to the medical facility at each division base, one of several standard policies considered in FM 101-10-1. The exact number of patients hospitalized for from one to seven days will be maintained and updated every twelve hours. An additional category of all patients hospitalized for eight days or more will also be maintained. A value greater than zero in this category is an indication that insufficient air evac sorties are being scheduled. To preclude this, an increasingly higher scheduling priority is assigned to air evac missions when patients at any division base have been hospitalized for four days or longer.

Scenario Assumptions

In order to limit the scope of the problems associated with the resupply system, and to reduce the complexity of modeling that system, several assumptions are made:

1. The three divisions are fully deployed and engaged in combat operations at the outset.

2. For the time period included in the scenario, the fighting does not result in large advances or retreats by either side, so that the three division headquarters do not move.

3. Division strengths remain constant at initial levels. Although troop reinforcements are not considered by the model, they are assumed to be accomplished by surface transportation and air evac prepositioning sorties. These sorties are those flown between Shiraz and the division bases by air evac configured aircraft.

4. The initial levels of supply quantities at each base, in each class, are arbitrarily set at a percentage of the desired fifteen-day supply.

5. No attrition of aircraft as a result of accidents or hostile fire is considered. The intent of the research effort is to evaluate alternative scheduling heuristics and supply class weights for determining priorities. Aircraft attrition should produce similar effects across all alternatives and is excluded to reduce complexity in the model.

6. To further reduce model complexity, and because visual flight conditions generally prevail in the Middle East, weather conditions are not considered.

7. While certain strategic airlift aircraft (C141B) could land at one of the division bases (Khatami), they are considered too valuable to the strategic airlift effort to be used in any tactical role.

8. Although conflicts between strategic airlift aircraft and C-130s at the APOD (Shiraz) would probably exist in

reality, to reduce model complexity, C-130 aircraft do not compete with these aircraft for ramp space and service facilities.

9. C-130 refueling time away from home station is assumed to be included in the time required for loading or offloading operations.

10. Strategic air and sealift is continuous and uninterrupted, such that adequate quantities of supply in all classes are always available for onload at the two PODs. The tactical aircraft alternate between PODs for onloading purposes.

11. Onloads of cargo and POL are conducted only at the PODs and offloads only at division headquarters bases. Aircraft do not travel between division bases.

12. Casualties are onloaded at division bases and offloaded at the APOD (Shiraz) only.

13. All bases have the necessary facilities to support airlift operations on a twenty-four hour per day basis.

14. Because of the large vehicles, in terms of size and tonnage, associated with class VII which exceed C-130 capabilities, all resupply of this class is accomplished by surface transportation.

Worth Assessment

As discussed in Chapter II, the use of a worth assessment technique can provide a relative ranking of the worth or value of each supply class to the Army. Time constraints precluded strict adherence to the worth assessment procedure suggested by Sage, but a modification of the procedure was used in a face-to-face interview with three Army officers to determine a ranking of the supply classes.

The three officers interviewed had considerable operational experience at the unit level in combat arms, one in infantry and two in armor. The inclusion of armor experienced officers was considered important because of the mechanized and armored divisions considered in the scenario. The individuals were given a brief description of the scenario, including the assumption that class VII supply is not considered for resupply by airlift.

Each officer was asked, in the presence of the others, to rank each of the supply classes considered, from the one considered least valuable to most valuable. After the least valuable class was determined, each remaining class was ranked according to how much more valuable it was than the least valuable. The rankings were then adjusted to ensure that the relative value of each class in relation to those ranked above and below it was accurate. The results of the individual elicitations are given in Table IX.

The individual assessments showed complete agreement between the group members as to the five least valuable classes, but there was disagreement on the ranking of the three classes

TABLE IX

Results of Individual Worth Assessments (22; 31; 36)

Infantry Officer		Armor Officer		Armor Officer	
Class Ranking	Numerical Value	Class Ranking	Numerical Value	Class Ranking	Numerical Value
V	12.0	IX	14.0	III	15.0
III	11.0	III	12.0	IX	14.5
IX	10.0	V	11.0	V	10.0
VIII	9.0	VIII	9.0	VIII	9.0
I	7.0	I	7.0	I	7.0
IV	4.0	IV	4.0	IV	4.0
II	1.0	II	1.0	II	1.0
VI	0.5	VI	0.5	VI	0.5

considered most critical to sustaining combat operations. The numerical values from the three officers for each of these classes were averaged with the following results:

Class	Average
IX	12.8
III	12.7
V	11.0

The final ranking using these average scores is given in Table X. Although the final ranking reflected only one of the three officer's preferences exactly, the other two officers agreed that they could accept these rankings as representative of the value they would place on each supply class given the specific scenario described (22; 31; 36). As a result of this consensus, the values given in Table X are used as the worth to the Army of each supply class, to quantify the level of user need satisfaction attained by the tactical airlift resupply effort. A discussion of how these values are used in the model to compute a score for each run is given in Chapter IV.

Summary

This chapter discusses the scenario selected to employ user need satisfaction as the measure of tactical airlift effectiveness. Justification for selecting a combat environment situated in Iran is given along with the geographical location and function of all bases included in the resupply

TABLE X

Combined Ranking of Supply Class Values (22; 31; 46)

Class	Description	Numerical Value
IX	Repair Parts and Components	12.8
III	POL	12.7
V	Ammunition	11.0
VIII	Medical Supplies	9.0
I	Subsistence	7.0
IV	Construction Materials	4.0
II	Clothing and Equipment	1.0
VI	Personal Demand Items	0.5

network. The scenario involves the aerial resupply of a U.S. Army force consisting of one armored and two mechanized divisions. The C-130 aircraft is specified as the aircraft used in the resupply effort, and a typical mission profile is outlined.

Three different aircraft configurations--palletized cargo, POL, and aeromedical evacuation--are discussed, including details of C-130 aircraft capabilities as well as how onload and offload times associated with each configuration were determined. Palletized cargo considered includes seven categories--subsistence, clothing and equipment, construction materials, ammunition, personal demand items, medical supplies, and spare parts--specified by the Army as separate supply classes. POL, although not palletized, is also a separate class of supply. Evacuation of casualties is considered using current casualty rates supplied by the Army.

Because all aircraft are not in commission at all times in a realistic scenario, in-commission rates and departure delays are included. Each day, only 82 percent of the total aircraft are in commission, and there is a 4.44 percent likelihood that an aircraft will experience a departure delay due to maintenance problems. These figures are based on actual historical data collected by the Military Airlift Command for the C-130. Maintenance delays range from 0 to 48 hours. Delays resulting from other sources are also considered.

Supply consumption is constant in all supply classes except classes III and V. Consumption in these two classes is based on intense, moderate, light, and reserve levels of combat, using Army supplied consumption figures. Changes in combat conditions are accomplished using a Markov one-step transition matrix which provides probabilities for transitioning from one combat level to another. A fifteen-day level of supplies in all classes is considered the desired stockpiled reserve; and as supply levels in a particular category are drawn down from this level, increased priority is given to the resupply of that category at the appropriate base. This "percentage of desired" priority criterion may be augmented by scheduling weights to account for differences in the importance of one class as compared to the others.

Assumptions to reduce the scope and complexity of the scenario are provided, as is a discussion of the modified worth assessment procedure conducted with Army officers for use in the model as a quantifier of user need satisfaction. The simulation model incorporating all elements, parameters, and assumptions associated with the scenario and outlined in this chapter are described in detail in the following chapter.

IV. Model Development and Computerization

Introduction

In order to experiment with the scenario outlined in the previous chapter, a computer model of the scenario was constructed using Pritsker's Simulation Language for Alternative Modeling (SLAM). SLAM is particularly well suited to this purpose because it allows for the movement of aircraft through the airlift system by the passage of entities through an interconnected network of nodes. SLAM includes many intrinsic functions and subroutines with a wide range of modeling applications, and also permits the inclusion of user written Fortran subroutines which allow consideration of complex, system specific decision processes.

The first portion of the chapter considers the causal relationships of the elements affecting the airlift resupply system, followed in the second portion by a description of the SLAM network in conceptual terms. The chapter concludes with a discussion of the functions and subroutines, both user written and those intrinsic to SLAM, used in the model. Discussion of the SLAM network and Fortran inserts in this chapter are descriptive in nature. Documented SLAM control statements and Fortran code are given separately in Appendices A and B.

Causal Relationships

The tactical airlift resupply scenario described in Chapter III can be studied as a system, composed of three major elements--external input, internal variables, and output. The external input to the system is the quantity of supplies made available at the two PODs, Bushehr and Shiraz, for distribution to the three divisions deployed in the theater. The output, or goal, of the system is combat capability and is directly related to the levels of supply in each class maintained at each division base. Combat capability is quantified by means of a numerical score and will subsequently be referred to as the response variable. The internal variables of the system influence the numerical value of the response variable, with higher values indicating greater system effectiveness. A diagram of the causal relationships between the various system elements is given in Figure 2.

There are nineteen internal system variables which ultimately affect the response variable. Figure 2 shows that the variables are classified by how they directly affect four distinct categories, referred to as intermediate responses. The direct effects these intermediate responses have on one another combine to affect the value of the response variable. The following discussion of the individual variables is categorized according to the intermediate responses affected.

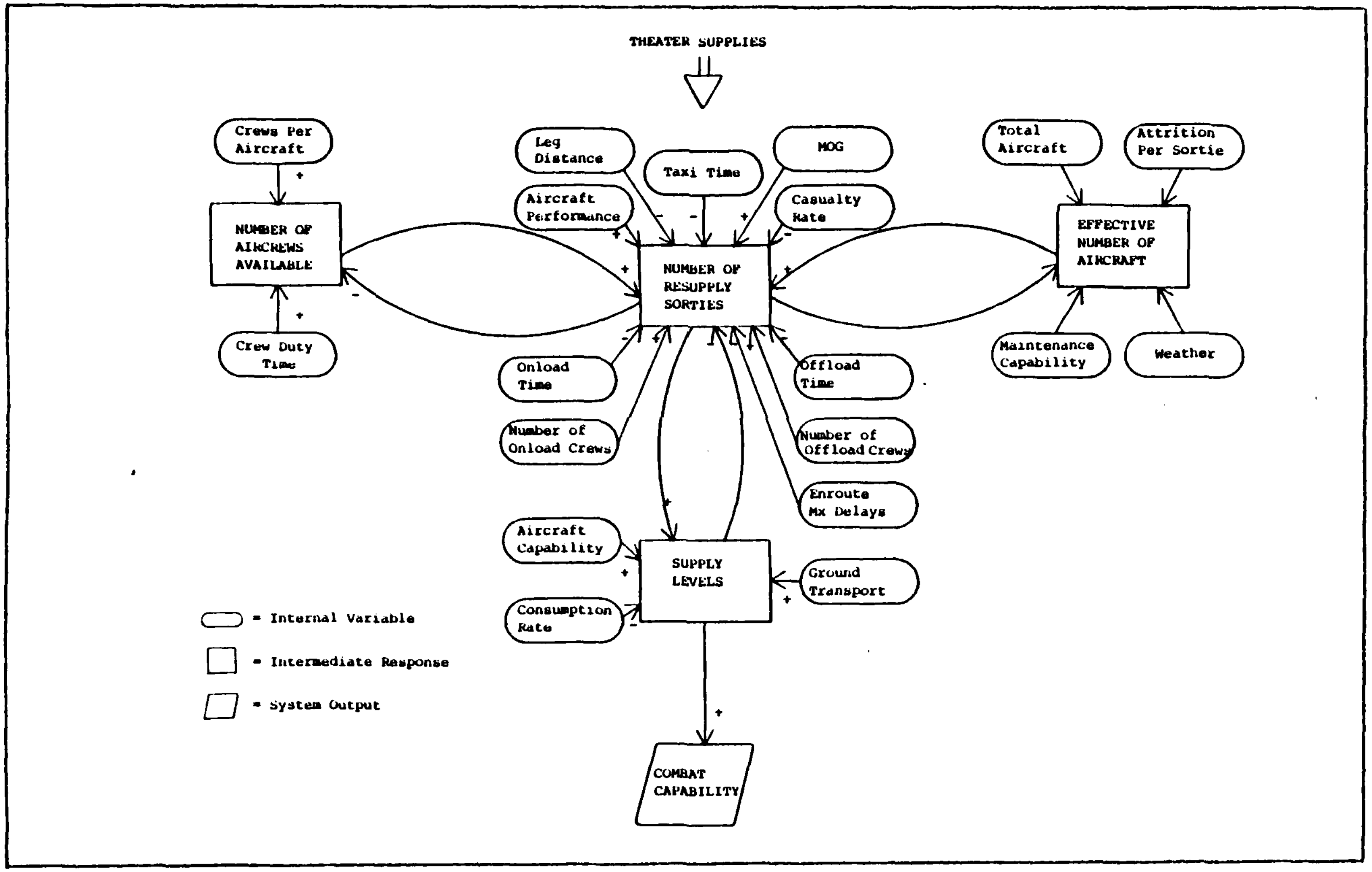

Figure 2. Causal Diagram

Number of Effective Aircraft:

1. Total number of aircraft--The number of aircraft assigned to the theater. As the total number of aircraft increases, the effective number increases. This variable is arbitrarily fixed at 120 aircraft, with 40 assigned to each base.

2. Combat attrition per sortie--The number of aircraft destroyed during combat operations, either from hostile fire or accident, negatively affects the number of effective aircraft. Although attrition could be a significant factor over time, its effect is not considered in the model, since it is assumed the effect will be similar across all scheduling and weighting alternatives.

3. Maintenance capability--The ability of the maintenance function to keep the aircraft operationally ready influences the effective number available. As the capability increases, the number of aircraft in commission increases. The variable is fixed, using a percentage of the total aircraft available which are mission capable on an average daily basis. A random number sampling determines the specific aircraft not available for mission tasking each day, based on data supplied by HQ MAC/LGXA.

4. Weather--Although a qualitative factor in reality, weather can be quantified in terms of how it affects the number of aircraft available. In poor weather (instrument flight

conditions), a greater amount of time separation between departures and arrivals is required, which may decrease the number of aircraft flying missions in a given time period. As the weather improves to visual flight conditions, required separation decreases and the effective number of aircraft is increased. Although changes in the weather significantly affect the system, the model assumes visual conditions throughout the period under consideration.

Number of Aircrews Available:

5. Number of crews per aircraft--Increasing the crew to aircraft ratio has a positive effect on the number of aircrews available. This variable is fixed in the model at the MAC standard ratio of two crews per aircraft.

6. Crew duty time--The number of consecutive hours an aircrew can be used directly affects the number available. Increasing the crew duty time positively affects the effective number available. This variable is fixed at a maximum of eighteen hours per day in accordance with MAC Regulation 55-130.

Number of Resupply Sorties:

7. Leg distance--As the distance between bases increases, the time to fly each sortie increases. This negatively affects the total number of sorties which can be flown. Distances are fixed according to the actual distance between all bases in the scenario.

8. Aircraft performance--As performance in terms of speed and fuel consumption increases, the number of sorties an aircraft can fly in a given time period increases. C-130 performance is fixed, and was provided in Chapter III.

9. Taxi time--Increased taxi time has a negative effect on the sortie rate because it decreases the number of sorties which can be flown in a given time period. Taxi times are arbitrarily fixed at 0.2 hours for taxi-in and 0.2 hours for taxi-out at each base.

10. Maximum number of aircraft on the ground at a base (MOG)--When increased up to the limits imposed by the physical size of the ramp facilities, MOG has a positive effect on the number of sorties, since it reflects the amount of ramp space available at a base.

11. Soldier casualty rate--An increased casualty rate will have a negative effect on the number of resupply sorties. As casualties increase, the number of aircraft dedicated to aeromedical evacuation will increase, thereby reducing the umber available for resupply. As stated in Chapter III, casualty rates depend on the level of combat experienced, and are fixed based on the figures given for each level.

12. Onload time--Increased onload time has an obviously negative effect on the number of sorties flown. These times vary stochastically with different distributions for each aircraft

configuration, based on minimum and maximum planning factor times used by HQ MAC and HQ USAF/SAGM and given in Chapter III.

13. Offload time--Increasing offload time has the same negative effect on sortie rate as onload time. Offload time also varies stochastically, but with different distributions than onload time, according to the available planning factor information.

14. Onload crews--Increasing the onload capability results in a greater sortie departure rate from the PODs by reducing the queue of aircraft waiting to be loaded. Onload crews at each base are grouped according to the three possible aircraft configurations. The number of crews at the two PODs does not exceed the MOG for each base.

15. Offload crews--Increasing offload capability at the division base will result in an increased sortie rate using similar rationale to that given for onload crews.

16. Enroute maintenance delays--Crew duty time lost while maintenance problems are corrected reduces time available for mission completion and reduces the number of resupply sorties flown. At each enroute stop, random number samplings determine whether an aircraft experiences a maintenance problem and the duration of the delay if a problem exists. The probabilities of both maintenance problems and delay durations are based on data obtained from HQ MAC/LGXA.

Supply Levels:

17. Aircraft cargo capability--An increased capability for transporting cargo has a positive effect on the levels of supply maintained because of the increased amount airlifted per sortie. This capability is fixed and corresponds to that of the C-130 aircraft.

18. Consumption rates--An increase in consumption will negatively affect the supply levels for a given sortie rate. While consumption figures are deterministic, based on planning factor data for the different division types, the values for classes III and V change with changing combat levels. These levels vary stochastically in the model, with resulting changes in consumption.

19. Quantity of less critical items transported by surface means--Increasing the quantity of less critical supplies delivered to the divisions by surface transportation will positively affect the supply levels. This variable is fixed in the model with the assumption that all Class VII resupply is accomplished via surface transportation.

Conceptual Model

After considering the three major system elements and their associated internal variables, a conceptual system model is developed. By considering the applicable variables in general terms, the sequence of events encountered by the aircraft and crews as they perform their missions is described.

From this conceptual framework, the required detail at each point in the sequence can be prescribed in the model's computerization.

The modeled system consists of eight bases. Three bases serve as home stations for forty C-130 aircraft each, with two aircrews assigned per aircraft. Two of the eight bases are the depots from which all supplies are distributed. The remaining three bases represent the division bases, which are the objects of the resupply effort (Figure 3). The flow of aircraft through the system is conducted in three phases--pre-mission activities at home station, depot and division base activities, and post-mission activities.

Pre-mission home station activities are depicted in Figure 4. The process begins with assignment of a crew to an aircraft. The aircraft and crew are then given a mission from a prioritized mission list prepared every twelve hours. As the crew performs its pre-flight duties, there is a possibility a maintenance problem will be discovered, resulting in a mission delay. If no problem is discovered, the aircraft departs at its scheduled departure time. If a problem is found and it can be corrected in less than four hours, the aircraft departs after the required maintenance action is performed. Because existing regulations require that a mission be canceled if it cannot depart within four hours of its scheduled departure time, a maintenance problem causing a delay of four hours

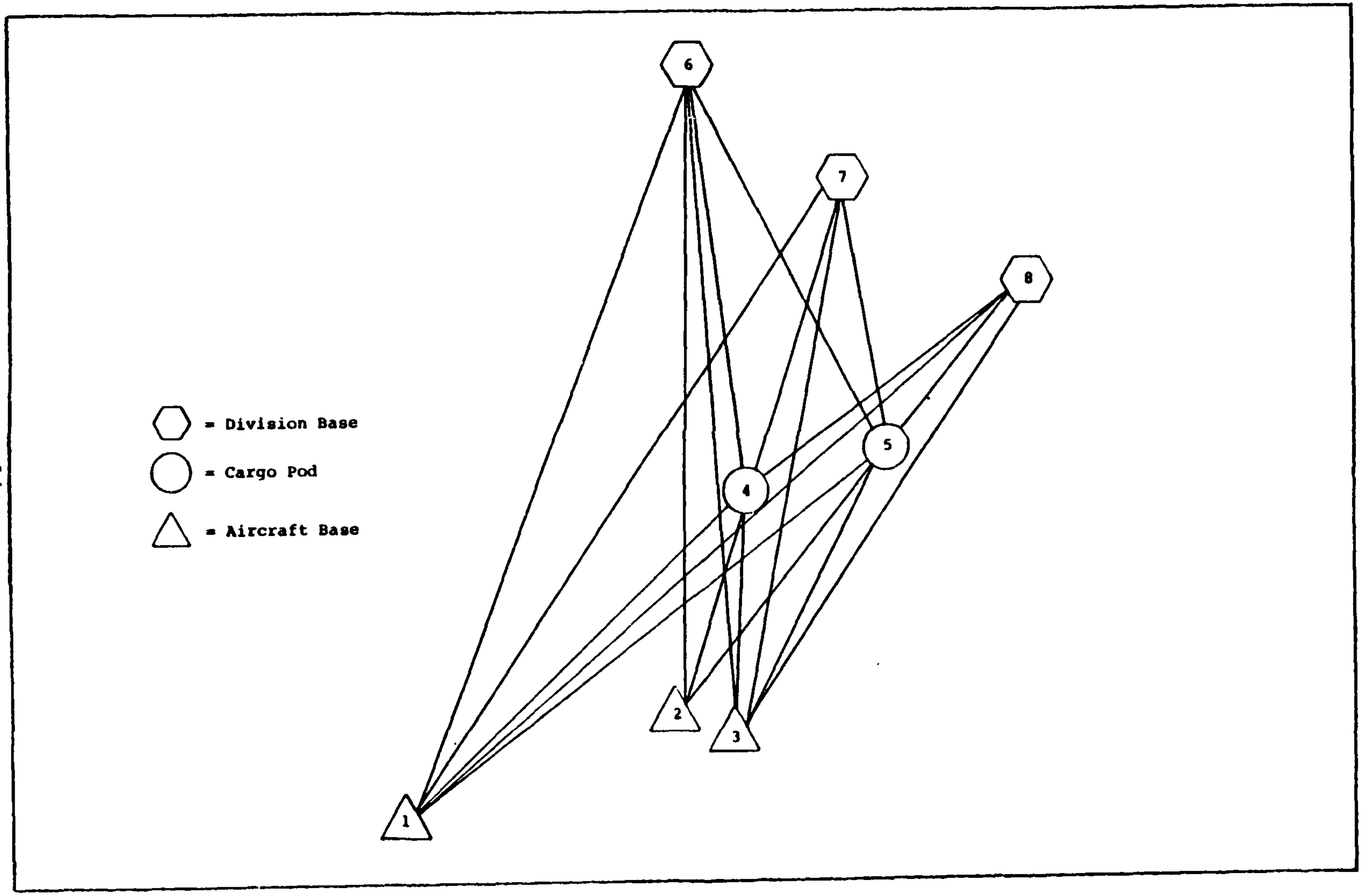

Figure 3. Base Network

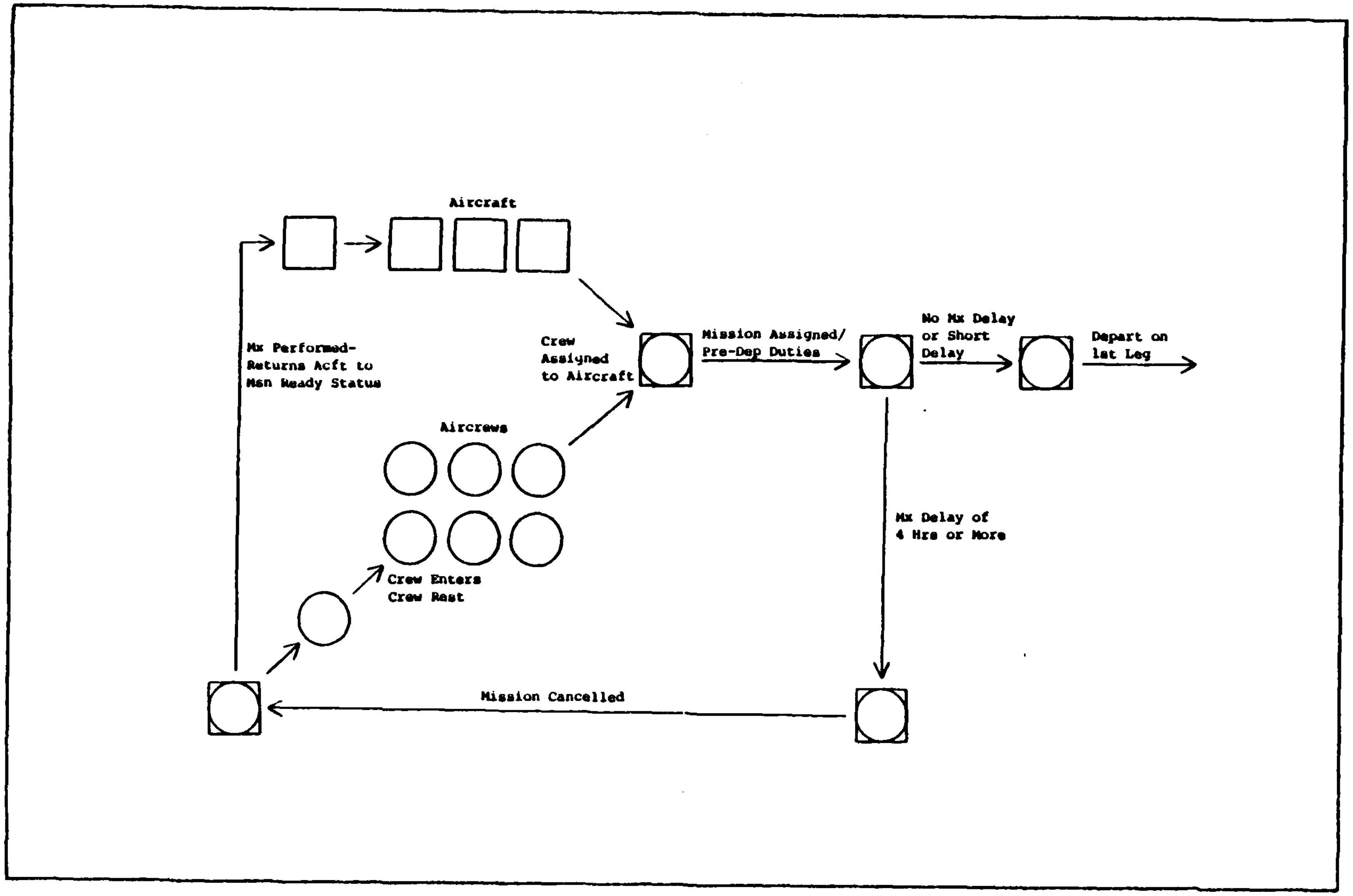

Figure 4. Pre-Mission Home Station Activities

or more results in the crew's return to crew rest. After a twelve-hour crew rest period, the crew is again available to fly a mission. The aircraft is repaired and other routine maintenance functions are performed before the aircraft becomes available for assignment to another mission.

After departure from its home station or any of the other bases, the aircraft proceeds to its next destination. The activities at depot and division bases are depicted in Figure 5. After the aircraft arrives and taxis in, it proceeds to the proper server (i.e., a crew equipped with materials handling equipment, fuel pumping equipment, or medical personnel) based on its configuration (cargo, POL, or aeromedical evacuation). It is then loaded or offloaded, as required, if a server is available.

If there are no free servers for the aircraft's configuration, it queues for service. Prior to departure, there is again a possibility the aircraft will develop a maintenance problem, or has accumulated excessive delays in queuing for service throughout its mission. If the aircraft has encountered little or no delay for either reason, it departs on its next mission leg, which could be to a depot, division base, or to its home station if its mission is complete. If, because of maintenance or queuing delays the aircrew has only enough crew duty time remaining to fly to its home station, the remainder of its mission is canceled and the aircraft returns to base

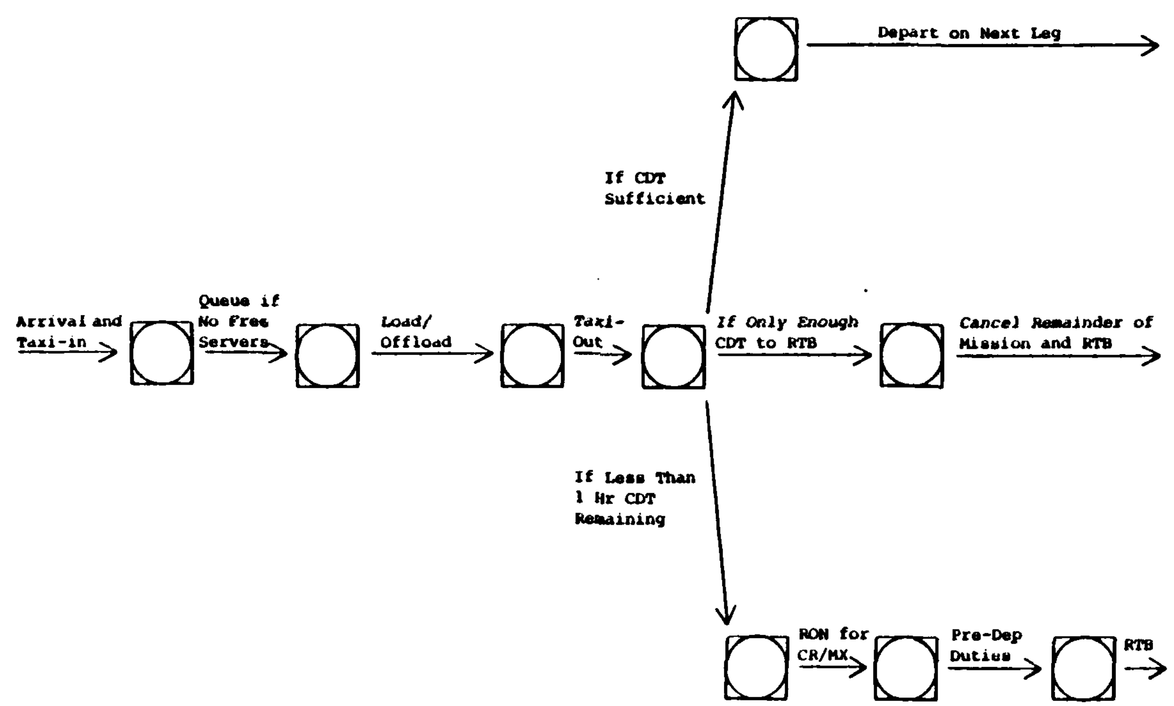

Figure 5. Depot/Division Base Activities

(RTB). If the crew has less than one hour of crew duty time remaining, it is assumed that returning to home station would exceed the specified maximum crew duty length. As a result, the aircraft remains overnight (RON) at its present location and the crew enters crew rest. After the crew rest period and pre-departure crew duties are completed, the aircraft will RTB unless maintenance actions require a longer period of time. In this case, the aircraft will RTB after maintenance is completed. Arrivals to, and departures from, depot and division bases continue in the above described fashion until the aircraft returns to its home base.

When an aircraft returns to its home station, the following sequence of events, depicted in Figure 6, occurs. Upon arrival, the flying time and length of crew day are recorded. The crew enters crew rest and the maintenance status of the aircraft is assessed. If the aircraft has no major maintenance problems, required minor maintenance functions are performed to make the aircraft ready for its next mission. If major maintenance problems exist, or if the aircraft is in need of a scheduled inspection or programmed maintenance, the aircraft is not available for mission tasking for a period of twenty-four hours. After the twenty-four hour period, the minor maintenance actions are performed and the aircraft is then ready for flight. After completion of crew rest, the crew is available for another mission at any time.

