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COMPARING THE EFFECTIVENESS OF TWO
KC-10 CONCEPTS OF OPERATION
--AN EXAMINATION OF TANKER/AIRLIFT SUPPORT
IN A FIGHTER DEPLOYMENT TO EUROPE

THESIS

JOHN DAVIS HUNSUCK, JR.
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AFIT/GST/ENC/86J-1

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Abstract*This thesis considers*

This thesis is the first AFIT research to have considered how the role of the tanker affects Closure Time in a fighter deployment scenario. Two KC-10 concepts of operation (or *roles*) were examined and compared for their effectiveness in deploying fighter squadrons from the CONUS to their forward bases. The *two* concepts *evaluated* were:

- 1) Dual Role, all KC-10s provided both airlift and air refueling (AR) on each mission. *and*
- 2) Distinct Role, some KC-10s carried only cargo, while the other KC-10s were organized into Tanker Task Forces (TTFs) to provide only air refuelings.

Closure Time (latest arrival of fighters and cargo at the destination) was selected as the appropriate measure of effectiveness and its minimization was the objective. It was assumed that only KC-10s would be used, *with no support* from KC-135 tankers or C-141/C-5 airlifters.

This thesis provides a foundational *tutorial*, describing the KC-10 operations in the context of a fighter deployment. A significant literature survey and an extensive bibliographical listing of relevant sources are also included.

A deterministic calculation of the Closure Time was developed *and* it was then used to calculate the apportioning of Distinct Role Tankers among the TTFs. Graphical analysis was used to determine the apportioning of KC-10s between the TTF and Airlifter-Only missions. The deterministic TTF model was computerized *to provide a tool* for calculating optimal KC-10 apportioning for any given set of fighter AR requirements. Two sources of aircraft flight performance data used in the analysis were the "Tanker" program provided by the Air Force Center for Studies and Analysis, and the "TAC Aircraft Profiler" program.

→ Using the deterministic equations, it was shown that the fastest fighter Closure Time occurs when the KC-10 is used in the Distinct Role concept of operation.

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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

John Davis Hunsuck, Jr., B.S.
Captain, USAF

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Preface

The purpose of this thesis was to explore two KC-10 concepts of operation in support of a large-scale fighter deployment. A new term, "Distinct Role," was coined to refer to the concept where some KC-10s perform solely as tankers while others perform only as airlifters. It should be pointed out that, although the deterministic methodology was designed to apportion KC-10s among several fighter air refueling tracks, it will work just as well for any type of receiver.

Since there was so little published research in this topic area, I developed a special "Tutorial" section in this thesis. Also included are an extensive Literature Review and Bibliography. I can also provide copies of the computer source codes on a 5 1/4 inch floppy disk.

I am indebted to Mr M.E. Estes (AFCSA/SACM), the Sponsor of this research, for many willing hours on the telephone and for vital feedback.

To my Advisor, Professor Dan Reynolds, I am appreciative of your willingness to let me freewheel with creative approaches to this problem, and for your for perserverance in "polishing" this paper.

To my Reader, Major Ken Feldman, I appreciate your practical critiques--your insight was always on target.

And most importantly, I thank my wife, Barbara, and my son, Michael. There are no words to express the value of your loving support during these endless months. The deadlines always came hard, and you have both paid dearly in lost sleep when you stayed up with me, and in the loneliness of empty arms when I spent the night with my studies. Your sacrifices have made this thesis possible, and it is truly yours as much as it is mine. We are indebted to our caring God, whose strength and love have carried us through together as a family.

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Abstract

This thesis is the first AFIT research to have considered how the role of the tanker affects Closure Time in a fighter deployment scenario. Two KC-10 concepts of operation (or "roles") were examined and compared for their effectiveness in deploying fighter squadrons from the CONUS to their forward bases. The two concepts evaluated were:

1. Dual Role: all KC-10s provided both airlift and air refueling (AR) on each mission.
2. Distinct Role: some KC-10s carried only cargo, while the other KC-10s were organized into Tanker Task Forces (TTFs) to provide only air refuelings.

Closure Time (latest arrival of fighters and cargo at the destination) was selected as the appropriate measure of effectiveness and its minimization was the objective. It was assumed that only KC-10s would be used, with no support from KC-135 tankers or C-141/C-5 airlifters.

Since there was no previously published literature to explain the operational concepts, this thesis provides a foundational "tutorial," describing the KC-10 operations in the context of a fighter deployment.

Initially, a simulation model was chosen as the methodology for studying the two KC-10 "roles," since it could duplicate the queuing and uncertainties of the operations. The simulation model was left in the prototype stage when it was discovered that several complex problems relating to the scheduling of TTF sorties had not yet been solved.

A deterministic calculation of the Closure Time was developed. It was then used to calculate the apportioning of Distinct Role Tankers among the TTFs. Graphical analysis was used to determine the apportioning of KC-10s between the TTF and Airlifter-Only missions. The deterministic TTF model was computerized to provide a tool for calculating optimal KC-10 apportioning for any given set of fighter AR requirements. Two sources of aircraft flight performance data used in the analysis were the "Tanker" program provided by the Air Force Center for Studies and Analysis, and the "TAC Aircraft Profiler" program.

Using the deterministic equations, it was shown that the fastest fighter Closure Time occurs when the KC-10 is used in its Distinct Roles.

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I. Problem Statement and Setting

Introduction

The KC-10 Mission in the Strategy of Forward Defense.

The US strategy for protecting its interests and commitments worldwide is called forward defense. Implementation of the forward defense strategy consists of two military tactics:

1. Forward basing--the semi-permanent positioning of military forces in a foreign nation.
2. Reinforcement--the augmenting of forward based military forces with units from the CONUS.

Clearly, the forward based forces, such as our fighter squadrons stationed in Europe, would be capable of an immediate military response to a threat. It is not possible, however, to forward-base large military forces in every threat location across the globe. Instead, the United States positions small forces in foreign nations, relying on our ability to rapidly deploy reinforcements from their home bases in the CONUS to wherever they are needed in time of conflict. Reinforcement, therefore, meets the need for flexibility, and allows many of the military people to be based in the USA, at a lower cost (8:2).

The obvious drawback of reinforcement is the necessity for an extensive "lift" capability to quickly move the military forces across the ocean. While the bulk of the load will be moved by ship, this may take 15 to 20 days to begin arriving (reference 10--only UNCLASSIFIED portions were used). Therefore, high urgency items must be sent by air:

The ability of the United States to successfully deter aggression, limit conflict, or wage war depends on our ability to rapidly deploy and sustain fighting units. Airlift provides the capability to deliver forces where they are needed in time to make a difference (Joint SECAF and CSAF Memorandum, 29 September 1983) (22:97).

The KC-10A Extender is being added to the Air Force inventory to ensure rapid deployment of tactical fighter squadrons called upon to carry out this mission of aerial reinforcement.

KC-10 Capabilities. The KC-10 has the unique capability of transporting both cargo and transferable fuel (for offload to receivers via inflight refueling.) Thus, the KC-10 is the first aircraft which can operate either as an airlifter or as a tanker, or both.

Because the KC-10 can play multiple-roles, its introduction into the Air Force inventory has been accompanied by controversy. Part of the sensitivity surrounding the KC-10 is the "who shall control" question, which results from the fact that it can refuel any type of receiver, including

Strategic Air Command (SAC) bombers, Military Airlift Command (MAC) airlifters, Tactical Air Command (TAC) fighters, and even Navy and Allied drogue-refueled aircraft. MAC is interested in KC-10 ownership because the KC-10 does have a significant airlift capability--much more than MAC's main work horse, the C-141B. In historical context, SAC was given charge of all tankers because the highest-priority refueling mission was to refuel SAC's bombers in the SIOP (the nuclear Single Integrated Operations Plan). Presently, only KC-135s are tasked to refuel SIOP bombers, and although SAC owns and operates the KC-10, the KC-10 currently has no part in the SIOP.

Even though each Command wants the KC-10 to play a role supporting its own self-interests, this research was not motivated by a desire to "justify" any Command's position. While it is likely the final conclusions of the thesis will "add fuel to someones fire," the author has sincerely tried to provide an unbiased examination of the KC-10 roles. Specifically, the question of how to most effectively utilize the KC-10 in support of deploying TAC squadrons (fighter, support equipment, and personnel) has been addressed.

The analysis involved the study and evaluation of KC-10s serving in one or the other of two major roles during the deployment of fighter squadrons:

1. Dual role: all KC-10s operate as tanker/airlifters. This means that the KC-10s deploy with the fighters, refueling them enroute and carry their support equipment and personnel to the destination.

2. Distinct role: For this scenario, some KC-10s serve as airlifters, while other KC-10s function as tankers. The tanker-only KC-10s fly "round-robin" (or yo-yo) missions: providing air refuelings and returning to their launch base. They are organized into Tanker Task Forces (TTFs) based at locations close to the deployment route.

The Statement of the Problem

The effectiveness of the roles KC-10s can play during the deployment of fighter squadrons to Europe needs to be evaluated.

This thesis solved the problem of determining the preferred role for KC-10s by achieving four objectives:

1. Develop an appropriate model to calculate the effectiveness of the deployments for each KC-10 role. (The measure of effectiveness is described in the next section).

2. Evaluate the sensitivity of the deployment effectiveness to changes in the following factors:

- a. reliability of the KC-10
- b. ratio of fighters to KC-10s for air refuelings
- c. location of the Tanker Task Force (in the distinct roles concept)

3. Select the combination of the above three factor settings that produces the best performance for each role.

4. Develop an analytic procedure that will reveal any significant difference in effectiveness between the Dual Role and Distinct Roles KC-10 support of the fighter deployment.

Methodology Overview

Measure of Effectiveness (MOE). In order to measure how effectively each KC-10 role supported the fighter deployment, a Measure of Effectiveness had to be specified. Since the primary evaluation of the two KC-10 roles focused on the speed of the fighter deployment, Closure Time was selected as the MOE.

Closure Time was operationally defined as the time of arrival of the last fighter or the last item of cargo at the destination base in Europe.

Models. An appropriate method for determining Closure Time had to be developed in order to accurately determine Closure Time. An accurate model of the deployment process needed to be built. Both computer simulations and deterministic equations were used.

Simulation models were constructed to depict the individual actors and actions in the deployment process, including the fighter and KC-10 flights, the cargo handling, aircraft maintenance and preparation, and aircrew duty and rest. When the last fighter landed or the last piece of

cargo was unloaded, the clock was checked and the Closure Time was recorded.

Deterministic equations, developed initially for the purpose of checking the reasonableness of the MOEs produced by the computer simulation, were designed to calculate Closure Time by solving a rate-time equation. For instance, if 150 loads of cargo had to be moved, and the KC-10s could move 50 loads per day, then Closure Time would be calculated as $150/50 = 3$ days. The complex part of constructing these equations involved finding ways to calculate the flow rate of cargo and fighters that could be sustained by the KC-10s.

Simulation. At the start of the research effort, it was thought the simulation models would be able to provide more information than the deterministic equations. It appeared such simulation models could provide valuable insights concerning the impact of random processes such as the duration of KC-10 maintenance and the variance in Closure Time, as well as facilitate a deeper understanding of complex systems dynamics. Thus, two simulation models were developed: one to model Dual Role and Airlifter KC-10s and another to model TTF KC-10s. These basic "prototype" models yielded results consistent with the deterministic Closure Time calculations.

At this point in the research effort, it was discovered that the problem of scheduling rendezvous times (ie: when the TTF KC-10s were to meet the fighters) could

not be handled by the simulation models. That is, the air refuelings could not be scheduled unless the following questions were answered:

1. How many KC-10s were at each TTF base?
2. How often would they fly?
3. What would be the required maintenance turn-around time for such a flying schedule?

Because the deterministic model could apportion the KC-10s among the TTF bases and could approximate the flying schedule with the flow rates based on an assumed value for the maintenance turn-around time, the research turned to the deterministic equations.

Deterministic Model By using a "best guess" value for TTF KC-10 ground turn-around time, (ie: by assuming turn-around time was not dependent on reliability or sortie rate), a KC-10 sortie rate was calculated. By breaking this interdependence of the turn-around time and reliability factors in the deployment, the deterministic equations were able, in addition to calculating Closure Time, to predict apportionment of TTF KC-10s to the AR tracks and TTF bases. Deterministic equations were also developed for calculating Closure Time for the Distinct Role Airlifter KC-10s and for Dual Role KC-10s. (All these equations are developed in Chapter IV.) The analysis of relative effectiveness of the

two KC-10 roles (Dual Role, Distinct Roles) was based on the Closure Times from these deterministic equations.

Both the methodology for determining TTF Closure Time and for apportioning KC-10s among several AR tracks and several TTFs were computerized.

The analysis of relative effectiveness of the two KC-10 Roles (Dual Role, Distinct Roles) was based on the Closure Times from these deterministic equations.

Sensitivity Analysis. The exact values for several parameters used in the deterministic model could not be specified with certainty. For instance, it was not known how "bulky" the cargo might be, thus creating uncertainty as to how much cargo could be carried by Distinct Role Airlifter KC-10s. Also, it was not clear how much maintenance would be required after each KC-10 sortie. The ground turn-around time for the KC-10, and the reliability of the KC-10 for any given turn-around time, were unknown values and, hence, had to be estimated. Thus, it was important to find out how sensitive Closure Time would be to variation in these values.

The Closure Time sensitivity to predictable variation was obvious from the equations. For instance, Closure Time is known to be inversely proportional to the number of KC-10s. Many such sensitivities were evaluated in this way by careful examination of the equations. To study more complex sensitivities several runs of deterministic model

had to be made to determine the variation that might be expected in values of unknown parameters.

The Delimitations

Although models could have been developed that were applicable to any scenario, time and manpower constraints dictated that the scope of this research be narrowed to examine a more specific scenario. Instead of modeling all of the individual fighter departure bases in the CONUS, bases were represented by one aggregate base located at their geographical "centroid": McConnell AFB, Kansas. Hahn AB, Germany, was chosen as the "centroid" base for the European destinations (reference 13). This served three purposes.

1. The revealing of sensitive information about our capabilities or national weaknesses was precluded since actual deployment bases were not used.

2. The scale of the deployment was kept realistic by using a very large force of fighter squadrons. The use of a single route, with all the fighters flying the same mission routing, ensured effects due to fighter type would be readily observable.

3. Calculation time was reduced by an order of magnitude.

This simplified scenario of a single route between two "centroid" bases provided adequate representation of a major

deployment. Insight concerning KC-10 usage could be gained, without getting bogged-down in the details of a more complex scenario.

Scenario Assumptions

To ensure the scenario was representative of a major fighter deployment eight assumptions were made.

1. It was assumed that unclassified data would provide an adequate foundation for assessment. This assumption was based on the reasoning that the relative effectiveness of the two KC-10 roles would be unchanged by small changes in routing or deployment scale. To keep this study unclassified, public sources and broad generalizations were used to create the hypothetical deployment scenario. For instance, instead of using actual information from the war plans, an unclassified peacetime deployment route was chosen (reference 23, 6). Similarly, the numbers of deploying fighters and tankers were assumed to be the 1990 aircraft inventories, as listed in Janes' All the World's Aircraft.

2. The locations of the fighter air refuelings (ARs) were assumed to be an unchangeable requirement. This meant that the KC-10s were forced to fly to wherever the fighters needed the refuelings. No attempt was made to optimize the given fighters' routing or refueling requirements. The routing and the AR Track locations were provided by Hq TAC/DOXD, in the form of printouts from the TACAP computer

program (reference 23). (See Appendix D for copies of the TACAP computer printouts. Maps showing the AR Track locations are presented in Chapter II.)

3. Only three TTF bases were used: Goose Bay, Canada; Loring AFB, Maine; and Mildenhall, England. Figure 1.1, on the following page, is a map showing these TTF Bases. In addition, this map shows the fighter deployment route from McConnell AFB, Kansas to the destination Hahn, Germany. Tanker Task Force Bases were selected based on proximity to the AR tracks, as well as publicly known ability to service fleets of large military aircraft including necessary fueling "pits" for fast service.

4. KC-10s at the TTF bases were unconstrained by time limits which are established by directives. This assumption freed the research from "planning" factors, so that potential capability could be demonstrated. The number of hours that would be flown by a KC-10 was limited only by how quickly maintenance and normal servicing could be accomplished.

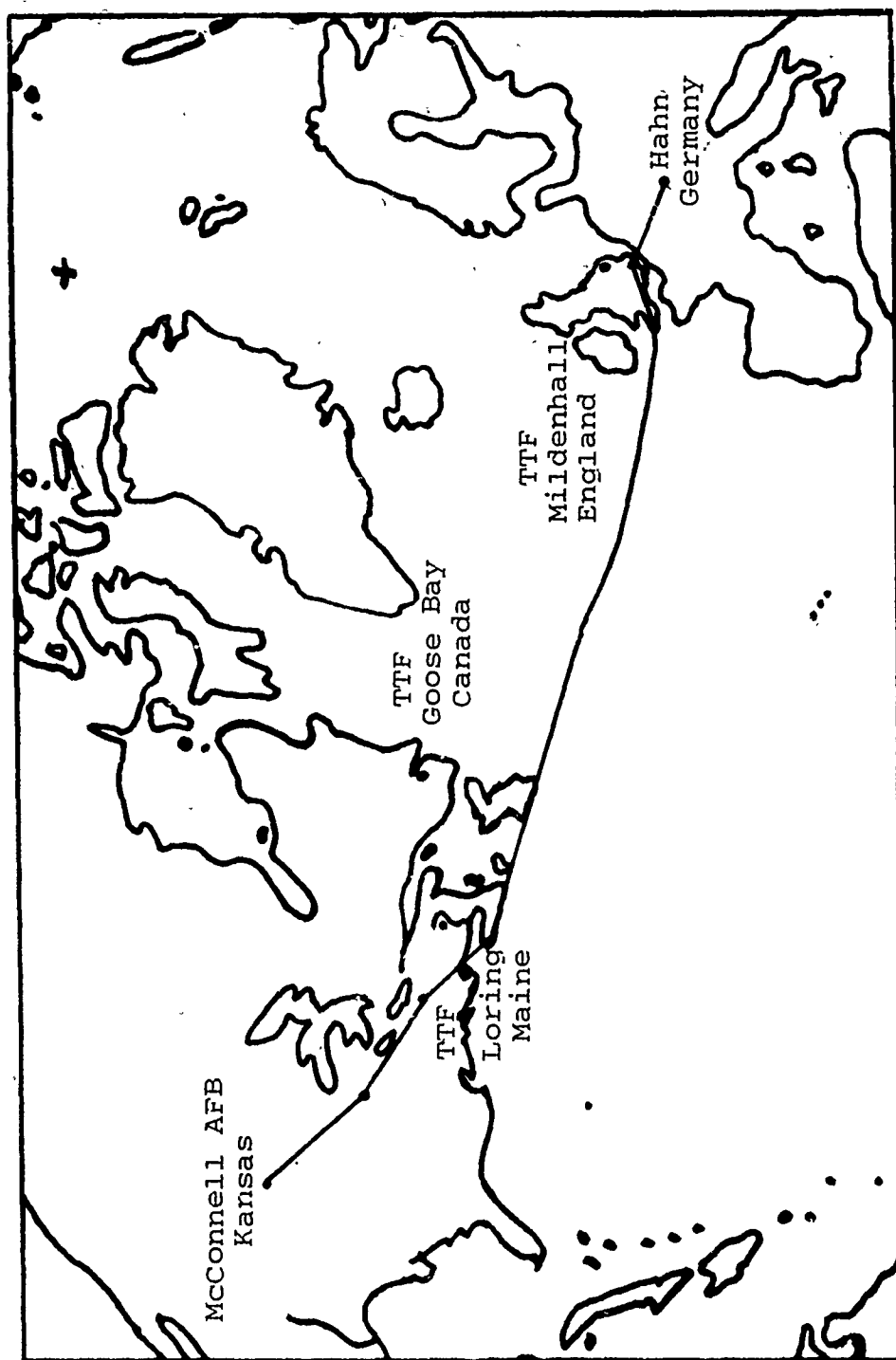


Figure 1.1. Map of TTF Locations relative to the Deployment Route.

5. The USAF KC-10 was assumed to be solely responsible for the tanker/airlift support of the deploying fighter squadrons. Specifically, this meant that:

- a. The allotted KC-10s were given no other duties.
- b. No other tankers (ie: KC-135s) were available for support of the deployment.
- c. No other airlifters (ie: C-141s, C-5s) were available for support of the deployment.

Thus, the research focused on the unaided capability of the KC-10.

6. For this scenario, a total of 60 KC-10s were available to support the fighter deployment. This number represented the projected KC-10 procurement for the year 1990 as published in Jane's All the Worlds' Aircraft (1:321). This was probably somewhat optimistic in that some KC-10s might be assigned to other missions or may be unavailable due to maintenance, but was close enough to the true value to be useful. More importantly this number is unclassified.

7. The research scenario assumed that the fighters available for the deployment were 700 F-16s, 300 F-15s, 100 F-111s, and 100 RF-4Cs. This was derived from information in Jane's. For example, Jane's predicts an acquisition of 2800 F-16s (1:260). Many of these will be stationed at forward bases around the globe. One fourth of the total 2800 are assumed to be in the CONUS, and ordered to deploy. Therefore it was estimated that 700 F-16s would deploy. The

number of types of fighters was similarly determined. It should be pointed out that no F-4s (other than reconnaissance RF-4Cs) were included since Jane's says they are being replaced by F-16 and F-15 aircraft. Similarly, A-7s were not included since they are not as capable as the F-16s. The deployment of A-10s was not modeled because they fly so slow as to require an overnight stay at the Azores for crew rest enroute to their destination. Thus, they couldn't fly the selected northern route.

8. Weather was considered to be favorable. In reality, adverse weather could cause the re-routing of missions, or even a lengthy delay. As soon as weather became favorable, however, the deployment would continue as planned under fair weather criteria.

This research provided the useful more information in fair weather.

Overview of Thesis

This first chapter has described the need for research concerning which role the KC-10 should play in a deployment to Europe of fighters and their associated cargo. The methodology used to accomplish this analysis has been outlined.

Chapter II, A Tutorial on KC-10 Operations, presents a detailed discussion concerning how the KC-10 is used in such fighter deployments. Since there is a severe lack of published information concerning the operation of tankers,

this section meets the need to provide a guide to understanding KC-10 operations. It is the product of numerous interviews of Air Force people involved in planning and flying tanker, fighter, and airlifter deployment missions.

Chapter III, The Literature Review, discusses the results of other research relevant to tanker/airlift support of fighter deployments. Several research tools are explored, followed by an explanation of why simulation was initially selected as the most desirable methodology for solving this specific problem.

Chapter IV, Methodology, describes the complexity of the scheduling and tanker apportionment problems which prevented the full development of the Simulation Models. In this chapter, the Deterministic Equations for finding the Closure Time, (and for solving the apportionment problems in the TTFs) are developed. A computerized model of the deterministic equations for TTF apportionment and Closure Time is also described.

Chapter V, Results and Analysis, graphically presents results of the modelling exercises, and states which role is better. Further insight is developed into the implications of the deterministic models. Also included are the results of sensitivity analysis performed on the models.

Finally, and most importantly, Chapter VI, Conclusions and Recommendations, discusses the conclusions reached during the course of this research, and provides recommendations for future analysis.

II. Tutorial of KC-10 Operations

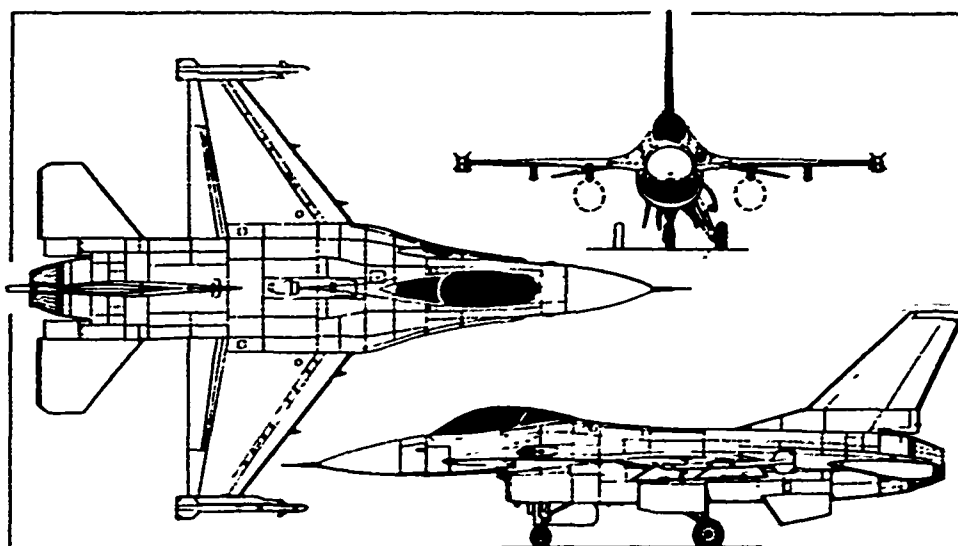
Introduction

This chapter continues the scenario development of Chapter I by providing a detailed description of the fighters, their support equipment and personnel, and the KC-10s as they deploy to Europe. The following sections provide a description of actions, decisions, rules, options, delays, and sources of uncertainty in the KC-10 operations. The fighter actions are described first. Next, the interactions of the KC-10 and fighters are explained. Finally, the description is expanded to include cargo transportation by Airlifter-Mission KC-10s and by Dual Role KC-10s.

Fighter Deployment Concepts

In the hypothetical 1990 scenario, 1200 fighter aircraft (700 F-16s, 300 F-15s, 100 F-111s, 100 RF-4Cs) are located at the fighter launch base, McConnell AFB, Kansas, which is a "centroid" base representing all the bases in the CONUS. All the squadrons have just been notified that they must deploy immediately to Europe. Their destination is Hahn, Germany. The aircrews are ready in a very short time. Since the fighters have fairly short ranges they cannot cross the Atlantic non-stop (approximately 9.5 hours) unless refueled. Several air refuelings (ARs) are needed for the long transAtlantic mission (2 refuelings for F-16s and

F-111s; 3 for F-15s; 5 for RF-4s) So, the fighters must wait on the ground until a KC-10 air refueling becomes available. Figures 2.1 through 2.8 depict the fighters and their AR tracks. Figures 2.9 through 2.10 depict the KC-10 and the KC-10 bases.



Wingspan = 31 ft
 Length = 49 ft
 Height = 17 ft

Max TO Gross Wt = 35,400 lbs
 Ferry Range (with drop tanks)
 2100 nm

Figure 2.1. Three-view Drawing of the F-16
 from Janes All the World's Aircraft

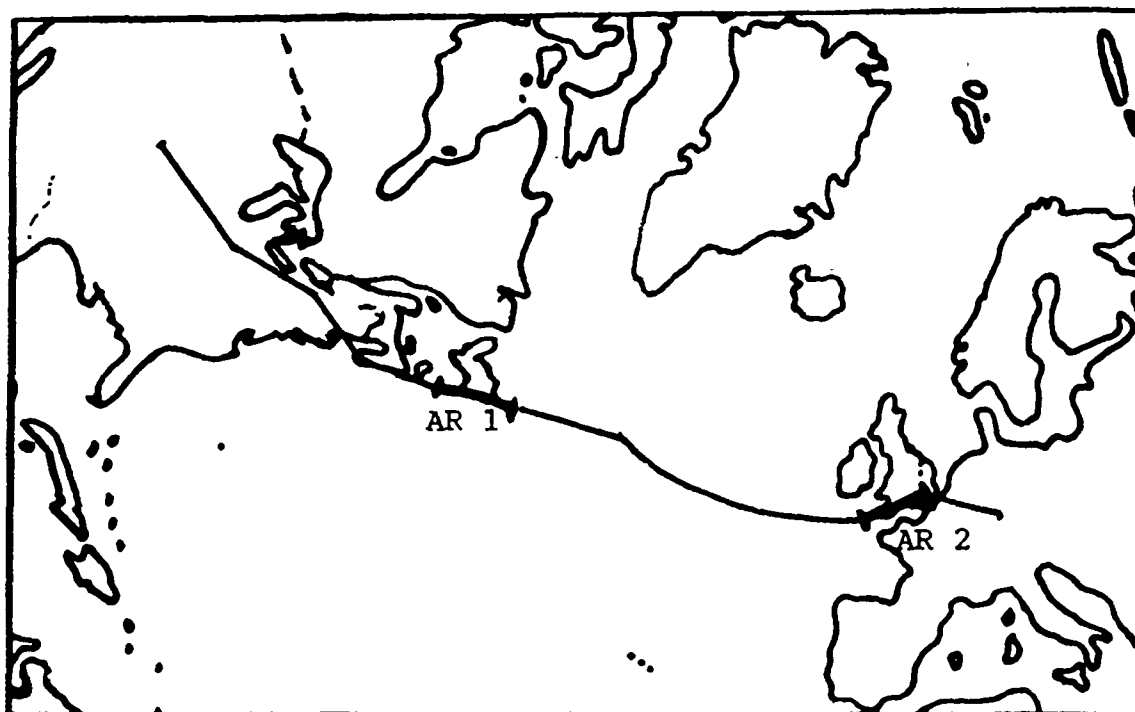
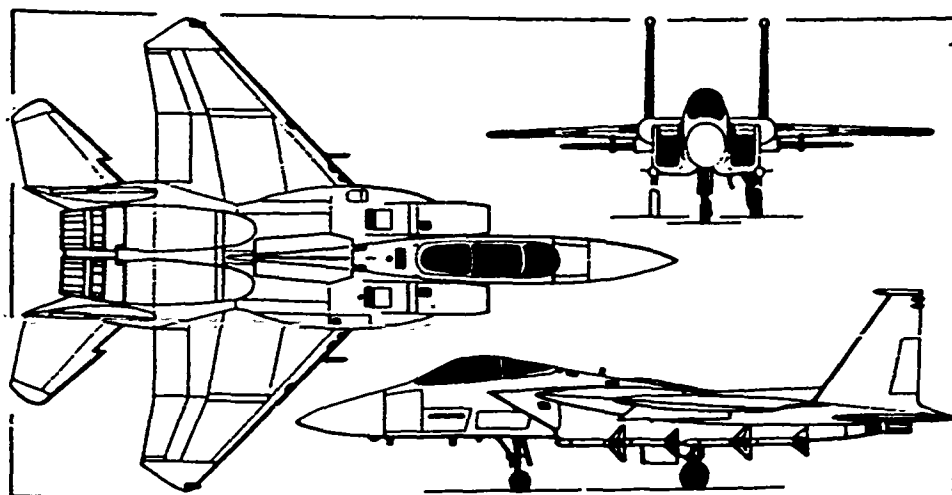


Figure 2.2. F-16 Air Refueling Tracks



Wingspan = 43 ft
 Length = 64 ft
 Height = 18 ft

Max TO Gross Wt = 58,470 lbs
 Ferry Range (unrefueled)
 2500 nm

Figure 2.3. Three-view Drawing of the F-15
 from Janes All the World's Aircraft

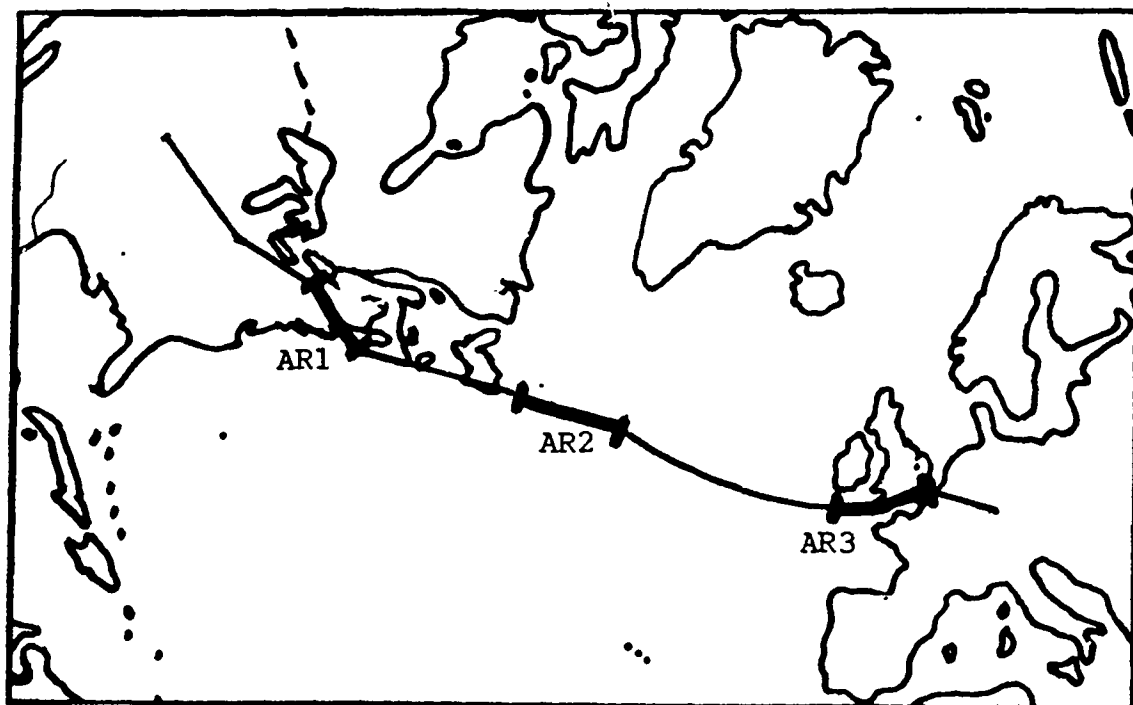


Figure 2.4. F-15 Air Refueling Tracks

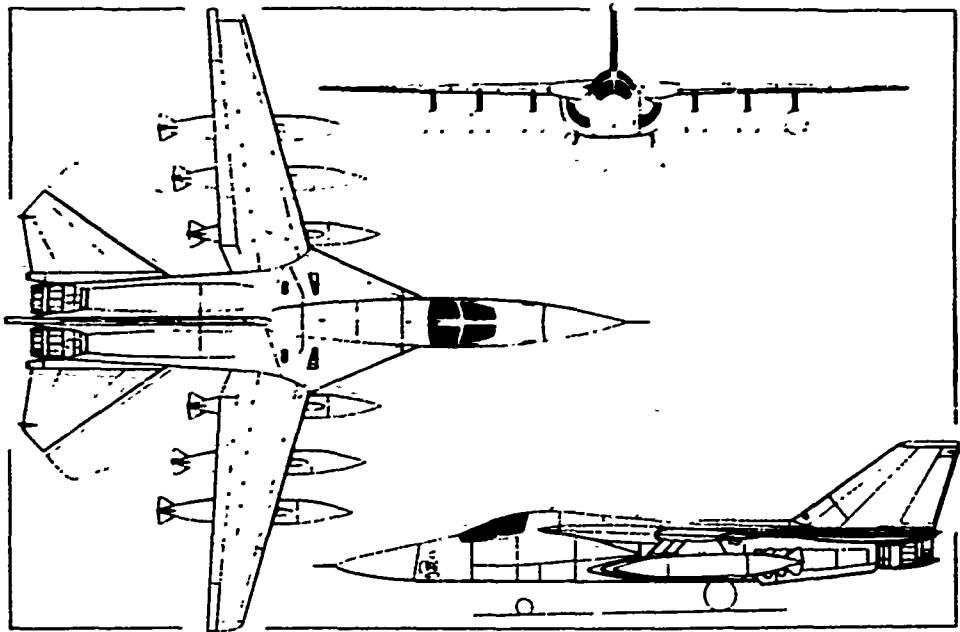
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Figure 2.5 Three-view Drawing of the F-111 from Janes All the World's Aircraft

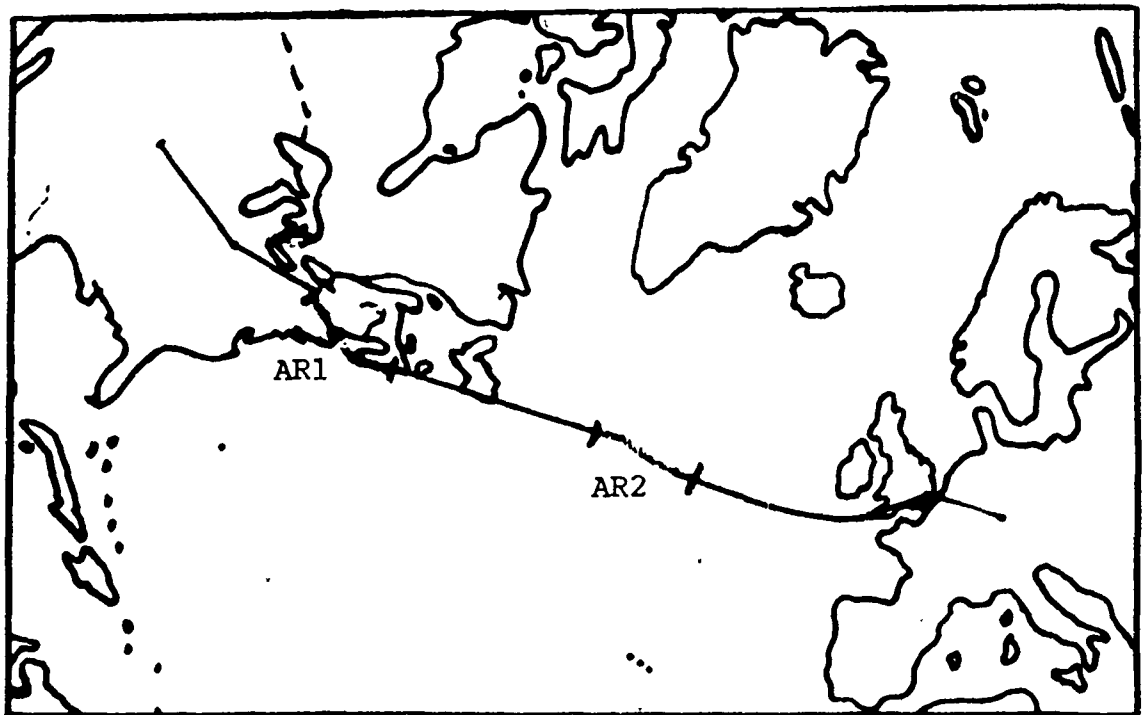
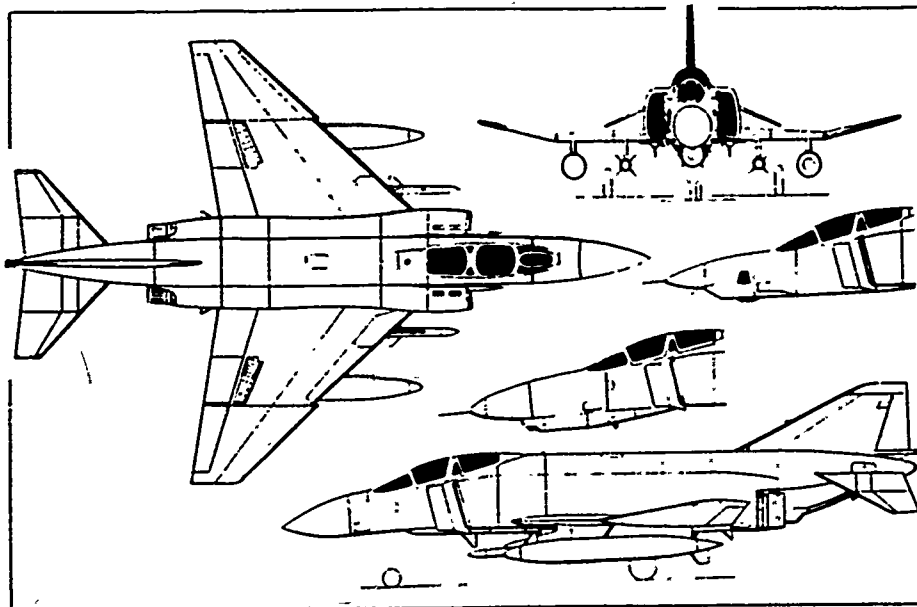


Figure 2.6. F-111 Air Refueling Tracks



Wingspan = 39 ft	Max TO Gross Wt = 61,795 lbs
Length = 63 ft	Ferry Range = 1,718 nm
Height = 16 ft	