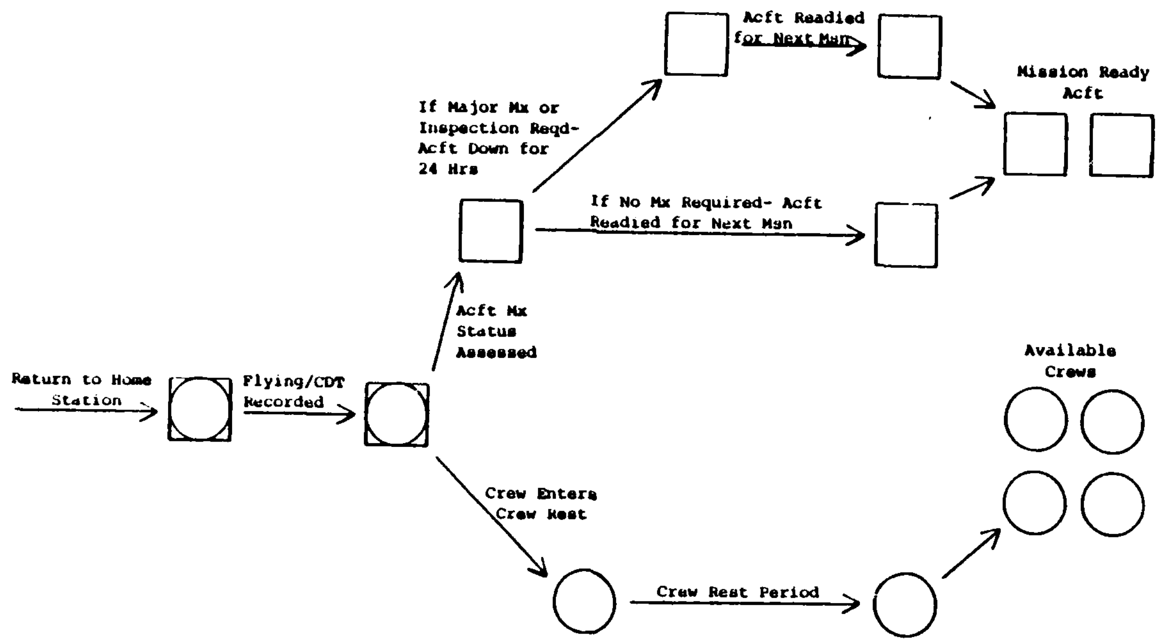

Figure 6. Post-Mission Home Station Activities

Computerization

Fortran subroutines, both user written and intrinsic to SLAM, are used in every phase of the simulation. In this discussion, the five intrinsic SLAM subroutines used--MAIN, EVENT, INTLC, OTPUT, and USERF--will be covered first, followed by a description of the user written subroutines.

1. Program MAIN

This section is used to allocate files for input and output and to initialize the dimension of NSET. Normally, default values are used; however, the default dimension for NSET proved to be inadequate in this case. Because of the large number of entities and attributes required by the simulation, the dimension of NSET was increased from the default value of 5000 to 30000.

2. Subroutine EVENT

This subroutine is used to call certain user written subroutines during the simulation. The use of the EVENT subroutine makes it possible to make these calls in one of two ways. The first is through the use of a special node in the SLAM network, the EVENT node. The second is through a call from within the Fortran program using the intrinsic SLAM subroutine SCHDL. Both methods are used in this model.

3. Subroutine INTLC

This subroutine is called once at the beginning of each simulation run and is used to set variables to their initial values. An alternate method of initializing variables is through the use of the INTLC statement in the SLAM control statements. The primary difference between the two methods of initializing variables lies in the fact that changing initial values is much simpler using the SLAM control statements. This is because any change to the INTLC subroutine requires that the entire package of Fortran subroutines be recompiled. However, this is not necessary when using the SLAM INTLC statements. For this reason, any variables which correspond to factors that may be varied between runs are initialized in the SLAM statements. All other variables are initialized in the INTLC subroutine.

4. Subroutine OTPUT

This subroutine is used for formatting output at the end of each simulation run. While SLAM provides a summary report when desired, subroutine OTPUT allows the user to print specific information when requirements go beyond the information provided in the summary.

5. Subroutine USERF

This subroutine inclues ten user written functions to provide for flexibility within the network:

a. USERF(1). This function is used to assign initial attribute values to the aircraft entities generated at the beginning of the simulation. While the value returned by USERF(1) assigns the aircraft tail number (attribute 1), other values set within the function are initial time for minor maintenance actions (attribute 3), the stop number (1) on the aircraft's first mission itinerary (attribute 7), and the time the aircraft first entered the system (attribute 15). The time required for initial aircraft preparation is uniformly distributed between three and five hours.

b. USERF(2). USERF(2) checks the aircraft's itinerary prior to departure from its current location and determines the next destination and the flying time to reach it. The amount of crew duty time remaining (attribute 14) prior to departure from each stop determines whether the aircraft continues its mission as scheduled, returns to its home base, or remains overnight at its present location. The particular configuration of the aircraft (attribute 11) and its current stop number (attribute 7) are factors in this determination. A POL aircraft has a longer expected onload and offload time than a cargo configured aircraft. Because of this, an aircraft on a POL mission which has just completed its first offload at a division base requires a greater amount of remaining crew duty time to proceed to a depot for a second onload, fly to another division base for offload, and return to its home station than would an aircraft on a cargo mission. Although both aircraft begin with enough crew duty time to complete their respective missions, the possibility of maintenance and queuing delays at each stop on the itinerary make the check of remaining crew duty time necessary to prevent an aircrew from exceeding the maximum eighteen-hour day. The function keeps a record of the number of missions completed, terminated early, and those required to remain overnight.

After determining the next stop, the function determines the distance between the two bases (using a value stored in the array "dist") and computes the low, high and mode values for the sample from a triangular distribution representing the flying time (attribute 9). The cumulative flying time (attribute 10) is also updated. The function returns a value of zero in all cases except one. If an aircraft must remain overnight, the value returned is 15.25 hours (the length of crew rest and pre-departure crew duties) minus the length of the delay for all delays less than 15.25 hours. This is done to account for the fact that the delay time is considered prior to the call to this function. For delays greater than 15.25 hours, the crew rest period is included in the delay time.

c. USERF(3). The service time required for an aircraft at depot and division bases is the value returned by this function. Service times depend on both the aircraft configuration and whether it is being onloaded or offloaded. The values returned are samples from triangular distributions based on these two factors. Additionally, the status in each supply class is updated, based on the aircraft load, after an offload of cargo of POL is completed at a division base. The number of casualties hospitalized at a division base is reduced by the appropriate amount if the aircraft is on an air evac mission.

d. USERF(4). This function collects statistics for each mission upon the aircraft's return to its home station. The length of the crew duty day, and cumulative mission flying time are recorded, the time for minor maintenance and predeparture crew duties (attribute 3) is assigned, and the stop number (attribute 7) is reset to one. The function returns a value of zero.

e. USERF(5) and USERF(6). These functions assign the aircraft attribute values discussed in USERF(1) for Bases 2 and 3, respectively.

f. USERF(7). USERF(7) determines the status of the aircraft, whether in or out of commission. When an aircraft returns to its home station, its status is evaluated if twenty-four hours have passed since it was last checked.

Based on the value of a random number (from the intrinsic function (DRAND), there is an 82 percent chance the aircraft will be in commission. If the aircraft fails this in-commission test, the function returns a value of twenty-four hours to simulate the aircraft's nonavailability due to maintenance requirements.

If an aircraft is delayed excessively due to maintenance problems prior to its scheduled departure from home station, the function returns the value associated with that delay.

g. USERF(8). This function determines the probability of a maintenance delay occurring at each point on the aircraft's mission itinerary and the associated time if a delay occurs. The value of a random number draw gives a 4.44 percent chance of a delay at each stop. If there is a delay, another random number determines the delay duration, ranging from 0 to 48 hours. The delay time (attribute 16) is the value returned by the function.

h. USERF(9). This function prevents a mission from being assigned that was not scheduled as part of the current scheduling period. The function determines the time for an entity, consisting of an aircraft and crew, to travel to the EVENT node that will call subroutine START and cause the entity to be assigned a mission. The function subjects the next mission that would be assigned to the entity, if it proceeded to the EVENT node with zero delay, to a pair of tests to determine whether the mission is current or will be when it departs. The first test is to determine whether the mission number is within the group of missions rescheduled in the current cycle. If it is not, the mission is not assigned. The second test is to determine if the scheduled departure time of the mission is after the time that the next scheduling cycle takes effect. If it is, then aircraft would be departing on an outdated mission, rather than one from the current scheduling cycle, and the mission is not assigned. If the mission is not assigned for either reason, the function returns a time that will delay the entity's arrival at the EVENT node until the next scheduling cycle has taken effect. This ensures that the mission that will be assigned to the entity when it reaches the EVENT node will be from the current scheduling period.

i. USERF(10). USERF(10) determines the required crew rest period. For all aircrews returning from a mission, the function returns a value of 15.25 hours, representing 12 hours of crew rest and 3.25 hours of pre-departure crew duties for the crew's next mission. An aircrew is required to cancel its mission and re-enter crew rest after delaying four hours for an aircraft maintenance problem prior to home station departure. In this event, the function returns the value of 15.25 plus 4.0 hours, to represent the crew rest period plus the delay time.

6. Subroutine SCHED

SCHED is initially called by an EVENT node in the SLAM network at the start of the simulation. After that, it schedules a return to itself every twelve hours in accordance with the twelve-hour scheduling cycle of the scenario. The purpose of the subroutine is to serve as the overall controller of the airlift scheduling process. SCHED ensures that the steps involved in scheduling are carried out in the correct sequence and at the appropriate time.

In the model, the schedule is updated every twelve hours. The scheduling sequence involves four steps, controlled by SCHED, which are repeated each time the schedule is updated. The first step is to update the status of the three divisions to reflect the effects of combat. In this step, the supply and casualty levels at the divisions are updated with the changes that have occurred over the preceding twelve hours. In the second step, this information is used to calculate scheduling priority. This calculation is carried out by comparing the actual supply and casualty status with the desired or standard level. The third step in the sequence is to plan airlift resupply missions to the division bases using the calculated priorities to make routing and load decisions. The final step is to integrate the planned missions into a flow plan that limits the number of aircraft arriving at each onload and offload base that require the same type of service at the same time. The purpose of the flow plan is to reduce time spent by aircraft in queues waiting for service.

These functions are carried out in the model by three subroutines--CONSUM, ROUTE, and FLOW--which are called, in order, by SCHED. SCHED updates the current status at the division bases by a call to subroutine CONSUM. This subroutine simulates the consumption of supplies and generation of casualties for the preceding twelve-hour period and updates the status accordingly. Next, SCHED calls ROUTE, which calculates scheduling priority based on this updated status and uses the results as a basis for scheduling the current group of missions. Finally, SCHED causes the missions to be inserted into an existing flow plan by a call to subroutine FLOW.

One of the key functions of the subroutine is to control a thirty-six hour cycle over which the available mission numbers are reused. This cycle is required because of the manner in which missions are stored in the program. Missions are stored in a three-dimensional array in which one of the dimensions is the mission number. Since the availability of mission numbers is limited, they must be reused throughout the simulation. Reusing the available mission numbers could conceivably create a problem. However, because if an aircraft were still out on a mission when its mission was rescheduled, the itinerary would be changed unpredictably. This possibility is prevented by the thirty-six hour cycle of mission rescheduling because in each scheduling period, one-third of the total mission numbers are rescheduled. Since the scheduling cycle is twelve hours long, this ensures that at least twenty-four hours have elapsed between the departure of a mission and the rescheduling of its mission number, by which time it will have returned to home station. In the case of a mission that experiences a delay causing it to be out more than twenty-four hours, the aircraft is routed directly back to its home base and is, therefore, unaffected by changes to its mission.

7. Subroutine CONSUM

• CONSUM is called by subroutine SCHED as the initial step in the scheduling process. The purpose of CONSUM is to update the status of the division bases to reflect the consumption of supplies and generation of casualties resulting from combat. This effect is expressed in terms of supply consumption and casualty generation which are directly related to the combat state of each division. An additional function of CONSUM is to control the process by which the combat states of the divisions change over time.

The initial action of CONSUM is to update the combat states at the three divisions when required. Since combat states are updated every twenty-four hours and CONSUM is called every twelve hours, this is done every other call. The divisions can be in one of four combat states--intense, moderate, light, and reserve--at any particular time and, once in a combat state, they remain in that same state for twenty-four hours. At the end of that time, the combat state may change or may remain the same. As outlined in Chapter III, the movement of the divisions' combat status from one combat state to another is modeled as a Markov process. As a result, the current state of a division influences the probability that it will be in any particular state in the future. For example, if a division is experiencing intense combat, it is less likely that it will transition to the light combat state the next day than if it had originally been in the reserve combat state. The process of determining the next combat state for each base starts with a random number draw. The next combat state is chosen by comparing this number to intervals of values corresponding to the different states. The width of these intervals and, therefore, the probability of choice vary, depending on the current combat state for the base. The probabilities for each possible transition are displayed in a one-step transition matrix included in Chapter III.

The next function of CONSUM is to update the status at the divisions to reflect the effects of the preceding twelve hours of combat. The rate of supply consumption in two categories--POL (class III) and ammunition (class V)--is directly related to the combat state at the divisions. The remaining supply categories are consumed at a constant rate regardless of combat state. Supply consumption rates are also dependent on which division is being considered because the armored division consumes supplies at a different rate than the two mechanized divisions for certain supply classes. There are five such classes: class II (clothing and equipment), class III (POL), class V (ammunition), class VI (personal demand items), and class IX (repair parts). The remaining classes of supply are consumed at the same rate for all divisions. Casualty generation rate is directly related to combat state but is the same for each of the divisions. Taking all these factors into account, CONSUM determines the changes to the divisions' status and changes the values stored in two arrays--"stat," which contains supply status for the divisions, and "cas" which contains their casualty status. The values in these arrays are used in subroutine ROUTE as a basis for priority calculations.

8. Subroutine ROUTE

This subroutine is called every twelve hours by subroutine SCHED as part of the airlift scheduling process. ROUTE has two main functions: assigning priority to user needs and scheduling airlift missions based on these assignments. The assignment of priority to user needs allows a single priority scale to be used in ranking airlift missions. Therefore, missions with different loads, or missions of different types, can be compared directly and ranked. This feature allows missions to be scheduled to meet the highest current priority need regardless of mission type.

Priority assignment is made in one of two ways depending on the mission type being considered. Priority for resupply missions is calculated by comparing the current status of supplies on hand in each of the eight supply categories considered to the desired level. This is calculated by dividing the desired level of supply, defined in this scenario as the expected consumption for fifteen days, by the current level. These levels are measured in units of pallets, except in the case of POL, which is measured in units of 100 gallons. The calculated priority in each category is multiplied by a scheduling weight for that particular category. For example, if the current level of ammunition (class V) is 2000 pallets, the fifteen day standard is 4000 and the scheduling weight is 2, then the calculated priority is 2x(4000/2000), or 4.

Scheduling weights are applied to supply categories only and do not apply to air evacuation missions.

Air evac priority is determined differently and is based on the evacuation policy in use, which, in this scenario, is to remove casualties from the field in seven days or less. Priority for air evac is based on both the number of casualties requiring evacuation and the length of time they have been in the field. This is calculated by breaking the total number of casualties at each of the division bases into groups that have been in the field for the same length of time. Eight groups are used for this calculation, the first seven corresponding to the groups that have been in the field for one through seven days. The eighth group contains all casualties who exceeded the evacuation policy and remained in the field for more than seven days. Priority is assigned to the groups, starting with group four, in a graduated fashion so that the longer a group has been awaiting evacuation, the higher its priority. The priority for air evac is calculated by summing the priority for each category larger than three. The priority for each category is set equal to the number of casualties in that particular category, divided by a factor which decreases as the number of the category increases. As a result, as the length of time a group of casualties has been in the field increases, the priority for the group also increases. This calculation is illustrated in Table XI in which priority for 100 casualties has been calculated for groups 4 through 8.

AD-A141 149 USER NEED SATISFACTION AS A BASIS FOR TACTICAL AIRLIFT SCHEDULING(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGINEERING J C BRYANT ET AL. MAR 84

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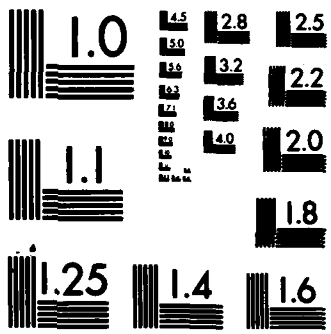


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE XI

Calculation of Priority for
Casualties by Category

Category	Factor	Calculated Priority for 100 Casualties
4	90	1.11
5	80	1.25
6	40	2.50
7	20	5.00
8	1	100.00

ROUTE uses scheduling priorities calculated in this manner to schedule mission itineraries and load makeup using an iterative process. The first step of this process is to calculate the scheduling priority for all supply categories and air evac at each of the three division bases. Next, a mission is scheduled to the division base with the highest calculated priority, and the aircraft load for the mission is planned based on the particular airlift need that generated that priority. Finally, the status of the division receiving the mission is updated to reflect the planned offload or onload. Updates are performed on separate arrays created for this purpose within the subroutine. Information on current status from the "stat" and "cas" arrays are copied initially into these internal arrays. As missions are scheduled, updates are made to these internal arrays only. "Stat" and "cas" are updated as a result of actual offloads and onloads performed when the aircraft arrive at the division bases.

This scheduling process is repeated until all missions for the current twelve-hour scheduling period have been planned. As an example of the process, suppose that the highest priority need is determined to be POL at the armored division. To meet this need, a mission is scheduled to one of the depots for a POL onload and then to the armored division base for a POL offload. The current POL status at the armored division in the internal status array is then incremented by one aircraft load (6500 gallons or 65 units) of POL. The priorities are then recalculated, with the priority for POL at the armored division reduced as a result of the planned offload, and the highest resulting priority used to schedule the next mission.

This description of the scheduling process is an oversimplification of the actual procedure, however. In the model, mission scheduling is complicated by several constraints that are inserted into the scheduling process as a result of the specific characteristics of the scenario. These constraints impact the scheduling process by causing it to deviate from a strict priority system. This occurs whenever a scheduling constraint prevents the subroutine from making scheduling decisions based on the highest overall scheduling priority.

One such scheduling constraint is caused by the fact that due to crew duty time limitations, no partial offloads or onloads are planned at any stop. As a result, once a division base has been chosen to receive a mission by the scheduling process, the entire aircraft load must be planned for that base. This causes a deviation from strict priority scheduling to occur whenever a palletized load is being planned. This deviation results from the requirement to plan offload of the entire load at a single base. Consequently, once the offload base has been chosen, and the first pallet of the load has been designated, the subsequent pallets in the load are chosen to meet the highest priority cargo needs for that particular division. To limit consideration to that one division, the priority for palletized cargo at the other two divisions is not considered. Therefore, the decisions made in assigning pallets to the load are not made based on a consideration of the highest overall priority but rather based on the situation at a single base.

An additional constraint to scheduling is imposed by the fact that aircraft in this scenario cannot be reconfigured once they have departed home station. This causes a limitation to airlift scheduling because each of the three mission types--palletized cargo, POL, and air evacuation--require a distinct aircraft configuration which is incompatible with the other two. This constraint causes a deviation from strict priority scheduling whenever the second onload and off-load of a mission is being scheduled. Because aircraft are not reconfigured after departure, the configuration of the second part of the mission is constrained to agree with the configuration already set for the first part. For example, if the first onload and offload consists of cargo pallets, the second onload and offload must be pallets also regardless of whether another mission type has higher priority. In this example, the subroutine would search for the highest cargo priority when planning the second part of the mission and would ignore POL and air evacuation priority in its search. As a result, higher priority needs may be overlooked.

Finally, there is a scheduling restriction that is due to the extra flying time required for aircraft based at Riyadh compared to the other two C-130 bases and the relatively long time required for POL onload and offload. As a result, Base 1 aircrews cannot complete a POL mission in a normal crew duty day. Consequently, Riyadh aircraft are not scheduled to fly POL missions. This restriction causes a deviation from priority scheduling because priority for POL is ignored when scheduling Riyadh aircraft.

In addition to these restrictions, ROUTE uses several scheduling conventions in planning itineraries. Missions are all planned to include two onloads and two off-loads and, as a result, all aircraft are scheduled to make five stops--two onloads, two offloads and the return to home base. Home station departure bases are assigned to missions in order, sequentially, so that every third mission is assigned to the same home departure base. In addition, the depots are alternated so that for each mission, the second onload occurs at a different depot from the first.

ROUTE schedules all missions for the period at one time, returning to SCHED with all missions listed by mission number and in order of priority in an array called "rte." This array contains all required information about the mission, such as mission itinerary, required configuration, and planned load.

9. Subroutine FLOW

This subroutine inserts the missions planned in ROUTE into an orderly flow that limits expected conflicts between missions to an acceptably low level. This is done in a sequential process which is controlled by SCHED. SCHED transfers missions from the "rte" array to the "dest" array, which contains those missions that have been sequenced in FLOW, and is used to control the movement of aircraft in the simulation. As each mission is inserted into the "dest" array, a call is made to FLOW to determine whether it will conflict with missions already sequenced. If it will, the mission is altered to resolve the conflicts.

The first function performed by FLOW is to assign a departure time for the mission being flown and, from that, determine an expected arrival time for each enroute stop. Mission departure times are assigned by adding twenty minutes to the last home station departure for the base in question, thereby assuring that home station departures are spaced evenly. Since all three bases use the same starting time, the result is that departures occur from the three bases simultaneously, spaced by twenty minutes. Once the departure time is set, the expected arrival time for each enroute stop can be calculated. This is done for the first stop by adding the enroute flying time to the departure time. For subsequent stops, the time spent taxiing, performing and onload or offload, and the enroute flying time is added to each succeeding arrival time. The expected arrival time for each stop is then used in FLOW to test for conflicts with the expected arrival times of other missions.

The process of integrating a new mission in the existing flow is an iterative one involving two stages. First, a test is made to see if the new mission conflicts unacceptably with missions already scheduled. If it does, the second step of the process occurs, in which the mission is changed as necessary to reduce the conflicts to an acceptable level. The mission is changed in stages, and after each change the test for conflicts is repeated. This process continues until the mission passes the test.

The test for conflicts is made by comparing the new mission with all existing missions that have a similar configuration. A test is run for each scheduled enroute stop in the mission where onload or offload is performed. If an existing mission has a scheduled arrival at the same base that is within a specified time of the new mission arrival time, a conflict exists. If the number of conflicts exceeds a specified limit, the mission fails the test. The time interval used and the maximum number of conflicts allowed varies depending on the service type and number of servers available for that type. In the case of palletized cargo, two tests are made, the first involving the period 0.9 hours prior to the expected arrival time and the second involving the period 0.9 hours after this time. The maximum number of conflicts allowed within either period is six. For air evacuation missions, the time intervals considered are the same as for palletized cargo. However, the maximum number of conflicts allowed in either period is reduced to two. POL missions are also subject to tests over two periods. The first of these covers the two-hour period prior to the scheduled arrival time, while the second test covers the two-hour period after the scheduled arrival time. In both cases, the maximum number of conflicts allowed is four. The purpose of these limits is not to eliminate queuing altogether but rather to slow the formation of queues by controlling the aircraft arrival rate. Limited queuing is permitted and, because it ensures that all available servers are being used, may even be desirable.

If the planned mission is found to have an unacceptable number of conflicts, an attempt is made to reschedule the mission and reduce the conflicts to permitted levels. Rescheduling is accomplished through a series of switches between the new mission and lower priority missions that have yet to be sequenced in FLOW. No changes are allowed to a previously scheduled mission in order to resolve a conflict. This is done to ensure that a scheduled mission is not altered to accommodate a lower priority mission.

The first type of switch used is to change the home station departure base of the mission. The reason for this is the possibility that changing the departure base will change the expected arrival times for the enroute stops in such a way that the number of conflicts will be reduced to acceptable levels. This is most effective when switching between base 1 and bases 2 and 3 due to the difference in the length of the positioning leg flown from these bases. The actual switch is made by exchanging the home station departure base of the mission with that of the next mission below it in the "rte" array. If this switch is not successful, it is reversed and a switch is made with the second mission below the mission being considered. This second switch is done to ensure that the mission has been attempted from all three bases. In each case, the same departure time is used. If the mission still fails the conflict test, the effects of this second switch are reversed.

The second type of mission alteration carried out starts with a search through the "rte" array for the next mission scheduled to depart from the same base as the first mission. If one is found, the two missions are switched so that a completely new itinerary results for the mission being considered. This mission is tested using the same time slot as before. If the mission still fails the test, the first switch is undone and another one is performed, this time with the second mission having the same home station departure base. This process is repeated until the mission passes the test or until all missions being scheduled in the current period have been considered. If the outcome is the latter case, the time slot for the home station departure is incremented by twenty minutes and the entire process is started over using the later departure time.

10. Subroutine START

START is called in response to the release of an EVENT node in the SLAM network. The node is released by the arrival of an entity consisting of an aircraft and crew that is ready to depart on a mission. The purpose of START is to assign a mission to the aircraft and pass all required information about the mission to the entity. This information is stored in attributes associated with the entity.

START chooses a mission to be assigned in an iterative search through the available missions, based on the home station departure base of the aircraft. START is not associated with any of the departure bases exclusively and assigns missions for departures from all three bases.

The first step of the search is to begin at the last mission assigned to an aircraft with the same home station base, and move down the list of missions until the next mission with the same scheduled departure base is found. If the scheduled departure time of the mission has passed, the mission is not assigned, and the search is repeated for the next mission with the same scheduled departure base. This search is continued until a mission having a scheduled departure time in the future (meaning it can depart on time) is found and assigned to the aircraft. Missions not assigned are eliminated from further consideration. The purpose of the search is to ensure that missions depart at their scheduled time in accordance with the overall flow plan. While this method may cause some missions to be bypassed, the beneficial effect of sequencing departures according to the flow plan should be overriding.

Once a mission is chosen, the attributes of the entity are assigned values accordingly. Attributes that correspond to the crew duty start time, crew duty completion time, current location, next location, mission number, and aircraft configuration are all assigned values.

11. Subroutine SCORE

This subroutine is called every twenty-four hours from subroutine SCHED. The purpose of this subroutine is to compare the current supply status for the division bases to the desired fifteen-day level, and from that comparison, compute an overall airlift score for each run of the model. This score is then used as the measure of effectiveness of the airlift resupply effort for the run.

The score is based on a running average which is computed by dividing the current status for each supply class by the fifteen-day supply standard. The resulting fraction is added to a running total, and this total is divided by the current number of days in the simulation to produce the average fraction of the desired level of supplies maintained over the period.

This running average is computed for each supply class at each of the division bases. For each supply class, the lowest of the averages for the three divisi ns is used for the airlift ore. The reason for this is th score based on another parameter, such as the average value, would fail to distinguish a situation in which two of the three bases were maintained at a comfortable level, while the third was allowed to run critically low. The average value, in this case, might be high, but would not give an accurate indication of user need satisfaction since the needs of one of the users was not met.

Once the minimum average has been determined for each supply class, it is multiplied by a worth factor for that class which was determined through worth assessment of the value of each class in a process described in Chapter III. The resulting score for each class is summed to give the overall airlift score.

12. Subroutine NEWSCD

This subroutine is called every twelve hours, three hours after SCHED is called. The call to NEWSCD coincides with the time that the updated schedule comes into effect. The purpose of the subroutine is to ensure that the mission numbers that were rescheduled in the last update are assigned to aircraft during the twelve-hour period in which the new schedule is current. When called, NEWSCD changes the group of mission numbers being assigned in subroutine START to agree with the group of mission numbers that were rescheduled in the current scheduling period.

Summary

This chapter discusses the development of the tactical airlift resupply system simulation model beginning with a discussion of the causal relationships between the various system elements. The flow of aircraft through the base network is then discussed in three phases--pre-mission home station, depot and division base, and post-mission activities. The remainder of the chapter provides a description of the purpose and function of the Fortran subroutines. Subroutines MAIN, EVENT, INTLC, OTPUT and USERF are intrinsic to SLAM and allocate file space, call other subroutines, initialize variables, and format output for each model run.

Eight user written subroutines provide the capability required to represent the complexities of the airlift resupply scenario in the model. Subroutine USERF consists of ten functions primarily used to assign attribute values and activity durations. SCHED is a routine which controls the airlift scheduling process and updates the schedule each twelve hours. Subroutine CONSUM is called by SCHED, and updates the status of the division bases to reflect supply consumption and casualty rates. CONSUM also controls the changing combat conditions at each base over time. Subroutine ROUTE, also called by SCHED, assigns priorities to the bases according to their needs, and schedules missions according to the priorities. FLOW is a routine which puts the missions scheduled in ROUTE into an orderly flow with the intent to reduce conflicts between aircraft in the system. Expected arrival times at each point on the mission itinerary are determined and tested for conflicts with other arrivals at the same base having the same configuration. By following a sequential process, using various scheduling alternatives, the conflicts are reduced to acceptable levels. Subroutine START assigns mission information to each aircraft before it departs from its home station including mission number, itinerary, configuration and load. The SCORE subroutine calculates an airlift score for each model run based on a comparison of current supply status in each class at each division base to the desired fifteen-day supply level in each class. This score is the MOE of the resupply effort for the run. NEWSCD is the subroutine called when the updated schedule becomes effective, three hours after SCHED. Its purpose is to insure that updated mission numbers are assigned to aircraft departing during the current scheduling period.

Documented SLAM and Fortran code for the base network and for each subroutine are given in Appendices A and B.

V. Verification and Validation

Introduction

Before the model described in Chapter IV was used for experimentation, measures were taken to show that it performed as intended, and that the model sufficiently represented a "real world" tactical airlift system. Model verification was a sequential process which ran concurrently with the development of the model from its simplest to its final form. Because tactical airlift scheduling is not currently based on satisfaction of user needs, as defined in Chapter II, the validity of the model could not be established based on its representation of a real world system. However, expert opinions were solicited from the Army and Air Force, both in the selection of appropriate model parameters and in the evaluation of its output. These opinions formed the basis of the model's "reasonableness" as a tool for analysis. The purpose of this chapter is to discuss the verification and validation processes.

Verification

Law and Kelton list five techniques which were used to verify that the airlift system model gave the intended output (29:334-337). Each of these steps, and how they were followed, is discussed in turn:

1. Write and debug the model in small modules--The final version of the model includes a network of eight bases, over eighty nodes, and complex Fortran subroutines. However, the original form of the model included only three bases (one aircraft base, one depot, and one division base), less than twenty nodes, and very simple subroutines. This simple version was debugged, and its results studied closely, to make sure the aircraft traveled properly through the simplified system. After this was accomplished, additional bases were gradually added to the network, no more than one or two at a time, in a "building block" approach. Network segments, new subroutines, and embellishments to existing routines were added and debugged one at a time. In this way, errors resulting in model runs after each addition was made were more easily pinpointed, either within the addition itself or as a conflict between the addition and an existing routine. This process was used throughout the model's development until the desired level of complexity was achieved.

2. All members of a group should be satisfied that a particular section of code written by one person is performing as intended--Because two people were involved in the model development process, this step was particularly important. Sections of code were written by each person and added to the model. When debugging was required, any change written was studied, line by line, by both team members. This "the whole

is greater than the sum of the parts" approach was successful in detecting errors which were repeatedly overlooked by the author of the new section, but which were detected by the other team member as the logic of the new process was reviewed and discussed.

3. Use of the "trace" capability of the simulation language--The trace feature of SLAM was used to verify that regular and service activity durations were correctly drawn from the appropriate probability distributions. This capability was also used extensively in the development of the model to determine the cause of a run's early termination, or the source of unreasonable output from a completed run. The trace information provided the value of critical attributes, and the specific location of all the aircraft in the system in the period leading up to, and including, the exact time of a failure. When a model run produced unreasonable output, studying the trace of the run often revealed incorrect attribute values responsible for the incorrect results.

Although the SLAM trace provided the aircraft locations and attribute values at the time of a program failure, the actual cause of the incorrect attribute values was not always readily apparent. For this reason, a user written trace subroutine was included which was called after the error occurred, but just before the point at which the error resulted in termination of the run. This trace routine produced a print of entire arrays, particularly the array including all missions and itineraries for the current scheduling period at the failure time. These prints provided information which was used to pinpoint the problem.