Figure 2.7 Three-view Drawing of the RF-4C
from Janes All the World's Aircraft

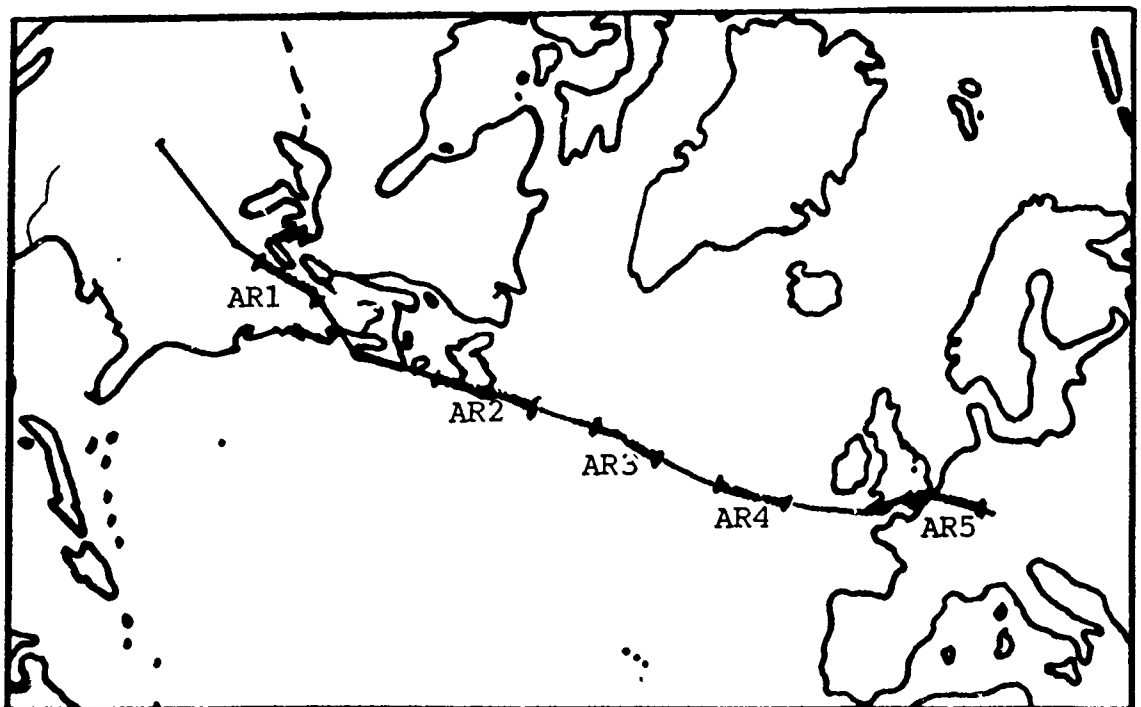
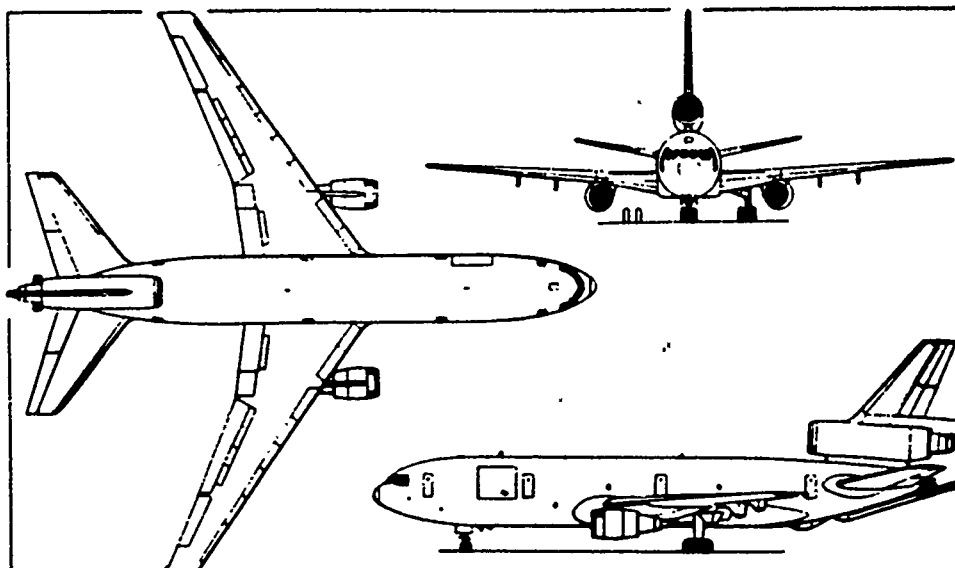


Figure 2.8 . RF-4C Air Refueling Tracks



Wingspan = 165 ft	Max TO Gross Wt = 588,200 lbs
Length = 181 ft	Range w/Max Cargo = 3,797 nm.
Height = 58 ft	w/No. Cargo = 9,993 nm

Figure 2.9. Three-view Drawing of the KC-10
from Jane's All the World's Aircraft

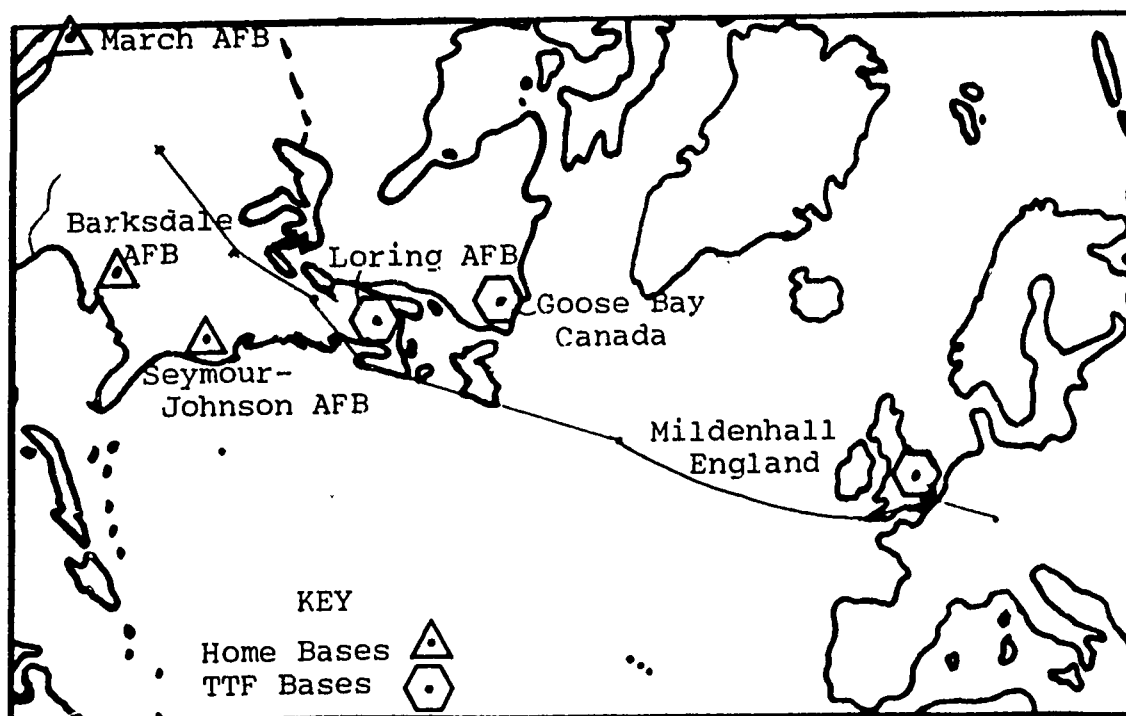


Figure 2.10. Map of KC-10 Home Bases and TTF Bases

Refuelings from a Tanker Task Force. When Air Refuelings are provided by TTF KC-10s, the fighters launch as necessary to meet a pre-planned rendezvous with the tanker (reference 24). Launching in flights of 4, 6, 8, the fighters fly alone until they rendezvous with the TTF KC-10. (The number of fighters in the flight is also called "fighter-tanker ratio".) Meanwhile the KC-10 launches from the TTF base for a rendezvous with the fighters at the ARCP (Air Refueling Control Point) at the pre-scheduled ARCT (Air Refueling Control Time). After the rendezvous, the KC-10 proceeds down the AR track, offloading the required fuel to each fighter in turn. Upon reaching the end of the AR track, the fighters continue alone to subsequent AR tracks. Meanwhile, the KC-10, while it has sufficient fuel, returns again to the ARCP to refuel subsequent flights of fighters. The KC-10 then returns to the TTF base for more fuel.

Dual Role KC-10 Air Refuelings. When air refuelings are provided by Dual Role KC-10s, the fighters launch simultaneously with the KC-10 which has been loaded with cargo at the fighter base. The fighters fly in close formation with the tanker all the way to the destination being refueled at the AR tracks along the way. At the destination, the fighters are readied for battle by the maintenance personnel who were carried on board the KC-10. When the KC-10 has been unloaded of all the fighters' support equipment, the KC-10 returns to the CONUS to pick up remaining fighters.

Figures 2.11 and 2.12 show the difference in KC-10 routing for refueling of fighters by TTF KC-10s and Dual Role KC-10s. Notice that the fighter path is unchanged (although the locations of the air refuelings are slightly changed). (See Appendix D for exact fighter route data.)

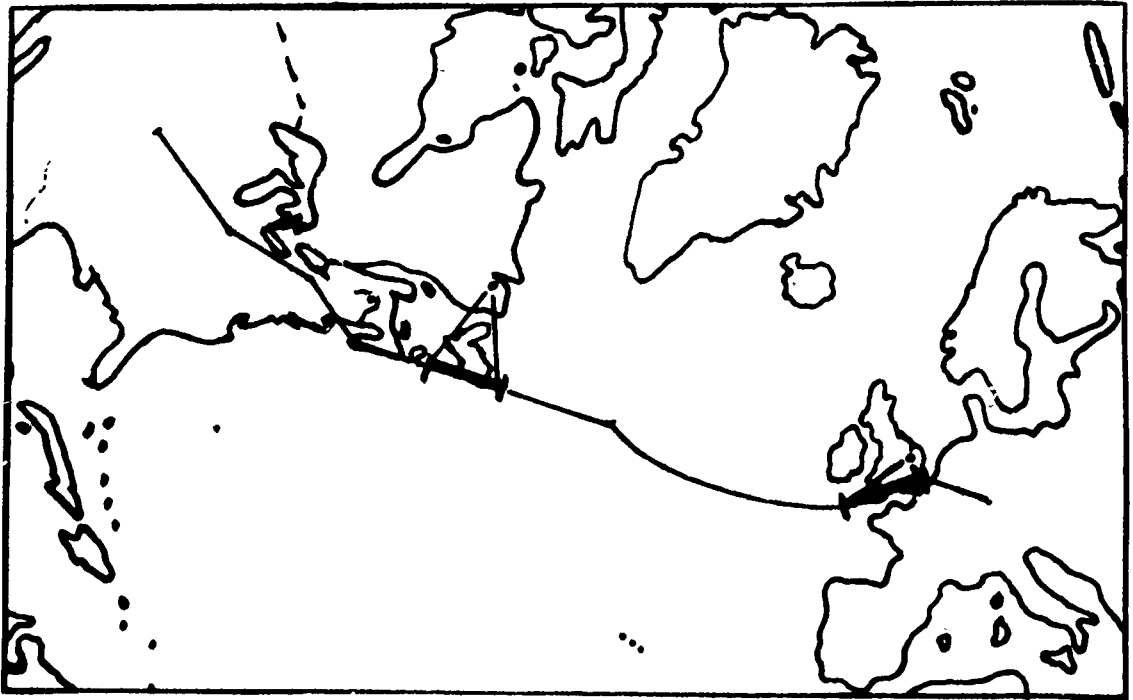


Figure 2.11. Fighters being refueled by TTF KC-10s.

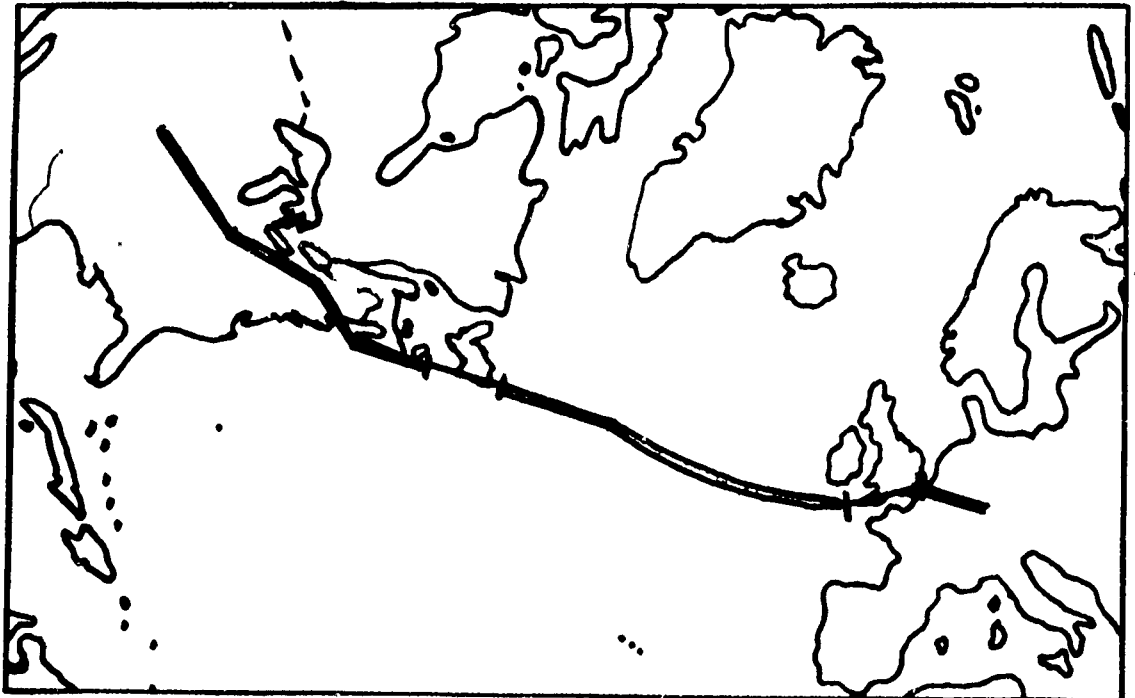


Figure 2.12. Fighters being refueled by Dual Role KC-10s.

Three things can happen at each ARCP:

1. Success. The single KC-10 (or possibly a formation) is there, on time, as planned. KC-10 becomes Formation Leader. The flight of fighters fly down the AR track, each receiving, in turn, his pre-planned fuel onload from the single KC-10. At the end of the AR track (EAR point), the KC-10 returns the leadership of the fighter flight back to the lead fighter aircraft. The fighters continue on their designated flight plan route to the subsequent ARCP(s) and eventually, to the destination.

2. Fighter Abort due to Failed Rendezvous. High technology and highly trained aircrews make the difficult rendezvous nearly a certainty, given that both the KC-10 and the flight of fighters are mechanically fit to arrive at the ARCP. Thus, a failed rendezvous (RZ) is almost always due to a "No-show" by the fighters or tanker (reference 26).

If the KC-10 does not arrive at the ARCP by ARCT+10 minutes, the entire flight of fighters will fly to an AR "Abort Base" (reference 25). There are usually 2 or 3 bases that are suitable for any given abort, so the flight leader chooses the most suitable base as he deems fit.

3. Abort due to Failed Refueling after a Successful Rendezvous. There are two sources of possible failed refueling, assuming that the KC-10 and fighter crews have sufficient skill and that weather is not a factor:

a. Fighter is broken. The fighter's refueling system is a complex electrical and mechanical system. If a fighter's system is unable to function, then that one fighter, plus his wingman (always flying in pairs for mutual support) must fly to an abort base. (See Aborted Fighters) The other fighters that are functioning properly may receive their refuelings and continue their mission as planned, or they may all abort together as a flight. About 1% of the fighters will abort due to some mechanical failure. If the fighters abort together in flights of six, then 6% of the 1200 fighter will abort for this reason (reference: 25).
Total: 72 aborted aircraft.

b. KC-10 breaks in-flight. If the KC-10 is so badly broken that it can no longer provide AR, then any unrefueled fighters (and their wingmen) must abort. Because of the high reliability of the KC-10 air refueling system (it has many backup sub-systems), it is assumed that the refueling is successful, with a degraded AR system, must be fixed on the ground after the sortie (reference 27). Thus, a failed AR system would only affect subsequent KC-10 ground turn-around time, and not the current fighters. (There is a need for better statistics on the maintainability and reliability of the KC-10, to verify this assumption.)

Aborted Fighters: Once the aborting fighters have arrived safely on the ground at the abort base of choice, the fighter crews have their aircraft immediately refueled. At best, if there are no other aircraft ahead of them in a queue for service, the fighters could be ready for launch within one hour. A two or three hour turn-around time is reasonable, assuming no queuing (13:5).

NOTE: There is a definite maximum rate that aircraft that can abort to a base before the service capacity of that base is exceeded. As the service capacity is approached, longer turnaround times will result. There is also a severe deployment restriction which would occur if the entire ramp space at the abort base is filled with aborted fighters. This is called a Maximum On Ground, or MOG restriction (reference 25). Since a subsequent missed refueling would then result in the aborting fighter having no place to safely land, the ARs which depend on that abort base must be cancelled until such a time as the number of fighters on the ramp is less than the MOG. Thus, the deployment would halt. Obviously, it is very important to verify whether significant queuing will occur. This thesis, however, was not able to obtain sufficient information on ramp space and service. The deterministic equations are based on the assumption of no queuing for service or ramp space.

The aircrews must enter crew rest (for 12 hours) if insufficient time for another sortie remains within their maximum (15 hour) crew duty day (13:5). When exiting crew

rest, or if sufficient crew duty day remains, the aircrews can take one of three actions. (This thesis assumes the first action is taken.)

1. Rejoin the planned routing, getting ARs where originally planned. To do so would have the effect of "bumping back" all the subsequently planned fighters to the next AR available. Another option (which would have the same effect on Closure Time) would be for the aborted fighters to wait for the "end of the line," and take the AR after the last fighters have deployed. The effect on Closure Time is that one more TTF AR must be made available. Thus, only one "track lap" or, at most one more KC-10 launch, must be added to the schedule. For fighters that abort in the last day of the deployment, this would be the fastest way for them to get to their destination.

2. Fly directly (unrefueled) to the destination. This is feasible for the fighters which abort the last AR prior to the destination.

3. "Island Hopping". The fighters could continue toward their destination without any ARs at all, by flying several short "hops." For example, F-16s can fly unrefueled from St. Johns (the abort base) to Goose Bay, Canada. There they would land, refuel on the ground, launch again, and fly to Keflavik, Iceland. Subsequent "hops" would be flown via Leuchars and then to Hahn (the Destination). Accounting for 3-hour turnarounds at each enroute base, and one crew rest

crew rest. The KC-10, when ready, is refueled by the ground crews, and launches on its mission of providing refuelings to several flights of fighters. This thesis assumed that these actions take a total of 36 hours (Therefore the first fighters arrived in Europe after 45 hours.)

TTF Refueling Missions. On each sortie, the KC-10 will:

1. Fly directly to the ARCP for the rendezvous with its scheduled receivers (the flight of fighters). The KC-10 arrives 10 minutes prior to the planned ARCT and enters an AR orbit pattern. There it waits for the fighters to arrive, and prepares for the rendezvous.

2. After a successful rendezvous, the KC-10 will fly down the AR track, offloading the planned amount of fuel to the fighters, one at a time (taking 6-14 minutes per fighter, depending on the quantity of fuel transferred).

3. Upon arriving at the planned End AR Point (EAR), the KC-10 will around and fly back to the ARCP to enter orbit to prepare for the arrival of the next flight of fighters.

4. Repeat steps 2 and 3 with the KC-10 making laps of the AR track (we'll call them "track laps") until the KC-10 must return to the TTF Base for more fuel.

The number of "track laps" that are feasible for the KC-10 depends on:

1. Fuel on board at launch. This is calculated by
$$\begin{aligned} \text{Max fuel Wt} &= \text{Max TO Gross Wt} - \text{Cargo Wt} - \text{Aircraft Empty Wt} \\ &= 588,200 - 0 - 243,209 = 344,991 \text{ pounds,} \end{aligned}$$

This could be further limited by field conditions. The following regression equation explains Maximum Takeoff Gross Weight (TOGW) in pounds as a function of runway length (RL) and field elevation (or pressure altitude, PA) in feet (15:97):

$$\text{TOGW} = 187,083 - 8.125x(\text{PA}) + 47.5x(\text{RL}) - .0013542x(\text{RL})x(\text{RL}) \\ - .0004688x(\text{PA})x(\text{RL})$$

For the TTF bases in this thesis, TOGW was not restricted by field conditions (reference 6).

2. Fuel consumed by the KC-10 to do all the following:

- a. fly from the TTF Base to the ARCP
- b. orbit at the ARCP
- c. fly down track and back (each track lap)
- d. fly back to TTF Base

The fuel calculations for this thesis were performed by the TANKER program (see modified Tanker subroutine in Appendix B).

3. Fuel Reserves (20,000 pounds) required for KC-10 safety (reference 5).

4. Fuel Transfer required by all the fighters being refueled, during several track laps. Fighter fuel requirements were dictated by TACAP flight plans. (See Appendix D.)

Since the above is fairly complex, I built a computer program which calls a subroutine based on AFCSA's "TANKER" program to calculate the KC-10 fuel consumptions, sortie durations, and the feasible number of "track laps" per KC-10

sortie. These calculations and the program are discussed in Chapter IV.

TTF Ground Turnaround. Once the pre-determined number of "track laps" has been completed and the KC-10 has returned to the TTF Base, the aircraft is refueled as quickly as possible. When necessary, unscheduled repairs are made for "safety-of-flight" and for "mission-essential" equipment. Every attempt is made to launch on the scheduled timing, in order to make the planned ARCT. If it is not possible to fix the KC-10 within this scheduled timing, the first AR must be cancelled and the fighters abort. Repairs continue in the attempt to make the subsequent ARCTs.

The aircrews continue to fly the same aircraft for several sorties until completing their 20 hour crew duty day (non-augmented crew, Higher Headquarters - Directed [HHD] mission) (reference 4). The thoroughly exhausted aircrew is immediately replaced with a fresh aircrew so as to continue the ground turnaround of the KC-10s at an uninterrupted pace.

Effect of the KC-10 Sortie Interval on Fighter Closure Time. The term "Sortie Interval" is defined in this thesis as the total time (flight time + ground turnaround time) per KC-10 sortie. This is the inverse of the sortie rate. Since airborne flight time is already predetermined, the only flexibility in scheduling this interval is to change the duration of the scheduled ground turnaround time.

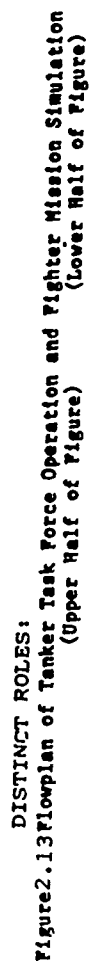
There are two opposing influences that act upon the proper choice of KC-10 Sortie Interval:

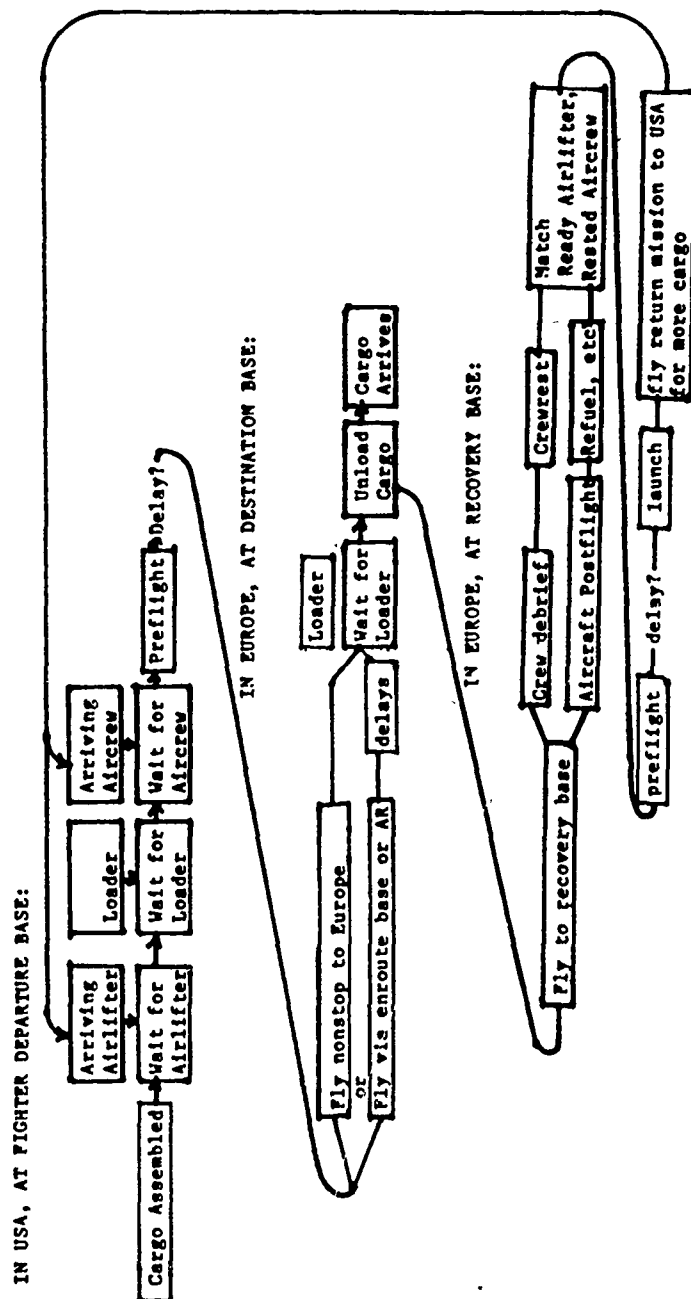
1. Maximize the AR rate. By reducing the scheduled sortie interval (ie: by reducing scheduled ground time), the KC-10s can fly more sorties per day. This results in more frequent refuelings of the fighters, and thus reduces Closure Time.

2. Minimize the Fighter Abort Rate. If a KC-10 is unable to launch within about 10-20 minutes of the schedule, the AR is cancelled, and the fighters end up at the abort base. Aborted Fighters will take 6 hours (with an additional AR) to 30 hours (island hopping) of extra time before arriving at the Battle. This is very undesirable! This means that the possibility of a KC-10 late launch must be minimized. To do this simply means giving the maintenance teams plenty of extra time to repair any malfunctions that might occur.

Thus, before deciding to reduce the scheduled sortie interval, the effects on both the increased sortie rate and the increased abort rate should be analyzed. (This is an area for further research. See Chapter VI.)

Figures 2.13, 2.14 on the following pages illustrate the flowplans of the Distinct Role TTF and Airlifter missions. They can be considered to be network representations of the "conceptual models" of the deployment.





DISTINCT ROLES:
Figure 2.1.4 Flowplan of Cargo Movement and KC-10 Transport Operation

Airlift Operations

Bulk Cargo and Passengers. When a fighter squadron deploys, it must also take along extra aircrews, staff, and maintenance personnel. In addition to their personal baggage, these people need the tools and equipment to do their jobs. Examples include power carts and other flightline equipment. Thus, most of the cargo that deploys with the fighter squadron is lightweight and bulky. Typically, a fighter squadron of 24 aircraft will have about 240,000 pounds of cargo to deploy. All this cargo must first be strapped onto standard (463L) pallets. In peacetime, this cargo preparation is typically accomplished by MAC ALCE units which are deployed to the fighter base in advance of the KC-10s (reference 28).

Cargo Loading. Once the cargo is palletized, it must be loaded onto the KC-10. This is no easy task, since the cargo deck of the KC-10 is 15 feet above the ground level. Currently, the KC-10 is totally dependent on external Material Handling Equipment (MHE), such as the Cochran Loader, to load and unload. (A certain forklift can also be used, but it is very slow.) If a Cochran Loader is not available, it must be dismantled at its location, flown in by a C-141B, and reassembled for KC-10 use. This is obviously time-consuming and expensive. Furthermore, because of the small number of available Cochran Loaders, the KC-10s may be forced to wait in line to use the Cochran Loader. One future concept (tentatively planned for the

1990 SAC Program Objective Memorandum) is the Integral Onboard Cargo Loader (IOCL). This cargo loader would be installed in the ceiling of the KC-10 cargo bay, making the KC-10 totally self-sufficient for cargo missions (14:35). Although this cargo loader will surely have more restrictive parameters (such as lighter and shorter cargo loads, and fairly calm winds), it would eliminate the problem of queuing for loaders.

In this thesis, it is assumed that the IOCL will be installed. Thus, unloading a full load of pallets should take less than 2 hours.

Cargo Capacity of the KC-10. The KC-10 can carry a maximum of 27 standard cargo pallets (see Figure 2.15). For bulky cargo, the pallets average only about 4000-5000 pounds. Since the airline-type passenger seats are also palletized, the equipment and personnel are in competition for space in the KC-10 cargo bay. A larger, nonstandard 55-seat pallet can also be loaded onto the plane, but only with a Cochran Loader (it will probably be too large for the IOCL). The following is a list of passenger/cargo combinations (14:14,15):

Table 2.1

KC-10 Passenger and Cargo Combinations

<u>Passengers</u>	<u>Cargo Pallets</u>
0	27
6	25
20	23
75	17

CAPACITY FOR 463L PALLETS OF KC-10A AND VARIOUS USAF CARGO AIRCRAFT

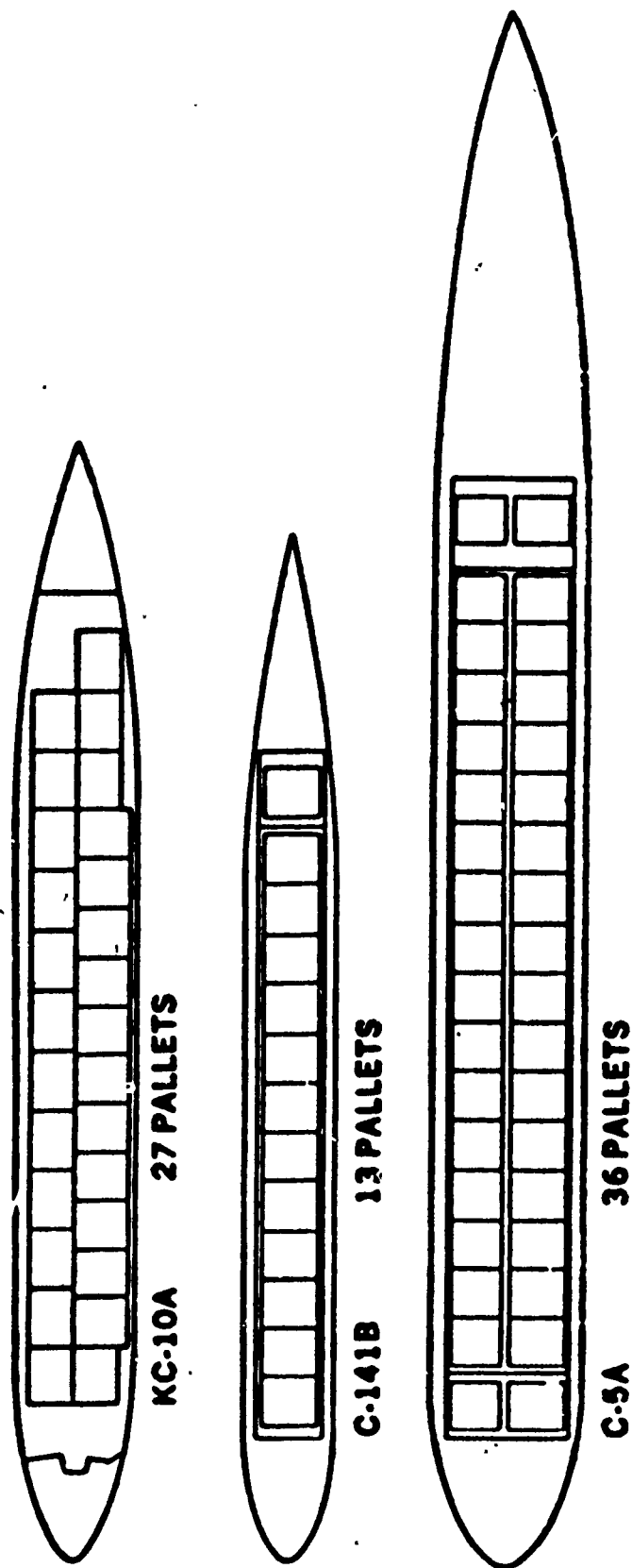


Figure 2.15. Comparison of Airlifter Pallet Capabilities (14:13).

Because of the large number of passengers that must be carried, the KC-10s will be limited to carrying only 17 to 23 pallets of equipment. (Note: A KC-10 could be forced to carry even fewer pallets when carrying large quantities of fuel, since it is limited by maximum takeoff gross weight. The Airlifter-Only KC-10s can carry a "bulky" load of cargo weighing 100,000 pounds for a distance of over 5000 nm. A Dual-Role KC-10, on the other hand, may not even be able to carry 20,000 pounds of cargo because of the large quantity of transferable fuel that it must carry.)

KC-10 Duty Day Limits. Dual Role KC-10s and Airlifter-Only KC-10s must fly back and forth between the fighter base and the destination. Since the duration of the flight is so long, the aircrews can only fly a one-way trip without exceeding the maximum aircrew duty day. The following are the maximum crew duty day limits for the SAC KC-10 crews.

Table 2.2

KC-10 Aircrew Duty Day Limits (reference 4)

Normal Mission	16 Hours
Higher Headquarters Directed Mission	20 Hours
JCS Directed (actual contingency) with Augmented Crew (ie: extra Pilot, Flight Engineer, Boom Operator)	26 Hours

Within that duty day, the Boom Operator/Cargomaster must accomplish the cargo loading and unloading, plus normal

aircrew "preflight" inspection of the aircraft. Usually, then, it is the Boom Operator who limits the aircrew's duty day.

Aircraft Maintenance. After every mission, certain inspections must be accomplished, in addition to checking the oil and filling up the gas tanks. Furthermore, the aircraft usually has one or more unsheduled "write-ups" of systems that have failed during the previous mission. When critical, these "write-ups" must be fixed. Thus, there is a requirement for a KC-10 repair team to do unscheduled maintenance.

Recovery Base. Usually the Fighter Destination Base does not have any KC-10 maintenance personnel or rested replacement aircrews. Also, the base may be in a hostile war zone, where it would be desireable to spend as little time as possible on the ground. For these reasons, the KC-10s in the Dual Role or Airlifter-Only Mission would probably be flown immediately to a Recovery Base, such as Mildenhall, England.

Staging or Main Operating Base. Similarly, on the trip back to the CONUS, the KC-10 may be sent via another base instead of directly to/from the Fighter Deployment Base. This would allow the aircraft to receive major maintenance if necessary. If the KC-10 was in good repair, the staging base could be used to swap crews so that the plane could continue the round-trip without delay.

Dual Role KC-10s

The Dual Role KC-10s must perform fighter air refueling and airlift simultaneously. The approximation is made that each fighter squadron has 240,000 pounds cargo, or about 10,000 pounds per fighter. The following Table 2.3 shows the fuel and cargo needs for each fighter. (The fuel needs were established by the TACAP printouts in Appendix D.)

Table 2.3

Weight of Fuel Offload and Cargo Transport per Fighter
(in pounds)

	<u>Fuel</u>	<u>Cargo</u>
F-16:	14,333	10,000
F-15:	41,277	10,000
F-111:	40,130	10,000
RF-4C:	49,588	10,000

Since the KC-10 must carry large quantities of fuel to transfer to the fighters, it cannot carry a full load of cargo. Ideally, the Dual Role KC-10 would be able to carry all the necessary support equipment and personnel for the fighters that it refuels. For long distance missions, or for fuel-hungry fighters (such as the F-4), the KC-10 cannot carry all the necessary cargo, plus sufficient fuel for itself and the fighters, and still remain below Maximum Takeoff Gross Weight. In these cases, the KC-10 could launch with fewer fighters and less cargo, or launch with less fuel and then be air refueled by another tanker. An extra AR would force the KC-10 to meet very tight and

closely coordinated schedules. The air refueling also adds one more fatigue factor to the already long and difficult mission.

Table 2.4 shows the trade-off of fuel to make room for extra cargo. In the deployment, fighters launch in flights. Table 2.4 thus indicates total weights of fuel and cargo that the KC-10 must carry in order to support fighter flights of various sizes.

Table 2.4

Dual Role Payload and KC-10 Fuel Requirements

	Total Fuel offload	Total Cargo Weight	Required KC-10 Onload (based on TANKER data)
4 F-16s	57,332	40,000	-4,296
5 "	71,665	50,000	20,037
6 "	85,998	60,000	44,370
7 "	100,331	70,000	68,703
8 "	114,664	80,000	83,036
2 F-15s	82,554	20,000	-2,032
3 "	123,831	30,000	49,245
4 "	165,108	40,000	100,522
5 "	206,385	50,000	151,799
6 "	247,662	60,000	203,076
2 F-111s	80,260	20,000	-33,329
3 "	120,390	30,000	16,801
4 "	160,520	40,000	66,931
5 "	200,650	50,000	117,061
6 "	240,780	60,000	167,191
2 RF-4Cs	99,176	20,000	-42,399
3 "	148,764	30,000	17,189
4 "	198,352	40,000	76,777
5 "	247,940	50,000	136,365
6 "	297,528	60,000	195,953

The first row of the table shows that a Dual Role KC-10 can refuel 4 F-16s and carry all 40,000 pounds of their support equipment and personnel. The KC-10 would arrive at the destination with an extra 4,296 pounds of fuel reserve. The second row of the table shows that, by adding a fifth F-16, the extra 10,000 pounds of cargo plus 14,333 of fuel would place the KC-10 20,037 pounds above the Maximum Takeoff Gross Weight. Therefore, in order to carry the cargo, the KC-10 would have to reduce its fuel load, and receive an AR of 20,032 pounds. Notice that the 10,000 pounds of cargo directly displaces 10,000 pounds of fuel.

The table also shows that the KC-10 can provide Dual Role support for 4 F-16s without requiring an additional KC-10 refueling. Since the other types of fighters require much more fuel per fighter, the KC-10 can only refuel two F-15s, two F-111s, or two RF-4Cs, while carrying their support equipment. Notice especially how inefficient each KC-10 sortie is in supporting F-111 and RF-4C deployments. When deploying with two F-111s, the KC-10 is underloaded by 33,329 pounds. When supporting two RF-4Cs, the KC-10 is underloaded by 42,399 pounds.

The flight route of the Dual Role KC-10 is basically the same as that of the Airlifter-Only KC-10. One significant difference between Dual Role and Airlifter-Only KC-10 mission profiles is that the Dual Role sorties must be at the same altitude and airspeed as the fighter aircraft which accompany them. This is a disadvantage to the KC-10

since it must fly at a lower altitude, and at a much higher indicated airspeed than its optimum. The Dual Role KC-10 thus consumes much more fuel.

Figure 2.13 shows the Dual Role Flowplan, which is a network summary of the "conceptual model" of the Dual Role deployment operations.

Summary

This chapter has provided an in-depth look at the fighter squadron deployment operation, explaining the two roles in which the KC-10s can be used to support the deployment. Flow chart representations of the fighter, tanker, cargo, and aircrew actions have summarized this deployment information into "conceptual models" of the operations. These flow charts are thus the direct basis for the simulation models, and contribute to understanding the more abstract deterministic equations which are developed in Chapter IV.

All this information was garnered from an extensive series of conversations with experts in tanker, fighter, airlifter fields. These telephone interviews can be seen, then, as an integral part of the Literature Review, in that they provided an operational description which was not available in published documents.

The following Literature Review Chapter is, in a sense, a forward looking section. Accomplished in the early phases of thesis activity, the search of published literature laid the foundations for the rest of the research.

III. Literature Review

Introduction

This particular Literature Review serves two purposes. First, it provides the reader with a thorough understanding of previous research carried out on support of tanker deployment. Secondly, it explores methodologies which might have been appropriate for reaching the research objective proposed for this effort. The Literature Review is, in a sense, a forward-looking section. Accomplished in the early phases of the thesis activity, it laid the foundation for what was yet to come.

In all, fourteen sources were applicable toward my thesis research: one journal report, seven AFIT theses, five military deployment models, and the Sponsor's previous research in the use of tankers for supporting fighter deployments. Exhaustive as this review turned out to be, only a small amount of material was discovered that directly addressed tanker's support of deployments.

A Journal Publication

Refueling Strategies. In an article titled "Vehicle fleet refueling Strategies to Maximize Operational Range," Mehrez and Stern considered mathematical concepts involved in various Naval fleet refueling concepts (3:320). These concepts helped to shed light on the theory of refueling. One concept, the inherent inefficiency of extending the

range of a receiver aircraft by using tanker aircraft to refuel them, was directly related to KC-10 useage.