4. Run the model under simplifying assumptions for which the results are known or can be easily computed--After the network was fully developed, aircraft entities were routed through the system with predetermined itineraries, configurations, and loads. This was done to make sure that the aircraft actually proceeded to the proper bases in the proper sequence, and on or offloaded the predetermined number of pallets in each specified supply class. The status of the supply levels in each class after the run confirmed that the pallets were delivered to the proper destinations.

5. Display output using graphics as an aid in the detection of subtle errors--Although graphics displays, such as histograms and plots, were not used, presentation of output (in addition to that in the SLAM Summary Reports) was used to verify the model's performance. A printout of the number of days each base was at each of the four combat levels was used to calculate the total quantity of supplies consumed during the simulated time period. The quantity of supplies actually delivered to selected bases in certain classes was determined from the entity counts for the applicable division base service activities given in the SLAM Summary Report. The

difference between the amount consumed and the amount resupplied was added to the supply level at the end of the simulation. This sum was compared to the starting quantity in that class, and the fact the two figures were equal provided further model verification.

It is important to note that no attempt was made to verify the performance of the random number generator or the actual mechanics of the SLAM language. These functions were assumed to perform as expected.

Validation

Validation of a simulation model is not a task to be accomplished only if time permits after the model is developed, but should be kept in mind throughout the model's development (29:338). The model was developed to determine the feasibility of basing tactical airlift scheduling on satisfaction of user needs, and using the degree to which those needs were met as the measure of effectiveness. Although representing a proposed rather than an existing, real world system, the model did contain variables and parameters present in any airlift system. It was considered essential that the model have high "face validity," i.e., its elements had to seem reasonable to people with knowledge of airlift systems and Army supply needs.

From the outset of the modeling effort, every attempt was made to seek the opinions and advice of people intimately familiar with critical parameters included in the model.

Classes of supply and their relative importance to the Army, combat intensities, consumption rates, force sizes and characteristics, and casualty rates were all areas particularly within the Army arena. General background information was solicited from Army logisticians, officers experienced in combat arms, and medical officers, and the answers to specific questions formed the basis for many model inputs. Information pertaining to C-130 maintenance reliability, aircraft basing locations, and aeromedical evacuation, among others, was obtained from Air Force personnel currently involved in each of these areas. The purpose of the model was explained to each expert interviewed, and that the validity of the results obtained was dependent on the "reasonableness" of the information provided.

In addition to expert opinion in the development of the model, existing published information and knowledge based on operational experience of the modelers were relied upon for validation. U.S. Army Field manuals, as well as Air Force manuals and regulations, were used to base certain parameters and elements of the scenario on current service doctrine or operational requirements. The modelers also drew upon over thirteen years of combined experience in both strategic and tactical airlift. They used insights gained from this experience to make decisions in certain areas, particularly onload and offload time distributions for which no historical data existed. Only vague planning factor data for onload and off-load times were available.

The final step in the process was to discuss the developed model with both Army and Air Force experts to determine their opinions of the model's validity. The Army officers who participated in the worth assessment of supply class values also asked questions and made general comments concerning the scenario from the Army point of view. An Air Force C-130 aircraft commander with worldwide experience in both airlift operations and scheduling was interviewed to obtain his assessment of model validity. The major concern of the experts was the assumption that sufficient quantities of supplies were always available at the PODs for transport to the division bases. Although the assumption might be unreasonable in a real world situation, they agreed that any impact on division combat capability due to interruptions in the flow of supplies to the PODs would not be a shortcoming of the airlift resupply system but rather a strategic transportation problem (22; 25; 31; 36). All four experts agreed that the model was sufficiently representative of a real world tactical airlift system.

Summary

This chapter discusses the procedures used to verify and validate that the computer simulation model performed as intended, and that it represented a reasonable real world scenario. Five steps in model verification given by Law and Kelton are stated, followed by the application to each step during the model's development. Validation consists primarily of establishing the face validity of the model by consultation with experts, both in the development of the scenario and parameters, and in the evaluation of the "reasonableness" of the model in its final form.

VI. Experimental Design and Analysis

Introduction

Once the model was verified and validated, experimentation was conducted to determine how the results changed as different scheduling heuristics and supply class weights were varied. This chapter provides a discussion of the policy determination process, simulated run time, sample size determination, experimental results, and analysis of those results.

Policy Determination

The experiment involved running the model with two different scheduling heuristics, each at two levels, and with three different sets of supply class weights. The model was run under each combination of these to determine if any one combination produced better results, as measured by the score at the end of the simulated time period. The two variations in scheduling involved the use of the FLOW subroutine and the subtraction of expected consumption in each supply class at each division base at the beginning of each scheduling period.

As discussed in Chapter IV, the purpose of the FLOW subroutine is to prevent conflicts at the PODs and division bases. Before scheduling an aircraft to onload or offload cargo at Base 6, for example, the FLOW scheduler checks the number of arrivals already scheduled at Base 6 within a certain time "window." This check takes the aircraft configuration and the onload or offload capability of Base 6 into account and seeks to avoid the large queue buildup which could occur if too many aircraft arrive within this window. If conflicts at Base 6 are likely, the FLOW scheduler determines the arrival situation for the same time period at Base 7, which has a lower scheduling priority. If fewer arrivals are scheduled to Base 7, conflicts there are less likely, so the aircraft will be scheduled to Base 7. The reasoning behind the "switch" from Base 6 to Base 7 is that even though scheduling priorities at Base 6 are such that large quantities of supplies are needed there, scheduling too many aircraft to arrive at Base 6 in too short a period of time may be counterproductive. The FLOW scheduler should provide for more efficient routing, with smaller average queue waiting times, by scheduling an aircraft to an alternate base rather than spend excessive and unproductive time in a queue at the primary destination. The model was exercised both with and without subroutine FLOW.

Subtraction of expected consumption (ECS) is used to artificially decrease the level of supply in each class before the initial scheduling priority is determined. The purpose of this subtraction is to increase the priorities of the classes with low current supply levels. For example, assume that the desired level of supply in class I is 100 pallets, and that

Base 7 currently has ten pallets on hand in this class. Assume further that the expected consumption (based on a moderate rate) is fifteen pallets. At this expected rate of consumption, Base 7 will reach the "zero level" in class I during the next twelve-hour period. By subtracting the expected consumption of fifteen pallets from the actual status, the result will be to give class I at Base 7 a priority of 100 (because the priority becomes the standard if the status of a supply class reaches zero or less). As a result, class I at this base should have a sufficiently high scheduling priority to preclude it from reaching the zero level during the period. The purpose of ECS is to maintain higher average levels of supply in all classes and to prevent classes from reaching the zero level. Model runs were made with and without expected consumption subtraction.

After the initial scheduling priorities are determined, three different sets of multipliers, or weights, are applied to the priorities in each supply class. The purpose of the class weights is to change the initial priorities (standard divided by current status). Applying the different weights should have the effect of maintaining the more heavily weighted classes at higher levels due to their "artificially" higher scheduling priorities. Consider the following example. After initial priorities are determined, classes III and IV at Base 6 both have a priority of 3.0. Because class III is considered more important than class IV, a weight of 2.0 is applied to class III while a weight of 1.0 is applied to class IV. The effect is that class III has a new priority of 6.0. Even if class IV had an initial priority greater than class V (as high as 5.99), applying the weights to both classes gives class III higher priority. Using this weighting differential over a period of time, class III should be maintained at a higher average level than class IV.

Although there are an infinite number of weight combinations which could be applied to the eight supply classes considered in the model, three specific sets were used to determine if significantly different scores resulted from their use. The first weight set consisted of equal weights (1.0) for all classes as a baseline case, resulting in no adjustment of the initially determined priorities. The second weighted all classes equally except classes III, V, and IX (POL, Ammunition, and Repair Parts). These classes were weighted 2.0, 3.0, and 5.0 respectively. The basis for weighting these classes more heavily than the others is the Army doctrine which considers classes III, V, and IX as critical supplies (13:p. 5-1). The third set weighted each class according to the results of the Army worth assessment (Chapter III, Table VIII). Applying these weights should give the classes scheduling priority according to their worth.

Exercising the model with the FLOW subroutine and ECS, each at two levels, and with the three sets of weights results in the twelve possible combinations, or policies, given in Table XII.

TABLE XII

Scheduling Policy Matrix

	No FLOW No ECS*	No FLOW ECS	FLOW No ECS	FLOW ECS
Weight Set 1	Policy 1	Policy 2	Policy 3	Policy 4
Weight Set 2	Policy 5	Policy 6	Policy 7	Policy 8
Weight Set 3	Policy 9	Policy 10	Policy 11	Policy 12

*ECS--Expected Consumption Subtraction

Run Length

The amount of computer time required to run the model increased with the number of days simulated. Because of this constraint, a decision had to made on a number of days to simulate which would provide a balance between computer time required and reliability of the results obtained. Using forty aircraft at each of the three C-130 bases, pilot runs with policy 4 for both thirty and sixty days were made with three replications per run. The variance between the scores in the sixty-day run was not reduced from that of the thirty-day case.

Because variance was not reduced with a larger run time, experimental runs were performed over a simulated thirty-day time period.

Sample Size and Reliability

The goal of simulating the airlift resupply system was to determine if there was one policy among all the policies evaluated which provided the highest level of combat capability, measured in terms of the policy score. Because a decision as to the best policy could not be made from only one run from each policy, a determination of the required number of runs, or sample size, was required.

The length of time required to run the model (approximately twenty minutes per run on the VAX 11/780 computer), computer system turnaround, and the number of policies to evaluate placed restrictions on the sample size. Ten replications of each policy were considered the maximum number allowable due to these restrictions. Each of the twelve policies was run the specified ten times, requiring 120 runs of the model. The mean response for each policy across the ten runs was then calculated. A multiple ranking procedure (MRP) given in Kleijnen was chosen to evaluate the policies based on the mean scores of the twelve populations.

If the mean scores of the policies are close together, a large number of runs is required to detect very small differences between the means. To preclude the requirement for large sample sizes, Bechofer proposed the "indifference zone approach." This approach proposes to guarantee the correct policy will be selected, with a certain specified probability P*, only if the highest population mean is at least a certain number of units, say δ^* , better than the next highest (27:602). If the highest mean is not δ^* units better than the next highest, the difference between the two populations is not considered statistically significant. All MRPs discussed by Kleijnen use the indifference zone approach. They assume independence of the observations within and between populations, and that the populations are normally distributed (27:605).

The particular MRP used depends on knowledge of the population variances. In this experiment, the variances were unknown, but assumed to be equal. Based on this assumption, the Bechofer, Dunnet, and Sobel two-stage procedure was used. The first stage of this procedure requires taking a sample of some n_0 observations from population i. Ten runs of the model were made with policy 1. S_0^2 , the unbiased estimator of the variance, was calculated using the method given in Kleijnen, resulting in a value of 2.58 (27:609). The second stage is normally followed to determine the final sample size to be used in the experiment based on the predetermined value of δ^* . In this case, because the sample size was set at ten, it was necessary to determine the value of δ^* which would give sufficiently reliable results based on this sample size. The value of δ^* was determined using the following relation:

$$n = 2S_0^2(h/\delta^*)^2$$

where

n = sample size

S_0^2 = estimator of the population variance

h = critical constant which is the solution of a multivariate t-distribution tabulated in the form $h\sqrt{2}$ by Gupta and Sobel (27:609).

The tabulated value of $h\sqrt{2}$ for a P* of .95 is 3.55, resulting in a value for h of 2.51 (20:962). Solving the above equation for δ^* gave a value of 1.80. This value of δ^* , and the assumption that all population variances were equal, implied that if the population with the largest mean was at least 1.80 units greater than the next highest mean, the policy with the highest mean could be selected as the best policy with 95 percent confidence (the level of P*).

After the calculation for δ^* was completed, the other eleven policies were replicated ten times each. The ten observations, mean, and S_0^2 for each policy are given in Table XIII. Before comparing the mean values to select the best policy or policies, it was observed that there was a relatively large difference between the variances of policies

TABLE XIII

Experimental Results

Run	P1	P2	P3	P4	P5	P6
1	24.89	25.21	25.35	25.33	30.37	30.59
2	26.54	26.79	26.48	27.38	31.43	32.20
3	23.50	23.88	24.08	24.02	29.05	29.46
4	22.74	23.66	23.34	23.67	28.56	28.58
5	25.96	26.50	26.33	26.62	30.83	31.20
6	26.13	26.70	26.22	26.60	30.98	31.78
7	22.22	22.16	22.25	22.46	27.41	27.71
8	25.74	26.38	26.12	26.72	30.89	31.35
9	22.69	22.61	22.92	22.84	28.05	28.08
10	24.68	25.18	24.84	25.11	30.23	30.83
Mean	24.51	24.91	24.79	25.08	29.78	30.18
S_0^2	2.58	3.01	2.43	3.08	1.96	2.58

TABLE XIII--Continued

Run	P7	P8	P9	P10	P11	P12
1	30.54	30.72	35.95	35.05	36.08	35.50
2	31.75	31.87	38.17	37.96	38.09	37.16
3	29.01	29.88	33.88	33.71	33.68	32.73
4	28.61	28.46	33.92	31.56	33.45	32.45
5	30.80	31.33	37.64	37.33	36.03	36.84
6	31.31	31.84	37.24	34.75	36.51	36.02
7	27.84	27.33	31.80	32.41	31.83	30.90
8	30.75	31.30	37.41	36.70	36.23	34.96
9	28.00	28.05	33.73	32.34	33.51	31.56
10	30.40	30.68	35.68	35.08	35.89	34.40
Mean	29.90	30.15	35.54	34.69	35.13	34.25
S_0^2	1.99	2.71	4.51	4.83	3.63	4.93

5 and 12. On the suspicion that the variances might not be equal, an F test was performed using the ratio of the smallest and largest variances (policies 5 and 12) to test the null hypothesis $H_0: \sigma_5^2 = \sigma_{12}^2$. Results of the F test procedure given in Devore showed that H_0 could not be rejected at the .05 level, so the variances were considered equal (16:312). Even though the null hypothesis of equal variances was accepted, the value of δ^* was recomputed using the S_0^2 for Policy 12 (4.93), the largest population variance. The new δ^* of 2.49 was a more restrictive value to be used with the Bechofer, Dunnet and Sobel MRP to distinguish between the policies. The ranking of the twelve policies based on their mean values is given in Table XIV. Because the value of the highest mean (policy 9) was not at least 2.49 units greater than those of policies 11, 10, and 12, no single "best" policy could be selected. The results of the procedure showed that while these four policies gave better results than the others, there was no statistical difference between the top four.

Analysis of Results

It was observed from the results that the average scores of the top four policies were obtained using weight set 3 (all supply classes weighted according to their worth) and that average scores using weight set 2 (classes III, V, and IX weighted more heavily) were higher than those for weight

TABLE XIV

Policy Ranking

Rank	Policy
1	9
2	11
3	10
4	12
5	6
6	8
7	7
8	5
9	4
10	2
11	3
12	1

set 1 (all classes weighted equally). The effect of weight sets on score is shown graphically in Figure 7.

The effect of weight sets can be explained by the fact that the heavier weights for the more critical (or valuable) classes of supply increase the scheduling priority for these classes. As a result, higher average supply levels are maintained in the critical classes. Because score is determined by taking the product of daily average in each class and class worth, summed across the classes, the resulting score was higher as the scheduling priorities of the most valuable classes increased. While it is true that levels of the classes given lower priority decreased, the effect of the increased levels maintained in the more valuable classes was overriding in terms of score.

Although the significance of the weights appeared obvious from the results in Table XIII, the other main effects, FLOW and ECS, did not appear to have any significant impact on policy score. A 3 x 2 x 2 (weight by FLOW by ECS) analysis of variance performed with the sample data confirmed that the effect of weight was significant and that FLOW and ECS were insignificant at the .05 level.

In addition to main effects, certain combinations of main effects may also be significant. Three combinations of two main effects (two-way interactions) were tested in the experiment--between weight and flow, weight and ECS, and

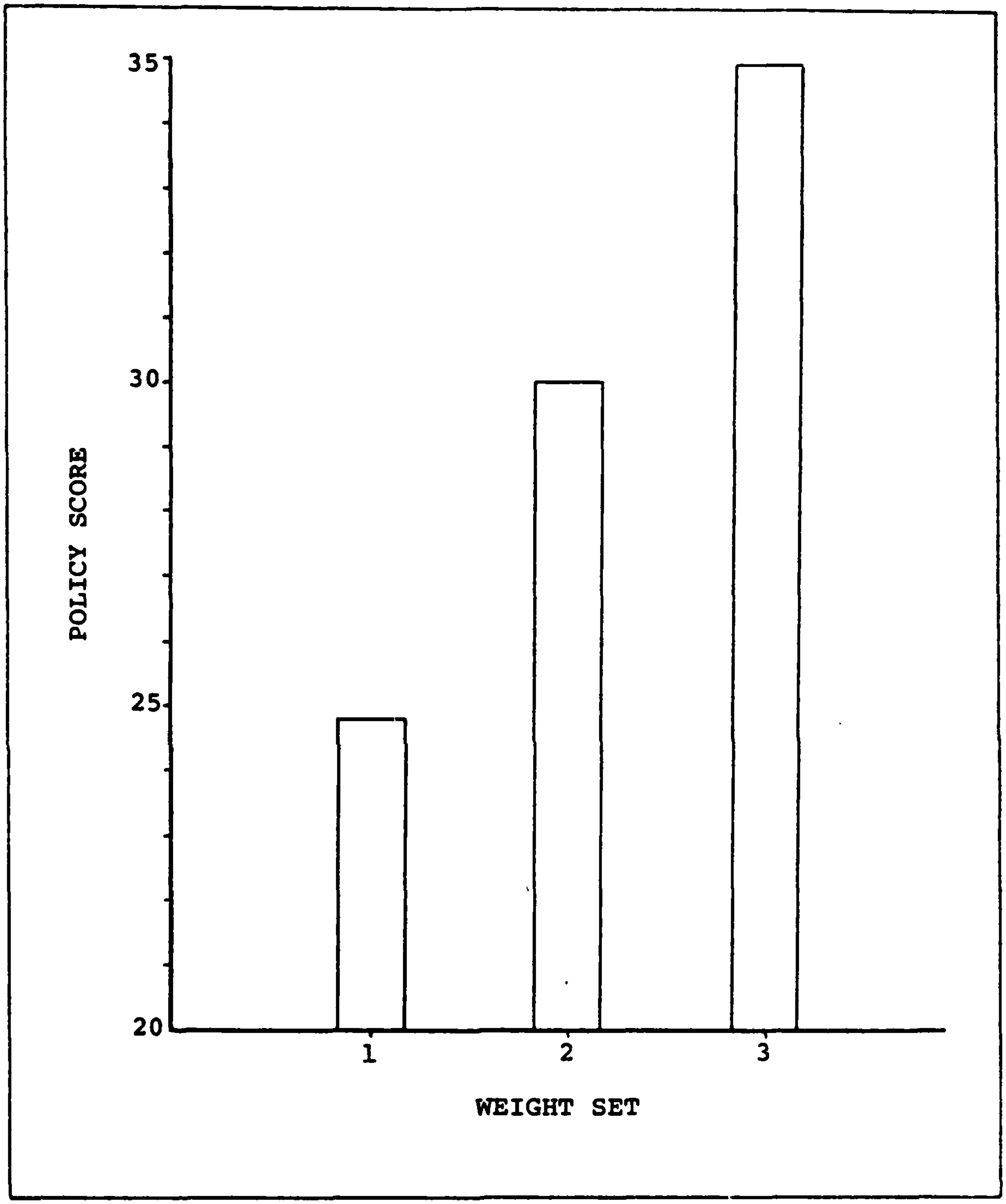


Figure 7. Effect of Weight Set on Score

between FLOW and ECS. Graphical representations show that while the main effects of FLOW and ECS were not significant, there was a significant interaction between weight and FLOW and weight and ECS, while the interaction between FLOW and ECS was not significant.

Figure 8 depicts the relationship between FLOW and weight. For weight sets 1 and 2, the effect of FLOW was to increase the mean policy score, while the opposite was true of weight set 3. The positive effect of FLOW on score using the first two weight sets is probably because of the reduction of queuing by aircraft as a result of the sequencing performed by the FLOW subroutine. The negative effect on score with weight set 3 was an unexpected result and one that is not easily explained.

The reason for this effect must be linked to the way the FLOW subroutine interacts with the effects of using scheduling weight 3. Compared to the other sets, the use of weight set 3 in scheduling causes the number of POL missions to increase, in response to the higher scheduling priority, and the number of cargo missions to decrease. This is because maintaining POL at high levels requires more sorties than other supply categories. As a result, it is likely that the reason for the negative effect of FLOW is related to the management of POL missions. Since the number of cargo missions is reduced, sequencing cargo missions in the FLOW subroutine may not be

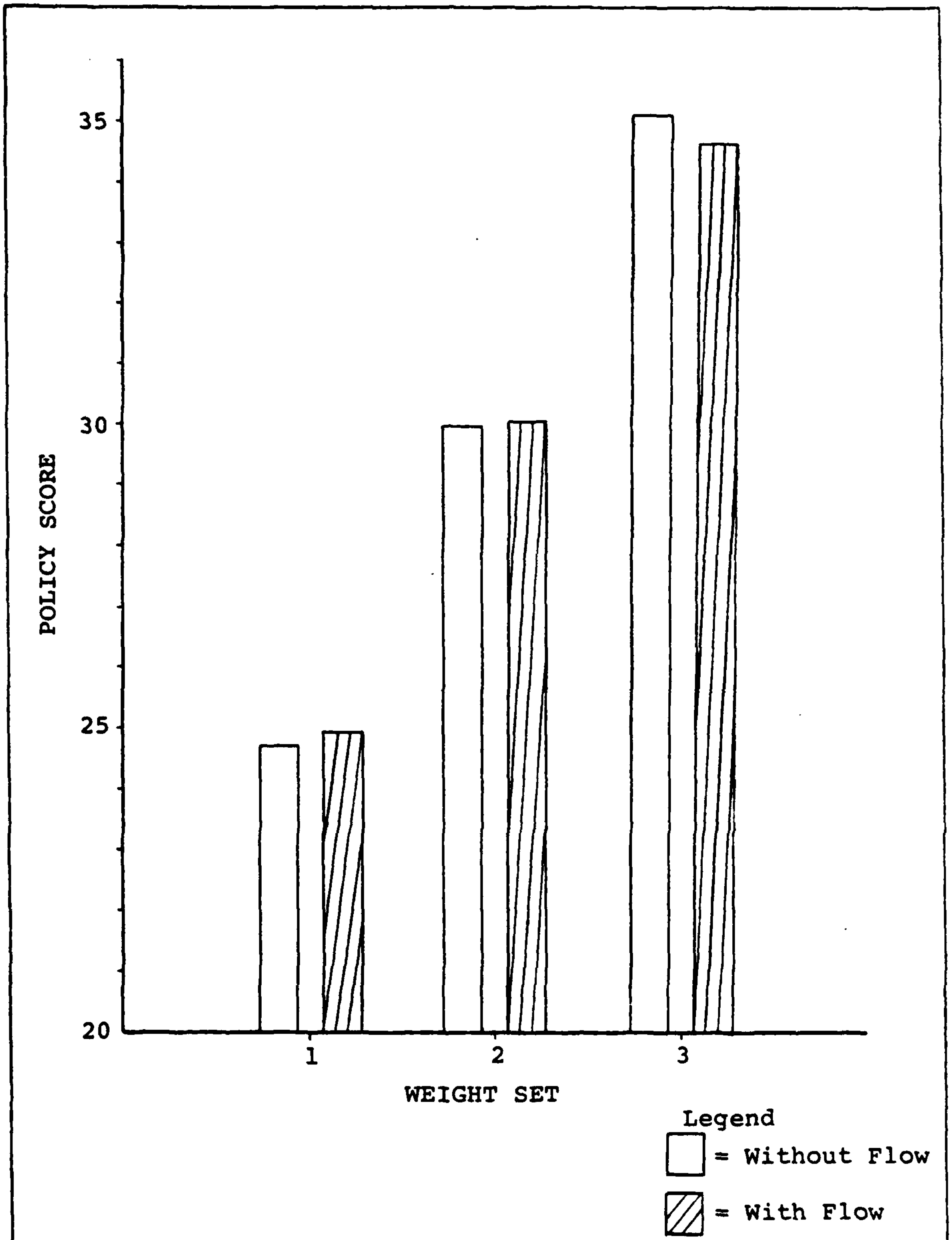


Figure 8. Interaction of FLOW and Weight Set

necessary, and may actually be counterproductive, because of an adverse effect on POL mission sequencing. This adverse effect may result from the method used in FLOW to avoid conflicts, which is to replace missions with ones with different itineraries or servicing requirements. As a consequence, POL missions may be put into the time slot of cargo missions to resolve cargo mission scheduling conflicts. POL missions can be substituted in this fashion until the number of conflicts with other POL missions, caused by substitution, exceeds the number permitted. Therefore, attempts to sequence cargo missions may result in a greater proportion of POL missions being scheduled with the number of expected conflicts at the maximum permitted level. Since this limit is larger than the number of servers available, the result is an increase in queuing by POL aircraft. When coupled with the increased number of POL missions caused by the use of weight set 3, this effect might cause an increase in queuing as a result of the action of the FLOW subroutine. Although the actual mechanism for this observed effect is not known, the results of sensitivity analysis described below support this explanation.

Sensitivity analysis was conducted on the system to determine the effect on airlift score of changing the FLOW subroutine. The model was run with two different flow policies combined with the three weight sets. Since there was no interaction between FLOW and ECS, it was not varied, and all runs were made with ECS included. The two FLOW policies used in the analysis varied from the base case policy by having different values for the maximum number of scheduling conflicts permitted. The first policy used, policy 1, was more restrictive than the base case for all mission types. The maximum number of conflicts permitted was reduced by one from the base case limit in each category. The resulting policy had the following maximum number of conflicts permitted: five for cargo missions, three for POL missions, and one for air evac missions.

The second policy, policy 2, imposed a more restrictive limit on POL missions, but a more relaxed limit on the other two mission types. The maximum number of conflicts permitted under policy 2 was set at eleven for cargo missions, three for POL missions, and three for air evac missions. The results from the sensitivity runs, including the average of the total time spent in all POL and cargo queues are shown in Table XV. Also included are the same results for the base case FLOW and the no-FLOW situation.

From Table XV, it can be seen that the effect of the different FLOW policies, relative to each other and to the no-FLOW case, is dependent on the weight set used. When weight set 1 is used, policy 1, which is the most restrictive FLOW policy, results in less time in both POL and cargo queues compared to the base case FLOW policy, and this policy has the

TABLE XV

Waiting Time/Average Score Comparison

Flow Policy	Average Waiting Time For All Queues (Hours)		Average Score
	POL	Cargo	
Weight Set 1			
No FLOW	0.568	0.111	24.91
Base Case	0.501	0.099	25.08
Policy 1	0.454	0.072	25.42
Policy 2	0.484	0.111	25.04
Weight Set 2			
No FLOW	0.770	0.199	30.18
Base Case	0.704	0.108	30.15
Policy 1	0.633	0.078	30.46
Policy 2	0.658	0.187	30.33

TABLE XV--Continued

Flow Policy	Average Waiting Time For All Queues (Hours)		Average Score
	POL	Cargo	
Weight Set 3			
No FLOW	1.826	0.030	34.69
Base Case	1.948	0.030	34.25
Policy 1	1.643	0.029	34.73
Policy 2	1.504	0.041	35.10

highest score overall. Policy 2, while reducing time spent in the POL queues, has no effect on the time spent in cargo queues, which is to be expected from the large number of cargo mission conflicts allowed for this policy. The fact that the score for policy 1 is higher than that of policy 2 is apparently due to the lack of control of these queues in policy 2. When compared to the no-FLOW case, the base case FLOW policy is effective in reducing waiting time in both POL and cargo queues but not to any great degree. This results in only a slight improvement in score over the no-FLOW case. These results, taken as a whole, indicate that for weight set 1, a FLOW policy that tightly controls the number of expected conflicts for both POL and cargo missions can improve the airlift score over the no-FLOW case.

When weight set 2 was used, the best score again occurred when FLOW policy 1 was used. As before, this policy was best at controlling waiting time in POL and cargo queues, but in this case, the control of cargo queue length is evidently less important when weight set 2 is used. This is shown by the fact that FLOW policy 2 resulted in nearly the same score as with policy 1, with an average time spent in cargo queues that was substantially longer than for policy 1. The base case FLOW policy again resulted in some improvement in time spent in queues, but this improvement is small, and the policy actually results in slight reduction in score for the runs made with ECS included. These results lead to the conclusion that, in the case of weight set 2, a FLOW policy that controls time spent in POL queues results in a higher score than in the no-FLOW case. The benefit from controlling time spent in cargo queues is evidently smaller than was the case with weight set 1, and may not be significant. These results are consistent with the fact that, as a result of the scheduling weight attached to POL requirements, more POL missions and fewer cargo missions are flown when using weight set 2 than when using weight set 1.

The results when using weight set 3 were distinctly different that with the other weight sets. The large scheduling weight attached to POL requirements increases the number of POL missions, while decreasing cargo missions to such an extent that there is no significant queuing problem for cargo missions. Furthermore, there appears to be a penalty imposed on FLOW policies that attempt to control cargo queue length. This is shown by the fact that the average time spent in POL queues was substantially higher for policy 1 than for policy 2, and by the same relationship between the base case and the FLOW policy. If no penalty existed, the time spent in the POL queues would be approximately equal for both policy 1 and 2, as it was with the two earlier weight sets, and the base case policy would show slight improvement over the no-FLOW case. As stated above, the reason for this penalty is not clear.

However, the results for both the base case policy and policy 1 are consistent with the explanation offered above. The fact that the score is better for policy 1 may be due to the more restrictive limit on expected POL conflicts in policy 1 compared to the base case. These results indicate that a FLOW policy that restricts POL conflicts but does not affect cargo missions gives a higher score than the no-FLOW case.

Taken as a whole, the results of sensitivity analysis on the FLOW subroutine indicate that, to be effective, the FLOW policy must be tailored to the weight set used. When this is done, the subroutine can reduce the time spent in queues by airlift aircraft and, as a result, increase the score. While the improvement shown in the score was not large, the best FLOW policy was consistently better than the no-FLOW case on individual runs for the three weight sets. In order to determine whether the difference was significant, the Friedman rank test was run comparing the best FLOW policy to the no-FLOW policy with each weight set. Using the procedures given in Daniel, the null hypothesis of no treatment effect was rejected for weight sets 1 and 2 at the 0.05 level, indicating that the effect of FLOW was significant. The null hypothesis could not be rejected for weight set 3, although the FLOW policy dominated the no-FLOW policy in eight out of ten runs (8:226).

The interaction between weight and ECS is given in Figure 9. The graph shows that subtracting expected consumption had a positive effect on score with weight sets 1 and 2, but that the opposite was true with weight set 3. The negative effect of ECS with weight set 3 was most likely due to the very wide differences in scheduling priority between the most valuable classes--repair parts (IX), POL (III), and ammunition (V)--and the least valuable--clothing and equipment (II) and personal demand items (VI). Because with weight set 3 the classes are given priority weights equal to their worth, the most valuable classes are given a much higher scheduling priority than the least valuable. Without subtracting expected consumption, the levels of classes II and VI have a low scheduling priority until they are at or near the zero level. The increased priority at this point improves the supply status temporarily, but the trend is for these classes to return to the zero level repeatedly because their low weights give them priority over the more heavily weighted classes only in the most extreme cases. Although the daily averages in these two classes are very low, the effect on the score is minor because of their low worth (1.0 and 0.5).

When expected consumption is subtracted, classes II and VI are given a higher scheduling priority than before, because the subtraction artificially reduces their status. The result is a drastic reduction in the number of scheduling

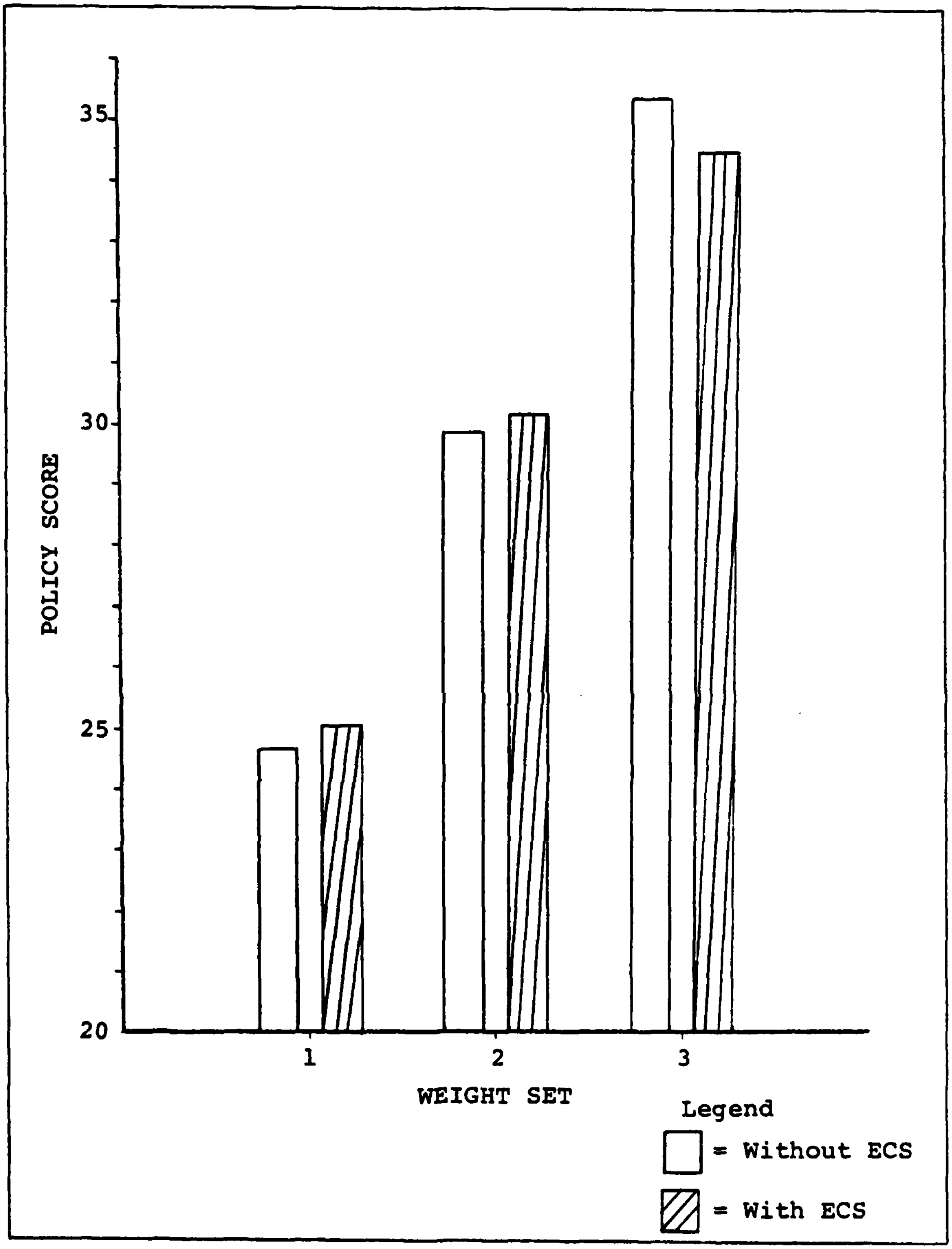


Figure 9. Interaction of Expected Consumption Subtraction and Weight Set

periods at or near the zero level, since the model "knows" that if these classes are not given increased priority, they will approach or reach the zero level. However, giving increased priority to classes II and VI reduces the number of sorties flown to resupply classes IX, III, and V, thereby decreasing the daily averages in these classes. Since the contribution to score is much greater from the more valuable classes, the reduction of their daily averages has a greater negative effect on score than the positive effect due to the increase in the averages of the less valuable classes.

Figure 10 shows that there is no interaction between FLOW and ECS. Results of the analysis of variance confirmed that the interactions of weight and FLOW and weight and ECS were significant, but that the interaction of FLOW and ECS was not significant at the 0.05 level.

Summary

This chapter discusses the experimentation with the model developed in Chapters III and IV. Different combinations of scheduling heuristics involving the FLOW subroutine and the subtraction of expected consumption were tested with three different supply class weights. Twelve possible combinations of these factors were replicated ten times each. The mean scores from each policy were ranked using a parametric multiple ranking procedure to determine if any one policy resulted in a

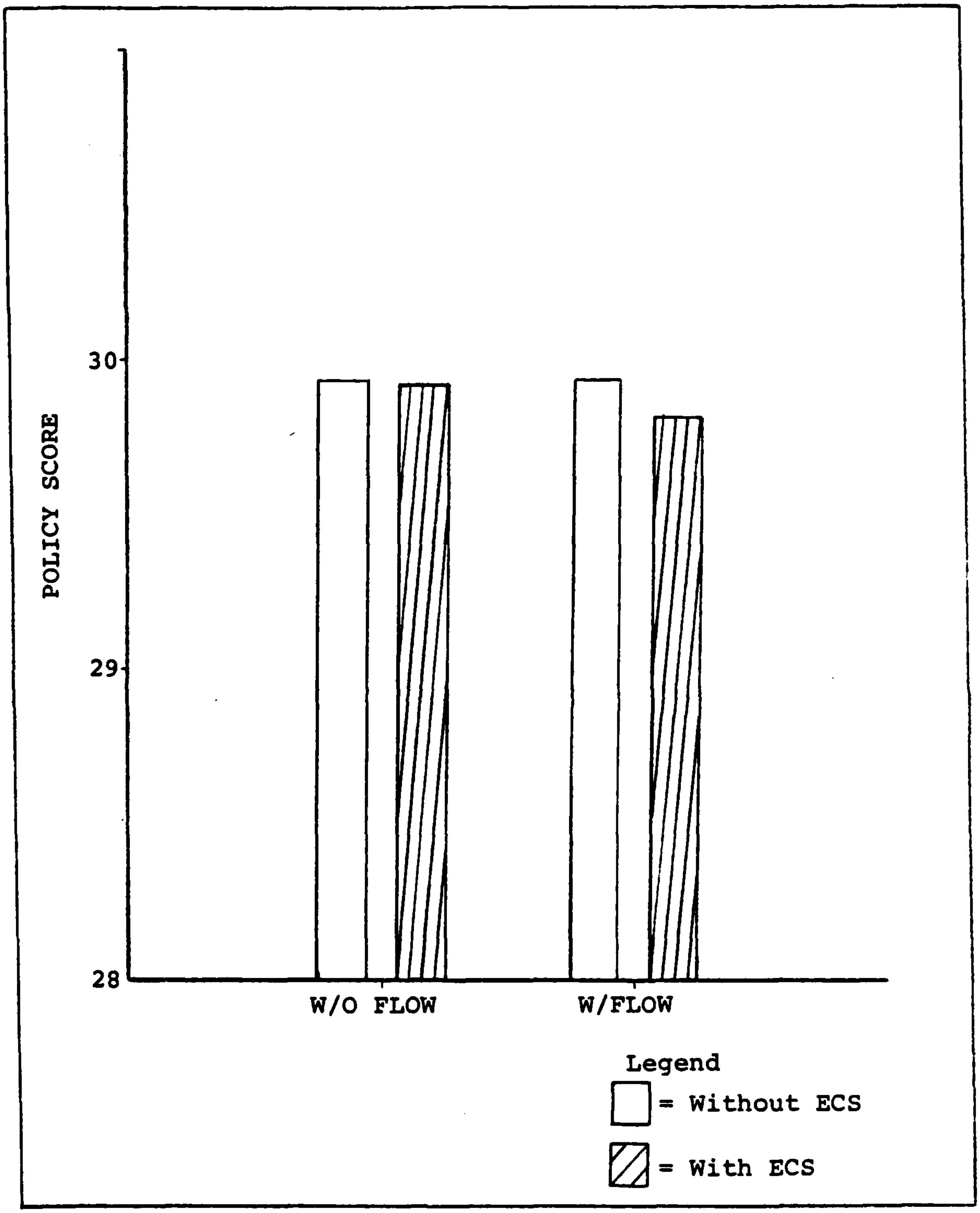


Figure 10. Interaction of Expected Consumption Subtraction and FLOW

significantly higher mean score. The significance of main effects and their interactions are discussed as well as the sensitivity analysis performed with two additional versions of the FLOW subroutine. Graphical and tabular representations of the experimental results are provided and possible reasons for unexpected results with weight set 3 are offered.

VII. Observations and Recommendations

Introduction

After the planning, modeling, experimentation, and analysis phases were complete, certain observations were made concerning the significance of what was done, and areas requiring further research were determined. Several constraints, most notably time, precluded a thorough analysis of all the factors which may have influenced the results. The results themselves posed many questions which were not considered when the research began. This chapter discusses some of the observations made based on the results of this project, and provides suggestions in several areas where further study is warranted.

Observations

One of the objectives of the research effort was to determine the impact of scheduling heuristics and supply class weighting on the satisfaction of user needs. The intent was not to find a single "best" combination of heuristics (FLOW and ECS) and class weighting (weight sets 1, 2, and 3), but rather to show whether different combinations significantly improved the score. From the results, it was found that the weight set chosen had a significant effect on the policy score.

While FLOW and ECS were not statistically significant, use of these rules of thumb in the scheduling process did show a consistent improvement except when applied with weight set 3. The sensitivity analysis done with FLOW and weight set 3 showed that different conflict test criteria for FLOW gave consistent improvement in score and that there was a relationship between score and the average queue waiting time. This confirmed the initial feeling that a controlled flow of aircraft through the system would reduce queue lengths and improve score, although the improvement was not nearly as significant as expected. The sensitivity analysis also showed that, for best results, a specific FLOW mechanism should be tailored to the weight set used.

Development of a new tactical airlift MOE was another research objective. The numerical score was chosen as the MOE based on the belief that user need satisfaction could be quantified by a single number. Perhaps the most significant observation of this research effort was that user need satisfaction depends on several factors which cannot be easily combined and measured on one scale.

Policies with weight set 1 gave the lowest scores, but average levels in all supply classes were at approximately 40 percent of the desired level at the end of the thirty-day period. Weight set 2 yielded higher scores, but less consistency in average supply levels because of the increased scheduling priority given to POL, ammunition, and repair parts (classes III, IV, and IX). Weight set 3 gave the highest scores by far but did not perform nearly as well as the other weight sets in two potentially important areas--classes with zero supply levels and casualty evacuation.

The fact that two classes of supply, clothing and equipment and personal demand items (classes II and VI) had significant periods of time with a zero supply balance shows that a score of 35 for a policy with weight set 3 is not clearly "better" than a score of 25 for a policy of weight set 1. Certainly, these two classes are of minor importance in relation to the most critical categories (according to the Army worth assessment), but depleting these less important classes to improve the status in other classes may be neither desirable nor justifiable.

Policies with weight set 3 also improved the score at the expense of casualty evacuations. While policies with weight sets 1 and 2 were able to meet the requirement that all casualties be evacuated from the division level within seven days of initial hospitalization, weight set 3 effectively reduced the air evac priority. As a result, casualties often remained at the division level for eight days or longer.

The effect of expected consumption subtraction with weight set 3 was to decrease the policy score. However, it had the desired effect of drastically reducing the number of scheduling periods classes II and VI were at the zero level, from 50 down to 5 percent of the time in some cases. To say that employing ECS with weight set 3 was detrimental to the satisfaction of user needs purely based on the reduction in score might not be a correct statement.

The major point to be made is that the scoring function used may not be adequate as the sole MOE of tactical airlift. It is affected primarily by the levels of supply maintained in the most valuable classes, with only a minor penalty inflicted by the maintenance of very low or zero levels in those classes least valuable. The needs and desires of Army decision makers in such areas as even levels of supply in each class, aeromedical evacuation priority, and other factors must be considered. The ability of policies with weight set 1 to maintain average supply levels at 40 percent in all classes and their ability to meet the casualty evacuation goal may make them preferred, even though they resulted in the lowest scores.

The model results were dependent on the specific Iranian scenario from which the model was developed and might change with a different scenario. A different locale for combat operations could result in different values for the supply classes. For example, operations in Central America might be more conducive to the use of infantry than armored forces. The relative worth of POL might decrease in this scenario due to fewer numbers of armored vehicles which consume large quantities of fuel. Having a more restrictive casualty evacuation policy would require an increased priority for air evac missions, thereby reducing the number of resupply sorties. Shorter leg distances between bases with no decrease in onload and offload time could result in queue buildups. All these possible effects would have to be considered if the model were used in other scenarios.

Certain model parameters, such as aircraft size and speed, onload and offload time, and maintenance reliability and delays would remain constant across all scenarios. Consumption figures, distances, MOG, relative supply class worth, and other parameters would change but could be determined and used in the existing model with minor modifications. The worth assessment procedure could be conducted with the Army decision makers involved to establish revised relative supply class rankings. The existing model could be modified and designed so as to incorporate appropriate combinations of FLOW, ECS, and weight set to satisfy the needs of the Army theater commanders for a given scenario. Actual experimentation with the model for different scenarios is among the areas requiring further study.

Recommendations for Further Research

The major recommendation for further research is that sensitivity analysis be conducted on the existing model. Because of time limitations, extensive sensitivity analysis was not carried out in this study, although it clearly would be valuable to do so. The model was based on a specific scenario and, as a result, the applicability of the results of this study to other scenarios may be limited. One of the purposes of sensitivity analysis would be to determine to what extent the results are scenario dependent. In addition to the model parameter changes outlined above, several other scenario changes might be considered. The first is to consider a short, intense war rather than the protracted one in the study. Modern warfare, because of advances in reliability and lethality of weapons, is likely to be shorter and more intense than in the past. In such a situation, tactical airlift scheduling priorities would change drastically. Another situation to consider is a resupply effort that is on a much smaller scale than the one in this study. The airlift requirements in the current study are high because the scenario precludes the use of ground transportation. In other scenarios, a significant portion of the resupply effort may be through surface movement of supplies and the airlift task correspondingly reduced. Another situation to consider is deployment.

The scheduling method in this study could be used to plan the sequence of missions. The worth of delivered supplies would depend on the proper sequence of arrivals in this case. For example, delivering large quantities of artillery ammunition prior to the arrival of the artillery itself would have little value.

An additional area for study by sensitivity analysis is the effect that changing scheduling factors--scheduling weights, FLOW policy, and ECS--has on the scheduling process. Because the purpose of this study was to establish the significance of these factors on airlift scheduling, no attempt was made to optimize the levels of these factors. Sensitivity analysis could provide information needed to choose the best levels for these factors for a given situation. Scheduling weight has the strongest effect on performance. By varying the scheduling weights in the model, different profiles of supply levels for the different supply classes can be generated. There is clearly a strong interaction between scheduling weights and FLOW policy, and this relationship should be explored. Finally, the use of ECS in selected supply classes and in selected situations should be explored.

A recommendation for further research is to explore the use of goal programming in airlift scheduling. Using goal programming, desired supply levels could be set as goals and a scheduling weight attached to deviations from these goals.

Varying these weights should have a similar effect to changing scheduling weights in the current model. Other factors of importance, such as compliance with the casualty evacuation policy, could also be included as goals.

Also worthy of further study is the subject of supply class priority weighting. As pointed out in Chapter VI, there are an infinite number of possible weight combinations which could be applied. An approach to reducing the magnitude of this problem would be the application of Multi-Attribute Utility Theory (MAUT) to assess utility curves for each supply class from appropriate Army decision makers. By experimenting with the model with each class weighted at various points along these curves, response surface methodology could be employed to determine "best" weight sets for use in particular scenarios which properly reflect the desires of the decision makers.

Appendix A: SLAM Variable Lists, Program Statements, and Diagrams

ATTRIBUTE LIST

Attribute Number	Description
1	Aircraft tail number
2	Home base number
3	Maintenance turn-around time at home base
4	Crew duty start time
5	Present aircraft location
6	Next aircraft destination
7	Itinerary stop number
8	Mission number
9	Current leg flying time
10	Cumulative flying time
11	Aircraft configuration
12	Delay from time mission is scheduled until takeoff time
13	Not used
14	Crew duty time remaining
15	Time of last aircraft maintenance assessment
16	Maintenance delay time
17	Assigned appropriate base number when home base maintenance Delay is excessive
18-100	Not Used

XX VARIABLE LIST

XX Variable	Function
1-28	Leg distances between the eight bases
29	Airspeed
30	Number of days simulated
31-33	Counters used to control the number of aircraft assigned to each C-130 base
34-39	Counters used in aircraft generation functions-- USERF 1, 6, and 7.
40	Counter used in SCHED to mark the passage of 24 hours
41	Counter used in NEWSCD to indicate passage of scheduling periods
42	Number of missions available for scheduling
43	Not used
44	Counter used in NEWSCD to keep track of current scheduling periods
45	Counter used in SCHED to keep track of current scheduling periods
46	Counter to indicate a zero level for a supply status has occurred
47	Counter used in ROUTE to keep track of home base assignment
48,49	Not used
50-52	Low value, mean value, and high value for triangular distribution returning enroute flying time
53-59	Not used
60	Counter used in ROUTE to alternate onload points
61-70	Not used

71-79	Scheduling weights
80-100	Not used

```
GEN,GORBRY,TEST,3/16/84,1;
LIMITS,29,17,450;
STAT,1,BASE 1 CREW DAY;
STAT,2,BASE 2 CREW DAY;
STAT,3,BASE 3 CREW DAY;
STAT,4,BASE 1 FLY DAY;
STAT,5,BASE 2 FLY DAY;
STAT,6,BASE 3 FLY DAY;
NETWORK;

;----------------------------------------------------------------
;-  THIS PROGRAM BLOCK INITIATES THE FIRST CALL TO THE USER    -
;-   WRITTEN SUBROUTINE SCHED AT THE START OF THE SIMULATION. -
;-   SUBSEQUENT CALLS ARE SCHEDULED WITHIN THE ROUTINE TO      -
;-   OCCUR AT 12 HOUR INTERVALS.                               -
;----------------------------------------------------------------

      CREATE,,,,1;
      EVENT,1;
      TERMINATE;


;*****************************************************************
;*****************************************************************
;**                                                             **
;**         PRE-MISSION DEPARTURE ACTIVITIES                    **
;**                                                             **
;*****************************************************************
;*****************************************************************


;----------------------------------------------------------------
;-          AIRCRAFT GENERATION FOR BASE 1 (RIYADH)             -
;-                                                              -
;- INITIAL AIRCRAFT GENERATION IS ACCOMPLISHED IN TWO PHASES    -
;-  IN THIS BLOCK.  HALF OF THE BASE AIRPLANES ARE GENERATED    -
;-  AT TIME 0.0 AND THE SECOND HALF ARE GENERATED 12 HOURS      -
;-  LATER.  THE PURPOSE OF THIS TWO PHASE PROCESS IS TO SPACE   -
;-  OUT THE INTRODUCTION OF AIRCRAFT ENTITIES TO THE SYSTEM.    -
;-  THIS INSURES A CONSTANT FLOW OF MISSIONS OVER THE FIRST     -
;-  24 HOUR PERIOD, RATHER THAN FLYING A LARGE NUMBER IN THE    -
;-  FIRST 12 HOURS AND A SMALL NUMBER IN THE SECOND.            -
;----------------------------------------------------------------

BEG1  CREATE,12.0,,,2;
ASN1  ASSIGN,ATRIB(1)=USERF(1),ATRIB(2)=1,2;
      ACT,,XX(34).LT.XX(31),ASN1;
      ACT;
```

```
;-------------------------------------------------------------
;- THE MAINTENANCE QUEUE (MXQ1) CONTAINS AIRCRAFT WAITING FOR  -
;-  MINOR MAINTENANCE ACTIONS ACCOMPLISHED BETWEEN MISSIONS.   -
;-------------------------------------------------------------

MXQ1  QUEUE(1);
      ACT(15)/1,ATRIB(3);

;-------------------------------------------------------------
;- THE AIRCRAFT QUEUE (AC1) CONTAINS MISSION-READY AIRCRAFT.   -
;-------------------------------------------------------------

AC1   QUEUE(2),,,,AS1;

;-------------------------------------------------------------
;- THE AIRCREW QUEUE (CR1) CONTAINS RESTED CREWS.  INITIALLY,  -
;-  IT CONTAINS A NUMBER OF CREWS EQUAL TO TWICE THE NUMBER OF -
;-  AIRCRAFT ASSIGNED TO THE BASE.                             -
;-------------------------------------------------------------

CR1   QUEUE(3),80,,,AS1;

;-------------------------------------------------------------
;- AN AIRCRAFT AND CREW ARE ASSEMBLED FOR A MISSION.           -
;-------------------------------------------------------------

AS1   SELECT,ASM,,,AC1,CR1;
      ACT,,,GO;

;-------------------------------------------------------------
;-          AIRCRAFT GENERATION FOR BASE 2 (DHARHAN)           -
;-               (IDENTICAL TO THAT OF BASE 1)                 -
;-------------------------------------------------------------

BEG2  CREATE,12.0,,,2;
ASN2  ASSIGN,ATRIB(1)=USERF(5),ATRIB(2)=2,2;
      ACT,,XX(36).LT.XX(32),ASN2;
      ACT;
MXQ2  QUEUE(4);
      ACT(15)/2,ATRIB(3);
AC2   QUEUE(5),,,,AS2;
CR2   QUEUE(6),80,,,AS2;
AS2   SELECT,ASM,,,AC2,CR2;
      ACT,,,GO;

;-------------------------------------------------------------
;-          AIRCRAFT GENERATION FOR BASE 3 (BAHRAIN)           -
;-               (IDENTICAL TO THAT OF BASE 1)                 -
;-------------------------------------------------------------

BEG3  CREATE,12.0,,,2;
```

```
ASN3  ASSIGN,ATRIB(1)=USERF(6),ATRIB(2)=3,2;
      ACT,,XX(38).LT.XX(33),ASN3;
      ACT;
MXQ3  QUEUE(7);
      ACT(15)/3,ATRIB(3);
AC3   QUEUE(8),,,,AS3;
CR3   QUEUE(9),80,,,AS3;
AS3   SELECT,ASM,,,AC3,CR3;
      ACT,,,GO;
GO    GOON;

;----------------------------------------------------------------
;- USER FUNCTION 9 PREVENTS ASSIGNMENT OF A CREW/AIRCRAFT TO A -
;-  MISSION WITH A SCHEDULED TAKEOFF TIME AFTER THE END OF THE -
;-  CURRENT SCHEDULING PERIOD.  THIS INSURES THE AIRCRAFT WILL -
;-  BE ASSIGNED A MISSION IN THE APPROPRIATE SCHEDULING PERIOD -
;-  WITH AN APPROPRIATE PRIORITY                                -
;----------------------------------------------------------------

      ACT,USERF(9),,STRT;

;----------------------------------------------------------------
;- EVENT 2 CALLS SUBROUTINE START.  IN THIS ROUTINE, THE        -
;-  AIRCRAFT IS ASSIGNED A NUMBER FOR A MISSION AND ITS         -
;-  ASSOCIATED DEPARTURE TIME, ITINERARY, AND CONFIGURATION.    -
;-  THE CREW DUTY EXPIRATION TIME FOR THE CREW IS ALSO          -
;-  CALCULATED.                                                 -
;----------------------------------------------------------------

STRT  EVENT,2;
      ACT,ATRIB(12),,DNHB;

DNHB  GOON;

;----------------------------------------------------------------
;- USER FUNCTION 8 DETERMINES WHETHER OR NOT THERE IS A MAIN-   -
;-  TENANCE PROBLEM, AND, IF SO, WHAT THE LENGTH OF THE DELAY   -
;-  WILL BE.                                                    -
;----------------------------------------------------------------

      ACT,USERF(8),,TFB;

;----------------------------------------------------------------
;- IF THE DELAY IS 4 HOURS OR GREATER, ATTRIBUTE 17 IS SET      -
;-  EQUAL TO 1, 2, OR 3 (HOME BASE NUMBER), AND THE MISSION     -
;-  IS CANCELLED.  THE CREW ENTERS CREW REST AND THE AIRCRAFT   -
;-  MAINTENANCE IS PERFORMED.  RET1, RET2, OR RET 3 RETURNS     -
;-  THE CREW AND AIRCRAFT TO THE PROPER HOME BASE.              -
;----------------------------------------------------------------

TFB   GOON,1;
      ACT,,ATRIB(17).EQ.1,RET1;
```

```
      ACT,,ATRIB(17).EQ.2,RET2;
      ACT,,ATRIB(17).EQ.3,RET3;
      ACT,,,NEXT;

NEXT  GOON;

;---------------------------------------------------------------
;- USER FUNCTION 2 DETERMINES THE FLYING TIME BETWEEN THE      -
;-  CURRENT LOCATION AND THE NEXT LOCATION ON THE MISSION      -
;-  ITINERARY, AND STORES THE TIME IN ATTRIBUTE 9.  THE NEXT   -
;-  LOCATION IS STORED IN ATTRIBUTE 6.  ANY CHANGES TO THE     -
;-  ITINERARY AS A RESULT OF MAINTENANCE OR QUEUEING DELAYS    -
;-  ARE MADE IN USER FUNCTION 2.                               -
;---------------------------------------------------------------

      ACT,USERF(2),,HUB;


;---------------------------------------------------------------
;- THE AIRCRAFT IS ROUTED TO ITS DESTINATION BASED ON          -
;-  THE VALUE OF ATTRIBUTE 9 (FLYING TIME) AND ATTRIBUTE 6     -
;-  (NEXT DESTINATION ON THE ITINERARY).                       -
;---------------------------------------------------------------

HUB   GOON,1;
      ACT/4,ATRIB(9),ATRIB(6).EQ.1,BAS1;
      ACT/5,ATRIB(9),ATRIB(6).EQ.2,BAS2;
      ACT/6,ATRIB(9),ATRIB(6).EQ.3,BAS3;
      ACT/7,ATRIB(9),ATRIB(6).EQ.4,BAS4;
      ACT/15,ATRIB(9),ATRIB(6).EQ.5,BAS5;
      ACT/23,ATRIB(9),ATRIB(6).EQ.6,BAS6;
      ACT/31,ATRIB(9),ATRIB(6).EQ.7,BAS7;
      ACT/39,ATRIB(9),ATRIB(6).EQ.8,BAS8;

;********** RETURN TO BASE 1 **********

BAS1  GOON;
      ACT,0.2;
B1G   GOON;
      ACT,USERF(4),,RET1;

;********** RETURN TO BASE 2 **********

BAS2  GOON;
      ACT,0.2;
B2G   GOON;
      ACT,USERF(4),,RET2;

;********** RETURN TO BASE 3 **********

BAS3  GOON;
```

```
      ACT,0.2;
B3G   GOON;
      ACT,USERF(4),,RET3;

;*****************************************************************
;*****************************************************************
;**                                                             **
;**             DEPOT/DIVISION BASE ACTIVITIES                  **
;**                                                             **
;*****************************************************************
;*****************************************************************



;----------------------------------------------------------------
;-       ** BASE 4 (BUSHEHR--SEA PORT OF DEBARKATION **        -
;----------------------------------------------------------------

BAS4  GOON;

;----------------------------------------------------------------
;- THE AIRCRAFT TAXIS IN AND PROCEEDS TO THE CORRECT SERVER    -
;-  BASED ON ITS CONFIGURATION (STORED IN ATTRIBUTE 11).       -
;----------------------------------------------------------------


      ACT,0.2;
B4CK  GOON,1;

;----------------------------------------------------------------
;- IF CARGO CONFIGURED, THE AIRCRAFT PROCEEDS TO THE CARGO     -
;-  SERVICING AREA.                                            -
;----------------------------------------------------------------

      ACT/8,,ATRIB(11).EQ.1,CAR4;

;----------------------------------------------------------------
;- IF CONFIGURED FOR POL, THE AIRCRAFT PROCEEDS TO THE POL     -
;-  SERVICING AREA.                                            -
;----------------------------------------------------------------

      ACT/9,,ATRIB(11).EQ.2,POL4;


;----------------------------------------------------------------
;- THE AIRCRAFT QUEUES IF NO FREE SERVER IS AVAILABLE AT THE   -
;-  THE SERVICING AREA CORRESPONDING TO ITS CONFIGURATION.     -
;-  AFTER QUEUEING AND SERVICING, THE AIRCRAFT TAXIS OUT FOR   -
;-  TAKEOFF.                                                   -
;----------------------------------------------------------------
```

```
CAR4  QUEUE(10);
      ACT(6)/11,USERF(3);
CG4   GOON;
      ACT,0.2,,DN4;
POL4  QUEUE(11);
      ACT(4)/12,USERF(3);
GG4   GOON;
      ACT,0.2,,DN4;
DN4   GOON;

;-----------------------------------------------------------------
;- THE POSSIBILITY OF A MAINTENANCE DELAY IS CONSIDERED IN      -
;-  USER FUNCTION 8.                                            -
;-----------------------------------------------------------------

      ACT,USERF(8),,B4DQ;

;-----------------------------------------------------------------
;- THE AIRCRAFT QUEUES FOR DEPARTURE IF THE RUNWAY IS IN USE    -
;-  BY ANOTHER DEPARTING AIRCRAFT.                              -
;-----------------------------------------------------------------

B4DQ  QUEUE(13);

;-----------------------------------------------------------------
;- A THREE MINUTE TAKEOFF INTERVAL IS SPECIFIED.  THE  ENTITY   -
;-  RETURNS TO THE 'NEXT' NODE.                                 -
;-----------------------------------------------------------------

      ACT/14,0.05,,NEXT;

;-----------------------------------------------------------------
;-        ** BASE 5 (SHIRAZ--AERIAL PORT OF DEBARKATION) **     -
;-                                                              -
;- ALL ACTIVITIES ARE IDENTICAL TO BASE 4 WITH ONE EXCEPTION.   -
;-  BASES 5, 6, 7, AND 8 INCLUDE THE LOADING OR OFFLOADING OF   -
;-  AEROMEDICAL EVACUATION PATIENTS.                            -
;-----------------------------------------------------------------


BAS5  GOON;
      ACT,0.2;
B5CK  ACT/16,,ATRIB(11).EQ.1,CAR5;
      ACT/17,,ATRIB(11).EQ.2,POL5;

;-----------------------------------------------------------------
;- IF THE AIRCRAFT IS CONFIGURED FOR PATIENTS, IT PROCEEDS TO   -
;-  THE PATIENT SERVICING AREA.                                 -
;-----------------------------------------------------------------

      ACT/18,,ATRIB(11).EQ.3,PT5;
```

```
CAR5  QUEUE(14);
      ACT(6)/19,USERF(3);
CG5   GOON;
      ACT,0.2,,DN5;
POL5  QUEUE(15);
      ACT(4)/20,USERF(3);
GG5   GOON;
      ACT,0.2,,DN5;
PT5   QUEUE(16);
      ACT(2)/21,USERF(3);
PG5   GOON;
      ACT,0.2,,DN5;
DN5   GOON;
      ACT,USERF(8),,B5DQ;

B5DQ  QUEUE(17);
      ACT/22,0.05,,NEXT;


;----------------------------------------------------------------
;-      ** BASE 6 (YAZD--ARMORED DIVISION HEADQUARTERS) **      -
;-                                                              -
;- ALL ACTIVITIES ARE IDENTICAL TO BASE 5.                      -
;----------------------------------------------------------------

BAS6  GOON;
      ACT,0.2;
B6CK  GOON,1;
      ACT/24,,ATRIB(11).EQ.1,CAR6;
      ACT/25,,ATRIB(11).EQ.2,POL6;
      ACT/26,,ATRIB(11).EQ.3,PT6;

CAR6  QUEUE(18);
      ACT(6)/27,USERF(3);
CG6   GOON;
      ACT,0.2,,DN6;
POL6  QUEUE(19);
      ACT(4)/28,USERF(3);
GG6   GOON;
      ACT,0.2,,DN6;
PT6   QUEUE(20);
      ACT(2)/29,USERF(3);
PG6   GOON;
      ACT,0.2,,DN6;
DN6   GOON;
      ACT,USERF(8),,B6DQ;

B6DQ  QUEUE(21);
      ACT/30,0.05,,NEXT;
```

```
;-------------------------------------------------------------
;-   ** BASE 7 (KHATAMI--MECHANIZED DIVISION HEADQUARTERS) **  -
;-                                                             -
;- ALL ACTIVITIES IDENTICAL TO BASE 5.                         -
;-------------------------------------------------------------

BAS7  GOON;
      ACT,0.2;
B7CK  GOON,1;
      ACT/32,,ATRIB(11).EQ.1,CAR7;
      ACT/33,,ATRIB(11).EQ.2,POL7;
      ACT/34,,ATRIB(11).EQ.3,PT7;

CAR7  QUEUE(22);
      ACT(6)/35,USERF(3);
CG7   GOON;
      ACT,0.2,,DN7;
POL7  QUEUE(23);
      ACT(4)/36,USERF(3);
GG7   GOON;
      ACT,0.2,,DN7;
PT7   QUEUE(24);
      ACT(2)/37,USERF(3);
PG7   GOON;
      ACT,0.2,,DN7;
DN7   GOON;
      ACT,USERF(8),,B7DQ;

B7DQ  QUEUE(25);
      ACT/38,0.05,,NEXT;

;----------------------------------------------------------
;-   ** BASE 8 (ARAK--MECHANIZED DIVISION HEADQUARTERS) **  -
;-                                                          -
;- ALL ACTIVITIES IDENTICAL TO BASE 5.                      -
;----------------------------------------------------------

BAS8  GOON;
      ACT,0.2;
B8CK  GOON,1;
      ACT/40,,ATRIB(11).EQ.1,CAR8;
      ACT/41,,ATRIB(11).EQ.2,POL8;
      ACT/42,,ATRIB(11).EQ.3,PT8;

CAR8  QUEUE(26);
      ACT(6))/43,USERF(3);
CG8   GOON;
      ACT,0.2,,DN8;
POL8  QUEUE(27);
      ACT(4)/44,USERF(3);
GG8   GOON;
      ACT,0.2,,DN8;
```

```
PT8   QUEUE(28);
      ACT(2)/45,USERF(3);
PG8   GOON;
      ACT,0.2,,DN8;
DN8   GOON;
      ACT,USERF(8),,B8DQ;

B8DQ  QUEUE(29);
      ACT/46,0.05,,NEXT;

;*****************************************************************
;*****************************************************************
;**                                                             **
;**          POST-MISSION HOME STATION ACTIVITIES               **
;**                                                             **
;*****************************************************************
;*****************************************************************



;-----------------------------------------------------------------
;- THE AIRCRAFT ARRIVES AND TAXIS IN AT ITS HOME BASE (BASE 1,   -
;   2, OR 3).                                                     -
;-----------------------------------------------------------------

BAS1  GOON;
      ACT,0.2;
B1G   GOON;


;-----------------------------------------------------------------
;- USER FUNCTION 4 RECORDS THE AIRCRAFT'S FLYING TIME AND CREW   -
;-  DUTY DAY LENGTH EACH TIME IT RETURNS FROM A MISSION.         -
;-----------------------------------------------------------------

      ACT,USERF(4),,RET1;

RET1  GOON;


;-----------------------------------------------------------------
;- USER FUNCTION 10 SPECIFIES THE LENGTH OF THE CREW REST        -
;-  PERIOD.  WHEN THE CREW RETURNS HOME FROM A MISSION, THIS     -
;-  VALUE IS 15.25 HOURS. IF THE CREW WAS DELAYED FOR 4 HOURS    -
;-  AT HOME STATION DUE TO A PRE-MISSION MAINTENANCE PROBLEM     -
;-  RESULTING IN MISSION CANCELLATION, THIS VALUE IS 15.25       -
;-  HOURS OF CREW REST PLUS THE 4 HOUR DELAY (I.E. THE CREW      -
;-  ENTERS 15.25 HOURS OF CREW REST AFTER THE 4 HOUR DELAY)      -
;-----------------------------------------------------------------
```

```
      ACT,USERF(10),,CR1;

;------------------------------------------------------------
;- USER FUNCTION 7 DETERMINES WHETHER OR NOT THE AIRCRAFT IS   -
;-  IN COMMISSION AFTER RETURNING FROM A MISSION.             -
;------------------------------------------------------------

      ACT,USERF(7),,MXQ1;

;------------------------------------------------------------
;- BASE 2 ACTIVITIES IDENTICAL TO BASE 1.                     -
;------------------------------------------------------------

BAS2  GOON;
      ACT,0.2;
B2G   GOON;
      ACT,USERF(4),,RET2;

RET2  GOON;
      ACT,USERF(10),,CR2;
      ACT,USERF(7),,MXQ2;

;------------------------------------------------------------
;- BASE 3 ACTIVITIES IDENTICAL TO BASE 1.                     -
;------------------------------------------------------------

BAS3  GOON;
      ACT,0.2;
B3G   GOON;
      ACT,USERF(4),,RET3;

RET3  GOON;
      ACT,USERF(10),,CR3;
      ACT,USERF(7),,MXQ3;

      ENDNETWORK;



INITIALIZE,0.0,720.0;
INTLC,XX(1)=210.,XX(2)=230.,XX(3)=335.,XX(4)=430.,XX(5)=590.;
INTLC,XX(6)=540.,XX(7)=590.,XX(8)=25.,XX(9)=165.,XX(10)=230.;
INTLC,XX(11)=470.,XX(12)=400.,XX(13)=405.,XX(14)=165.,XX(15)=225.;
INTLC,XX(16)=475.,XX(17)=395.,XX(18)=390.,XX(19)=100.,XX(20)=320.;
INTLC,XX(21)=230.,XX(22)=250.,XX(23)=315.,XX(24)=200.,XX(25)=165.;
INTLC,XX(26)=135.,XX(27)=270.,XX(28)=130.,XX(29)=290.;
INTLC,XX(31)=20,XX(32)=20,XX(33)=20;
FIN;
```