Consider the effect of a KC-10 refueling a KC-10 (equal size tanker and receiver). If either KC-10 were to launch with maximum fuel on board, it could fly an unrefueled one-way range of approximately 8900 miles. Mehrez and Stern indicate the optimal refueling concept, assuming the two aircraft launch from the same base, would be for the two (identical) KC-10s to fly together for $1/3$ of their maximum range. At that point, one KC-10 would fill up the other KC-10 ($1/3$ tank of gas transfer). After the air refueling, the receiver KC-10 would be full, and the tanker KC-10 would have just enough fuel to make the return trip. But the overall effect would be that 1 tanker sortie had been used to increase the flight distance of 1 receiver by only one-third (to 11,866 nm).

The authors proved that even an infinite number of tanker KC-10s, all launched together, could not get the receiver KC-10 any farther than the mathematical limit: $1\frac{1}{2}$ times the unrefueled range of a single KC-10 (13,350 nm)! The inefficiency is due to the fuel each tanker has to burn to make its own round-trip to the launch base (3:328).

Several important air refueling concepts that had a direct impact on the methodology of this thesis were gained from this mathematical exercise:

1. Even a small improvement in the range of receiver aircraft (ie: fighter and cargo aircraft) greatly reduces the required number of tanker sorties.

2. Inefficient operations occur when the tanker is smaller or equal in size to the receiver. In an ideal mission, the tanker would be able to offload a very large quantity of fuel, while consuming very little of the fuel itself. Therefore, large, efficient tankers would be most profitable.

3. There is a mathematical limit to the effectiveness of tankers which launch from the same base as their receiver. If a tanker were to be prepositioned at a base half-way between the receiver's launch base and its destination, then that 1 tanker could do what an infinite number of tankers (all launched from the same base as the receiver) could not do: double the range of the receiver! Therefore, forward positioning of the tanker base, such as in a Tanker Task Force, will yield great increases in effectiveness.

AFIT Theses

Fighter deployment in 72 hours. Capt Robert D. Reynolds, in his AFIT Thesis, "Optimum Utilization of the KC-10 for Fighter Aircraft Deployments," used Integer Linear Programming to determine the minimum number of KC-10s required to rapidly deploy fighter squadrons to Europe (18:14). This is the only document available that

specifically studied the use of the KC-10 in support of a fighter deployment.

Based on the operational constraints on the KC-10, Capt Reynolds' objective was to "maximize the number of fighters deployed per KC-10 sortie." He assumed that all associated cargo for each fighter must be carried by the KC-10, thus setting up a simple proportionality concept: if a KC-10 can refuel, say, 4 of the 24 fighters in the squadron it must also carry $4/24$ of the cargo. In this case, then, 6 KC-10 sorties, each carrying $4/24$ of the squadron, are required to deploy the squadron in a European deployment scenario. The model reduces the number of fighters until the trip is feasible without refueling.

Capt Reynolds' deterministic approach to the problem, using the methodology of Integer Linear Programming, was appropriate since his objective was to find the optimal integer number of KC-10s needed to achieve a given time constraint. In contrast to my thesis which seeks to minimize Closure Time, given a fixed number of KC-10s, his thesis tries to justify an increased number of KC-10s. Since my thesis searches for the best way to use the KC-10s that are rapidly coming into the inventory, our objectives are totally different. Thus, Linear Programming was determined to be inappropriate for my thesis research.

Minimizing fuel consumption when refueling airlifters.
In his 1982 AFIT Master's thesis, Capt Tenny Lindholm used Dynamic Programming to "determine optimal rendezvous points,

fuel offloads, and tanker departure bases, using the total fuel consumed by both airlifter and tanker as the measure of effectiveness" (16:ii). It was hoped that this thesis methodology would be applicable to the deployment scenario where flights of fighters are refueled.

Capt Lindholm considered only a C-141 or C-5 airlifter being refueled (only once) by a KC-135 or KC-10 tanker. His model is very credible: it allows tankers to depart from any location, and includes subroutines which accurately calculate the non-linear fuel consumption rates of the aircraft. It specifically ensures that the airlifters will have safety reserve fuel to fly from the "optimal" air refueling location to the air refueling abort base if the AR is unsuccessful. It also allows any route of flight, not just great circle routes.

In some situations, however, it might be more desirable to optimize MOEs other than fuel consumption. Capt Lindholm's model does not guarantee minimum number of tankers used or minimum deployment time, nor does it consider the use of the tanker in a multiple-refueling situation (ie: one KC-10 refueling several receivers as is the case in a TTF refueling). Since Capt Lindholm's thesis was designed to explore refueling of MAC airlifters, it obviously was not designed to consider the KC-10 in the fighter-refueling role. Indeed, the model might become

overwhelmed by complexity if several receivers were to be considered.

Furthermore, his model only considered a single lap by each airlifter. In a high-throughput scenario, such as a full-scale mobility, other factors which were not considered may become dominant (examples might be aircrew availability, aircraft maintenance, and cargo offload time).

Thus, while Capt Lindholm's model effectively optimizes a single sortie, it lacks the flexibility to analyze an entire mobility scenario. Dynamic Programming was therefore rejected as a methodology for my thesis research.

Simulation to Analyze the Air Refueling of Airlifters.

In their 1981 AFIT thesis, Major John Marcotte and Capt Vernon Bordelon used a computerized simulation model to examine the factors that affect fuel consumption. This was the first simulation model I explored. My objective for studying this thesis was to find an accurate fuel model for the tanker (a need that was virtually met by a program provided by my thesis sponsor).

Major Marcotte and Capt Bordelon they analyzed the effects of varying takeoff fuel loads and rendezvous points. One conclusion was that optimal takeoff fuel loads are a function of relative fuel efficiencies of the tanker and the receiver (9:57). The most efficient aircraft should be tasked to carry the greater percentage of fuel. The minimum fuel consumption is achieved "by minimizing the combined percentage of fuel capacity used by the two aircraft"

(9:59). This means that a larger tanker (such as KC-10) should carry most of the total mission fuel, allowing the smaller receivers (such as C-141B) to operate more efficiently at lower weights.

One significant finding directly applicable to Dual Role KC-10s was that, when the airlifter carries maximum feasible cargo weights, the optimal rendezvous point is as close as possible to the airlifter's takeoff base (ie: if it takes off with very little fuel, it can carry more cargo, but needs to be refueled as early as feasible) (9:58). A conclusion applicable to the TTF KC-10s was that it also helps somewhat for the airlifter to fly closer to the tanker's base if the tanker base is enroute to the airlifter's destination (9:59).

Major Marcotte's and Capt Bordelon's methodology was deemed appropriate since computerized simulation models could be built to depict the stochastic flow of entities of the "deployment" process.

Simulation of Strategic Airlift to Europe. In their 1981 AFIT thesis, Captains Holck and Ticknor developed a SLAM simulation model to study factors within the MAC airlift system which produce significant changes in the system's daily cargo delivery rate. This thesis provided a basic conceptual model for airlifter deployments. Four factors were studied: aircrew, maintenance, supply, and aerial port (16:viii). Although MAC uses a totally

different concept of aircrew management than SAC uses, this simulation model provided the logic and structure for developing my SLAM model of the Distinct Roles Airlifter KC-10 Mission.

Improved Maintenance Model. Capt Wayne P. Stanberry, in his 1982 AFIT thesis, developed a detailed SLAM simulation model to describe the aircraft maintenance in MAC's airlift system (21:vii). It was hoped that this thesis would provide an adequate model for the maintenance of the KC-10, which is so critical in the TTF operation.

Capt Stanberry examined maintenance manning at the Air Force Specialty Code level. He modeled the maintenance discrepancies and distributions for repair times (based on LtC Shaw's dissertation (20:35)) for the major aircraft subsystems and tested his maintenance model by inserting it into the airlift model developed by Captains Holck and Ticknor.

Since maintenance turn-around time is a critical factor in TTFs which fly at high sortie rates, I closely examined this maintenance model for possible use in my SLAM models. Unfortunately, the Air Force does not accumulate the maintenance statistics that would be needed to use Capt Stanberry's model. It therefore could not be used to model KC-10 maintenance (reference 32).

Analytical Methodology for Predicting Repair Time Distributions. In his December 1985 AFIT thesis, Captain Dennis Dietz concluded that analytical methods were more

efficient than simulation for predicting aircraft repair time distributions. His major assumptions were that aircraft subsystems fail with an exponential distribution (with a parameter of Mean Time Between Failure, MTBF), and that, given a failure, each subsystem will have a lognormal distribution (with mean = Mean Time to Repair, MTTR, and standard deviation = 0.29 MTTR) (12:1-4). Since the ability to properly schedule a TTF operation depends on an accurate understanding of the Maintenance Repair Time distribution, it was hoped that this thesis would provide a way to calculate that distribution for the KC-10.

I attempted to use Captain Dietz's estimates for the distribution parameters, in combination with Captain Stanberry's improved maintenance simulation model (see TTF simulation model in Appendix G). Data used was obtained from the Maintenance and Operation Data Access System (references 32,33). I found that it gave unrealistically high overall Times to Repair. This is because it assumes that every subsystem is a mandatory item for flight. This is inconsistent with the redundancy of KC-10 systems as indicated in the KC-10 Minimum Equipment List. Thus, I was not able to find an adequate model for KC-10 maintenance.

Computer Programs Currently Used to Analyze Deployments

In addition to reviewing AFIT theses, a search for relevant government studies was accomplished through the Defense Technical Information Center (DTIC). All their

research related to airlifting Army units to Europe, and were not directly applicable to fighter deployments. A review of the Catalog of Wargaming and Military Simulation Models provided the information on the following computer programs currently being used by government agencies to analyze deployment scenarios (reference 7). It will be seen that none of these computer programs have the ability to model air refueling of the deploying airlifters. Also, none of them considers the deployment of fighters. In short, there is a total lack of analysis in the field of fighter deployments using tankers.

OJCS "MACE" Model. The Military Airlift Capability Estimate (MACE) is an analytical computer program which is used by the Joint Chiefs of Staff J-4 to estimate the minimum "closure time" of large-scale troop and cargo movements (7:202). It does not consider the tanker side of the deployment. This model accomplishes the following:

Input:	load description
	aircraft ground time
	distance between APOE and APOD
	(Aerial Port of Embarkation, Debarcation)
Output:	force closure time (arrival of last cargo load)
	summary of aircraft utilization
	traces of individual sorties/movement of types of cargo

OJCS "RAPIDSIM" Model. Rapid Intertheater Deployment Simulator (RAPIDSIM) is also used by the OJCS J-4. Certain inputs are simple constants: maximum number of available cargo "vehicles", vehicle speed, capacity, and time for loading/unloading. This program cannot model air refueling

the cargo aircraft at all (7:261).

Army's "TRANSMO" Model. The Army Concepts Analysis Agency uses this analytical computer program to "determine the arrival time of the US Forces in overseas theaters of operation." Given specified "lift" assets, it can determine the time-table for a deployment scenario. Or, given a required deployment schedule, it can determine the "lift" requirements to meet the schedule (7:365). Air refueling of the airlifters is not considered.

Military Traffic Management Command. The MTMC Operations Analysis Division has published several studies with the objective of identifying the fastest method and optional methods of deploying specific Army divisions to Europe (references 10,11). These studies use computer simulation to model deployment via sealift and/or via C-5 and C-141 aircraft. Because they reveal current capabilities in minute detail, these reports are either SECRET or CONFIDENTIAL. Although the major conclusions cannot be discussed, these reports were very useful because they revealed many factors which are vital to building an accurate deployment model. Furthermore, these reports contained several unclassified portions which provided relevant data.

Unfortunately, these studies (and all the apparently redundant models mentioned above) fail to consider the possibility of using air refueling at all, much less

optimizing the use of air refueling for force deployments.

MAC's M-14 Model. This program does model air refueling of airlifters but does not explicitly model the tankers which are providing the refuelings. A computerized (FORTRAN) simulation model, the M-14 is a detailed representation of MAC's strategic airlift system. "It individually models each component of the system in terms of airfields, aircraft, cargo, people, and support equipment. The model details more than 400 airfields, and realistically defines airlift aircraft in terms of performance and capability" (15:ix). Each of these details can be changed to accurately describe a given scenario. As a simulation model, it also has the flexibility of allowing changes in policies, such as which cargo has higher priority or the length of the maximum aircrew duty day. Most importantly, the M-14 presents the opportunity to examine the cumulative and interactive effects of all the variables that it models (15:iii).

The M-14, although supposedly able to model the KC-10, has not been updated with KC-10 reliability and maintainability data. As a ball-park approximation, the KC-10 is assumed to be similar to the C-5. Further, the M-14 does not look at the KC-10 as a tanker, but as an airlifter (reference 29).

The model assumes that an unlimited number of KC-135 tankers will be available at every air refueling point, each capable of offloading 70,000 pounds of fuel (15:57). Since

the model does not specifically track tanker aircraft, it merely assigns an 80% probability that a tanker will be available if the air refueling area is not congested. It then assigns a 99% chance of successful rendezvous, and a 95% probability of successful air refueling. Thus, the M-14 does not consider the interactions which would affect the availability of tankers to provide the air refuelings. It did, however, provide excellent historical data which was used in this thesis effort to develop my simulation model. The available data includes payload-range equations, fuel consumption rates, and probability distributions for the times required to perform various maintenance and flight activities. These distributions are summarized on the following page:

Table 3.1

Known KC-10 Distributions for Use in Simulation
(reference 15)

Mission Duration
to overhead destination = planned $\pm$ 10 minutes (Uniform)

Penetration $\sim$ Uniform(7,10) minutes

Final Approach $\sim$ Uniform(1.2,1.6) minutes

Landing = constant 2 minutes

Taxi off runway = constant 5 minutes

Taxi into park = Erlang(min 0, avg 6, max 45)

The following activities are mostly concurrent:

Through-Flight Inspection = constant 1 hour + 10 minutes

Refueling by Fuel "Pit" = 15.3 minutes + (quantity)(.000349)

by Truck = -17.5 minutes + (quantity)(.00125)

Scheduled Fleet Service $\sim$ Normal(.4,.1)

	Min	Avg	Max
Cargo Offload or Onload			
Palletized Cargo			
using Cochran Loader	1.5	2.0	4.0 hrs

MACREG 28-2 Planning Factors for the KC-10

Onload cargo = 4 hrs + 15 min (any type cargo)

Offload cargo = 3 hrs + 15 min (" " ")

Enroute Stop = 1 hr + 45 min ("gas and go")

Sponsor's Research

TACAIR Deployment Alternatives. This study was accomplished in 1983-1984 by the thesis sponsor, Mr M. E. Estes of AFCSA/SAGM. He examined the tradeoff between fighter enroute time and the number of tankers used. Tactical Aircraft deploying over great distances can travel non-stop (least time used) by using aerial tankers for rapid closure. Alternatively, the fighters can land at enroute bases, sacrificing closure time for tanker savings. Mr Estes found that significant savings in tankers could be realized if delays in Closure Time were acceptable (13:5)

This study was designed to provide a tool for the TAC deployment planner for use in estimating the enroute time, enroute bases, and tanker support required to deploy selected TACAIR squadrons from the CONUS to the forward area. Since tanker shortages may exist during periods of high tension, alternative deployment procedures, such as fighters landing at intermediate bases, may make the deployment less dependent on tankers.

This was a deterministic type of study. The duration of each flight was calculated based on mission distance, fighter speed, and specified wind conditions. As an example, an F-15 deploying non-stop from Langley AFB, VA to Hahn, Germany requires 7.3 hours. The number of tankers required was calculated using the "TACAP" flight profiles (see description following) and AFCSA's "Tanker" program (also described below). Tankers were assumed to be

available at the closest tanker base. The tanker mission calculations were based on the tankers flying in the tanker-only role (as in a TTF). For each flight of six F-15s in the above non-stop flight to Germany, this study determined that 4 KC-10s would be necessary.

For fighters landing at intermediate bases (instead of being air refueled), the assumption was made that the aircraft would always be ready for launch in 3 hours. Thus, closure time was calculated simply as the sum of flight durations, turn-around times, and crew rests (as needed).

It should be noted that transportation of fighter support equipment was not considered in this study.

TAC's TACAP Program. This computer program was the primary source of information concerning the fighters' fuel consumption. The "TAC Aircraft Profiler" model is a FORTRAN and COBOL based computer program. Given a departure base, destination, route, abort bases, and type of fighter, it calculates an entire fuel log for all the fighters. This includes determining the air refueling locations and the amount of fuel onload that each fighter requires. The model can provide this information based on orbit or track types of refuelings (references 23,25).

Since TAC trusts the accuracy of TACAP's output, my thesis simulation models were based on TACAP data for fighter fuel consumption.

AFCSA's "Tanker" Program. This interactive FORTRAN program calculates accurate mission fuel consumption by KC-135A, E, R or KC-10 tankers (reference 25). It can iterate to find the maximum feasible number of fighters that can be refueled by a KC-10. Data from this program was the foundation of my thesis calculations. By making a few slight modifications to enable it to calculate the feasible number of flights of fighters, and to make it modular, I was able to use it as a subroutine within my Deterministic Model of TTF Closure Time.

Conclusion

Very little information was found in the available literature which directly pertains to the KC-10s use in fighter deployments. Several AFIT simulations dealt with aspects of MAC airlifters supporting deployment. These studies were somewhat helpful, especially in building my simulation model for the Airlifter missions. No studies were found to be adequate for modeling the KC-10 maintenance, which leaves a critical need unmet for studying the TTF operations. Of several computer programs reviewed, none modeled the tanker's role in the deployment. This thesis' sponsor, Mr M.E. Estes of Center for Studies and Analysis, has carried out significant deterministic analysis of tankers supporting fighter deployments. His research, however, did not involve the examination of the total picture of fighter and cargo deployment.

At the conclusion of the Literature Review, simulation was considered to be the most relevant methodology for modeling complex operational concepts such as the KC-10 missions. As will be seen in the next Chapter, initial simulation results were promising, but the research had to turn to deterministic equations to address the complexities of the TTF operation.

IV. Methodology

Two Methodologies

Two methodological tools were used in the search for the best KC-10 deployment concept: computer simulation and deterministic equations. As it turned out, both methodologies contributed to solving the problem of which was the most effective KC-10 role.

Simulation was important in that it required the initial development of a detailed conceptual model which gave structure to the problem. The prototype computerized simulation models enabled the researcher to develop a better understanding of the "working" of the deployment process. This eventually led to the assimilation of the knowledge into a compact deterministic model of the deployment.

A set of deterministic equations was developed initially for the purpose of obtaining a "ballpark" estimation for the deployment Closure Time. As it turned out, the predictions of the deterministic "flow rate" equations coincided very closely to the results of the first Tanker Task Force simulation model, substantiating the deterministic assumption of a constant flow of fighters.

The thesis research then placed its emphasis on the simulation models for the purpose of gaining an understanding of queuing effects, stochastic variances, and factor interactions. The simulation work, however, bogged down with the complex problem of "pre-determining" the Air

Refueling schedules for the TTF deployment. For the Dual Role simulation, there was no scheduling problem at all since, in real life, the fighters can wait on the ground until the KC-10, located at the same base, is ready to launch. This could be easily modeled by a simple queue. But when the fighters were to be refueled by Distinct Role TTF KC-10s, it would have been unrealistic to make a simulation model where the fighters queue until a KC-10 becomes available. Fighters do not queue in the air--they abort to a landing base if the KC-10 is not available when needed. It thus became apparent that, as in the real world, the scheduling of launches and ARCTs in the simulation model must be known prior to the first launch.

The scheduling of ARCTs, however, was not simple since the scheduling of air refuelings depended on how many KC-10s were assigned to each AR track and how many missions each KC-10 could fly during the deployment. It also became apparent that the apportioning of KC-10s among AR tracks was dependent on the desired number and duration (ie: schedule) of missions to be flown to each track.

Once the interdependent nature of the scheduling and apportioning problems became obvious, the simulation models were set aside. The thesis research returned to the deterministic models to search for a solution to the scheduling and apportioning problems. (See Appendix G for description of the prototype simulation models).

Deterministic Assumptions

This deterministic modelling of the deployment process implies, by its name, that there is no uncertainty in the time required for scheduled events. Also the deterministic equations make no allowance for extra time which might be spent if excessive queuing were to occur (such as for KC-10 parts or maintenance, for servicing of aborted fighters, or for resting aircrews).