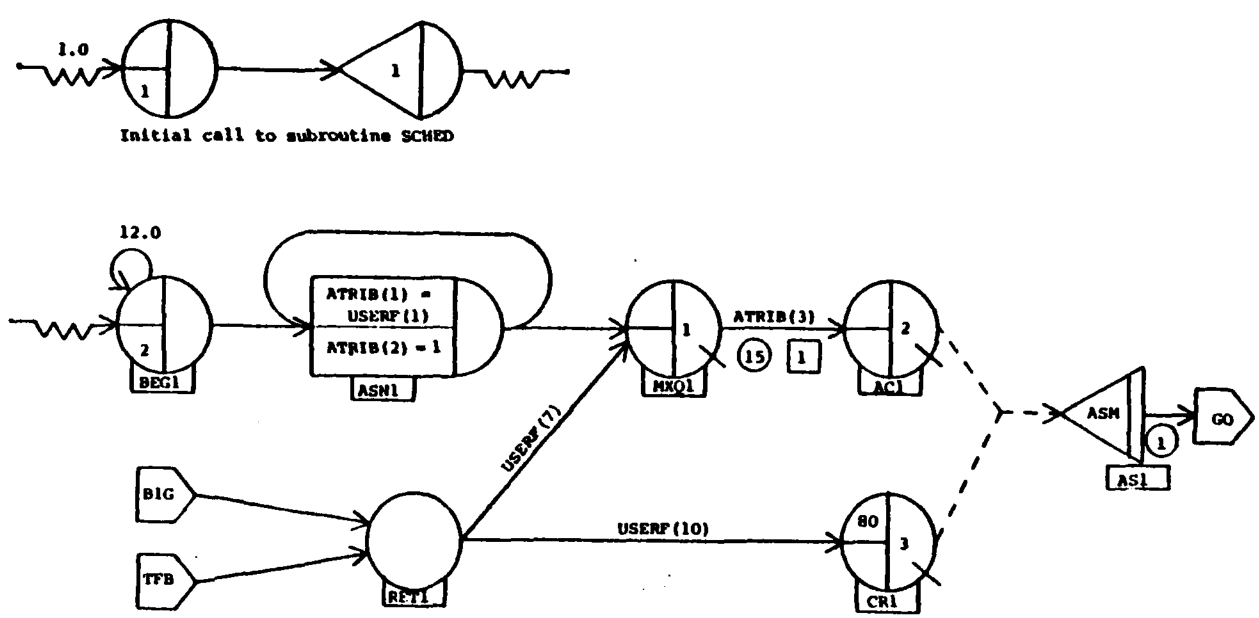


Figure 11. Initial Aircraft Generation/Aircraft Turnaround and Crew Rest (Base 1 Depicted)

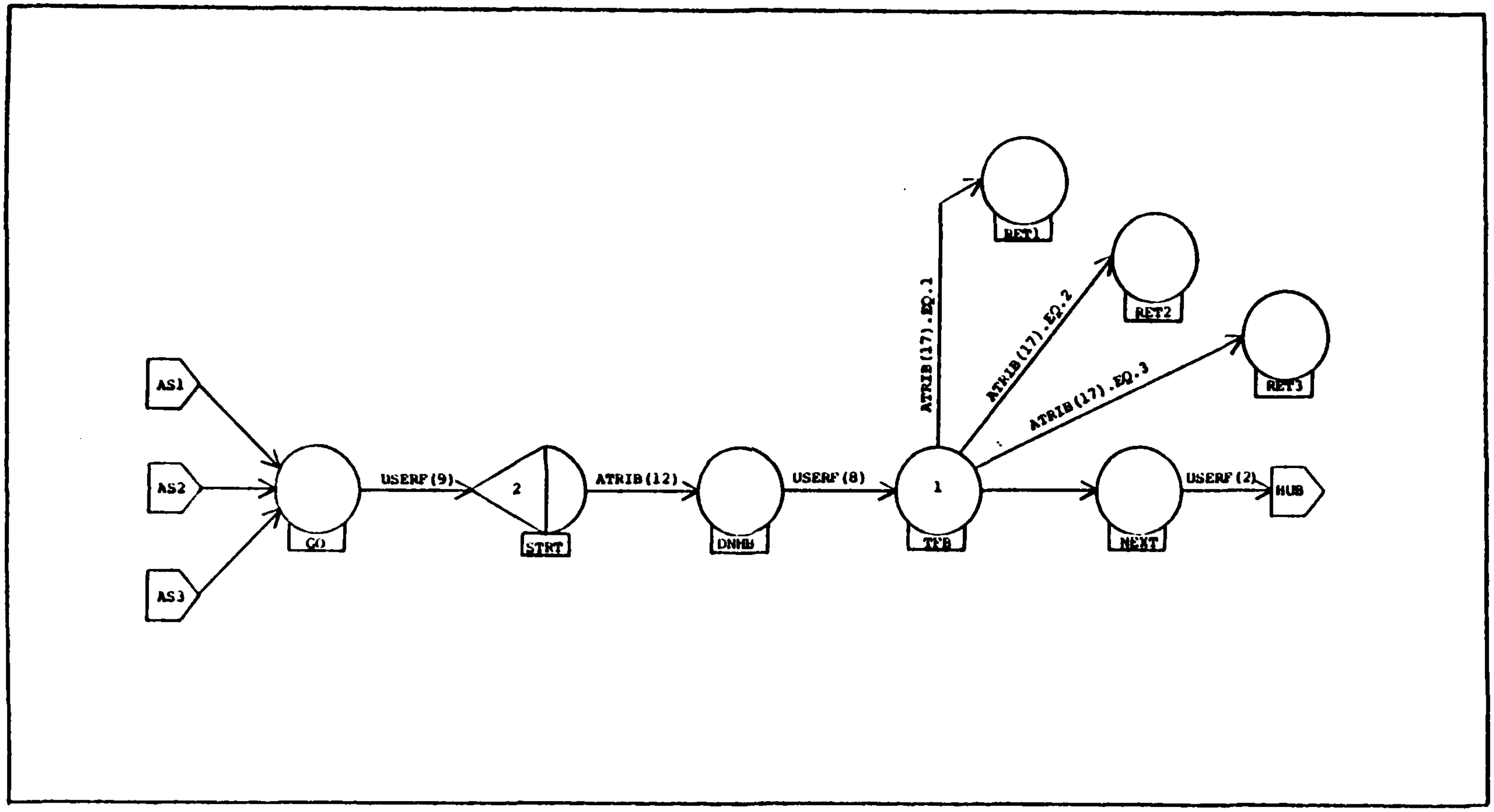


Figure 12. Mission Assignment and Initial Departure From Home Base

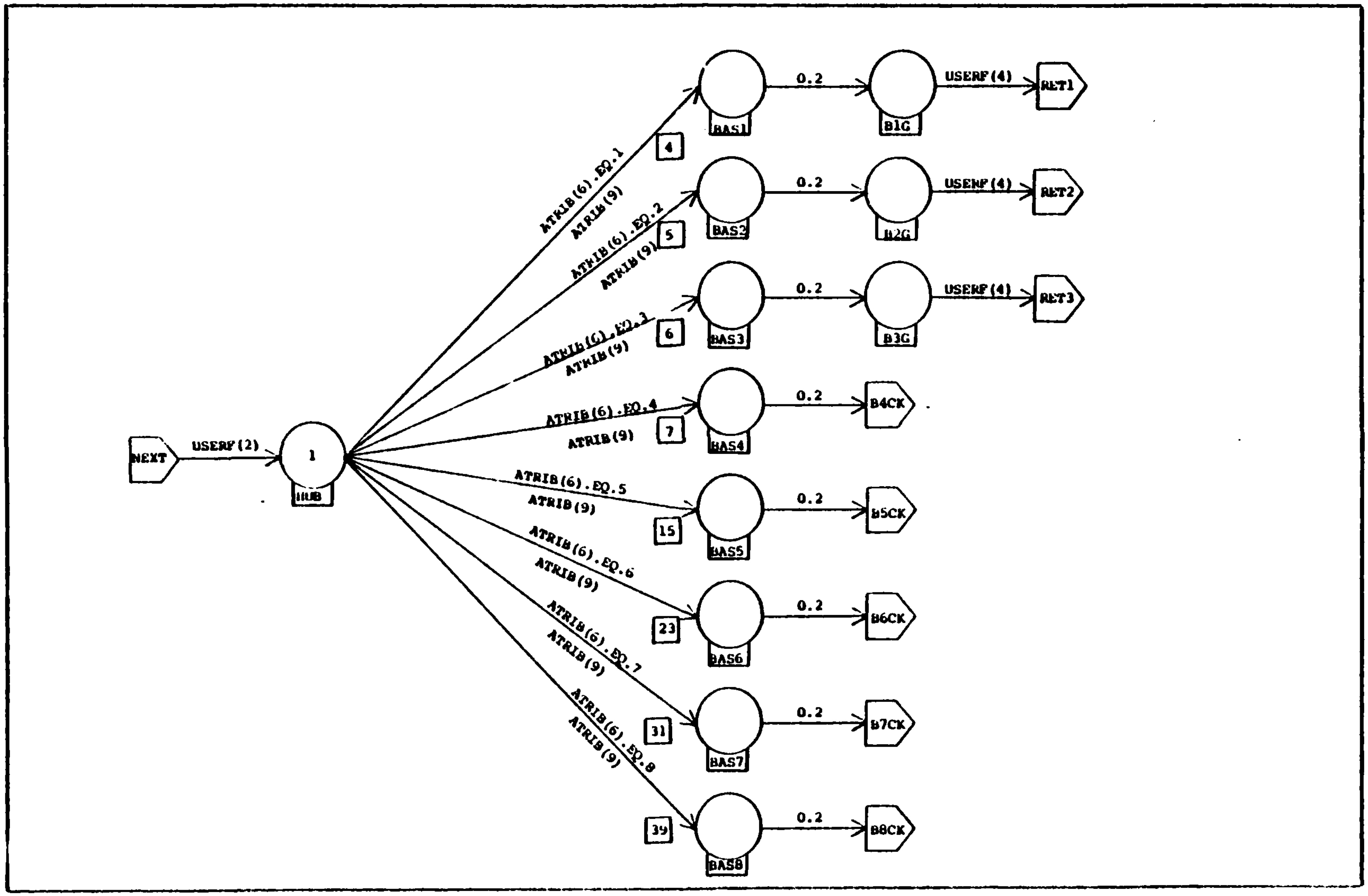


Figure 13. Destination Routing

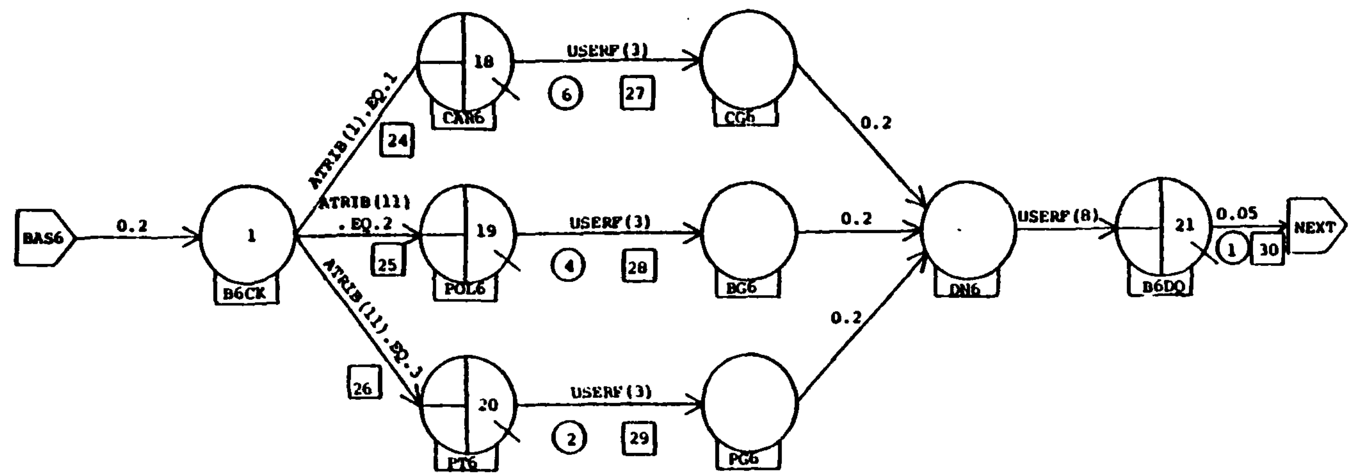


Figure 14. Typical Depot/Division Base Subnet
(Base 6 Depicted)

Appendix B: User Written Subroutine FORTRAN Statements

```
C***********************************************************************
C***********************************************************************
C****                                                               ****
C****                       PROGRAM MAIN                            ****
C****                                                               ****
C***********************************************************************
C***********************************************************************

C-----------------------------------------------------------------------
C-         THE DIMENSION OF NSET IS RESET IN THIS SECTION FROM ITS    -
C-      DEFAULT VALUE TO 30000.                                       -
C-----------------------------------------------------------------------

      PROGRAM MAIN
      DIMENSION NSET(30000)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)

      COMMON QSET(30000)
      EQUIVALENCE(NSET(1),QSET(1))
      NNSET=30000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      CALL SLAM
      STOP
      END

C***********************************************************************
C***********************************************************************
C****                                                               ****
C****                     SUBROUTINE EVENT                          ****
C****                                                               ****
C***********************************************************************
C***********************************************************************


      SUBROUTINE EVENT(NNE)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)
      GO TO (1,2,3),NNE
1     CALL SCHED
      RETURN
2     CALL START
      RETURN
3     CALL NEWSCD
```

```
      RETURN
      END


C*************************************************************************
C*************************************************************************
C****                                                                 ****
C****                      SUBROUTINE USERF                           ****
C****                                                                 ****
C*************************************************************************
C*************************************************************************

C------------------------------------------------------------------------
C-            USERF CONTAINS 10 USER WRITTEN FUNCTIONS.                 -
C------------------------------------------------------------------------


      FUNCTION USERF(NNU)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)
      COMMON/UCOM4/DAYSUM(6:8,9),INC(3),NCOMP(3),NTDY(3),NBTDY(8)
     1,NFIG(3,3)


      GO TO (1,2,3,4,5,6,7,8,9,10),NNU

C------------------------------------------------------------------------
C-          VARIABLES IN USERF:                                         -
C-                                                                      -
C-        --CAS(6:8,8)--                                                -
C-            THIS ARRAY CONTAINS THE CASUALTY STATUS FOR THE THREE     -
C-      DIVISIONS.  CASUALTIES ARE DIVIDED INTO EIGHT CATEGORIES,       -
C-      DEPENDING ON THE NUMBER OF DAYS THEY HAVE BEEN IN THE FIELD.    -
C-      CATEGORIES ONE THROUGH SEVEN CONTAIN THE NUMBER OF CASUALTIES   -
C-      THAT HAVE BEEN IN THE FIELD FOR ONE THROUGH SEVEN DAYS, WHILE   -
C-      CATEGORY EIGHT HAS THE CASUALTIES THAT HAVE BEEN IN THE FIELD   -
C-      FOR MORE THAN SEVEN DAYS.  THE FIRST DIMENSION OF THE ARRAY     -
C-      CORRESPONDS TO THE NUMBER OF THE DIVISION BEING CONSIDERED,     -
C-      WHILE THE SECOND DIMENSION CORRESPONDS TO THE EIGHT CATEGORIES. -
C-                                                                      -
C-        --DEST(300,7,8)--                                             -
C-            THE 'DEST' ARRAY SERVES AS THE AIR TASKING ORDER FOR      -
C-      THE SIMULATION. IT CONTAINS ALL REQUIRED INFORMATION ABOUT THE  -
C-      PLANNED MISSIONS.  THE FIRST DIMENSION OF THE ARRAY CORRESPONDS -
C-      TO THE MISSION NUMBER.  THEREFORE, 300 MISSION NUMBERS ARE      -
C-      AVAILABLE FOR USE.  POSITIONS ONE THROUGH SIX IN THE SECOND     -
C-      DIMENSION CORRESPOND TO THE INITIAL DEPARTURE AND FIVE PLANNED  -
C-      STOPS FOR EACH MISSION.  POSITION SEVEN IN THE SECOND DIMENSION -
C-      IS USED FOR GENERAL INFORMATION.  POSITION ONE IN THE THIRD     -
```

```
C-    DIMENSION IS THE PLANNED DEPARTURE BASE, WHILE POSITION TWO IS   -
C-    A COUNTER INDICATING WHETHER AN ONLOAD (+1) OR OFFLOAD (-1) IS   -
C-    BEING PERFORMED AT THE STOP.  FOR PALLETIZED CARGO MISSIONS,     -
C-    POSITIONS THREE THROUGH EIGHT IN THE THIRD DIMENSION CONTAIN     -
C-    THE SUPPLY CLASS OF EACH OF THE PALLETS ON THE LOAD, FOR THE     -
C-    ONLOAD AND OFFLOAD POINTS.                                       -
C-                                                                     -
C-      --DIST(8,8)--                                                  -
C-          THIS ARRAY CONTAINS THE ENROUTE DISTANCES BETWEEN ANY TWO  -
C-    OF THE EIGHT BASES.  THE TWO DIMENSIONS CORRESPOND TO THE BASES  -
C-    BEING CONSIDERED, SO THAT, FOR EXAMPLE,                          -
C-    DIST(1,5)=470, WHICH THE DISTANCE BETWEEN BASES ONE AND FIVE.    -
C-    THIS ARRAY IS INITIALIZED IN SUBROUTINE INTLC USING              -
C-    THE INTRINSIC SLAM 'XX' VARIABLES.  THESE VARIABLES ARE IN TURN  -
C-    INITIALIZED USING THE SLAM INTLC CONTROL STATEMENT.  AS A        -
C-    RESULT, THE ENROUTE DISTANCES BETWEEN BASES CAN BE VARIED        -
C-    BETWEEN RUNS BY CHANGING THE SLAM CONTROL STATEMENTS.            -
C-                                                                     -
C-      --FLY(3)--                                                     -
C-         THIS ARRAY CONTAINS THE ACCUMULATED FLYING TIME             -
C-    FOR THE THREE C-130 BASES.  WHEN DIVIDED BY THE TOTAL            -
C-    NUMBER OF AIRCRAFT AT THE BASE, AND THE NUMBER OF DAYS           -
C-    IN THE SIMULATION, AIRCRAFT UTILIZATION RATE IS DETERMINED.      -
C-                                                                     -
C-      --NBTDY(8)--                                                   -
C-         THIS ARRAY IS USED TO RECORD THE NUMBER OF TIMES THAT       -
C-    AIRCREWS HAVE CREW RESTED AWAY FROM HOME STATION AND THE BASE    -
C-    WHERE THIS OCCURRED.                                             -
C-                                                                     -
C-      --NTDY(3)--                                                    -
C-         THIS ARRAY RECORDS THE NUMBER OF TIMES THAT AIRCREWS FROM   -
C-    THE THREE HOME BASES HAVE BEEN FORCED TO CREW REST AWAY FROM     -
C-    HOME STATION.                                                    -
C-                                                                     -
C-      --STAT(6:8,9)--                                                -
C-         THIS ARRAY CONTAINS THE CURRENT STATUS AT EACH OF THE       -
C-    THREE DIVISIONS.  THE FIRST DIMENSION OF THE ARRAY CORRESPONDS   -
C-    TO THE NUMBER OF THE DIVISION, AND THE SECOND TO THE EIGHT       -
C-    CLASSES OF CARGO CONSIDERED AND CASUALTIES (STORED IN            -
C-    POSITION SEVEN).  AS AN EXAMPLE, STAT(7,5) CONTAINS THE          -
C-    CURRENT NUMBER OF PALLETS OF CLASS V (AMMUNITION) ON HAND        -
C-    AT BASE SEVEN.                                                   -
C-----------------------------------------------------------------------
```

```
C---------------------------------------------------------------------
C-                              USERF 1                              -
C-        THE PURPOSE OF THIS FUNCTION IS TO GENERATE AIRCRAFT       -
C-    ENTITIES AT BASE 1.  IT IS CALLED TWICE, ONCE AT THE START OF  -
C-    THE SIMULATION, AND ONCE 12 HOURS LATER, SO THAT 2 TIMES XX(31) -
C-    TOTAL AIRCRAFT ARE GENERATED.  AS THE AIRCRAFT ENTITIES ARE    -
C-    GENERATED, THE FUNCTION ASSIGNS VALUES TO THREE ATTRIBUTES:    -
C-    ATRIB(3), WHICH IS THE TIME REQUIRED FOR MAINTENANCE BEFORE THE -
C-    AIRCRAFT IS MISSION READY, ATRIB(7), WHICH IS THE STOP THE     -
C-    AIRCRAFT IS ON IN ITS ITINERARY, AND ATRIB(15), WHICH IS THE   -
C-    TIME THE AIRCRAFT WAS LAST SUBJECT TO THE POSSIBILITY OF A 24  -
C-    HOUR DELAY IN USERF 7.  THE COUNTER XX(35) IS INCREMENTED EACH -
C-    TIME AN AIRCRAFT IS GENERATED AND THIS VALUE IS RETURNED BY THE -
C-    FUNCTION AS THE AIRCRAFT TAIL NUMBER.  THE VALUE FOR XX(31) IS -
C-    SET IN THE INTLC STATEMENT IN THE SLAM CONTROL STATEMENTS.     -
C---------------------------------------------------------------------

1     XX(34)=XX(34)+1
      XX(35)=XX(35)+1
      USERF=XX(35)
      IF (INT(XX(34)).EQ.INT(XX(31))+1) XX(34)=1
      ATRIB(3)=UNFRM(3.0,5.0,9)
      ATRIB(7)=1
      ATRIB(15)=TNOW
      RETURN

C---------------------------------------------------------------------
C-                             USERF 2                               -
C-       USERF 2 IS CALLED WHENEVER AN AIRCRAFT IS PREPARED TO DEPART -
C-    ONE BASE FOR ANOTHER.  THE PURPOSE OF THIS FUNCTION IS TO ASSIGN -
C-    THE ENROUTE FLYING TIME TO ATRIB(9), WHICH IS THEN USED IN THE  -
C-    SLAM NETWORK AS THE DURATION OF THE ACTIVITY CONNECTING THE DE- -
C-    PARTURE POINT AND THE DESTINATION.  A CHECK IS MADE TO SEE IF  -
C-    THE AIRCREW HAS ENOUGH CREW DUTY DAY REMAINING TO COMPLETE THE  -
C-    NEXT PLANNED OFFLOAD.  IF NOT, THE AIRCRAFT IS ROUTED DIRECTLY -
C-    TO ITS HOME BASE.  IF THE AIRCREW HAS INSUFFICIENT CREW DUTY DAY -
C-    REMAINING TO RETURN TO ITS HOME BASE, THE CREW ENTERS CREW REST -
C-    AT ITS PRESENT LOCATION, AND RETURNS TO ITS HOME BASE WHEN CREW -
C-    IS COMPLETED.                                                   -
C---------------------------------------------------------------------

2     IF (INT(ATRIB(7)).NE.1) ATRIB(5)=ATRIB(6)
        CDR=ATRIB(14)-TNOW
```

```
C------------------------------------------------------------------------
C-        THE TESTS ARE MADE BASED ON THE VALUE OF ATRIB(7), WHICH     -
C-    IS THE NUMBER OF THE STOP THE MISSION IS ON OF ITS PLANNED       -
C-    SIX-STOP ITINERARY.  THE VARIABLE 'CDR' IS THE CREW DUTY TIME    -
C-    REMAINING FOR THE AIRCREW.  IF THE VALUE OF 'CDR' IS GREATER     -
C-    THAN THE MINIMUM, THE MISSION CONTINUES AS SCHEDULED.  IF NOT,   -
C-    THE MISSION IS ROUTED HOME, UNLESS 'CDR' IS LESS THAN ONE        -
C-    HOUR, IN WHICH CASE THE CREW GOES INTO CREW REST.                -
C-    THE MINIMUM TIME FOR 'CDR' IS A FUNCTION OF THE PARTICULAR STOP  -
C-    THE AIRCRAFT IS ON AND THE MISION TYPE, AS INDICATED BY THE      -
C-    AIRCRAFT CONFIGURATION (ATRIB(11)).  ATRIB(11) EQUALS ONE IF THE -
C-    CONFIGURATION IS FOR PALLETIZED CARGO, TWO IF IT IS FOR POL, AND -
C-    THREE IF IT IS FOR AEROMEDICAL EVACUATION (AIR EVAC).            -
C-        IF A MISSION IS ROUTED HOME BECAUSE OF INSUFFICIENT CREW     -
C-    DUTY DAY, THE 'INC' ARRAY IS INCREMENTED TO RECORD THE FACT.     -
C------------------------------------------------------------------------

      IF (INT(ATRIB(7)).EQ.3) THEN
        IF (INT(ATRIB(11)).EQ.3) THEN
          IF (CDR.LT.6.0.AND.CDR.GE.1.0) THEN
            ATRIB(6)=ATRIB(2)
            INC(INT(ATRIB(2)))=INC(INT(ATRIB(2)))+1
            USERF=0.0
            GO TO 20
          ENDIF
        ELSE IF (INT(ATRIB(11)).EQ.2) THEN
          IF (CDR.LT.8.0.AND.CDR.GE.1.0) THEN
            ATRIB(6)=ATRIB(2)
            INC(INT(ATRIB(2)))=INC(INT(ATRIB(2)))+1
            USERF=0.0
            GO TO 20
          ENDIF
        ELSE IF (INT(ATRIB(11)).EQ.1) THEN
          IF (CDR.LT.6.2.AND.CDR.GE.1.0) THEN
            ATRIB(6)=ATRIB(2)
            INC(INT(ATRIB(2)))=INC(INT(ATRIB(2)))+1
            USERF=0.0
            GO TO 20
          ENDIF
        ENDIF
      ELSE IF (INT(ATRIB(7)).EQ.4) THEN
        IF (INT(ATRIB(11)).EQ.3) THEN
          IF (CDR.LT.4.0.AND.CDR.GE.1.0) THEN
            ATRIB(6)=ATRIB(2)
            INC(INT(ATRIB(2)))=INC(INT(ATRIB(2)))+1
            USERF=0.0
            GO TO 20
          ENDIF
        ELSE IF (INT(ATRIB(11)).EQ.2) THEN
          IF (CDR.LT.5.0.AND.CDR.GE.1.0) THEN
            ATRIB(6)=ATRIB(2)
```

```
            INC(INT(ATRIB(2)))=INC(INT(ATRIB(2)))+1
            USERF=0.0
            GO TO 20
          ENDIF
        ELSE IF (INT(ATRIB(11)).EQ.2) THEN
          IF (CDR.LT.8.0.AND.CDR.GE.1.0) THEN
            ATRIB(6)=ATRIB(2)
            INC(INT(ATRIB(2)))=INC(INT(ATRIB(2)))+1
            USERF=0.0
            GO TO 20
          ENDIF
        ELSE IF (INT(ATRIB(11)).EQ.1) THEN
          IF (CDR.LT.6.2.AND.CDR.GE.1.0) THEN
            ATRIB(6)=ATRIB(2)
            INC(INT(ATRIB(2)))=INC(INT(ATRIB(2)))+1
            USERF=0.0
            GO TO 20
          ENDIF
        ENDIF
      ELSE IF (INT(ATRIB(7)).EQ.4) THEN
        IF (INT(ATRIB(11)).EQ.3) THEN
          IF (CDR.LT.4.0.AND.CDR.GE.1.0) THEN
            ATRIB(6)=ATRIB(2)
            INC(INT(ATRIB(2)))=INC(INT(ATRIB(2)))+1
            USERF=0.0
            GO TO 20
          ENDIF
        ELSE IF (INT(ATRIB(11)).EQ.2) THEN
          IF (CDR.LT.5.0.AND.CDR.GE.1.0) THEN
            ATRIB(6)=ATRIB(2)
            INC(INT(ATRIB(2)))=INC(INT(ATRIB(2)))+1
            USERF=0.0
            GO TO 20
          ENDIF
        ELSE IF (INT(ATRIB(11)).EQ.1) THEN
          IF (CDR.LT.4.0.AND.CDR.GE.1.0) THEN
            ATRIB(6)=ATRIB(2)
            INC(INT(ATRIB(2)))=INC(INT(ATRIB(2)))+1
            USERF=0.0
            GOTO 20
          ENDIF
        ENDIF
      ENDIF


C-----------------------------------------------------------------------
C-         IF CREW DUTY TIME REMAINING IS LESS THAN 1 HOUR, THE AIR-    -
C-    CRAFT AND CREW REMAIN OVERNIGHT WHERE THEY ARE.  IN THIS CASE     -
C-    THE FUNCTION WILL RETURN THE DELAY THAT THE CREW WILL EXPERIENCE -
C-    AT THE BASE.  IF THE DELAY IS THE RESULT OF A MAINTENANCE        -
C-    PROBLEM, THE DURATION OF THE DELAY WILL BE STORED IN ATRIB(16)   -
```

```
C-    AND USERF 2 IS CALLED WHEN THE AIRCRAFT IS READY.  IF THIS DELAY -
C-    IS LESS THAN 15.25 HOURS, IT IS ASSUMED THAT THE CREW STARTED    -
C-    CREW REST WHEN THE PROBLEM WAS DISCOVERED, AND WILL DEPART WHEN  -
C-    THEIR CREW REST IS COMPLETE.  IF THE DELAY IS LONGER THAN THE    -
C-    CREW REST PERIOD, THE MISSION WILL DEPART AS SOON AS THE AIR-    -
C-    CRAFT IS READY.                                                  -
C-         THE AIRCRAFT IS ROUTED DIRECTLY TO HOME STATION BY          -
C-    ASSIGNING THE VALUE IN ATRIB(2), THE HOME STATION, TO ATRIB(6)   -
C-    WHICH IS THE NEXT DESTINATION.  THE HOME BASE OF EACH AIRCRAFT   -
C-    CREW RESTING AWAY FROM HOME STATION IS RECORDED IN ARRAY 'NTDY', -
C-    AND THE BASE WHERE THIS OCCURRED IS RECORDED IN ARRAY 'NBTDY'.   -
C-------------------------------------------------------------------------


        IF (CDR.LT.1.0) THEN
           IF (ATRIB(16).LT.15.25) THEN
             USERF=15.25-ATRIB(16)
             ATRIB(4)=TNOW+(15.25-ATRIB(16))
           ELSE IF (ATRIB(16).GE.15.25) THEN
             USERF=0.0
             ATRIB(4)=TNOW
           ENDIF
           ATRIB(6)=ATRIB(2)
           NTDY(INT(ATRIB(2)))=NTDY(INT(ATRIB(2)))+1
           NBTDY(INT(ATRIB(5)))=NBTDY(INT(ATRIB(5)))+1
           GO TO 20
        ENDIF




C-------------------------------------------------------------------------
C-         IF THE AIRCRAFT IS ON ITS FIFTH STOP AND HAS                -
C-    SUFFICIENT CREW DUTY TIME TO RETURN TO HOME STATION, IT          -
C-    WILL COMPLETE ITS SCHEDULED MISSION. ARRAY 'NCOMP' IS            -
C-    USED TO RECORD THIS FACT FOR EACH HOME BASE.                     -
C-------------------------------------------------------------------------

      IF (INT(ATRIB(7)).EQ.5) THEN
        NCOMP(INT(ATRIB(2)))=NCOMP(INT(ATRIB(2)))+1
        USERF=0.0
        ATRIB(6)=ATRIB(2)
        GOTO 20
      ENDIF

C-------------------------------------------------------------------------
C-         IF A MISSION IS NOT ON ITS LAST LEG AND HAS SUFFICIENT      -
C-    CREW DUTY DAY TO CONTINUE, ATRIB(6) IS ASSIGNED THE              -
C-    BASE NUMBER OF THE NEXT DESTINATION.  THIS INFORMATION IS        -
C-    TAKEN FORM THE 'DEST' ARRAY.  THE ITINERARY IS STORED IN THF     -
C-    ARRAY FOR EACH MISSION NUMBER (ATRIB(8)).                        -
C-------------------------------------------------------------------------
```

```
      USERF=0.0
      ATRIB(6)=DEST(INT(ATRIB(8)),INT(ATRIB(7))+1,1)
      ATRIB(7)=ATRIB(7)+1

C-----------------------------------------------------------------------
C          THE ENROUTE FLYING TIME IS CALCULATED USING THE DISTANCE    -
C-    FROM THE CURRENT LOCATION (ATRIB(5)) TO THE NEXT LOCATION         -
C-    (ATRIB(6)) OBTAINED FROM THE 'DIST' ARRAY.  THE RESULTING         -
C-    DISTANCE IS DIVIDED BY THE AIRCRAFT'S CRUISE AIR SPEED (XX(29))   -
C-    TO GIVE THE EXPECTED FLYING TIME FOR THE LEG.                     -
C-----------------------------------------------------------------------

20    XX(51)=DIST(INT(ATRIB(5)),INT(ATRIB(6)))/XX(29)
      XX(50)=0.8*XX(51)
      XX(52)=1.2*XX(51)
      IF (XX(51).LT.0.0001) THEN
        WRITE(6,27)ATRIB(5),ATRIB(6),ATRIB(7),ATRIB(8)
        WRITE(6,28)ATRIB(4),ATRIB(14),ATRIB(16)
        CALL TRACE
        CALL OTPUT
      ENDIF
27    FORMAT('ATRIB(5)= ',F3.0,' ATRIB(6)= ',F3.0,' ATRIB(7)= ',F3.0,
     *' ATRIB(8)= ',F4.0,/)
28    FORMAT('ATRIB(4)=',F7.2,' ATRIB(14)=',F7.2,' ATRIB(16)=',F7.2,/)


C-----------------------------------------------------------------------
C-         THE ACTUAL FLYING TIME IS DETERMINED USING A DRAW FROM A     -
C-    TRIANGULAR DISTRIBUTION.  THE EXPECTED FLYING TIME (XX(51))       -
C-    IS THE MODE OF THE DISTRIBUTION, WHILE 80% AND 120% OF THIS       -
C-    VALUE (XX(50) AND XX(52) RESPECTIVELY) SERVE AS THE LOW AND       -
C-    HIGH VALUES.  THE ENROUTE FLYING TIME IS ASSIGNED TO ATRIB(9),    -
C-    AND THIS IS ADDED TO ATRIB(10), WHICH IS THE CUMULATIVE FLYING    -
C-    TIME FOR THE MISSION.                                             -
C-----------------------------------------------------------------------

      ATRIB(9)=TRIAG(XX(50),XX(51),XX(52),9)
      ATRIB(10)=ATRIB(10)+ATRIB(9)
      ATRIB(16)=0.0
      RETURN
C-----------------------------------------------------------------------
C-                              USERF 3                                 -
C-         USERF 3 IS USED TO DETERMINE THE GROUND TIME FOR AIRCRAFT    -
C-    THAT ARE ONLOADING OR OFFLOADING.  IF THE VALUE IN THE SECOND     -
C-    POSITION FOR THAT MISSION NUMBER AND STOP NUMBER IN THE 'DEST'    -
C-    ARRAY IS +1, AN ONLOAD IS PERFORMED, IF IT IS -1, AN OFFLOAD IS   -
C-    IS PERFORMED.  THE GROUND TIME REQUIRED DEPENDS ON THE AIRCRAFT   -
C-    CONFIGURATION (ATRIB(11)) AND IS DETERMINED BY A DRAW FROM A      -
C-    TRIANGULAR DISTRIBUTION.                                          -
C-----------------------------------------------------------------------
```

```
3     IF (DEST(INT(ATRIB(8)),INT(ATRIB(7)),2).GT.0.0) THEN
        IF (INT(ATRIB(11)).EQ.1) THEN
          USERF=TRIAG(0.5,1.0,1.5,9)
        ELSE IF (INT(ATRIB(11)).EQ.2) THEN
          USERF=TRIAG(1.5,2.0,2.5,9)

C-----------------------------------------------------------------------
C-         IN THE CASE OF AN AIR EVAC MISSION, AN ONLOAD OF CASUALTIES -
C-    IS PERFORMED.  THE 'CAS' AND 'STAT' ARRAYS ARE UPDATED TO        -
C-    REFLECT THE REMOVAL OF 74 CASUALTIES.                            -
C-----------------------------------------------------------------------

        ELSE IF (INT(ATRIB(11)).EQ.3) THEN
          USERF=TRIAG(0.5,0.62,0.75,9)
          STAT(INT(ATRIB(6)),7)=STAT(INT(ATRIB(6)),7)-74.0
          IF (STAT(INT(ATRIB(6)),7).LT.0.0) STAT(INT(ATRIB(6)),7)=0.0
          NU1=8
          CAS(INT(ATRIB(6)),NU1)=CAS(INT(ATRIB(6)),NU1)-74.0
40        IF (CAS(INT(ATRIB(6)),NU1).LT.0.0) THEN
        CAS(INT(ATRIB(6)),NU1-1)=CAS(INT(ATRIB(6)),NU1-1)+
     *CAS(INT(ATRIB(6)),NU1)
            CAS(INT(ATRIB(6)),NU1)=0.0
          ENDIF
          IF (CAS(INT(ATRIB(6)),NU1-1).LT.0.0) THEN
            IF (NU1-1.EQ.1) THEN
              CAS(INT(ATRIB(6)),NU1-1)=0.0
            ELSE
              NU1=NU1-1
              GOTO 40
            ENDIF
          ENDIF
        ENDIF
      ELSE IF (DEST(INT(ATRIB(8)),INT(ATRIB(7)),2).LT.0.0) THEN

C-----------------------------------------------------------------------
C-         IF A CARGO OFFLOAD IS PERFORMED, THE 'STAT' ARRAY IS        -
C-    UPDATED TO REFLECT THE ADDITIONAL SUPPLIES AT THE DIVISION.      -
C-    THIS IS DONE BY CONSIDERING EACH PALLET IN THE LOAD THAT IS      -
C-    STORED IN 'DEST' FOR THIS MISSION AND STOP NUMBER.               -
C-----------------------------------------------------------------------

        IF (INT(ATRIB(11)).EQ.1) THEN
          USERF=TRIAG(0.5,0.75,1.0,9)
          DO 110 I=3,8
            K=DEST(INT(ATRIB(8)),INT(ATRIB(7)),I)
            STAT(INT(ATRIB(6)),K)=STAT(INT(ATRIB(6)),K)+1
110   CONTINUE
C-----------------------------------------------------------------------
C-         A POL OFFLOAD RESULTS IN THE 'STAT' ARRAY FOR THAT          -
C-    DIVISION BEING INCREMENTED BY 65 UNITS IN CLASS III (POL).       -
C-----------------------------------------------------------------------
```

```
        ELSE IF (INT(ATRIB(11)).EQ.2) THEN
          USERF=TRIAG(1.5,2.0,2.5,9)
          STAT(INT(ATRIB(6)),3)=STAT(INT(ATRIB(6)),3)+65.
        ELSE IF (INT(ATRIB(11)).EQ.3) THEN
          USERF=TRIAG(0.75,0.87,1.0,9)
        ENDIF
      ENDIF
      RETURN

C-----------------------------------------------------------------------
C-                              USERF 4                                -
C          USERF 4 IS USED TO COLLECT DATA ON COMPLETED MISSIONS.      -
C-    STATISTICS ARE COLLECTED ON THE FLYING TIME PER MISSION AND      -
C-    AIRCREW DUTY DAY.  ARRAY 'FLY', IS INCREMENTED WITH THE FLYING   -
C-    TIME FOR THE MISSION.  ATRIB(3), THE TIME REQUIRED TO            -
C-    PREPARE THE AIRCRAFT FOR A NEW MISSION, IS SET, AND              -
C-    ATRIB(7) IS RESET TO ONE.                                        -
C-----------------------------------------------------------------------

4     FLY(INT(ATRIB(2)))=FLY(INT(ATRIB(2)))+ATRIB(10)
      CRDAY=TNOW-ATRIB(4)+2.25
      FLDAY=ATRIB(10)
      IF (INT(ATRIB(2)).EQ.1) THEN
        CALL COLCT(CRDAY,1)
        CALL COLCT(FLDAY,4)
        NFIG(1,INT(ATRIB(11)))=NFIG(1,INT(ATRIB(11)))+1
      ELSE IF (INT(ATRIB(2)).EQ.2) THEN
        CALL COLCT(CRDAY,2)
        CALL COLCT(FLDAY,5)
        NFIG(2,INT(ATRIB(11)))=NFIG(2,INT(ATRIB(11)))+1
      ELSE
        CALL COLCT(CRDAY,3)
        CALL COLCT(FLDAY,6)
        NFIG(3,INT(ATRIB(11)))=NFIG(3,INT(ATRIB(11)))+1
      ENDIF
      ATRIB(3)=TRIAG(3.0,4.0,5.0,9)+2.25
      ATRIB(7)=1
      USERF=0.0
      RETURN

C-----------------------------------------------------------------------
C-                           USERF 5 AND 6                             -
C-         USERF 5 AND 6 PERFORM THE SAME FUNCTION FOR BASES TWO AND   -
C-    THREE AS USERF 1 PERFORMS FOR BASE 1.  THE TOTAL NUMBER OF       -
C-    AIRCRAFT GENERATED AT BASE 2 IS TWO TIMES XX(32) AND FOR BASE 3  -
C-    IS TWO TIMES XX(33).                                             -
C-----------------------------------------------------------------------

5     XX(36)=XX(36)+1
      XX(37)=XX(37)+1
      USERF=XX(37)
```

```
      IF (INT(XX(36)).EQ.INT(XX(32))+1) XX(36)=1
      ATRIB(3)=UNFRM(3.0,5.0,9)
      ATRIB(7)=1
      ATRIB(15)=TNOW
      RETURN

6     XX(38)=XX(38)+1
      XX(39)=XX(39)+1
      USERF=XX(39)
      IF (INT(XX(38)).EQ.INT(XX(33))+1) XX(38)=1
      ATRIB(3)=UNFRM(3.0,5.0,9)
      ATRIB(7)=1
      ATRIB(15)=TNOW
      RETURN


C-----------------------------------------------------------------------
C-                             USERF 7                                 -
C-         THIS FUNCTION IS CALLED BY AIRCRAFT THAT ARE AT HOME         -
C-    BASE, PREPARING TO ENTER THE MAINTENANCE QUEUE FOR THE           -
C-    BASE.  THE PURPOSE OF USERF 7 IS TO ENSURE THAT THE NUMBER OF    -
C-    AIRCRAFT ACTUALLY AVAILABLE FOR USE IS APPROXIMATELY 82% OF      -
C-    THE TOTAL NUMBER, IN ACCORDANCE WITH THE LIMITS OUTLINED         -
C-    IN THE MODEL SCENARIO.  A RANDOM DRAW IS MADE, AND, IF IT IS     -
C-    LESS THAN 0.18, THE AIRCRAFT IS MADE UNAVAILABLE FOR 24 HOURS.   -
C-         ATRIB(15) IS USED TO RECORD THE                              -
C-    LAST TIME AN AIRCRAFT HAS BEEN SUBJECT TO FAILURE IN THIS        -
C-    FUNCTION.  IF IT HAS BEEN LESS THAN 24 HOURS, THE FUNCTION       -
C-    RETURNS THE VALUE OF ATRIB(16), WHICH IS ANY EXISTING            -
C-    MAINTENANCE DELAY INCURRED BY THE AIRCRAFT AT ITS CURRENT        -
C-    BASE.  IF THE TIME IS GREATER THAN 24 HOURS, A RANDOM            -
C-    DRAW IS MADE TO DETERMINE WHETHER THE AIRCRAFT WILL BE           -
C-    REMOVED FROM THE SYSTEM FOR 24 HOURS.  IF IT IS,                 -
C-    THE FUNCTION RETURNS 24 HOURS PLUS ATRIB(16), WHICH IS           -
C-    THE TIME UNTIL IT ARRIVES AT THE MAINTENANCE QUEUE.              -
C-    AFTER EACH TEST, ATRIB(15) IS RESET.                             -
C-----------------------------------------------------------------------
7     IF (TNOW-ATRIB(15).LT.24.0) THEN
          USERF=ATRIB(16)
      ELSE
        Z1=DRAND(2)
        IF (Z1.LT.0.18) THEN
          USERF=24.0+ATRIB(16)
          ATRIB(15)=TNOW+24.0+ATRIB(16)
        ELSE
          USERF=ATRIB(16)
          ATRIB(15)=TNOW+ATRIB(16)
        ENDIF
      ENDIF
      ATRIB(17)=0
      ATRIB(16)=0.0
```

```
      RETURN
C-----------------------------------------------------------------------
C-                              USERF 8                                -
C-         THIS FUNCTION IS CALLED AT EVERY STOP AND IS USED TO SIM-   -
C-    ULATE THE OCCURRENCE OF MAINTENANCE DELAYS.  THERE IS A 0.0444   -
C-    PROBABILITY THAT A MAINTENANCE DELAY WILL OCCUR AT ANY STOP.      -
C-    A RANDOM DRAW IS MADE TO DETERMINE WHETHER THIS HAS OCCURRED.    -
C-    IF IT HAS, ANOTHER RANDOM DRAW IS MADE TO DETERMINE THE DURATION -
C-    OF THE DELAY.  THE DURATION OF THE DELAY, IF ANY, IS ASSIGNED TO -
C-    ATRIB(16). IF THE DELAY IS GREATER THAN FOUR HOURS AND OCCURS AT -
C-    ONE OF THE HOME BASES, THE AIRCREW IS RETURNED TO CREW REST AND  -
C-    THE AIRCRAFT IS ROUTED BACK TO THE APPROPRIATE MAINTENACE QUEUE. -
C-    THIS IS DONE BY ASSIGNING THE BASE NUMBER TO ATRIB(17), WHICH IS -
C-    USED IN THE SLAM NETWORK TO ROUTE THE AIRCRAFT TO THE CORRECT    -
C-    MAINTENANCE QUEUE.                                               -
C-----------------------------------------------------------------------

8     Z2=DRAND(3)
        IF (Z2.LE.0.0444) THEN
          XY=DRAND(4)
            IF (XY.LE.0.3) DELAY=UNFRM(0.0,1.0,8)
            IF (XY.GT.0.3.AND.XY.LE.0.5) DELAY=UNFRM(1.0,2.0,8)
            IF (XY.GT.0.5.AND.XY.LE.0.61) DELAY=UNFRM(2.0,3.0,8)
            IF (XY.GT.0.61.AND.XY.LE.0.67) DELAY=UNFRM(3.0,4.0,8)
            IF (XY.GT.0.67.AND.XY.LE.0.76) DELAY=UNFRM(4.0,8.0,8)
            IF (XY.GT.0.76.AND.XY.LE.0.88) DELAY=UNFRM(8.0,24.0,8)
            IF (XY.GT.0.88) DELAY=UNFRM(24.0,48.0,8)
        ELSE
          DELAY=0.0
        ENDIF
        ATRIB(16)=DELAY
          IF (INT(ATRIB(7)).EQ.1.AND.DELAY.GE.4.0) THEN
            IF (INT(ATRIB(2)).EQ.1) ATRIB(17)=1
            IF (INT(ATRIB(2)).EQ.2) ATRIB(17)=2
            IF (INT(ATRIB(2)).EQ.3) ATRIB(17)=3
            USERF=0.0
          ELSE
            USERF=ATRIB(16)
          ENDIF
        RETURN
C-----------------------------------------------------------------------
C-                              USERF 9                                -
C-         THIS FUNCTION IS CALLED BY AN AIRCRAFT AND CREW ENTITY EN-  -
C-    ROUTE TO THE EVENT NODE THAT WILL CALL SUBROUTINE START, AND     -
C-    CAUSE THE ENTITY TO BE ASSIGNED A MISSION.  IF THE MISSION TO    -
C-    BE ASSIGNED TO THE ENTITY IS OUTDATED OR WILL BE BY THE TIME     -
C-    IT DEPARTS, THE ENTITY IS DELAYED SO THAT IT WILL ARRIVE AT THE  -
C-    EVENT NODE AFTER THE CURRENT SCHEDULING PERIOD HAS CHANGED.      -
C-         A SEARCH IS MADE THROUGH THE 'DEST' ARRAY TO FIND           -
C-    THE NEXT MISSION THAT IS ASSIGNED TO AIRCRAFT FROM THE CORRECT   -
C-    BASE.  XX(44) IS SET TO ONE, TWO OR THREE, DEPENDING ON WHICH OF -
C-    THE THREE SCHEDULING PERIODS IS CURRENT.  BASED ON THIS VALUE,   -
```

```
C-    A TEST IS MADE TO SEE IF THE NEXT MISSION NUMBER IS LARGER THAN  -
C-    THE LARGEST CURRENTLY SCHEDULED.  THIS MAXIMUM NUMBER IS EITHER  -
C-    1/3, 2/3, OR 3/3 THE VALUE OF XX(42), WHICH IS THE TOTAL NUMBER  -
C-    OF MISSIONS AVAILABLE TO BE SCHEDULED.  IF IT IS NOT, THE        -
C-    SEARCH IS CONTINUED UNTIL A MISSION WITH THE SAME HOME STATION   -
C-    DEPARTURE POINT AS THE ENTITY IS FOUND.  IF THE BASE NUMBER OF   -
C-    THE SECOND STOP IS GREATER THAN 25, THIS MEANS THAT THE          -
C-    SCHEDULED TAKEOFF TIME OF THE MISSION WAS SET IN SUBROUTINE FLOW -
C-    TO A TIME AFTER THE NEXT SCHEDULING PERIOD COMES INTO EFFECT.    -
C-    IF THIS OCCURS, OR IF THE NEXT MISSION NUMBER EXCEEDS            -
C-    THE LAST MISSION SCHEDULED IN THIS PERIOD, THE MISSION IS        -
C-    DELAYED.  IN THIS CASE, THE FUNCTION RETURNS A DELAY THAT        -
C-    WILL ENSURE THAT THE ENTITY ARRIVES AT THE EVENT NODE            -
C-    AFTER THE NEXT SCHEDULING PERIOD TAKES EFFECT.                   -
C------------------------------------------------------------------------

9      NEXMSN=MSN(INT(ATRIB(2)))
30     NEXMSN=NEXMSN+1
        IF (INT(XX(44)).EQ.1) THEN
          IF (NEXMSN.GT.XX(42)/3) THEN
            USERF=(12.0*XX(41)+3.1)-TNOW
            RETURN
          ENDIF
        ELSE IF (INT(XX(44)).EQ.2) THEN
          IF (NEXMSN.GT.2*(XX(42)/3)) THEN
            USERF=(12.0*XX(41)+3.1)-TNOW
            RETURN
          ENDIF
        ELSE IF (INT(XX(44)).EQ.3) THEN
          IF (NEXMSN.GT.XX(42)) THEN
            USERF=(12.0*XX(41)+3.1)-TNOW
            RETURN
          ENDIF
        ENDIF
       IF (INT(DEST(NEXMSN,1,1)).NE.INT(ATRIB(2))) GOTO 30
       IF (INT(DEST(NEXMSN,2,1)).GT.25) THEN
          USERF=(12.0*XX(41)+3.1)-TNOW
      ELSE IF (INT(DEST(NEXMSN,2,1)).LE.25) THEN
        USERF=0.0
      ENDIF
      RETURN

C------------------------------------------------------------------------
C-                            USERF 10                                 -
C-         THIS FUNCTION IS USED TO ASSIGN CREW REST TO CREWS          -
C-    RETURNING TO HOME BASE.                                          -
C------------------------------------------------------------------------

10    IF (ATRIB(16).LT.4.0) THEN
        USERF=15.25
      ELSE IF (ATRIB(16).GE.4.0) THEN
        USERF=15.25+4.0
```

```
      ENDIF
      RETURN

      END

C***********************************************************************
C***********************************************************************
C****                                                               ****
C****                    SUBROUTINE INTLC                           ****
C****                                                               ****
C***********************************************************************
C***********************************************************************


C-----------------------------------------------------------------------
C-         THIS SUBROUTINE IS CALLED AT THE START OF EACH SIMULATION   -
C-    RUN AND IS USED TO SET VARIABLES TO THEIR INITIAL VALUES.        -
C-----------------------------------------------------------------------

      SUBROUTINE INTLC
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)
      COMMON/UCOM4/DAYSUM(6:8,9),INC(3),NCOMP(3),NTDY(3),NBTDY(8)
     1,NFIG(3,3)
      COMMON/UCOM5/NZ(6:8,9)

      DIST(1,2)=XX(1)
      DIST(1,3)=XX(2)
      DIST(1,4)=XX(3)
      DIST(1,5)=XX(4)
      DIST(1,6)=XX(5)
      DIST(1,7)=XX(6)
      DIST(1,8)=XX(7)
      DIST(2,3)=XX(8)
      DIST(2,4)=XX(9)
      DIST(2,5)=XX(10)
      DIST(2,6)=XX(11)
      DIST(2,7)=XX(12)
      DIST(2,8)=XX(13)
      DIST(3,4)=XX(14)
      DIST(3,5)=XX(15)
      DIST(3,6)=XX(16)
      DIST(3,7)=XX(17)
      DIST(3,8)=XX(18)
      DIST(4,5)=XX(19)
      DIST(4,6)=XX(20)
      DIST(4,7)=XX(21)
      DIST(4,8)=XX(22)
      DIST(5,6)=XX(23)
      DIST(5,7)=XX(24)
```

```
      DIST(5,8)=XX(25)
      DIST(6,7)=XX(26)
      DIST(6,8)=XX(27)
      DIST(7,8)=XX(28)

      DO 90 I=1,300
        DO 100 J=1,7
          DO 110 K=1,8
            DEST(I,J,K)=0.0
110       CONTINUE
100     CONTINUE
90    CONTINUE
      DO 10 I=1,8
        DIST(I,I)=0.0
        NBTDY(I)=0
10    CONTINUE
      DO 20 I=1,8
        DO 30 J=1,8
          IF (J.GT.I) DIST(J,I)=DIST(I,J)
30     CONTINUE
20    CONTINUE

      CAS(6,1)=208.
      CAS(6,2)=90.
      CAS(6,3)=44.
      CAS(6,4)=148.
      CAS(6,5)=148.
      CAS(7,1)=148.
      CAS(7,2)=208.
      CAS(7,3)=208.
      CAS(7,4)=44.
      CAS(7,5)=90.
      CAS(8,1)=44.
      CAS(8,2)=90.
      CAS(8,3)=148.
      CAS(8,4)=208.
      CAS(8,5)=208.

      DO 120 I=6,8
        DO 130 J=6,8
          CAS(I,J)=0.0
130     CONTINUE
120   CONTINUE
      DO 140 I=6,8
        DO 150 J=1,9
          DAYSUM(I,J)=0.0
          NZ(I,J)=0
150     CONTINUE
140   CONTINUE
      DO 180 I=1,3
        DO 190 J=1,3
          NFIG(I,J)=0
```

```
190      CONTINUE
180    CONTINUE
       DO 160 I=6,8
         DO 170 J=1,4
           NCDAY(I,J)=0
170      CONTINUE
160    CONTINUE

       STAT(6,1)=135.
       STAT(6,2)=171.
       STAT(6,3)=13428.
       STAT(6,4)=150.
       STAT(6,5)=2181.
       STAT(6,6)=83.
       STAT(6,7)=638.
       STAT(6,8)=10.
       STAT(6,9)=191.
       STAT(7,1)=90.
       STAT(7,2)=203.
       STAT(7,3)=13065.
       STAT(7,4)=225.
       STAT(7,5)=2498.
       STAT(7,6)=60.
       STAT(7,7)=698.
       STAT(7,8)=8.
       STAT(7,9)=180.
       STAT(8,1)=180.
       STAT(8,2)=135.
       STAT(8,3)=14625.
       STAT(8,4)=150.
       STAT(8,5)=2997.
       STAT(8,6)=120.
       STAT(8,7)=698.
       STAT(8,8)=5.
       STAT(8,9)=135.

       DO 60 I=1,3
         FLY(I)=0.0
         MSN(I)=0
         INC(I)=0
         NCOMP(I)=0
         NTDY(I)=0
 60    CONTINUE

       W(1)=XX(71)
       W(2)=XX(72)
       W(3)=XX(73)
       W(4)=XX(74)
       W(5)=XX(75)
       W(6)=XX(76)
       W(7)=XX(77)
       W(8)=XX(78)
```

```
      W(9)=XX(79)

      WORTH(1)=7.0
      WORTH(2)=1.0
      WORTH(3)=12.7
      WORTH(4)=4.0
      WORTH(5)=11.0
      WORTH(6)=0.5
      WORTH(7)=1.0
      WORTH(8)=9.0
      WORTH(9)=12.8
      XX(40)=-1
      XX(37)=2*XX(31)
      XX(39)=4*XX(31)
      XX(42)=297
      XX(60)=1
      NCMBT(6)=1
      NCMBT(7)=2
      NCMBT(8)=3
      DO 70 I=6,8
        IF (I.EQ.6) THEN
          STD(I,2)=255.
          STD(I,3)=20475.
          STD(I,5)=3255.
          STD(I,6)=165.
          STD(I,9)=255.
        ELSE
          STD(I,2)=270.
          STD(I,3)=19500.
          STD(I,5)=3330.
           STD(I,6)=180.
          STD(I,9)=270.
        ENDIF
        STD(I,1)=270.
        STD(I,4)=450.
        STD(I,7)=1.
        STD(I,8)=15.
70    CONTINUE
      RETURN
      END


C***********************************************************************
C***********************************************************************
C****                                                               ****
C****                         SUBROUTINE SCHED                      ****
C****                                                               ****
C***********************************************************************
C***********************************************************************
```

```
C-------------------------------------------------------------------
C-        THE PURPOSE OF THIS SUBROUTINE IS TO CONTROL THE SCHEDULING -
C-    PROCESS.  THIS IS DONE BY MAKING CALLS TO SUBROUTINES CONSUM,   -
C-    ROUTE, AND FLOW, EACH OF WHICH CARRY OUT PART OF THE PROCESS.   -
C-------------------------------------------------------------------

      SUBROUTINE SCHED
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)
      COMMON/UCOM2/RTE(300,6,8),COUNT(3)

C-------------------------------------------------------------------
C-          VARIABLES IN SCHED:                                      -
C-                                                                   -
C-      --COUNT(3)--                                                 -
C-        THIS ARRAY IS USED TO INCREMENT DEPARTURE TIMES ASSIGNED   -
C-    TO MISSIONS IN SUBROUTINE FLOW.                                -
C-                                                                   -
C-      --RTE(300,6,8)--                                             -
C-        THIS ARRAY IS ANALOGOUS TO THE 'DEST' ARRAY AND CONTAINS   -
C-    ESSENTIALLY THE SAME INFORMATION.  THIS INFORMATION IS PUT     -
C-    INTO THE ARRAY IN SUBROUTINE ROUTE AS PART OF THE SCHEDULING   -
C-    PROCESS.  EACH MISSION, IN TURN, IS ADDED TO 'DEST' FROM       -
C-    THE 'RTE' ARRAY AND THEN THE NEW MISSION IS INTEGRATED INTO    -
C-    THE FLOW PLAN IN SUBROUTINE FLOW.                              -
C-------------------------------------------------------------------

C-------------------------------------------------------------------
C-        XX(45) IS USED AS A COUNTER TO CONTROL THE SEQUENCE OF     -
C-    THE THREE SCHEDULING PERIODS.                                  -
C-------------------------------------------------------------------

      XX(45)=XX(45)+1
      IF (INT(XX(45)).EQ.4) XX(45)=1

C-------------------------------------------------------------------
C         A CALL TO SCHED IS SCHEDULED TO OCCUR IN 12 HOURS, AND     -
C-    A CALL TO NEWSCD IN THREE HOURS.  THE TWO SUBROUTINES          -
C-    ARE CLOSELY RELATED.  IN SCHED, A GROUP OF MISSION NUMBERS EQUAL -
C-    TO ONE THIRD OF THE TOTAL AVAILABLE IS RESCHEDULED.  THE       -
C-    SCHEDULED DEPARTURE TIMES FOR THESE MISSIONS START THREE       -
C-    HOURS AFTER THE MISSIONS HAVE BEEN SCHEDULED AND CONTINUES FOR -
C-    THE NEXT 12 HOURS.  WHEN NEWSCD IS CALLED, IT CAUSES THE       -
C-    CURRENT MISSION NUMBER BEING ASSIGNED TO AIRCRAFT IN SUBROUTINE -
C-    START TO BE CHANGED TO AGREE WITH THE FIRST MISSION IN         -
C-    THE NEW SCHEDULING PERIOD.  OVER THE NEXT 12 HOURS, MISSIONS   -
C-    ASSIGNED IN SUBROUTINE START WILL BE FROM THE CURRENT SCHEDULING -
C-    PERIOD, AS A RESULT OF THIS CHANGE.                            -
C-------------------------------------------------------------------
```