An important prerequisite to developing this model was the deletion of certain interactions. For instance, it is known that the KC-10 flying schedule directly affects the reliability and maintainability of the KC-10. In order to estimate the flying schedule, however, it was essential to assume a constant maintenance time. In the equations that follow, KC-10 ground time is scheduled to be 3 hours duration.

In real life, a schedule can be made using the discrete times when each fighter launches, air refuels, and arrives at the destination. This deterministic model, however, assumes an average, continuous flow of fighters. Continuous flows are the result of "smoothing out" the discrete, integer mission schedules. For instance, if 1 KC-10 can refuel 12 fighters on each mission, and can fly 2 such missions per day, then the continuous flow rate of fighter air refuelings is 24 per day, or 1 per hour.

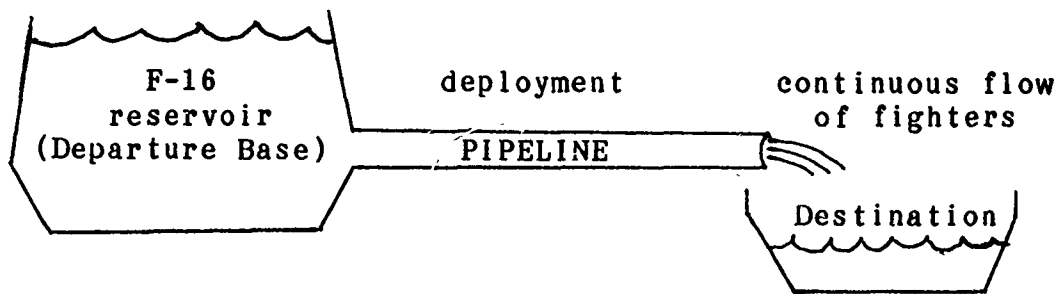


Figure 4.1 Flow Illustration

It is also assumed that all four types of fighters are deployed simultaneously with no type of fighter having priority. Thus, with "parallel" deployments of F-16s, F-15s, F-111s, and RF-4Cs, the optimal overall deployment Closure Time is achieved if the last F-16 arrives at the same time as the last F-15, the last F-111, and the last RF-4C. In relation to the above figure, there are 4 reservoirs (F-16, F-15, F-111, RF-4C). Proportional flow rates were established so that all 4 reservoirs would be emptied at exactly the same instant.

Distinct Role Equations

Calculating "Closure Time" for TTF. The following paragraphs develop an equation to calculate Closure Time for fighters refueled by Distinct Role TTF KC-10s. This section also develops the apportioning of KC-10s among the 11 AR tracks, and by inference, the apportioning of KC-10s among the TTF bases. (The subsequent section, beginning on page 4-18, develops the equations for the Distinct Role Airlifters.)

By setting the Closure Times equal for each type of fighter, it is possible to apportion the TTF KC-10s among the AR tracks and TTF bases so that all the fighters receive refuelings according to their proportional flow rates. The total time to deploy fighters is described as the sum of the times required for five events (ie: five addends).

Closure Time =

- Time to Set-up TTF [1st addend]
- + Time for KC-10 to fly to the ARCP (for 1st "track lap"). (Assume fighters launch as necessary to arrive on time.) [2nd addend]
- + Time it takes the TTF KC-10s to transport sufficient fuel to the ARCP to refuel all the fighters. [3rd addend]
- + Time for last fighter to fly from ARCT to destination. [4th addend]
- + Time necessary for aborted fighters to arrive at destination. [5th addend]

The above addends are illustrated on the following page in Figure 4.2.

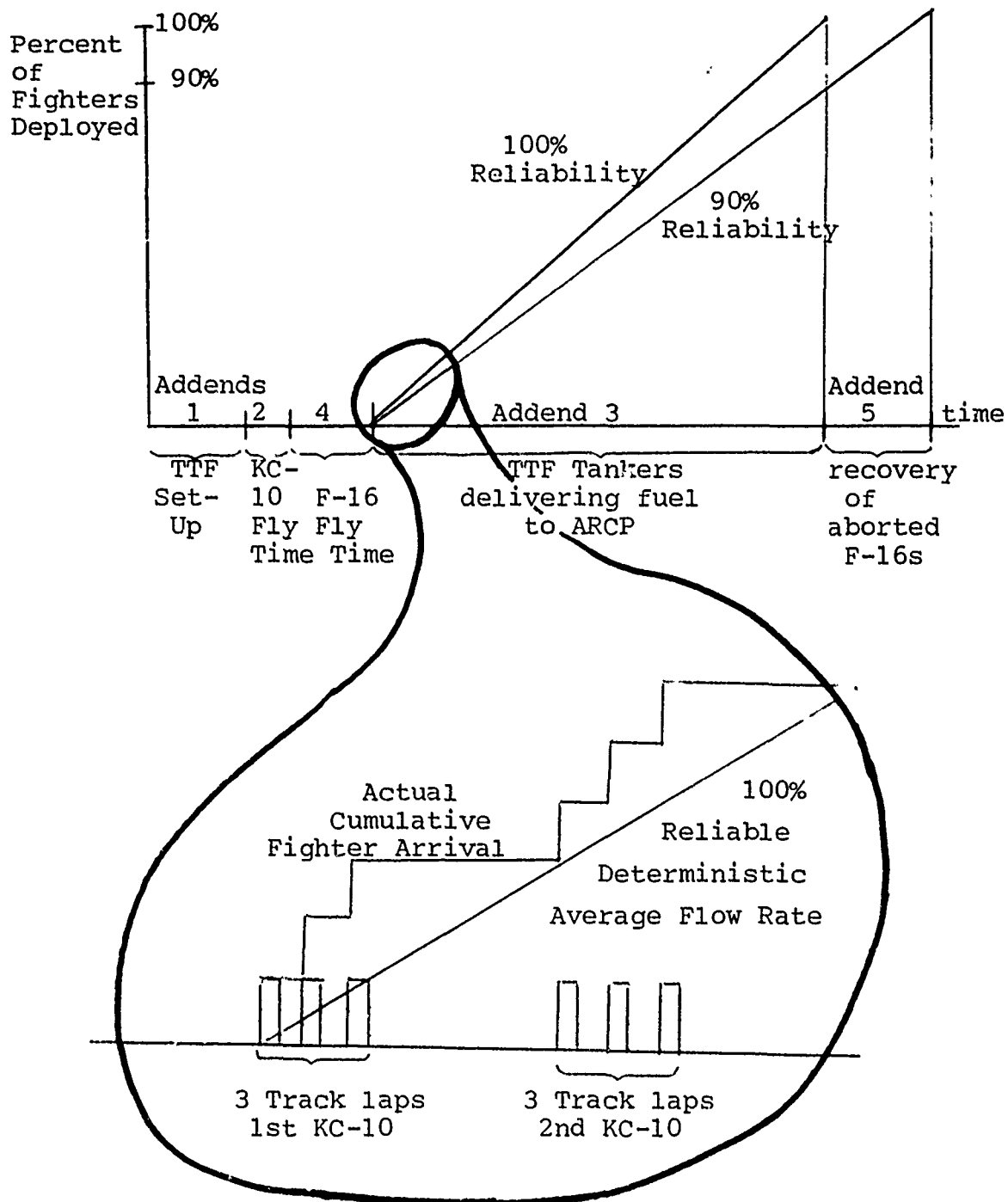


Figure 4.2. Graphical Illustration of Fighter Arrivals, related to Deterministic TTF Closure Time Equations.

It should be noted from Figure 4.2 that the extra time needed to refuel aborted fighters [5th Addend], can also be represented in terms of planned times [3rd Addend], and AR reliability. (This thesis assumes that all aborted fighters must be re-scheduled into the AR track from which they aborted, as opposed to flying directly to the destination, or "island hopping," as described in Chapter II.)

$$[3\text{rd Addend}] + [5\text{th Addend}] = \frac{[3\text{rd Addend}]}{\text{Average AR Reliability}}$$

This is because the [3rd Addend] is based on 100% reliability. It should be understood that the fighter arrival rate (or the slope of the cumulative fighter arrival line on Figure 4.2) is simply the scheduled (or 100% reliable) AR rate minus the abort rate. Thus, the vertical "rise" of the fighter arrivals is decreased by the number of fighter aborts. Therefore, the Closure Time is increased according to the new horizontal "run" of the graph in Figure 4.2.

Next, let's look more closely at the 3rd Addend, which is the only addend dependent on the KC-10 allocation. Since this addend is dependent on the number of KC-10s which are carrying fuel to the ARCP, then the ARCPs could be pictured as flow restrictions in the pipeline of deploying fighters. Thus, the 3rd Addend can be expanded in much further detail in terms of the number of fighters and the refueling sorties that they require of the KC-10s:

[3rd Addend] = Total Time to transport all required fuel to the ARCP (same for each KC-10 assigned to the track)

= (Time Interval, including flight and ground turn-around time, per KC-10 sortie.)

x $\frac{\text{Number of KC-10 Sorties required}}{\text{Number of KC-10s assigned to the AR track}}$

= (Time interval/sortie) x (Sorties/KC-10)

Each of the above two factors can be further explained.

The first factor is essentially an overall "interval."

$(\text{Time interval/sortie}) = \frac{\text{Airborne mission time} + \text{Ground Time}}{\text{KC-10 Sortie}}$

in terms of hours/sortie

The second factor, "Sorties per KC-10" can be represented as the product of many factors, as seen in the following derivation:

$\frac{\# \text{ of KC-10 Sorties required}}{\text{KC-10}} = \frac{\text{Sorties per AR Track}}{\text{KC-10s per AR Track}}$

The denominator, "KC-10s per AR Track", is a constant which will be calculated later in this section. The term, "Sorties per AR Track," can be further explained as a requirement to provide a certain number of refuelings:

$\frac{\# \text{ of KC-10 Sorties required}}{\text{AR Track}} = \frac{\# \text{ of Fighters/AR Track}}{\# \text{ of Fighters/KC-10 Sortie}}$

Since all of each type of fighter must go through all their AR tracks then "# of F-16s/AR Track" is equal to the Total

Number of that type of fighters deploying. For example, all 700 F-16s must go through each of the 2 F-16 AR tracks.

The maximum feasible number of fighters that can be refueled by one KC-10 sortie (ie: # Fighters/Sortie) is determined by fighter fuel onload requirements and by the transferable KC-10 fuel available. Recall that, in the TTF concept, instead of refueling many fighters consecutively (the last fighter would run out of gas before it was his turn to refuel), the fighters are refueled in several flights of approximately six receivers each. Thus, the KC-10 must refuel one flight of fighters, then fly back to the ARCP to meet the next flight of fighters. The KC-10 will fly several laps of the AR track, refueling a flight of fighters on each east-bound leg, until the KC-10 must return to base for fuel. Thus the "# of fighters per Sortie" term can be further expanded as follows:

$$\frac{\text{Fighters}}{\text{KC-10 Sortie}} = \frac{\# \text{ Fighters}}{\text{track lap}} \times \frac{\# \text{ of track laps}}{\text{KC-10 Sortie}}$$

In summary, the [3rd addend] of the Closure Time has been expanded to the following:

$$\begin{aligned} \text{[3rd Addend]} &= \text{Time to transport all fuel (for one type of fighter) to ARCP, per KC-10} \\ &= \frac{\text{Airborne Mission Time} + \text{Ground turn-around time}}{\text{KC-10 sortie}} \\ &\times \frac{(\# \text{ Fighters/AR Track})}{(\text{KC-10s/AR Track}) \frac{(\# \text{ Fighters}) (\text{track laps})}{(\text{track lap}) (\text{KC-10 sortie})}} \end{aligned}$$

Derivation of the TTF Apportionments

For the sake of simplifying the explanation of the derivation, let us derive the apportionment of two TTFs of KC-10s (at Goose Bay and Mildenhall) providing ARs at the designated ARCPs. The equation will work just as well for scenarios with any number of TTFs, providing ARs at any number of AR tracks.

Consider the deploying F-16s. The F-16s must flow at an equal rate through each of the two consecutive AR tracks. This is important since the ARs do occur in sequence, the flow is only as fast as the minimum rate. Therefore, there must be a restriction that the Mildenhall TTF, which provides refuelings in the second AR track, be able to provide the same number of ARs as provided in the first AR track by the Goose Bay TTF.

For a hypothetical example, say that, on the average, a single Goose Bay KC-10 could refuel 2 fighters per hour. If a Mildenhall KC-10 could refuel 4 fighters per hour (due to closer TTF Base distance from ARCP, and smaller required offloads per fighter), then the obvious apportioning requirement would be for twice as many Goose Bay KC-10s as Mildenhall KC-10s. This can be shown mathematically as

$$\text{Rate}_{\text{AR track 1}} = \text{Rate}_{\text{AR track 2}}$$

$$\begin{aligned} & \frac{(2 \text{ Fighters/hr})}{(\text{KC-10})} \times (\# \text{ of KC-10s at Goose Bay}) \\ &= \frac{(4 \text{ Fighters/hr})}{(\text{KC-10})} \times (\# \text{ of KC-10s at Mildenhall}) \end{aligned}$$

Note that this thesis assigns the AR Track responsibility to the closest TTF.

Notation. For notational abbreviation, the inverse of AR Rate, or refueling interval for each AR track (ie: average time between air refuelings) is indicated by lower case letters. The number of tankers assigned to each AR track is indicated by upper case letters. The type of letters indicate the type of fighter: associate a or A with F-16s, b or B with F-15s, c or C with F-111s, and d or D with RF-4Cs. Subscripted numbers represent the number of the AR track. The number of KC-10s assigned to each track are upper case letters. These are summarized in Table 4.2 on the following page.

Table 4.2

Summary of Notational Abbreviations

F-16s

a_1 = refueling interval for AR 1	A_1 = # KC-10s assigned to AR 1
a_2 = " " " AR 2	A_2 = " " " AR 2

F-15s

b_1 = refueling interval for AR 1	B_1 = # KC-10s assigned to AR 1
b_2 = " " " AR 2	B_2 = " " " AR 2
b_3 = " " " AR 3	B_3 = " " " AR 3

F-111s

c_1 = refueling interval for AR 1	C_1 = # KC-10s assigned to AR 1
c_2 = " " " AR 2	C_2 = " " " AR 2

RF-4Cs

d_1 = refueling interval for AR 1	D_1 = # KC-10s assigned to AR 1
d_2 = " " " AR 2	D_2 = " " " AR 2
d_3 = " " " AR 3	D_3 = " " " AR 3
d_4 = " " " AR 4	D_4 = " " " AR 4
d_5 = " " " AR 5	D_5 = " " " AR 5

Greek letters:

Proportionality between tracks

$$\begin{aligned}\alpha &= 1 + a_2/a_1 \\ \beta &= 1 + b_2/b_1 + b_3/b_1 \\ \gamma &= 1 + c_2/c_1 \\ \delta &= 1 + d_2/d_1 + d_3/d_1 + d_4/d_1 + d_5/d_1\end{aligned}$$

Proportionality between Fighter Types

$$\begin{aligned}\theta &= B_1/A_1 \\ \phi &= C_1/A_1 \\ \psi &= D_1/A_1\end{aligned}$$

For example, since it is feasible for a Goose Bay KC-10 to refuel 18 F-16s on AR track number 1 (in three laps, refueling flights of 6 F-16s each lap) every 9.4 hours, then $a_1 = 9.4/18 = .52$ hours/fighter. Similarly, since a Mildenhall KC-10 servicing AR track 2, can provide refuelings to 42 F-16s per sortie (in seven laps) every 13.4 hours, then $a_2 = 13.4/42 = .32$ hours/fighter. (Notice again, that the Mildenhall KC-10s can perform more ARs per sortie because the offloads are smaller, and the KC-10 has less distance to fly between the TTF Base and the AR Tracks.)

The problem to be solved is, "What are the values of A_1 , A_2 , the number of KC-10s assigned to each track?" The proportionality of flow rates (represented by the Greek letters), which was based on equal Closure Times for all types of fighters, was used to solve this problem.

Apportionment Equations. First, the flow rates through consecutive AR tracks need to be equated (ie: same number of fighters refueled in each track).

Recall that the [3rd Addend] of Closure Time was defined as:

[3rd Addend] = Time to transport all fuel (for one type of fighter) to ARCP, per KC-10

$$= \frac{\text{Airborne Mission Time}}{\text{sortie}} + \text{Ground turn around time}$$

$$\times \frac{(\# \text{ Fighters/AR Track})}{(\text{KC-10s/AR Track})} \frac{(\# \text{ Fighters})}{(\text{track lap})} \frac{(\text{track laps})}{(\text{sortie})}$$

Note that this is equivalent to:

$$[3\text{rd Addend}] = \frac{\text{Time/AR Track}}{\text{KC-10s/AR Track}}$$

where Time/AR Track = a_1 for F-16 Track 1

and KC-10s/AR Track = A_1 for F-16 Track 1.

Therefore, the equality of "fighter flow" through consecutive AR tracks results in equal values for Addend 3, time required for the KC-10s to carry all the fuel to each ARCP:

$$\begin{array}{ccc} \text{[Goose Bay]} & & \text{[Mildenhall]} \\ (F-16 \text{ Addend } 3) \text{ TRACK } 1 & = & (F-16 \text{ Addend } 3) \text{ TRACK } 2 \\ \text{or} & & \\ & \frac{a_1}{A_1} = & \frac{a_2}{A_2} \end{array}$$

In order to obtain values for a_1 and a_2 (Time/AR Track), the KC-10 fuel consumption need to be calculated for each TTF mission route. This information was obtained by using the FORTRAN TANKER program, provided by the Air Force Center for Studies and Analysis. The output of the (modified) TANKER program included Airborne Mission Time, and the number of feasible tracklaps/sortie. Using the TANKER information, the equation became:

$$\frac{(700 \text{ F-16s/AR Track}) \times (6.4 + 3.0 \text{ hours/sortie})_1}{(6 \text{ F-16s/track lap}) (3 \text{ tracklaps/sortie}) (A_1)}$$

[Goose Bay]

$$= \frac{(700 \text{ F-16s/AR Track}) \times (10.4 + 3.0 \text{ hrs/sortie})_2}{(6 \text{ F-16s/track lap}) (7 \text{ tracklaps/sortie}) (A_2)}$$

[Mildenhall]

(Note: For computational efficiency, in the computerized version of these equations, the identical terms were cancelled out of the above equations.)

Using the above equation to solve for the relative proportions of tankers on each track:

$$\begin{aligned} A_2 &= \frac{a_2}{a_1} A_1 \\ &= .697 A_1 \end{aligned}$$

Similarly, for each of the other types of fighters, the proportions among tracks are:

$$\begin{array}{lll} B_2 = (b_2/b_1)B_1 & C_2 = (c_2/c_1)C_1 & D_2 = (d_2/d_1)D_1 \\ B_3 = (b_3/b_1)B_1 & & D_2 = (d_2/d_1)D_1 \\ & & D_4 = (d_4/d_1)D_1 \\ & & D_5 = (d_5/d_1)D_1 \end{array}$$

It is important to remember that, for the purposes of the mathematical derivation, KC-10s are essentially permanently assigned to each Track. That is, once a KC-10 was assigned to an AR track, it would only be allowed to fly to that track.

The next constraint was that the total number of KC-10s allocated to all the AR tracks had to equal to the number of available tankers. That is:

$$(A_1 + A_2) + (B_1 + B_2 + B_3) + (C_1 + C_2) + (D_1 + D_2 + D_3 + D_4 + D_5) = 100\% \text{ of TTF Tankers}$$

or,

$$100\% = (A_1 + [a_2/a_1]A_1) + (B_1 + [b_2/b_1]B_1) + (C_1 + [c_2/c_1]C_1) + (D_1 + [d_2/d_1]D_1 + [d_4/d_1]D_1 + [d_5/d_1]D_1)$$

or,

$$100\% = A_1(1 + a_2/a_1) + B_1(1 + b_2/b_1 + b_3/b_1) + C_1(1 + c_2/c_1) + D_1(1 + d_2/d_1 + d_3/d_1 + d_4/d_1 + d_5/d_1)$$

or,

$$100 = \alpha A_1 + \beta B_1 + \gamma C_1 + \delta D_1$$

Thus, the above constrained equation set up the proportionality among AR tracks. Still, there has the remaining unknown of the relationship between A_1 , B_1 , C_1 , and D_1 , that is, the apportioning of KC-10s among the types of fighters. Thus, we must still had to answer the questions, "What number of KC-10s should refuel F-16s (A_1)? What number of KC-10s should refuel F-15s (B_1)? ...F-111s (C_1)?...RF-4Cs (D_1)?"