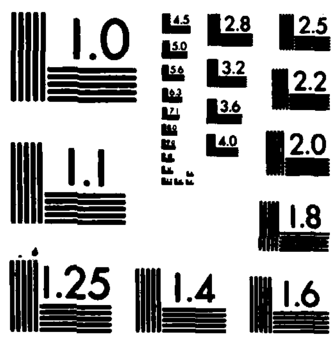
```
C*********************************************************************
C*********************************************************************
C****                                                             ****
C****                     SUBROUTINE START                        ****
C****                                                             ****
C*********************************************************************
C*********************************************************************

C--------------------------------------------------------------------
C-          THE PURPOSE OF THIS SUBROUTINE IS TO ASSIGN MISSIONS TO    -
C-     ENTITIES THAT CONSIST OF AN AIRCREW THAT HAS COMPLETED CREW     -
C-     REST AND AN AIRCRAFT THAT HAS COMPLETED PRE-DEPARTURE           -
C-     MAINTENANCE.                                                    -
C--------------------------------------------------------------------

      SUBROUTINE START
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)
      INTEGER MAXMSN,NLAST,IM,NCURR

C--------------------------------------------------------------------
C-       VARIABLES IN START:                                           -
C-       --MSN(3)--                                                    -
C-          THIS ARRAY MAINTAINS THE NUMBER OF THE LAST MISSION        -
C-     ASSIGNED TO AIRCRAFT FROM EACH OF THE THREE DEPARTURE BASES.    -
C-     IT IS RESET IN SUBROUTINE NEWSCD TO THE FIRST MISSION           -
C-     NUMBER ASSIGNED IN THE LATEST SCHEDULING CYCLE.                 -
C--------------------------------------------------------------------

C--------------------------------------------------------------------
C-          THIS SECTION OF THE SUBROUTINE SEARCHES THROUGH THE        -
C-     UNASSIGNED MISSIONS FOR THE NEXT ONE THAT IS SCHEDULED TO       -
C-     DEPART FROM THE SAME HOME STATION AS THAT OF THE AIRCRAFT       -
C-     AND CREW.  IF THE SCHEDULED DEPARTURE TIME OF THE MISSION       -
C-     HAS ALREADY PASSED, THE SUBROUTINE WILL SEARCH FOR THE          -
C-     NEXT MISSION WITH THE SAME DEPARTURE BASE.  IT WILL CONTINUE    -
C-     TO DO SO UNTIL A MISSION IS FOUND WITH A DEPARTURE TIME         -
C-     IN THE FUTURE, OR UNTIL ALL AVAILABLE MISSIONS HAVE BEEN CHECKED.-
C-         THE HIGHEST CURRENT MISSION NUMBER, 'MAXMSN',               -
C-     IS DETERMINED BY THE VALUE OF XX(44).  THIS COUNTER IS          -
C-     SET EQUAL TO ONE, TWO, OR THREE, DEPENDING ON WHICH THIRD       -
C-     OF THE AVAILABLE MISSION NUMBERS IS CURRENT.  THIS COUNTER      -
C-     IS RESET IN SUBROUTINE NEWSCD EVERY TIME THE CURRENT            -
C-     GROUP OF MISSION NUMBERS CHANGES.  THE LAST MISSION NUMBER CON- -
C-     SIDERED FOR ASSIGNMENT IS MAINTAINED IN 'NLAST' AND IS ASSIGNED -
C-     IF THE SEARCH DOES NOT PRODUCE A MISSION THAT CAN DEPART        -
C-     AT ITS SCHEDULED TIME.                                          -
C--------------------------------------------------------------------
```

```
      IM=MSN(INT(ATRIB(2)))
      NCURR=IM
      NLAST=IM
10    IM=IM+1
      IF (INT(DEST(IM,1,1)).EQ.INT(ATRIB(2))) MSN(INT(ATRIB(2)))=IM
      IF (INT(XX(44)).LT.2) THEN
        MAXMSN=INT(XX(42)/3)
        IF (IM.GT.MAXMSN) THEN
          MSN(INT(ATRIB(2)))=NLAST
          GOTO 20
        ENDIF
      ELSE IF (INT(XX(44)).EQ.2) THEN
        MAXMSN=INT(2*(XX(42)/3))
        IF (IM.GT.MAXMSN) THEN
          MSN(INT(ATRIB(2)))=NLAST
          GOTO 20
        ENDIF
      ELSE IF (INT(XX(44)).EQ.3) THEN
        MAXMSN=INT(XX(42))
        IF (IM.GT.MAXMSN) THEN
          MSN(INT(ATRIB(2)))=NLAST
          GOTO 20
        ENDIF
      ENDIF
      IF (MSN(INT(ATRIB(2))).NE.IM) GO TO 10
      IF (DEST(MSN(INT(ATRIB(2))),2,1).GT.25.0) THEN
        MSN(INT(ATRIB(2)))=NLAST
        GOTO 20
      ENDIF
      IF (DEST(MSN(INT(ATRIB(2))),7,1).LT.TNOW) THEN
        NLAST=IM
        GOTO 10
      ENDIF
20    NCURR=NCURR+1
      IF (NCURR.GT.MAXMSN) GOTO 40
      IF (INT(DEST(NCURR,1,1)).NE.INT(ATRIB(2))) GOTO 20
      IF (NCURR.NE.MSN(INT(ATRIB(2)))) THEN
        DO 30 I=2,6
          DEST(NCURR,I,1)=99
30      CONTINUE
        GOTO 20
      ENDIF
```

```
C-----------------------------------------------------------------------
C-          ONCE A MISSION HAS BEEN CHOSEN, THE FOLLOWING ATTRIBUTE     -
C-     ASSIGNMENTS ARE MADE: ATRIB(4) (DEPARTURE TIME),                 -
C-     ATRIB(14) (CREW DUTY COMPLETION TIME), ATRIB(5) AND ATRIB(6),    -
C-     (PRESENT AND NEXT LOCATION), ATRIB(8) (MISSION NUMBER), AND      -
C-     ATRIB(11) (AIRCRAFT CONFIGURATION).  ATRIB(10) (CUMULATIVE       -
C-     FLYING TIME) IS SET TO ZERO.                                     -
C-----------------------------------------------------------------------

40    ATRIB(4)=DEST(MSN(INT(ATRIB(2))),7,1)
      ATRIB(14)=ATRIB(4)+14.75
      ATRIB(5)=INT(DEST(MSN(INT(ATRIB(2))),1,1))
      ATRIB(6)=INT(DEST(MSN(INT(ATRIB(2))),2,1))
      ATRIB(8)=INT(MSN(INT(ATRIB(2))))
      ATRIB(11)=INT(DEST(MSN(INT(ATRIB(2))),1,3))
      ATRIB(10)=0.

C-----------------------------------------------------------------------
C-         ATRIB(12) IS USED TO DELAY THE LAUNCH OF MISSION AIRCRAFT    -
C-    UNTIL SCHEDULED DEPARTURE.  IF THE AIRCRAFT IS MISSION READY      -
C-    AFTER ITS SCHEDULED DEPARTURE, IT DEPARTS IMMEDIATELY, AND THE    -
C-    VALUES OF ATRIB(4) AND ATRIB(14) ARE CHANGED TO REFLECT THIS.     -
C-----------------------------------------------------------------------

      IF (ATRIB(4)-TNOW.LT.0.0) THEN
        ATRIB(12)=0.0
        ATRIB(4)=TNOW
        ATRIB(14)=ATRIB(4)+14.75
       ELSE
        ATRIB(12)=ATRIB(4)-TNOW
      ENDIF
      RETURN
      END

C***********************************************************************
C***********************************************************************
C****                                                               ****
C****                     SUBROUTINE NEWSCD                         ****
C****                                                               ****
C***********************************************************************
C***********************************************************************
```

AD-A141 149 USER NEED SATISFACTION AS A BASIS FOR TACTICAL AIRLIFT SCHEDULING(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF ENGINEERING J C BRYANT ET AL. MAR 84 3/3

UNCLASSIFIED AFIT/GST/OS/84M-4 F/G 15/5 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
C------------------------------------------------------------------------
C-         THE PURPOSE OF THIS SUBROUTINE IS TO ENSURE THAT             -
C-    AIRCRAFT BEING ASSIGNED MISSIONS IN SUBROUTINE START              -
C-    RECEIVE CURRENT MISSION NUMBERS.  WHEN THE NEW SCHEDULE           -
C-    COMES INTO EFFECT, THREE HOURS AFTER IT WAS ACCOMPLISHED,         -
C-    A CALL TO NEWSCD IS MADE.  NEWSCD THEN SETS THE CURRENT           -
C-    VALUE IN THE 'MSN' ARRAY TO THE FIRST MISSION NUMBER              -
C-    THAT WAS RESCHEDULED.                                             -
C------------------------------------------------------------------------

      SUBROUTINE NEWSCD
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)

C------------------------------------------------------------------------
C-         XX(44) IS A COUNTER USED TO DETERMINE WHICH MISSION          -
C-    SCHEDULING CYCLE IS CURRENT.                                      -
C------------------------------------------------------------------------

      XX(44)=XX(44)+1
      IF (INT(XX(44)).EQ.4) XX(44)=1
      XX(41)=XX(41)+1.0
      IF (INT(XX(44)).EQ.1) THEN
        DO 13 I=1,3
          MSN(I)=0
13      CONTINUE
      ELSE IF (INT(XX(44)).EQ.2) THEN
        DO 23 I=1,3
          MSN(I)=INT(XX(42)/3)
23      CONTINUE
      ELSE IF (INT(XX(44)).EQ.3) THEN
        DO 33 I=1,3
          MSN(I)=INT(2*(XX(42)/3))
33      CONTINUE
      ENDIF
      RETURN
      END

C************************************************************************
C************************************************************************
C****                                                                ****
C****                       SUBROUTINE ROUTE                         ****
C****                                                                ****
C************************************************************************
C************************************************************************
```

```
C-----------------------------------------------------------------------
C-         SUBROUTINE ROUTE CARRIES OUT TWO MAIN FUNCTIONS--           -
C-    THE ASSIGNMENT OF PRIORITY TO USER NFEDS, AND THF                -
C-    SCHEDULING OF MISSIONS BASED ON THAT PRIORITY.                   -
C-----------------------------------------------------------------------

      SUBROUTINE ROUTE(KR1,KR2)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)
      COMMON/UCOM2/RTE(300,6,8),COUNT(3)
      INTEGER AMMO,PALLET
      REAL PRIO(6:8,9),WAG(6:8,9),WAGC(6:8,8)

C-----------------------------------------------------------------------
C-      VARIABLES IN ROUTE:                                            -
C-                                                                     -
C-      --WAG(6:8,9)--                                                 -
C-         THE PURPOSE OF THIS ARRAY IS TO SERVE AS A 'SCRATCH PAD'    -
C-    FOR THE SCHEDULING PROCESS.  INFORMATION ON CURRENT STATUS       -
C-    IS COPIED ONTO THIS ARRAY AT THE START OF THE SCHEDULING         -
C-    PROCESS.  AS MISSIONS ARE SCHEDULED, THF STATUS AT THE DIVISIONS -
C-    RECEIVING THE ONLOAD OR OFFLOAD IS UPDATED TO REFLECT THE        -
C-    EFFECT OF THE PLANNED MISSION IN THE 'WAG' ARRAY.  PRIORITY      -
C-    ASSIGNMENTS ARE MADE USING THE STATUS IN THE 'WAG' ARRAY,        -
C-    SO THAT THE EFFECT OF SCHEDULING EARLIER MISSIONS IS TAKEN       -
C-    INTO ACCOUNT WHEN SCHEDULING NEW ONES.                           -
C-                                                                     -
C-      --WAGC(6:8,8)--                                                -
C-         THIS ARRAY HAS THF SAME PURPOSE AS THE 'WAG' ARRAY, BUT     -
C-    IS USED FOR RECORDING CHANGES TO THE CASUALTY STATUS AT THE      -
C-    DIVISIONS.  IT CCPIES INFORMATION FROM THE 'CAS' ARRAY AT THF    -
C-    START OF THE PROCESS.                                            -
C-                                                                     -
C-      --PRIO(6:8,9)--                                                -
C-         THIS ARRAY CONTAINS THE CURRENT PRIORITIES FOR EACH         -
C-    SUPPLY CLASS AND EACH DIVISION.  POSITION SEVEN IN THE ARRAY     -
C-    CONTAINS AIR EVAC PRIORITY.                                      -
C-----------------------------------------------------------------------

C-----------------------------------------------------------------------
C-         RTE ARRAY IS SET TO ZERO AT THE START OF EACH CALL FROM     -
C-    SCHED.                                                           -
C-----------------------------------------------------------------------
      DO 100 I=1,300
        DO 110 J=1,6
          DO 111 K=1,8
            RTE(I,J,K)=0.0
111       CONTINUE
110     CONTINUE
```

```
100   CONTINUE

C-----------------------------------------------------------------------
C-          THE WAG ARRAY IS SET TO CURRENT STATUS MINUS EXPECTED      -
C-    CONSUMPTION.                                                     -
C-----------------------------------------------------------------------

        DO 10 I=6,8
          WAG(I,1)=STAT(I,1)-9.0
          WAG(I,2)=STAT(I,2)-9.0
          WAG(I,3)=STAT(I,3)-650.0
          WAG(I,4)=STAT(I,4)-15.0
          WAG(I,5)=STAT(I,5)-111.0
          WAG(I,6)=STAT(I,6)-6.0
          WAG(I,7)=STAT(I,7)
          WAG(I,8)=STAT(I,8)-1.0
          WAG(I,9)=STAT(I,9)-9.0
10      CONTINUE

C-----------------------------------------------------------------------
C-          THE 'WAGC' ARRAY IS SET EQUAL TO CURRENT CAS ARRAY.         -
C-----------------------------------------------------------------------

      DO 150 I=6,8
        DO 160 J=1,8
          WAGC(I,J)=CAS(I,J)
160     CONTINUE
150   CONTINUE
      DO 200 KR=KR1,KR2

C-----------------------------------------------------------------------
C-          INITIAL DEPARTURF BASES ARF ALTERNATED BETWEEN THE         -
C-    THREE C-130 BASES.                                               -
C-----------------------------------------------------------------------

      XX(43)=XX(43)+1
      RTE(KR,1,1)=XX(43)
      RTE(KR,6,1)=XX(43)
      IF (INT(XX(43)).EQ.3) XX(43)=0

C-----------------------------------------------------------------------
C-          TWO LEGS, EACH CONSISTING OF AN ONLOAD AND AN OFFLOAD,     -
C-    ARE SCHEDULED FOR EACH MISSION.                                  -
C-----------------------------------------------------------------------

      DO 20 NRN=1,2
        AMMO=0
        PALLET=2
        RMAX=0.0
```

```
C-----------------------------------------------------------------
C-        THE BASE WITH THE HIGHEST PRIORITY IS DETERMINED.      -
C-    PRIORITY FOR AIR EVAC MISSIONS IS CALCULATED               -
C-    BASED ON THE NUMBER OF PATIENTS IN THE FIELD FOR OVER      -
C-    4 DAYS WITH LONGER DELAYS GIVEN HIGHER PRIORITY.  POL MISSIONS -
C-    ARE RESTRICTED TO BASES 2 AND 3.                           -
C-----------------------------------------------------------------

      IF (INT(RTE(KR,1,3)).LT.2) THEN
        DO 30 I=6,8
          DO 40 J=1,9
        IF (J.NE.7) THEN
            IF (WAG(I,J).LT.1.0) THEN
              PRIO(I,J)=STD(I,J)*W(J)
            ELSE IF (STD(I,J)/WAG(I,J).LE.1.0) THEN
              PRIO(I,J)=0.01
            ELSE
              PRIO(I,J)=(STD(I,J)/WAG(I,J))*W(J)
            ENDIF
        ELSE IF (J.EQ.7) THEN
          PRIO(I,7)=WAGC(I,8)+WAGC(I,7)/20.+WAGC(I,6)/40.+WAGC(I,5)/80.+
     *WAGC(I,4)/90.
        ENDIF
        IF (INT(RTE(KR,1,1)).EQ.1.AND.J.EQ.3) PRIO(I,J)=0.0
        IF (INT(RTE(KR,1,3)).EQ.1.AND.J.EQ.3) PRIO(I,J)=0.0
        IF (INT(RTE(KR,1,3)).EQ.1.AND.J.EQ.7) PRIO(I,J)=0.0
        IF (INT(XX(47)).EQ.2) THEN
          IF (INT(RTE(KR,1,1)).EQ.2.AND.J.EQ.3) PRIO(I,J)=0.0
        ELSE IF (INT(XX(47)).EQ.3) THEN
          IF (INT(RTE(KR,1,1)).EQ.3.AND.J.EQ.3) PRIO(I,J)=0.0
        ENDIF
            IF (PRIO(I,J).GT.RMAX) THEN
              NR1=I
              NR2=J
              RMAX=PRIO(I,J)
            ENDIF
40        CONTINUE
30      CONTINUE
      ENDIF

C-----------------------------------------------------------------
C-        THE CONFIGURATION REQUIRED FOR THE MISSION IS ASSIGNED, -
C-    BASED ON THE CATEGORY WITH THE HIGHEST PRIORITY.  ONCE SET, -
C-    THIS CONFIGURATION IS NOT CHANGED FOR THE SECOND LEG OF THE -
C-    MISSION.                                                   -
C-----------------------------------------------------------------

      IF (NRN.EQ.1) THEN
        IF (NR2.EQ.3) THEN
```

```
        XX(47)=INT(RTE(KR,1,1))
        RTE(KR,1,3)=2
      ELSE IF (NR2.EQ.7) THEN
        RTE(KR,1,3)=3
      ELSE
        RTE(KR,1,3)=1
      ENDIF
    ENDIF
50    RMAX=0.0

C-----------------------------------------------------------------
C-       IF THE HIGHEST PRIORITY WAS ASSIGNED TO A CARGO CLASS,    -
C-    PALLETS ARE ASSIGNED TO THE AIRCRAFT.  THE PALLETS FOR THE   -
C-    LEG BEING SCHEDULED ARE ALL SENT TO THE BASE WITH THE        -
C-    HIGHEST PRIORITY IN THE CALCULATION ABOVE.  IN THESE         -
C-    CALCULATIONS, PRIORITY FOR POL AND AIR EVAC IS SET TO        -
C-    ZERO.                                                        -
C-----------------------------------------------------------------

      IF (INT(RTE(KR,1,3)).EQ.1) THEN
        DO 60 J=1,9
          IF (WAG(NR1,J).LT.1.0) THEN
            PRIO(NR1,J)=STD(NR1,J)*W(J)
          ELSE IF (STD(NR1,J)/WAG(NR1,J).LT.1.0) THEN
            PRIO(NR1,J)=0.01
          ELSE
            PRIO(NR1,J)=(STD(NR1,J)/WAG(NR1,J))*W(J)
          ENDIF
          IF (J.EQ.3) PRIO(NR1,J)=0.0
          IF (J.EQ.7) PRIO(NR1,J)=0.0
          IF (PRIO(NR1,J).GT.RMAX) THEN
            NR2=J
            RMAX=PRIO(NR1,NR2)
          ENDIF
60      CONTINUE
        PALLET=PALLET+1
        WAG(NR1,NR2)=WAG(NR1,NR2)+1
        IF (NRN.EQ.1) RTE(KR,3,PALLET)=NR2
        IF (NRN.EQ.2) RTE(KR,5,PALLET)=NR2
        IF (NR2.EQ.5) AMMO=AMMO+1
        IF (PALLET.LT.8.AND.AMMO.LT.5) GOTO 50
      ENDIF

C-----------------------------------------------------------------
C-        IF, AS A RESULT OF THE INITIAL PRIORITY DETERMINATION,   -
C-    THE ARCRAFT CONFIGURATION HAS BEEN SET TO 2 (POL),           -
C-    THIS SECTION DETERMINES THE BASE WITH HIGHEST PRIORITY FOR POL -
C-    FOR BOTH LEGS. THE 'WAG' ARRAY IS UPDATED IN EACH CASE WITH THE -
C-    PLANNED OFFLOAD.                                             -
C-----------------------------------------------------------------
```

```
      IF (INT(RTE(KR,1,3)).EQ.2) THEN
        DO 90 I=6,8
          IF (WAG(I,3).LT.1.0) THEN
            PRIO(I,3)=STD(I,3)*W(3)
          ELSE
            PRIO(I,3)=(STD(I,3)/WAG(I,3))*W(3)
          ENDIF
          IF (PRIO(I,3).GT.RMAX) THEN
            NR1=I
            NR2=3
            RMAX=PRIO(I,3)
          ENDIF
90      CONTINUE
        WAG(NR1,NR2)=WAG(NR1,NR2)+65.
      ENDIF

C-----------------------------------------------------------------------
C-          IF THE HIGHEST INITIAL PRIORITY WAS FOR AIR EVAC,             -
C-     THE BASE WITH THE HIGHEST PRIORITY FOR AIR EVAC IS DETERMINED      -
C-     IN THIS SECTION FOR BOTH LEGS.  THE 'WAGC' ARRAY IS UPDATED WITH   -
C-     THE PLANNED ONLOAD.                                                -
C-----------------------------------------------------------------------

      IF (INT(RTE(KR,1,3)).EQ.3) THEN
        DO 130 I=6,8
          PRIO(I,7)=WAGC(I,8)/20.+WAGC(I,7)/40.+WAGC(I,6)/80.+
     *WAGC(I,5)/90.
          IF (PRIO(I,7).GT.RMAX) THEN
            NR1=I
            NR2=7
            RMAX=PRIO(I,7)
          ENDIF
130     CONTINUE
        NR3=8
        WAGC(NR1,NR3)=WAGC(NR1,NR3)-74.0
170     IF (WAGC(NR1,NR3).LT.0.0) THEN
          WAGC(NR1,NR3-1)=WAGC(NR1,NR3-1)+WAGC(NR1,NR3)
          WAGC(NR1,NR3)=0.0
        ENDIF
        IF (WAGC(NR1,NR3-1).LT.0.0) THEN
          IF (NR3-1.EQ.1) THEN
            WAGC(NR1,NR3-1)=0.0
          ELSE
            NR3=NR3-1
            GOTO 170
          ENDIF
        ENDIF
      ENDIF
```

```
C-----------------------------------------------------------------------
C-        ROUTING FOR POL AND CARGO MISSIONS IS SET BASED ON AN        -
C-    INITIAL STOP AT ONE OF THF DEPOTS.  AIR EVAC MISSIONS            -
C-    ROUTED SEPARATELY AND ARE SENT TO ONE OF THE THREE DIVISION      -
C-    BASES INITIALLY.                                                 -
C-----------------------------------------------------------------------

        IF (INT(RTE(KR,1,3)).NE.3) THEN
          IF (NRN.EQ.1) THEN
            XX(60)=-XX(60)
            RTE(KR,2,2)=1
            RTE(KR,3,1)=NR1
            RTE(KR,3,2)=-1
            IF (XX(60).GT.0.0) THEN
              RTE(KR,2,1)=4
              RTE(KR,4,1)=5
            ELSE
              RTE(KR,2,1)=5
              RTE(KR,4,1)=4
            ENDIF
          ELSE
            RTE(KR,4,2)=1
            RTE(KR,5,1)=NR1
            RTE(KR,5,2)=-1
          ENDIF
        ELSE IF (INT(RTE(KR,1,3)).EQ.3) THEN
          IF (NRN.EQ.1) THEN
            RTE(KR,2,1)=NR1
            RTE(KR,2,2)=1
            RTE(KR,3,1)=5
            RTE(KR,3,2)=-1
          ELSE
            RTE(KR,4,1)=NR1
            RTE(KR,4,2)=1
            RTE(KR,5,1)=5
            RTE(KR,5,2)=-1
          ENDIF
        ENDIF
20    CONTINUF
200   CONTINUE
      RETURN
      END

C***********************************************************************
C***********************************************************************
C****                                                               ****
C****                      SUBROUTINE CONSUM                        ****
C****                                                               ****
C***********************************************************************
C***********************************************************************
```

```
C-----------------------------------------------------------------------
C-         THIS SUBROUTINE PERFORMS TWO FUNCTIONS.  THE FIRST IS       -
C-    TO CONTROL THE CHANGES IN COMBAT STATE AT THE DIVISIONS.  THE    -
C-    SECOND IS TO CHANGE THE STATUS AT THE DIVISIONS BASED ON         -
C-    THEIR COMBAT STATUS.                                             -
C-----------------------------------------------------------------------

      SUBROUTINE CONSUM
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)
      COMMON/UCOM5/NZ(6:8,9)

C-----------------------------------------------------------------------
C-      VARIABLES IN CONSUM:                                           -
C-                                                                     -
C-      --NCDAY(6:8,4)--                                               -
C-         THE PURPOSE OF THIS ARRAY IS TO KEEP A RECORD OF THE NUMBER -
C-    OF DAYS THAT EACH DIVISION HAS BEEN IN THE DIFFERENT             -
C-    COMBAT STATES.                                                   -
C-                                                                     -
C-      --NCMBT(6:8)--                                                 -
C-         THIS ARRAY CONTAINS THE CURRENT COMBAT STATE FOR EACH       -
C-    DIVISION.                                                        -
C-                                                                     -
C-      --NZ(6:8,9)--                                                  -
C-         THE 'NZ' ARRAY RECORDS THE NUMBER OF SCHEDULING PERIODS     -
C-    THAT ANY OF THE SUPPLY LEVELS WAS REDUCED TO ZERO BY             -
C-    CONSUMPTION AT ANY OF THE DIVISIONS.                             -
C-----------------------------------------------------------------------
      DO 10 I=6,8

C-----------------------------------------------------------------------
C-         THE CHANGE OF COMBAT STATES IS MODELED AS A MARKOV          -
C-    PROCESS.  A RANDOM DRAW IS MADE AND THIS DRAW IS USED TO         -
C-    DETERMINE THE NEXT COMBAT STATE.  THE RANGES OF VALUES THAT      -
C-    CORRESPOND TO THE VARIOUS STATES IS DEPENDENT ON THE             -
C-    CURRENT COMBAT STATE.  THE COUNTER XX(40) IS USED TO ENSURE      -
C-    THAT THE COMBAT STATES CHANGE ONCE EVERY 24 HOURS.               -
C-----------------------------------------------------------------------

      IF (XX(40).GT.0.0) THEN
        NCDAY(I,NCMBT(I))=NCDAY(I,NCMBT(I))+1
        X=DRAND(1)
        IF (NCMBT(I).EQ.1) THEN
          IF (X.LE.0.4)NCMBT(I)=1
          IF (X.LE.0.9.AND.X.GT.0.4) NCMBT(I)=2
          IF (X.GT.0.9) NCMBT(I)=3
        ELSE IF (NCMBT(I).EQ.2) THEN
          IF (X.LE.0.2) NCMBT(I)=1
```

```
          IF (X.LE.0.7.AND.X.GT.0.2) NCMBT(I)=2
          IF (X.LE.0.9.AND.X.GT.0.7) NCMBT(I)=3
          IF (X.GT.0.9) NCMBT(I)=4
        ELSE IF (NCMBT(I).EQ.3) THEN
          IF (X.LE.0.2) NCMBT(I)=1
          IF (X.LE.0.7.AND.X.GT.0.2) NCMBT(I)=2
          IF (X.LE.0.9.AND.X.GT.0.7) NCMBT(I)=3
          IF (X.GT.0.9) NCMBT(I)=4
        ELSE IF (NCMBT(I).EQ.4) THEN
          IF (X.LE.0.5) NCMBT(I)=2
          IF (X.LE.0.9.AND.X.GT.0.5) NCMBT(I)=3
          IF (X.GT.0.9) NCMBT(I)=4
        ENDIF
      ENDIF

C-----------------------------------------------------------------------
C-         EVERY 24 HOURS, THE CASUALTIES IN EACH CATEGORY MOVE UP     -
C-    ONE CATEGORY.                                                    -
C-----------------------------------------------------------------------

        IF (XX(40).GT.0.0) THEN
          CAS(I,8)=CAS(I,8)+CAS(I,7)
          DO 20 J=6,1,-1
            CAS(I,J+1)=CAS(I,J)
20        CONTINUE
        CAS(I,1)=0.0
        ENDIF
        IF (I.EQ.6) THEN
          STAT(I,2)=STAT(I,2)-8.5
          STAT(I,6)=STAT(I,6)-5.5
          STAT(I,9)=STAT(I,9)-8.5
        ELSE IF (I.NE.6) THEN
          STAT(I,2)=STAT(I,2)-9.0
          STAT(I,6)=STAT(I,6)-6.0
          STAT(I,9)=STAT(I,9)-9.0
        ENDIF
        STAT(I,1)=STAT(I,1)-9.0
        STAT(I,4)=STAT(I,1)-15.0
        STAT(I,8)=STAT(I,8)-0.5

C-----------------------------------------------------------------------
C-         THE CONSUMPTION OF TWO SUPPLY CLASSES--POL (CLASS 3)        -
C-    AND AMMUNITION (CLASS 5)--ARE DEPENDENT ON COMBAT STATE.         -
C-    ALL OTHER CONSUMPTION RATES ARE CONSTANT.  THE GENERATION        -
C-    OF CASUALTIES IS ALSO DEPENDENT ON COMBAT STATE.                 -
C-----------------------------------------------------------------------

        IF (NCMBT(I).EQ.1) THEN
          IF (I.EQ.6) THEN
            STAT(I,3)=STAT(I,3)-942.5
            STAT(I,5)=STAT(I,5)-152.5
```

```
          ELSE
            STAT(I,3)=STAT(I,3)-910.
            STAT(I,5)=STAT(I,5)-156.
          ENDIF
          STAT(I,7)=STAT(I,7)+112.
          CAS(I,1)=CAS(I,1)+112.
        ELSE IF (NCMBT(I).EQ.2) THEN
          IF (I.EQ.6) THEN
            STAT(I,3)=STAT(I,3)-682.5
            STAT(I,5)=STAT(I,5)-108.5
          ELSE
            STAT(I,3)=STAT(I,3)-650.
            STAT(I,5)=STAT(I,5)-111.
          ENDIF
          STAT(I,7)=STAT(I,7)+80.
          CAS(I,1)=CAS(I,1)+80.
        ELSE IF (NCMBT(I).EQ.3) THEN
          IF (I.EQ.6) THEN
            STAT(I,3)=STAT(I,3)-422.5
            STAT(I,5)=STAT(I,5)-65.5
          ELSE
            STAT(I,3)=STAT(I,3)-390.
            STAT(I,5)=STAT(I,5)-67.
          ENDIF
          STAT(I,7)=STAT(I,7)+48.
          CAS(I,1)=CAS(I,1)+48.
        ELSE IF (NCMBT(I).EQ.4) THEN
          IF (I.EQ.6) THEN
            STAT(I,5)=STAT(I,5)-32.
          ELSE
            STAT(I,5)=STAT(I,5)-32.5
          ENDIF
          STAT(I,3)=STAT(I,3)-195.
          STAT(I,7)=STAT(I,7)+24.
          CAS(I,1)=CAS(I,1)+24.
        ENDIF
      DO 30 J=1,9
        IF (J.NE.7) THEN
          IF (STAT(I,J).LE.0.0) THFN
            STAT(I,J)=0.0
            NZ(I,J)=NZ(I,J)+1
            XX(46)=-1
          ENDIF
        ENDIF
30    CONTINUE
10    CONTINUE
      RFTURN
       END
```

```
C*********************************************************************
C*********************************************************************
C****                                                             ****
C****                    SUBROUTINE SCORE                         ****
C****                                                             ****
C*********************************************************************
C*********************************************************************

C--------------------------------------------------------------------
C-        THE PURPOSE OF THIS SUBROUTINE IS TO CALCULATE THE        -
C-    RUNNING AVERAGE OF SUPPLY LEVELS USED AS THE BASIS OF         -
C-    THE AIRLIFT SCORE.                                            -
C--------------------------------------------------------------------

      SUBROUTINF SCORE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)
      COMMON/UCOM3/DAYAVE(6:8,9),VALUE
      COMMON/UCOM4/DAYSUM(6:8,9),INC(3),NCOMP(3),NTDY(3),NBTDY(8)
     1,NFIG(3,3)
      REAL MINAVE(9),LIST(6:8)

C--------------------------------------------------------------------
C-      VARIABLES IN SCORE:                                         -
C-      --DAYAVE(6:8,9)--                                           -
C-          THIS ARRAY CONTAINS THE RUNNING AVERAGE OF THE SUPPLY   -
C-    LEVELS AT EACH OF THE DIVISIONS.                              -
C-                                                                  -
C-      --DAYSUM(6:8,9)                                             -
C-          THE FRACTION OF THE DESIRED LEVEL OF EACH OF THE SUPPLY -
C-    CLASSES ON HAND AT THE TIME THE SUBROUTINE IS CALLED IS       -
C-    ADDED TO A RUNNING SUM STORED IN 'DAYSUM'.                    -
C-                                                                  -
C-      --MINAVE(9)--                                               -
C-          FOR EACH SUPPLY CLASS, THE MINIMUM AVERAGE IN 'DAYAVE'  -
C-    AMONG THE THREE DIVISIONS IS DETERMINED AND STORED IN         -
C-    'MINAVE'.                                                     -
C-                                                                  -
C-      --VALUE--                                                   -
C-          THIS VARIABLE IS THE CURRENT AIRLIFT SCORE, AND IS      -
C-    CALCULATED BY MULTIPLYING THE MINIMUM AVERAGE FOR EACH        -
C-    SUPPLY CLASS BY THE WORTH OF THAT CLASS.                      -
C-                                                                  -
C-      --WORTH(9)--                                                -
C-          THIS ARRAY CONTAINS THE WORTH FACTOR FOR EACH OF THE    -
C-    SUPPLY CLASSES.                                               -
C--------------------------------------------------------------------
```

```
      DO 10 I=6,8
        DO 20 J=1,9
          DAYSUM(I,J)=DAYSUM(I,J)+STAT(I,J)/STD(I,J)
          DAYAVE(I,J)=DAYSUM(I,J)/XX(30)
20      CONTINUE
10    CONTINUE
      DO 30 J=1,9
        DO 40 I=6,8
          LIST(I)=DAYAVE(I,J)
40      CONTINUE
        MINAVE(J)=MIN(LIST(6),LIST(7),LIST(8))
30    CONTINUE
      VALUE=0.0
        DO 60 J=1,9
         IF (J.NE.7) VALUE=VALUE+WORTH(J)*MINAVE(J)
60      CONTINUE
      RETURN
      END

C***********************************************************************
C***********************************************************************
C****                                                               ****
C****                     SUBROUTINE FLOW                           ****
C****                                                               ****
C***********************************************************************
C***********************************************************************

C-----------------------------------------------------------------------
C-          THIS SUBROUTINE SEQUENCES MISSIONS SCHEDULED IN            -
C-     SUBROUTINE ROUTE.  IT DOES THIS BY TESTING EACH MISSION         -
C-     FOR SCHEDULING CONFLICTS.  IF THE NUMBER OF EXPECTED            -
C-     CONFLICTS EXCEEDS A MINIMUM VALUE, THE MISSION                  -
C-     ITINERARY IS CHANGED TO CORRECT THIS.                           -
C-----------------------------------------------------------------------

      SUBROUTINE FLOW(NMSN,MAXMSN)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)
      COMMON/UCOM2/RTE(300,6,8),COUNT(3)
      INTEGER NPRIOR(2:5),NAFTER(2:5)
      REAL SWITCH(6,8)
```

```
C-----------------------------------------------------------------------
C-       VARIABLES IN FLOW:                                            -
C-                                                                     -
C-       --COUNT(3)--                                                  -
C-          ONE OF THE FUNCTIONS CARRIED OUT IN THIS SUBROUTINE        -
C-     IS THE ASSIGNMENT OF THE DEPARTURE TIME FOR EACH MISSION.       -
C-     MISSION DEPARTURES FOR EACH BASE ARE SEPARATED BY 0.33          -
C-     HOURS.  ARRAY 'COUNT' IS INCREMENTED WITH EACH SCHEDULED        -
C-     DEPARTURE TO KEEP TRACK OF THE CURRENT TIME SLOT.               -
C-                                                                     -
C-       --NAFTER(2:5)--                                               -
C-          THIS ARRAY CONTAINS THE NUMBER OF EXPECTED CONFLICTS       -
C-     WITH OTHER  AIRCRAFT HAVING THE SAME CONFIGURATION AT THE SAME  -
C-     BASE, WITHIN THE TIME PERIOD FOR THE SERVER TYPE, AFTER         -
C-     THE EXPECTED ARRIVAL OF THE AIRCRAFT.  THE TIME PERIODS USED    -
C-     ARE 0.9 HOURS FOR CARGO AND AIR EVAC, AND 2.0 HOURS FOR         -
C-     POL.                                                            -
C-                                                                     -
C-       --NPRIOR(2:5)--                                               -
C-          THIS ARRAY CONTAINS THE SAME INFORMATION AS 'NAFTER'       -
C-     WITH THE EXCEPTION THAT THE CONFLICTS DETECTED OCCUR            -
C-     WITHIN THE TIME PERIOD FOR THE SERVER TYPE PRIOR TO             -
C-     THE EXPECTED ARRIVAL OF THE AIRCRAFT.                           -
C-                                                                     -
C-       --SWITCH(6,8)--                                               -
C-          THIS ARRAY SERVES AS A 'SCRATCH PAD' FOR THE SUBROUTINE.   -
C-     WHEN MISSIONS ARE SWITCHED WITH EACH OTHER, INFORMATION         -
C-     FROM THE 'RTE' ARRAY IS TEMPORARILY STORED IN 'SWITCH'          -
C-     WHILE THE SWITCH IS GOING ON.                                   -
C-----------------------------------------------------------------------

      DEST(NMSN,7,8)=0
      NF1=1

C-----------------------------------------------------------------------
C-           THIS SECTION INCREMENTS THE COUNTERS FOR THE THREE BASES  -
C-     USED TO SEPARATE HOME STATION LAUNCHES BY 0.33 HOURS.           -
C-     DEPARTURE TIMES ARE STORED IN THE 'DEST' ARRAY.                 -
C-----------------------------------------------------------------------

300   IF (INT(DEST(NMSN,1,1)).EQ.1) THEN
        COUNT(1)=COUNT(1)+1
        DEST(NMSN,7,1)=TNOW+3.0+(1.0/3.0)*COUNT(1)
      ELSE IF (INT(DEST(NMSN,1,1)).EQ. 2) THEN
        COUNT(2)=COUNT(2)+1
        DEST(NMSN,7,1)=TNOW+3.0+(1.0/3.0)*COUNT(2)
      ELSE IF (INT(DEST(NMSN,1,1)).EQ.3) THEN
        COUNT(3)=COUNT(3)+1
        DEST(NMSN,7,1)=TNOW+3.0+(1.0/3.0)*COUNT(3)
      ENDIF
```

```
C-----------------------------------------------------------------------
C-          IF THE SCHEDULED DEPARTURE TIME IS GREATER THAN THE        -
C-     CURRENT TIME PLUS FIFTEEN HOURS, THEN THF MISSION WOULD         -
C-     DEPART AFTER THE NEXT SCHEDULING PERIOD CAME INTO EFFECT.       -
C-     TO PREVENT AN AIRCRAFT FROM BEING ASSIGNED SUCH A MISSION, ITS  -
C-     SCHEDULED STOPS ARE SET TO 99.  IF A MISSION WITH THESE         -
C-     VALUES IS DETECTED BY USERF 9, AIRCRAFT ARF DELAYED TO          -
C-     PREVENT THEIR ARRIVAL AT THE START SUBROUTINE UNTIL             -
C-     AFTER THE NEW SCHEDULING PERIOD COMES INTO EFFECT.              -
C-----------------------------------------------------------------------

      IF (DEST(NMSN,7,1).GT.TNOW+15.0) THEN
        DO 130 I=2,6
          DEST(NMSN,I,1)=99
130     CONTINUE
        RETURN
      ENDIF
      DEST(NMSN,7,8)=DFST(NMSN,7,8)+1
      IF (DEST(NMSN,7,8).GE.50) THEN
        IF (NF1.EQ.4) THEN
          NF1=5
          GOTO 210
        ELSE
          RETURN
        ENDIF
      ENDIF
      DO 50 I=2,5
        NPRIOR(I)=0
        NAFTER(I)=0
50    CONTINUE

C-----------------------------------------------------------------------
C-          THIS SECTION COMPUTES THE SCHEDULED DEPARTURE TIME         -
C-     FOR EACH HOME BASE DEPARTURE AND THE EXPECTED ARRIVAL           -
C-     TIME FOR EACH SUBSEQUENT ENROUTE STOP.                          -
C-----------------------------------------------------------------------

      DEST(NMSN,7,2)=DEST(NMSN,7,1)+
     *DIST(INT(DEST(NMSN,1,1)),INT(DEST(NMSN,2,1)))/XX(29)
      DO 10 I=2,5
        ENRTE=DIST(INT(DEST(NMSN,I,1)),INT(DEST(NMSN,I+1,1)))/XX(29)
        IF (INT(DEST(NMSN,1,3)).EQ.1) THEN
          IF (DEST(NMSN,I,2).GT.0.0) THEN
            DEST(NMSN,7,I+1)=DEST(NMSN,7,I)+ENRTE+1.4
          ELSE IF (DEST(NMSN,I,2).LT.0.0) THEN
            DEST(NMSN,7,I+1)=DEST(NMSN,7,I)+ENRTE+1.15
          ENDIF
        ELSE IF (INT(DEST(NMSN,1,3)).EQ.2) THFN
          IF (DEST(NMSN,I,2).GT.0.0) THEN
            DEST(NMSN,7,I+1)=DEST(NMSN,7,I)+ENRTE+2.4
```

```
        ELSE IF (DEST(NMSN,I,2).LT.0.0) THEN
          DEST(NMSN,7,I+1)=DEST(NMSN,7,I)+ENRTE+2.4
        ENDIF
      ELSE IF (INT(DEST(NMSN,1,3)).EQ.3) THEN
        IF (DEST(NMSN,I,2).GT.0.0) THEN
          DEST(NMSN,7,I+1)=DEST(NMSN,7,I)+ENRTE+1.02
        ELSE IF (DEST(NMSN,I,2).LT.0.0) THEN
          DEST(NMSN,7,I+1)=DEST(NMSN,7,I)+ENRTE+1.27
        ENDIF
      ENDIF
10    CONTINUE

C-----------------------------------------------------------------------
C-         EACH MISSION ITINERARY IS CHECKED FOR CONFLICTS WITH        -
C-    OTHER MISSIONS ALREADY SCHEDULED.                                 -
C-----------------------------------------------------------------------

      DO 30 J=1,INT(XX(42))
        IF (INT(DEST(J,1,3)).EQ.INT(DEST(NMSN,1,3))) THEN
          IF (J.NE.NMSN) THEN
            DO 20 I=2,5
              NBASE=INT(DEST(NMSN,I,1))
              TIME=DEST(NMSN,7,I)
              DO 120 K=2,5
                IF (INT(DEST(J,K,1)).EQ.NBASF) THEN
                  IF (NCNFG.EQ.2) THEN
                    IF (DEST(J,7,K).GT.(TIME-2.0).AND.DEST(J,7,K).LT.
     *TIME) THEN
                      NPRIOR(I)=NPRIOR(I)+1
                    ENDIF
                    IF (DEST(J,7,K).LT.(TIME+2.0).AND.DEST(J,7,K).GT.
     *TIME) THEN
                      NAFTER(I)=NAFTER(I)+1
                    ENDIF
                  ELSE IF (NCNFG.NE.2) THEN
                    IF (DEST(J,7,K).GT.(TIME-0.9).AND.DEST(J,7,K).LT.
     *TIME) THEN
                      NPRIOR(I)=NPRIOR(I)+1
                    ENDIF
                    IF (DEST(J,7,K).LT.(TIME+0.9).AND.DEST(J,7,K).GT.
     *TIME) THEN
                      NAFTER(I)=NAFTER(I)+1
                    ENDIF
                  ENDIF
                ENDIF
120           CONTINUE
20          CONTINUE
          ENDIF
        ENDIF
30    CONTINUE
      NFLCT=0
```

```
C-----------------------------------------------------------------------
C-         THE EXPECTED NUMBER OF CONFLICTS IS COMPARED TO A STANDARD   -
C-    FOR EACH SERVICE TYPE.  IF THE STANDARD IS EXCEEDED, THE          -
C-    MISSION IS RESCHEDULED.                                           -
C-----------------------------------------------------------------------

      DO 40 I=2,5
        IF (INT(DEST(NMSN,1,3)).EQ.1) THEN
          IF (NPRIOR(I).GE.7) NFLCT=1
          IF (NAFTER(I).GE.7) NFLCT=1
        ELSE IF (INT(DEST(NMSN,1,3)).EQ.2) THEN
          IF (NPRIOR(I).GE.5) NFLCT=1
          IF (NAFTER(I).GE.5) NFLCT=1
        ELSE IF (INT(DEST(NMSN,1,3)).EQ.3) THEN
          IF (NPRIOR(I).GE.3) NFLCT=1
          IF (NAFTER(I).GF.3) NFLCT=1
        ENDIF
40    CONTINUE
      IF (NFLCT.EQ.0) THEN
        IF (NF1.EQ.4) THEN
          NF1=5
        ELSE
          RETURN
        ENDIF
      ENDIF

C-----------------------------------------------------------------------
C-         THE FIRST RESCHEDULING EFFORT IS TO SWITCH THE DEPARTURE     -
C-    BASE WITH THE DEPARTURE OF THE FOLLOWING MISSION.  A TEST         -
C-    IS MADE TO PRECLUDE AN ATTEMPT TO SWITCH WITH A MISSION           -
C-    NOT BEING SCHEDULED IN THE PRESENT 12 HOUR CYCLE.                 -
C-    ADDITIONALLY, A SWITCH THAT WOULD RESULT IN A BASE 1 AIRCRAFT     -
C-    BEING ASSIGNED A POL MISSION IS PREVENTED.                        -
C-----------------------------------------------------------------------

      IF (NF1.EQ.1) THEN
        IF (NMSN+1.GT.MAXMSN) GOTO 300
        IF (INT(DEST(NMSN,1,1)).EQ.1.AND.INT(RTE(NMSN+1,1,3)).EQ.2) THEN
          NF1=2
          COUNT(INT(RTE(NMSN,1,1)))=COUNT(INT(RTE(NMSN,1,1)))-1.0
          GOTO 400
        ENDIF
        IF (INT(DEST(NMSN,1,3)).EQ.2.AND.INT(RTE(NMSN+1,1,1)).EQ.1) THEN
          NF1=2
          COUNT(INT(RTE(NMSN,1,1)))=COUNT(INT(RTE(NMSN,1,1)))-1.0
          GOTO 400
        ENDIF
      ENDIF
        IF (NF1.EQ.1) THEN
          DEST(NMSN,1,1)=RTE(NMSN+1,1,1)
```

```
        DEST(NMSN,6,1)=RTE(NMSN+1,6,1)
        RTE(NMSN+1,1,1)=RTE(NMSN,1,1)
        RTE(NMSN+1,6,1)=RTE(NMSN,6,1)
        COUNT(INT(RTE(NMSN,1,1)))=COUNT(INT(RTE(NMSN,1,1)))-1.0
        NF1=2
        GOTO 300
      ENDIF

C-----------------------------------------------------------------
C-          IF THE FIRST SWITCH DID NOT RESOLVE THE CONFLICT, THF   -
C-     EFFECTS OF THE FIRST SWITCH ARE UNDONE.                      -
C-----------------------------------------------------------------

      IF (NF1.EQ.2) THEN
        RTE(NMSN+1,1,1)=DEST(NMSN,1,1)
        RTE(NMSN+1,6,1)=DEST(NMSN,6,1)
        DEST(NMSN,1,1)=RTE(NMSN,1,1)
        DEST(NMSN,6,1)=RTE(NMSN,6,1)
        COUNT(INT(RTE(NMSN+1,1,1)))=COUNT(INT(RTE(NMSN+1,1,1)))-1.0
      ENDIF

C-----------------------------------------------------------------
C-          THE MISSION DEPARTURE BASE IS SWITCHED WITH THE DEPARTURE   -
C-    BASE OF THE MISSION TWO MISSIONS AFTER THE CURRENT ONE.            -
C-----------------------------------------------------------------

400   IF (NF1.EQ.2) THEN
        IF (NMSN+2.GT.MAXMSN) THEN
          NF1=3
          GOTO 500
        ENDIF
      IF (INT(DEST(NMSN,1,1)).EQ.1.AND.INT(RTE(NMSN+2,1,3)).EQ.2) THEN
        NF1=3
        GOTO 500
      ENDIF
      IF (INT(DEST(NMSN,1,3)).EQ.2.AND.INT(RTE(NMSN+2,1,1)).EQ.1) THEN
        NF1=3
        GOTO 500
      ENDIF
      ENDIF
      IF (NF1.EQ.2) THEN
        DEST(NMSN,1,1)=RTE(NMSN+2,1,1)
        DEST(NMSN,6,1)=RTE(NMSN+2,6,1)
        RTE(NMSN+2,1,1)=RTE(NMSN,1,1)
        RTE(NMSN+2,6,1)=RTE(NMSN,1,1)
        NF1=3
        GOTO 300
      ENDIF
```

```
C----------------------------------------------------------------------
C-        IF THE CONFLICT STILL EXISTS, THE EFFECTS OF THE            -
C-    PRECEDING SWITCH ARE UNDONE.                                    -
C----------------------------------------------------------------------

      IF (NF1.EQ.3) THEN
        RTE(NMSN+2,1,1)=DEST(NMSN,1,1)
        RTE(NMSN+2,6,1)=DEST(NMSN,6,1)
        DEST(NMSN,1,1)=RTE(NMSN,1,1)
        DEST(NMSN,6,1)=RTE(NMSN,6,1)
        COUNT(INT(RTE(NMSN+2,1,1)))=COUNT(INT(RTE(NMSN+2,1,1)))-1.0
      ENDIF

C----------------------------------------------------------------------
C-        THE MISSION IS SWITCHED WITH THE NEXT MISSION HAVING THE    -
C-    SAME HOME DEPARTURE BASE AS THE CURRENT MISSION.                -
C----------------------------------------------------------------------

500   IF (NF1.EQ.3) THEN
        NCK=NMSN
110     NCK=NCK+1
        IF (NCK.GT.MAXMSN) THEN
          NF1=1
          COUNT(INT(RTE(NMSN,1,1)))=COUNT(INT(RTE(NMSN,1,1)))+1.0
          GOTO 300
        ENDIF
        IF (INT(RTE(NCK,1,1)).NE.INT(RTE(NMSN,1,1))) GOTO 110

        DO 60 I=1,6
          DO 70 J=1,8
            DEST(NMSN,I,J)=RTE(NCK,I,J)
            RTE(NCK,I,J)=RTE(NMSN,I,J)
70        CONTINUE
60      CONTINUE
        NF1=4
        GOTO 300
      ENDIF

C----------------------------------------------------------------------
C-        IF CONFLICTS STILL EXIST, THE SWITCH IS UNDONE AND THE      -
C-    MISSION IS CYCLED THROUGH THE SWITCH ROUTINE WITH ITS HOME      -
C-    STATION DEPARTURE TIME SET 0.33 HOURS LATER THAN INITIALLY      -
C-    SCHEDULED.  THIS PROCESS IS REPEATED AS NECESSARY UNTIL THE     -
C-    EXPECTED NUMBER OF CONFLICTS IS REDUCED TO AN ACCEPTABLE LEVEL. -
C----------------------------------------------------------------------

      IF (NF1.EQ.4) THEN
        DO 80 I=1,6
          DO 90 J=1,8
            RTE(NCK,I,J)=DEST(NMSN,I,J)
```

```
          DEST(NMSN,I,J)=RTE(NMSN,I,J)
90      CONTINUE
80     CONTINUE
       COUNT(INT(RTE(NMSN,1,1)))=COUNT(INT(RTE(NMSN,1,1)))-1.0
140    NCK=NCK+1
       IF (NCK.GT.MAXMSN) THEN
         NF1=1
         COUNT(INT(RTE(NMSN,1,1)))=COUNT(INT(RTE(NMSN,1,1)))+1.0
         GOTO 300
       ENDIF
       IF (INT(RTE(NCK,1,1)).NE.INT(RTE(NMSN,1,1))) GOTO 140
       DO 150 I=1,6
         DO 160 J=1,8
           DEST(NMSN,I,J)=RTE(NCK,I,J)
           RTE(NCK,I,J)=RTE(NMSN,I,J)
160      CONTINUE
150    CONTINUE
       GOTO 300
      ENDIF
210   IF (NF1.EQ.5) THEN
       NCHNG=NMSN
170    NCHNG=NCHNG+1
       IF (NCHNG.EQ.NCK) RETURN
       IF (INT(RTE(NCHNG,1,1)).NE.INT(RTE(NMSN,1,1))) GOTO 170
       DO 180 I=1,6
         DO 190 J=1,8
           SWITCH(I,J)=RTE(NCHNG,I,J)
           RTE(NCHNG,I,J)=RTE(NCK,I,J)
           RTE(NCK,I,J)=SWITCH(I,J)
190      CONTINUE
180    CONTINUE
       IF (NCK.GT.NCHNG) GOTO 170
      ENDIF

      RETURN
      END

C***********************************************************************
C***********************************************************************
C****                                                               ****
C****                     SUBROUTINE OTPUT                          ****
C****                                                               ****
C***********************************************************************
C***********************************************************************

C-----------------------------------------------------------------------
C-        THIS SUBROUTINE IS CALLED AT THE END OF EACH RUN.  IT        -
C-    IS USED TO FORMAT AND PRINT RESULTS NOT INCLUDED IN THE          -
C-    NORMAL SLAM SUMMARY REPORT.                                      -
C-----------------------------------------------------------------------
```

```
      SUBROUTINE OTPUT
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)
      COMMON/UCOM3/DAYAVE(6:8,9),VALUE
      COMMON/UCOM4/DAYSUM(6:8,9),INC(3),NCOMP(3),NTDY(3),NBTDY(8)
     1,NFIG(3,3)
      COMMON/UCOM5/NZ(6:8,9)

      WRITE(6,45)
45    FORMAT(/,'********* DAILY AVERAGES *********',/)
      DO 20 I=6,8
        WRITE(6,75)I,(DAYAVE(I,J),J=1,9)
20    CONTINUE
      WRITE(6,55)
55    FORMAT(/,'************** STATUS **************',/)
      DO 120 I=6,8
        WRITE(6,15)I,(STAT(I,J),J=1,9)
120   CONTINUE
      WRITE(6,85)
85    FORMAT(/,'************* CASUALTIES ************',/)
      DO 10 I=6,8
        WRITE(6,95)I,(CAS(I,J),J=1,8)
10    CONTINUE
      WRITE(6,135)
135   FORMAT(/,'*********** COMBAT STATES ***********',/)
      DO 150 I=6,8
        WRITE(6,145)I,(NCDAY(I,J),J=1,4)
150   CONTINUE
      WRITE(6,165)
165   FORMAT(/,'***** MISSION TYPES PER C-130 BASE *****',/)
      DO 160 I=1,3
        WRITE(6,175)I,(NFIG(I,J),J=1,3)
160   CONTINUE
      IF (XX(46).LT.-0.5) THEN
        WRITE(6,185)
185     FORMAT(/,'********* PERIODS AT ZERO LEVEL ********',/)
        DO 170 I=6,8
          WRITE(6,195)I,(NZ(I,J),J=1,9)
170     CONTINUE
      ENDIF
195   FORMAT(3X,I2,5X,I3,3X,I3,3X,I3,3X,I3,3X,I3,3X,I3,3X,I3,3X,I3,
     *3X,I3)
175   FORMAT(5X,I2,5X,I4,5X,I4,5X,I4)
145   FORMAT(5X,I2,7X,I3,5X,I3,5X,I3,5X,I3)
95    FORMAT(3X,I2,3X,F6.1,3X,F6.1,3X,F6.1,3X,F6.1,3X,F6.1,3X,F6.1,
     *3X,F6.1,3X,F6.1)
75    FORMAT(3X,I2,3X,F7.3,3X,F7.3,3X,F7.3,3X,F7.3,3X,F7.3,3X,F7.3,
     *3X,F7.3,3X,F7.3,3X,F7.3)
15    FORMAT(3X,I2,3X,F7.1,3X,F7.1,3X,F7.1,3X,F7.1,3X,F7.1,3X,F7.1,
```

```
     *3X,F7.1,3X,F7.1,3X,F7.1)
      WRITE(6,25)1,(FLY(1)/(2*XX(31)))/XX(30)
      WRITE(6,25)2,(FLY(2)/(2*XX(32)))/XX(30)
      WRITE(6,25)3,(FLY(3)/(2*XX(33)))/XX(30)
25    FORMAT(/,3X,'UTE RATE FOR BASE ',I2,' = ',F5.2)
      WRITE(6,65)VALUE
65    FORMAT(/,'   SCORE= ',F6.2)
      WRITF(6,155)TNOW
155   FORMAT(/,'TNOW = ',F7.2,/)
      DO 130 I=1,3
      WRITE(6,105)I,INC(I)
      WRITF(6,115)I,NCOMP(I)
      WRITE(6,117)I,NTDY(I)
115   FORMAT('COMPLETED MISSIONS FOR BASE ',I2,' = ',I4)
105   FORMAT(/,'MISSIONS W/ INSUFFICIENT CREW DAY--BASE',I2,' =',I4)
117   FORMAT('MISSIONS DELAYED OVERNIGHT--BASE',I2,' =',I4)
130   CONTINUE
      DO 140 I=4,8
        WRITE(6,125)I,NBTDY(I)
140   CONTINUE
125   FORMAT(/,'MISSIONS STAYING OVERNIGHT AT BASE ',I2,' = ',I4)
      RETURN
      END

C**********************************************************************
C**********************************************************************
C****                                                             ****
C****                     SUBROUTINE TRACE                        ****
C****                                                             ****
C**********************************************************************
C**********************************************************************

C---------------------------------------------------------------------
C-          THIS SUBROUTINE WAS USED TO PRINT OUT THE CURRFNT VALUES OF -
C-    MANY OF THE VARIABLES IN THE PROGRAM.  IT WAS CALLED WHEN THIS   -
C-    INFORMATION WAS NEEDED TO DIAGNOSE PROBLEMS OR FOR VERIFICATION  -
C-    OF THE PROGRAM.                                                  -
C---------------------------------------------------------------------
      SUBROUTINE TRACE
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON/UCOM1/DEST(300,7,8),STAT(6:8,9),DIST(8,8),FLY(3),MSN(3)
     1,W(9),NCMBT(6:8),STD(6:8,9),WORTH(9),CAS(6:8,8),NCDAY(6:8,4)
      COMMON/UCOM2/RTE(300,6,8),COUNT(3)

      WRITE(6,25)
25    FORMAT('******************** TRACE ***********************',/)
      WRITE(6,35)NNQ(11),NNQ(15)
35    FORMAT(/,'BASE 4 POL QUEUE= ',I3,'  BASE 5 POL QUEUE= ',I3)
      WRITE(6,45)NNQ(19),NNQ(23),NNQ(27)
45    FORMAT('BASES 6,7,AND 8 POL QUEUES= ',I3,2X,I3,2X,I3)
```

```
      WRITE(6,55)TNOW
55    FORMAT('TNOW = ',F6.2)
      WRITE(6,85)
85    FORMAT(/,'******************** ROUTE **********************',/)
      DO 20 I=1,INT(XX(42))
        WRITE(6,65)I,RTE(I,1,4),INT(RTE(I,1,3)),0
        WRITE(6,75)(RTE(I,J,1),J=1,6)
20    CONTINUE
      WRITE(6,95)
95    FORMAT(/,'******************** DEST ***********************',/)
      DO 10 I=1,INT(XX(42))
        WRITE(6,65)I,DEST(I,1,4),INT(DEST(I,1,3)),INT(DEST(I,7,8))-1
        WRITE(6,75)(DEST(I,J,1),J=1,6)
        WRITE(6,75)(DFST(I,7,J),J=1,6)
10    CONTINUE
65    FORMAT(/,'MSN NUMBER=',I3,'  PRIORITY=',F7.2,'  CONFIG=',
     *I2,'  SWITCH=',I3)
75    FORMAT(5X,F6.2,3X,F6.2,3X,F6.2,3X,F6.2,3X,F6.2,3X,F6.2)

      RETURN
      END
*EOR
```

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