The solution was derived from our objective of having equal Closure time for all the types of fighters. Thus, we must also had to equality of the [3rd Addend] among all the types of fighters. That is,

$$\begin{aligned} (\text{Addend } 3)_{F-16} &= (\text{Addend } 3)_{F-15} \\ &= (\text{Addend } 3)_{F-111} = (\text{Addend } 3)_{RF-4C} \end{aligned}$$

A specific example (equating F-16s and F-15s) may help make the numbers more apparent. (Notationally, the fighter subscripts, such as F-16, indicate that the KC-10 support is for the first AR track for that type of fighter.)

$$\begin{aligned} \text{time}_{F-16} &= \frac{(700 \text{ Total F-16s}) \times (6.4 + 3.0 \text{ hrs/sortie})_1}{(6 \text{ F-16s/tracklap})(3 \text{ tracklaps/sortie})(A_1)} \\ &= \text{time}_{F-15} = \frac{(300 \text{ Total F-15s}) \times (4.4 + 3.0 \text{ hrs/sortie})_1}{(6 \text{ F-15s/tracklap})(1 \text{ tracklap/sortie})(B_1)} \end{aligned}$$

Solving for the relationship between A_1 and B_1 ,

$$\begin{aligned} B_1 &= A_1 \frac{(300 \text{ F-15s})(4.4 + 3 \text{ hrs/sortie})_{F-15}}{(700 \text{ F-16s})(6.4 + 3 \text{ hrs/sortie})_{F-16}} \\ &\quad \frac{(6 \text{ F-16s/tracklap})}{(6 \text{ F-15s/tracklap})} \times \frac{(3 \text{ tracklaps/sortie})_{F-16}}{(1 \text{ tracklaps/sortie})_{F-15}} \\ &= \theta A_1 \end{aligned}$$

Similarly, for the other types of fighters, the ratios of the remaining terms were indicated by the following Greek letters:

$$C_1 = \phi A_1$$

$$D_1 = \psi A_1$$

Overall, then, the following equations were derived:

$$\begin{aligned} [\text{Addend 3}] &= \frac{(700 \text{ F-16s/AR Track}) (6.4 + 3.0 \text{ hrs/sortie})}{(6 \text{ F-16s/tracklap})(3 \text{ tracklaps/sortie})(A_1)} \\ &= \frac{365.55}{A_1} \end{aligned}$$

where the apportionment of KC-10s to F-16 AR Track 1 was:

$$A_1 = 100\% / (\alpha + \beta \theta + \gamma \phi + \delta \psi)$$

and where the values of the above Greek letters were obtained by a simple process of substitution.

Solution:

For each type of fighter, the following parameters were selected to represent the relationship between the AR tracks:

$$\begin{aligned} \text{[F-16]} \quad \alpha &= 1 + (a_2/a_1) = 1 + \frac{[(10.4 + 3)/7]}{[(6.4 + 3)/3]} = 1.611 \end{aligned}$$

$$\begin{aligned} \text{[F-15]} \quad \beta &= 1 + (b_2/b_1) + (b_3/b_1) \\ &= 1 + \frac{[(6.2 + 3)/2]}{[(4.4 + 3)/1]} + \frac{[(8.6 + 3)/5]}{[(4.4 + 3)/1]} = 1.935 \end{aligned}$$

$$\begin{aligned} \text{[F-111]} \quad \gamma &= 1 + (c_2/c_1) \\ &= 1 + \frac{[(7.9 + 3)/2]}{[(5.1 + 3)/1]} = 1.673 \end{aligned}$$

$$\begin{aligned} \text{[RF-4C]} \quad \delta &= 1 + (d_2/d_1) + (d_3/d_1) + (d_4/d_1) + (d_5/d_1) \\ &= 1 + \frac{[(5.3 + 3)/2]}{[(7.8 + 3)/2]} + \frac{[(7.5 + 3)/3]}{[(7.8 + 3)/2]} + \\ &\quad + \frac{[(8.4 + 3)/3]}{[(7.8 + 3)/2]} + \frac{[(11.7 + 3)/6]}{[(7.8 + 3)/2]} = 3.574 \end{aligned}$$

The ratios between fighter AR₁ tracks were as follows:

$$[F-15s/F-16s]_1$$

$$\begin{aligned} \theta &= \frac{(300 \text{ F15s})(4.4 + 3 \text{ hours/sortie})_{F15}}{(700 \text{ F16s})(6.4 + 3 \text{ hours/sortie})_{F16}} \\ &\times \frac{(6 \text{ F16s/tracklap})(3 \text{ tracklaps/sortie})_{F16}}{(6 \text{ F15s/tracklap})(1 \text{ tracklap/sortie})_{F15}} = 1.012 \end{aligned}$$

$$[F-111s/F-16s]_1$$

$$\phi = \frac{(100 \text{ F111s})(8.1)(6)(3)}{(700 \text{ F-16s})(9.4)(6)(1)} = 0.369$$

$$[RF-4Cs/F-16s]_1$$

$$\psi = \frac{(100 \text{ RF4Cs})(10.8)(6)(3)}{(700 \text{ F-16s})(9.4)(6)(2)} = 0.246$$

Therefore, the apportionment of KC-10s to F-16 AR Track 1 was

$$\begin{aligned} A_1 &= 100\% / [(1.611) + (1.935)(1.012) \\ &\quad + (1.673)(0.369) + (3.574)(0.246)] \\ &= 100\% / 5.066 \\ &= 19.74\% \text{ of the Total KC-10s} \end{aligned}$$

From the above value, the remaining values were calculated. First, the apportionment of KC-10s to F-16 AR Track 2 was:

$$A_2 = (a_2/a_1) A_1 = (0.611)(19.74) = 12.06\% \text{ of the KC-10s}$$

Likewise, for the F-15 AR Tracks:

$$B_1 = \theta A_1 = (1.012)(19.74) = 19.977\% \text{ of the KC-10s}$$

$$B_2 = (b_2/b_1) B_1 = (0.622)(19.977\%) = 12.42\%$$

$$B_3 = (b_3/b_1) B_1 = (0.314)(19.977\%) = 6.263\%$$

For the F-111 AR Tracks:

$$C_1 = \phi A_1 = (0.369)(19.74) = 7.248\% \text{ of the KC-10s}$$

$$C_2 = (c_2/c_1) C_1 = (0.673)(7.248) = 4.901\%$$

For the RF-4C AR Tracks:

$$D_1 = \psi A_1 = (0.246)(19.74) = 4.856\% \text{ of the KC-10s}$$

$$D_2 = (d_2/d_1) D_1 = (0.768)(4.856\%) = 3.731\%$$

$$D_3 = (d_3/d_1) D_1 = (0.648)(4.856\%) = 3.147\%$$

$$D_4 = (d_4/d_1) D_1 = (0.704)(4.856\%) = 3.417\%$$

$$D_5 = (d_5/d_1) D_1 = (0.454)(4.856\%) = 2.205\%$$

The following table summarizes KC-10 track apportionments:

Table 4.3						
APPORTIONMENT OF TTF KC-10 S						
AMONG AR TRACKS						
FIGHTER	AR 1	AR 2	AR 3	AR 4	AR 5	
F-16	19.7 %	12.1 %				
F-15	20.0	12.4	6.26			
F-111	7.3	4.9				
RF-4C	4.9	3.7	3.1	3.4	2.2	

Finally, since the TTFs were to be allocated in accordance with the rule "the closest TTF must refuel the AR Track" then, following the above AR Track apportionments, the TTFs' apportionments had to be:

$$\begin{aligned} \text{Goose Bay TTF} &= A_1 + (B_1 + B_2) + (C_1 + C_2) \\ &\quad + (D_1 + D_2 + D_3) = 76.055\% \end{aligned}$$

$$\begin{aligned} \text{Mildenhall TTF} &= A_2 + B_3 \\ &\quad + (D_4 + D_5) = 23.945\% \end{aligned}$$

Thus, the value of the [3rd Addend] could be calculated as follows:

$$\text{time} = 365.55 / 19.74 = 18.52 \text{ hours (if 100 TTF tankers)}$$

$$\begin{aligned} \text{time} &= 18.52 / .60 = 30.86 \text{ hours} \\ &\quad \text{(if 60 TTF tankers)} \end{aligned}$$

$$\begin{aligned} \text{time} &= 18.52 / .20 = 92.60 \text{ hours} \\ &\quad \text{(if 20 TTF tankers)} \end{aligned}$$

Closure Time was then calculated using the following values for the remaining addends:

$$\begin{aligned} [\text{1st Addend}] &= \text{TTF Set-up Time} = 3 \text{ hours notification} \\ &\quad + 5 \text{ hours preparation} \\ &\quad + 3 \text{ hours cargo loading} \\ &\quad + 2 \text{ hours preflight} \\ &\quad + 5 \text{ hours flight time} \\ &\quad + 3 \text{ hours unloading} \\ &\quad + 13 \text{ hours crew rest} \\ &\quad + 2 \text{ hours preflight} \\ &= 36 \text{ hours} \end{aligned}$$

[2nd Addend] = KC-10 Flight Time to ARCP = 2 hours

[4th Addend] = Fighter Flight Time
from ARCP to Destination = 7 hours

$$\begin{aligned} [3rd \text{ Addend}] + [5th \text{ Addend}] &= \frac{[3rd \text{ Addend}]}{\text{KC-10 AR reliability}} \\ &= 92.6 \text{ hours, } 100\% \text{ reliable} \\ \text{or} &= 97.5 \text{ hours, } 95\% \text{ reliable} \\ \text{or} &= 102.9 \text{ hours, } 90\% \text{ reliable} \end{aligned}$$

Thus, for this fighter deployment scenario, with 20 KC-10s in the Distinct Roles TTF mission (assigned to Goose Bay and Mildenhall), using fighter to tanker ratios of 6:1, assuming scheduled ground times of 3 hours, and a TTF launch reliability of 95%, then the expected Closure Time for the fighters was computed to be:

$$36 + 2 + 7 + 97.5 = \underline{142.5 \text{ hours}}$$

(or 6 days, 4 hours)

Computerized Model. The above equations for finding the TTF Closure Time and KC-10 apportionment among AR Tracks are fairly complex, and certainly tedious to calculate manually. Thus, in order to accomplish further analysis for this thesis, and hopefully, for other future researchers, a computerized model of the TTF Deterministic Equations was built. The computerized model verified the hand-calculated results shown on the previous pages. Also, the computer output is found in Appendix B. The self-documenting source code is found in Appendix B. This computer model accomplishes the following:

<u>Input</u>	<u>Major Functions</u>	<u>Output</u>
All AR Track Information	Calculate Great Circle Distances between TTFS, AR Tracks	Track and TTF Apportionment of KC-10s
Locations of TTFS	Search for closest TTF to each AR Track	Closure Time
	Call modified "TANKER" -determines sortie duration -maximum feasible number of "tracklaps"	
	Use Deterministic Equations -KC-10 apportionment -Fighter Closure Time	

Figure 4.3 Overview of Deterministic Computer Program

The "input" information required by the FORTRAN program "TTFDETERM" is listed in Figure 4.4 on the following page.

For every AR Track:

Coordinates (Latitude, Longitude) of the ARCP, EAR

Names of fighter (ie: "F-15") being refueled

Air refueling attitude

"	"	calibrated airspeed
"	"	time down track
"	"	distance down track
"	"	fuel offload

For every TTF:

Coordinates of the airfield (latitude, longitude)

Name of the airfield (ie: "Mildenhall")

KC-10 Maximum Takeoff Gross Weight at that airfield

For the deployment:

Numbers of deploying fighters, by type

Number of fighters in each flight
(ie: fighter to tanker ratio)

Number of KC-10s supporting the deployment

KC-10 Reliability

KC-10 Ground Turn-around Time

TTF Setup time

Figure 4.4. Input to Deterministic Program

Using the above information, the program follows the following pseudo-code logic:

Call "CalcDistance" to find:

Distances between TTFs and ARCPs
by calling "GreatCircle"
(based on spherical trigonometry (2:199))

Distances between TTFs and EARs
by calling "GreatCircle"

Call "NonDominated" to find:

Closest TTF to each AR Track

For every fighter

With the TTF closest to each AR Track

Call "Tanker" to determine:

The maximum feasible # Tracklaps/KC-10 sortie
KC-10 sortie duration

Call "Closure Time" to get:

Optimal apportionment of KC-10s to AR Tracks, TTFs
Closure Time for deploying fighters

Figure 4.5. Deterministic Program Logic

Distinct Role Airlifter-only KC-10s and Dual Role KC-10s

Basis for the Equations. In deriving these Airlifter equations, it was necessary to assume that there was no queuing of KC-10s (such as waiting for fighters, cargo, cargo loaders, or aircrews), and that every mission was independent of the others. Based on these two assumptions, the time to deploy (Closure Time) was computed as the sum of the time required for consecutive deterministic events to occur. Consecutive events were transAtlantic laps by individual cargo-carrying airlifter (or Dual Role) KC-10s. The important assumption was made that the KC-10s should fly concurrent missions, or "carry their own load." That is, all KC-10s were to fly an equal portion of the missions. Thus, with every transAtlantic lap flown by every KC-10 having the exact same duration, the Closure Time (C.T.) for the cargo closure for Distinct Role Airlifter KC-10s (and fighter and cargo closure for Dual Role KC-10s) would be:

$$C.T. = \sum_{\substack{\text{number} \\ \text{of laps}}} (\text{time per lap})$$

Equation for Airlifter or Dual Role Missions. On Airlifter-Only missions, the KC-10s in this scenario can carry approximately 80,000 to 120,000 pounds of cargo. For Dual Role missions, the KC-10 carries 10,000 pounds of cargo for each fighter that deploys with the KC-10. So, the Dual Role KC-10s can be modelled with the airlifter equations. The only difference is that the Dual Role KC-10s carry much

less cargo per lap because of the increased quantity of transferable fuel that must also be carried. Thus, the equation is the same for both Distinct Role Airlifter and for Dual Role KC-10s.

Cargo Closure Time is simply the sum of set-up time plus (Time/Trip) x (No. of Trips). To be mathematically strict, for developing a Closure Time equation, the KC-10s must make one "one-way" trip, followed by several "two-way" trips, or "laps" across the Atlantic. Thus, the cargo Closure Time equation is:

$$\begin{aligned} \text{Closure Time} = & \left[\frac{(\text{Total Cargo})}{(\text{Cargo per KC-10, per lap})} \times \frac{1}{(\text{No. of KC-10s})} \right. \\ & \left. - 1 \text{ Trip} \right] \text{ laps} \\ & \times (\text{Time per lap}) \\ & + (\text{Preparation Time} + \text{First One-way Trip}) \end{aligned}$$

In the above equation, the terms "Total Cargo" and "Cargo per KC-10 per lap" could also be expressed in terms of cargo per fighter:

$$\begin{aligned} \text{Total Cargo} &= \frac{(\text{pounds of Cargo})}{(\text{Fighter})} \times (\text{Number of Fighters}) \\ \frac{\text{Cargo}}{\text{KC-10 - lap}} &= \frac{(\text{No. of Pallets})}{(\text{KC-10 - lap})} \times \frac{(\text{Pounds of Cargo})}{\text{Pallet}} \end{aligned}$$

Therefore, Closure Time becomes:

$$\begin{aligned}
 \text{Cargo Closure Time} = & \frac{(\text{pounds of Cargo}) \times (\text{Number of Fighters})}{(\text{Fighter})} \\
 & \% \frac{[(\text{No. of Pallets}) \frac{(\text{Pounds of Cargo})}{\text{Pallet}}]}{[(\text{KC-10} - \text{lap})]} \\
 & \% [\text{No. of KC-10s}] - 1 \text{ Trip} \\
 & \times (\text{Time/lap}) \\
 & + (\text{Preparation Time} + \text{First One-way Trip})
 \end{aligned}$$

Example of Closure Time for Distinct Role Airlifters. The total amount of cargo that had to be deployed in this scenario was:

$$\begin{aligned}
 (1200 \text{ Fighters}) \times (10,000 \text{ lbs cargo/fighter}) \\
 = 12,000,000 \text{ lbs cargo}
 \end{aligned}$$

Consider a fleet of Airlifter-Only KC-10s which can each carry 80,000 pounds of cargo on each trip they make across the Atlantic. Each lap takes 45 hours. Let Preparation plus First Trip time also be 45 hours. For this situation, Cargo Closure Time would be:

$$\begin{aligned}
 \text{Cargo Closure Time} = & \frac{12,000,000 \text{ lbs}}{(80,000 \text{ pounds}/(\text{KC-10 lap}))} \times \frac{1}{(\text{No. of KC-10s})} - 1 \text{ trip} \\
 & \times 45 \text{ hrs/lap} \\
 & + 45 \text{ hrs for Preparation and 1st One-way Trip} \\
 = & 168 \text{ hours (ie: 1 week)}
 \end{aligned}$$

By combining terms, we can see that 150 KC-10 laps are required:

$$\begin{aligned} &= 150 \text{ KC-10 laps} \times \frac{1}{(\text{No. of KC-10s})} - 1 \\ &\quad \times 45 \text{ hours/lap} \\ &\quad + 45 \text{ hours for Preparation and 1st Trip} \end{aligned}$$

If we had 150 KC-10s available for the airlifter-only mission, the cargo deployment could be accomplished in a single one-way trip. Any smaller number of KC-10s would necessitate return "laps" to pick up the remaining cargo. For instance, if we had 50 KC-10s, 3 trips would be required: all the KC-10s would make one "one-way trip" to Europe, then return for 2 more "laps."

Note that the Cargo Closure Time is inversely proportional to the number of KC-10s in the Airlifter-Only Mission. That is, 150 KC-10s deploy all the cargo in one lap, but when the number of KC-10s was decreased to 50, one-third of the original, the number of laps triples. If a graph were drawn of "KC-10s versus laps," it would have a hyperbolic shape. These graphs will be discussed in Chapter 5, Results and Conclusions.

Explanation of Dual Role Closure Time. As was stated earlier, the same Closure Time equation used for Dual Role KC-10s was used for Distinct Role Airlifters. The amount of cargo carried by the Dual Role KC-10, however, is much less than carried by the Airlifter-Only KC-10s. This is because of the requirement to carry large quantities of transferable fuel to offload to the fighters. Because of higher KC-10 fuel consumption in the Dual Role, less transferable fuel can be transported. Specifically, the Dual Role KC-10s consumed approximately 30,000 pounds more fuel (depending on fighter refueling speed and cruise altitude) in the given scenario. (See Tanker Data for Dual Role, in Appendix C). The Dual Role KC-10s could therefore carry less payload of cargo and transferable fuel.

Recall the discussion in Chapter II which showed that unrefueled Dual Role KC-10s could only deploy the following numbers of fighters plus their supporting cargo:

4 F-16s	+	40,000 pounds cargo	
2 F-15s	+	20,000	" "
2 F-111s	+	20,000	" "
2 RF-4Cs	+	20,000	" "

For the Dual Role KC-10s, the number of KC-10 trips required to deploy each type of fighter is:

$$\begin{aligned}
 \text{KC-10 trips(F-16s)} &= \frac{10,000 \text{ lbs}}{\text{Fighter}} \times 700 \text{ F-16s} \\
 &\times \frac{1 \text{ KC-10 trip}}{40,000 \text{ lbs}} \\
 &= 175 \text{ trips}
 \end{aligned}$$

$$\begin{aligned}
 \text{KC-10 trips(F-15s)} &= \frac{10,000 \text{ lbs}}{\text{Fighter}} \times 300 \text{ F-15s} \\
 &\times \frac{1 \text{ KC-10 trip}}{20,000 \text{ lbs}} \\
 &= 150 \text{ trips}
 \end{aligned}$$

$$\begin{aligned}
 \text{KC-10 trips(F-111s)} &= \frac{10,000 \text{ lbs}}{\text{Fighter}} \times 100 \text{ F-111s} \\
 &\times \frac{1 \text{ KC-10 trip}}{20,000 \text{ lbs}} \\
 &= 50 \text{ KC-10 trips}
 \end{aligned}$$

$$\begin{aligned}
 \text{KC-10 trips(RF-4Cs)} &= \frac{10,000 \text{ lbs}}{\text{Fighter}} \times 100 \text{ RF-4Cs} \\
 &\times \frac{1 \text{ KC-10 trip}}{20,000 \text{ lbs}} \\
 &= 50 \text{ KC-10s trips}
 \end{aligned}$$

Summing the above numbers, the Total number of KC-10 trips required for deploying all four types of fighters is

$$175 + 150 + 50 + 50 = 425 \text{ KC-10 trips}$$

Now, solving for Closure Time,

$$\begin{aligned}
 \text{C.T.} &= \left[\frac{425 \text{ KC-10 trips}}{\text{No. of KC-10s (ie: 60)}} - 1 \text{ trip} \right] \text{ laps} \times 45 \text{ hrs/lap} \\
 &+ \text{ set up time (ie: 36 hrs)} \\
 &+ \text{ flight time for 1st one-way trip (ie: 9 hrs)}
 \end{aligned}$$

$$\begin{aligned}
 \text{C.T.} &= [(7.08) - 1] \times 45 + 36 + 9 \\
 &= 319 \text{ hrs} \\
 &= 1 \text{ week, 6 days, 7 hours}
 \end{aligned}$$

Conclusion

This chapter explained that, although simulation would have been preferred, the research returned to deterministic equations to provide the calculations for the apportionment of the TTF KC-10s to all the AR tracks. The deterministic Closure Time equations were developed for

1. fighters refueled by Distinct Role TTF KC-10s
2. cargo, whether by Airlifter-Only KC-10s or by Dual Role KC-10s.

In the following chapter, Results and Analysis, the better KC-10 role is selected, based on the Closure Time MOE. Also, the implications of the deterministic equations are discussed as they relate to sensitivity analysis. Graphs of "Closure Time versus Number of KC-10s" are used to explain the apportionment of KC-10s between the Distinct Role TTF and Airlifter Missions.

V. Results and Analysis

Introduction

As stated in Chapter I, the problem of finding the better KC-10 Role was solved by meeting four objectives. The first objective, develop an appropriate model to calculate Closure Time for each KC-10 Role, was accomplished in Chapter IV. This chapter will summarize the results of those calculations and then discuss the accomplishment of the remaining three objectives--evaluate model sensitivity, select the best factor settings, and then determine if there is a significant difference between the alternatives of Dual Role or Distinct Role KC-10 operation.

Closure Time Results

In the previous chapter, it was shown the the Closure Time for the (unrefueled) Dual Role KC-10s was more than twice that of the Distinct Role KC-10s.

Dual Role (based on 60 Dual Role KC-10s, unrefueled)

Closure Time = 319 hrs = 1 wk, 6 days, 7 hrs

Distinct Roles

Fighters (based on 20 TTF KC-10s)

Closure Time = 142 hrs = 5 days, 22hrs

Cargo (based on 40 Airlifter-Only KC-10s)

Closure Time = 141 hrs = 5 days, 21 hrs

Overall

Closure Time = Greater of (142, 141 = 142 hours

Figure 5.1. Summary of Closure Time Results

Sensitivity Analysis

Overview. The above results were based on specific values of terms in the deterministic Closure Time Equations. Because those values were uncertain, it was important to examine how sensitive the Closure Time was to changes in those terms.

After a review of the sensitivity analysis, it will be explained how the TTF KC-10s were apportioned among the AR tracks. The decision as to how to apportion the 60 Distinct Role KC-10s between the TTF and Airlifter Missions is shown using their hyperbolic curves. Finally this section will examine the sensitivity of the choice between Dual Role and Distinct Roles.

Analysis of TTF Equations. Recall that the TTF Closure Time equation was described as the sum of the times required for five events (ie: five addends).

Closure Time =

- Time to Set-up TTF [1st addend]
- + Time for KC-10 to fly to the ARCP (for 1st "track lap"). (Assume fighters launch as necessary to arrive on time.) [2nd addend]
- + Time it takes the TTF KC-10s to transport sufficient fuel to the ARCP to refuel all the fighters. [3rd addend]
- + Time for last fighter to fly from ARCT to destination. [4th addend]
- + Time necessary for aborted fighters to arrive at destination. [5th addend]

The [3rd addend] of the Closure Time was:

[3rd Addend] = Time to transport all fuel (for one type of fighter) to ARCP, per KC-10

= Sortie interval x Number of consecutive Sorties required

= $\frac{\text{Airborne Mission Time} + \text{Ground turn around time}}{\text{sortie}}$

x $\frac{(\# \text{ Fighters/AR Track})}{(\text{KC-10s/AR Track})} \frac{(\# \text{ Fighters}) (\text{track laps})}{(\text{track lap}) (\text{sortie})}$

The effect of fighters aborting their missions due to missed ARs (due to KC-10 reliability) was that the deployment took longer because they had to be refueled again:

$[\text{3rd Addend}] + [\text{5th Addend}] = \frac{[\text{3rd Addend}]}{\text{Average AR Reliability}}$

Using these TTF equations, the sensitivity of Closure Time on changes in each term was then analyzed using mathematic relationships of the terms in the equation. Because the equation is deterministic, a change in one factor causes a predictable effect on the MOE, Closure Time. This cause-effect relationship will now be described for all of the terms in the equation, starting with the 1st addend:

First Addend: Time to set-up TTF. Any error in this term is directly add. to the Closure Time. For example, this scenario used an estimated TTF Set-up Time of 36 hours. If TTF Set-up Time were actually 48 hours, then Closure Time would also increase by 12 hours: $142 + 12 =$

154 hours. Notice that, although this error is directly additive to the Closure Time, the scale of the error is relatively insignificant: a 12 hour (half-day) error is only about 8.5% of the total Closure Time value. This term, Time to Set up, will be discussed again, later, in reference to how it affects the overall decision between Distinct Roles and Dual Role.

Second Addend: Time for KC-10 to fly to the ARCP. Again, as with every addend, error in this term adds directly to the MOE, Closure Time. This term, however, introduces extremely little error, because it is small (less than 3 hours) and it is accurately predicted (flight times are accurate within minutes).

Third Addend: Time for the KC-10s to carry all fuel to the ARCP. this is the most significant term in the TTF Closure Time equation. In this scenario, the 3rd Addend = 92.6 hrs, or about 65% of the Closure time (142 hours). The 3rd Addend is the product of two major terms:

[3rd Addend] =

Sortie interval x Number of consecutive Sorties required

1. Sortie Interval. Any error in this term is multiplied into the error of the 3rd Addend. Considering the scale of the 3rd Addend, a 10% change in Sortie interval

would cause about a 6.5 % change in Closure Time. The term Sortie Interval is actually the sum of two other terms:

Sortie interval =

$$\frac{\text{Airborne Mission Time}}{\text{sortie}} + \text{Ground turn around time}$$

a. Airborn Mission Time. This term is very accurate, contributing only a few minutes to the error in sortie interval.

b. Ground Turn-Around Time. This term is the crux of the whole TTF concept. This term has direct, but unknown effects on the mission reliability of the KC-10, thus affecting fighter abort rate. The value of this term is, therefore, the result of a managerial decision that will have to be made in the future. Many operators "feel" that 3 hours is reasonable (reference 27,28,31) MACREG 28-2 specifies as little as 1 hour + 45 minutes for "gas and go." My own simulation model (See Appendix G) produced an unrealistically large value of 8 hours (to obtain a 91.3% KC-10 launch reliability). This is a very significant range of values.

Notice that the effect of this value on Sortie Interval depends on the relative sizes of the two terms, Airborne Mission Time and Ground Turn-around Time. Airborne Mission Time, however, is different for every AR track. If Airborne Mission Time was 7 hours

(typical of Goose Bay TTF missions) and Ground Turn-around Time was 3 hours, then a ± 1 hour variance in Ground Turn-around Time would cause Sortie Interval to be $7 + 3 = 10$ hours, ± 1 hour. Thus, a ± 1 hour variance in Ground Turn-around Time would have the following effects: 10% change in Sortie Interval, which would cause a 10% change in Addend 3, which would cause a 6.5% change in Closure Time. But, if Airborne Mission Time was 10 hours (typical of Mildenhall TTF missions, since less fuel is offloaded per AR, making possible more ARs per sortie) then uncertainty in Ground Turn-around Time would have significantly less impact: Sortie Interval = 13 hours ± 1 hour. This would only be a 7.7% change in Addend 3, causing a 5% change in Closure Time. In general, if Ground Turn-around Time is a large portion of Sortie Interval, then it has a greater effect on Closure Time.

This implies that the decision-maker's choice of Ground Turn-around time should be different for each TTF, since the effect on Closure Time would be different.

The following graph displays the resulting effect on Closure Time caused by different selections of values for Ground Turn-around Time. It should be realized that changes in Ground Turn-around Time would change the apportionment of KC-10s among the AR Tracks. Changes in Ground Turn-around Time would also affect

reliability (for instance, if available maintenance time were increased, reliability would also increase).

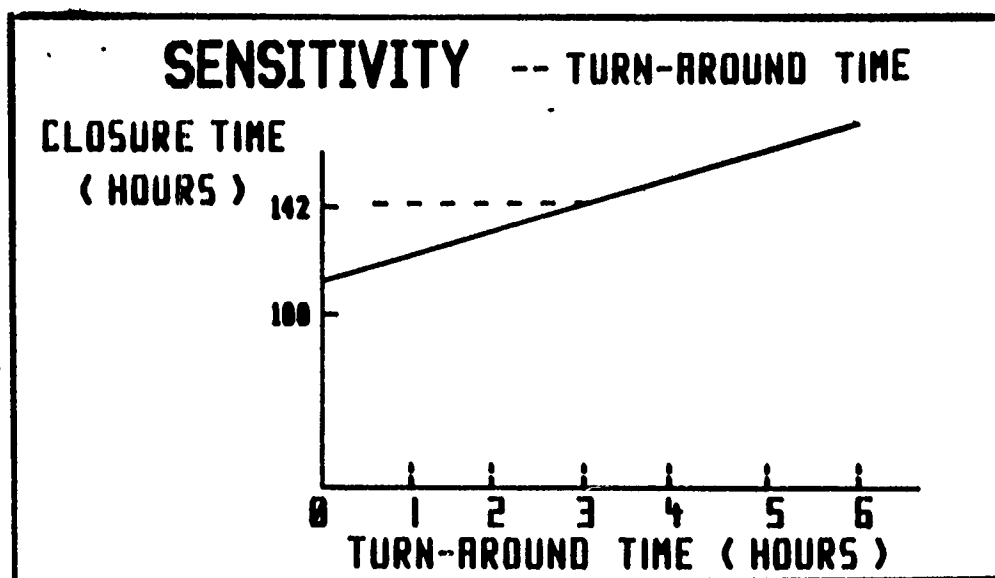


Figure 5.2 Sensitivity of Closure Time to changes in TTF Ground Time

2. Number of consecutive sorties required. This term is also very significant. Because it is a "multiplicand" (ie: a factor), any change in this term would cause a proportional change in Addend 3. Recall that this term was also the product of several factors:

Number of consecutive sorties required =

$$\frac{(\# \text{ Fighters/AR Track})}{(\text{KC-10s/AR Track})} \frac{(\# \text{ Fighters})}{(\text{track lap})} \frac{(\text{track laps})}{(\text{sortie})}$$

a. Number of Fighters/AR Track. Since this term is in the numerator, it is apparent that changes in this term would cause proportional changes in Addend 3. For instance, if, instead of 1200 fighters, the deployment were increased by 120 (a 10% increase, of every type fighter) to 1320 fighters, then Addend 3 would increase by 10%. It should be noted that if the quantity of only one type of fighter (F-16s, for instance) were to be changed, then the apportionment of tankers would also change to meet the increased need of that one type of fighter. In that case, the change in Addend 3 would not be 10%, but would depend on the relative efficiency of the refuelings provided to that fighter. For example, an increase of 120 F-16s, which use very little fuel, would cause less change in Closure Time than would an increase of 120 fuel-hungry RF-4Cs.

b. Number of KC-10s per AR Track. This is the "apportionment" term. Since this term is in the denominator, a change in the number of KC-10s would cause an "inversely proportional" change in Addend 3. For example, a doubling of the number of available KC-10s would halve the value of Addend 3. The following hyperbolic curve on the next page illustrates this inverse proportionality:

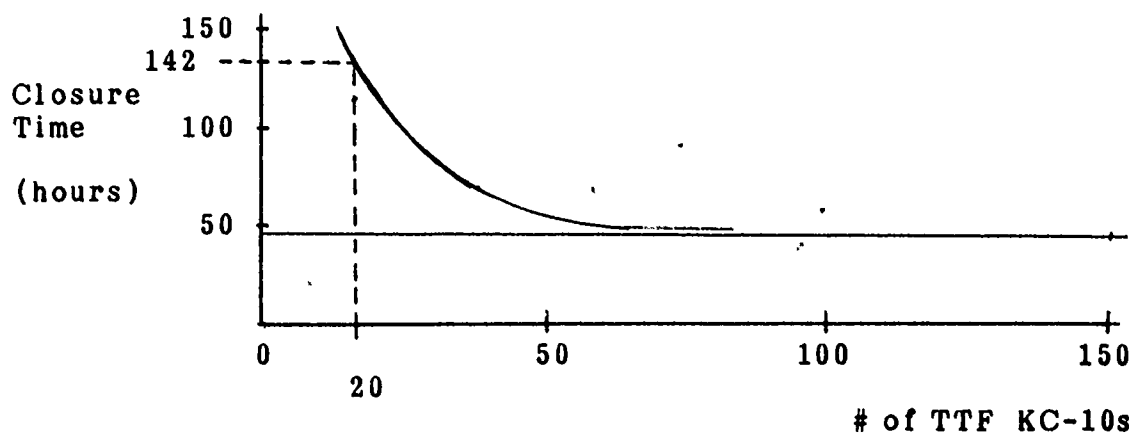


Figure 5.3. Sensitivity of Closure Time
to Number of TTF KC-10s

c. Number of Fighters/Sortie. This term is the product of two factors: Fighters/Tracklap (also known as Fighter-Tanker Ratio) and Track Laps/Sortie. Again, since the terms are in the denominator of the Third Addend equation, they cause an inversely proportional effect. It should be pointed out, however, that a change in Fighter-Tanker Ratio affects the values of Track Laps/Sortie and Airborne Mission Time. Furthermore, it would cause a change in KC-10 apportionment. Thus, the selection of Fighter-Tanker Ratio, which could be calculated for each type of fighter, would be very scenario dependent.

Fourth Addend: Time for the last fighter to fly from the ARCT to the Destination. Like all other addends, the effect of any error in this term would cause an "additive" error to Closure Time. This Fourth Addend is

known very accurately, to within minutes, therefore adding minimal error to the value of Closure Time.

Fifth Addend: Time for aborted fighters to fly to destination. Recall that this term was expressed in terms of the Third Addend and AR Reliability:

$$[3\text{rd Addend}] + [5\text{th Addend}] = \frac{[3\text{rd Addend}]}{\text{Average AR Reliability}}$$

As was mentioned earlier, AR Reliability (which, from the maintenance point of view is Probability of Launching on Time) is dependent upon the value chosen for TTF Ground Turn-around Time (which is essentially Time Allowed for KC-10 Repair). The nature of this relationship is presently unknown. There is therefore, a need for a future study to calculate the "Time to Repair" distribution for the KC-10.

In the meantime, the issue was addressed in the following manner: Choose a value for Ground Turn-around Time, which, in turn, determines the value of Addend 3. Based on that value, vary the AR Reliability to examine sensitivity. Figure 5.5, on the following page, shows several curves of Closure Time versus AR Reliability, based on different values of Ground Turn-around Time.

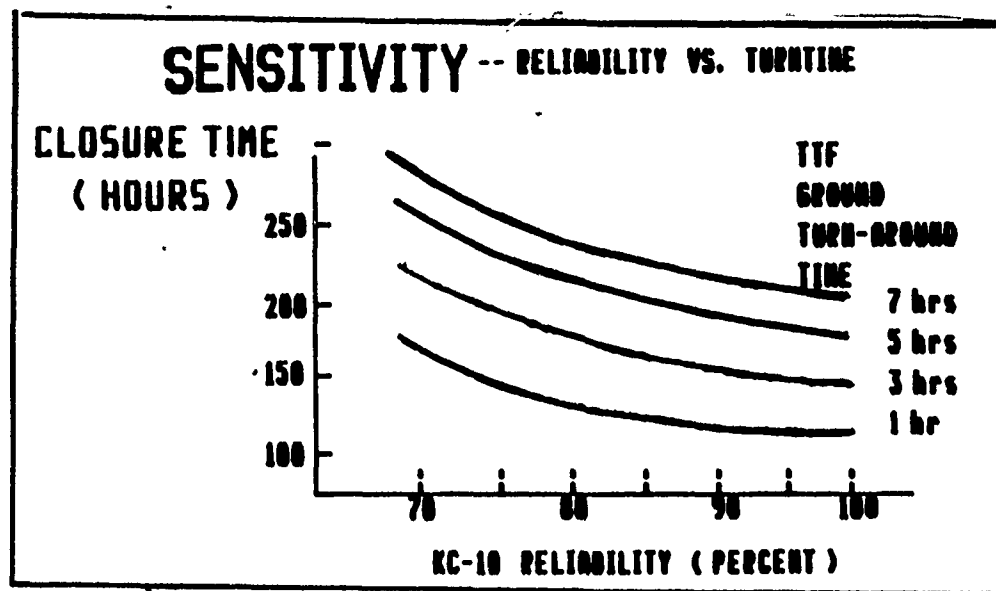


Figure 5.5. Sensitivity of Closure Time to TTF AR Reliability.

From this type of graph, a future decision-maker could see that it would be better to have a 5 hour Ground Turn-around Time with a 95% reliability than a 1.75 hour Turn-around Time with a 75% reliability. This graph, if used in conjunction with a graph of the "Time to Repair" distribution, would allow the decision-maker to choose the Ground Turn-around Time which would yield the best Closure Time. Both graphs are essential to the process. Figure 5.6 is a hypothetical example of a Maintenance Repair Time Distribution. (Appendix G contains the Maintenance Repair Time Distribution from the SLAM model of KC-10 maintenance.)

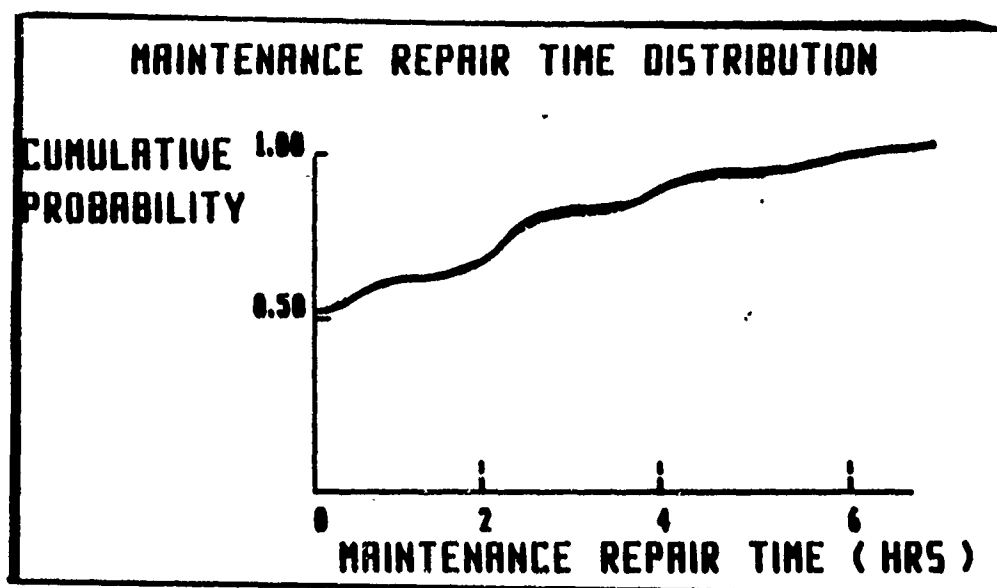


Figure 5.6. Hypothetical Maintenance Repair Time Distribution

Because the "Time to Repair" distribution is currently not available, it is impossible at this time to pick the best Ground Turn-around Time.

Analysis of Airlifter-Only Equations. Recall that the Airlifter (and Dual Role) Equation was derived as:

$$\begin{aligned}
 \text{Cargo Closure Time} = & \frac{(\text{pounds of Cargo}) (\text{Number of Fighters})}{(\text{Fighter})} \\
 & \% \frac{[(\text{No. of Pallets}) (\text{Pounds of Cargo})]}{[(\text{KC-10} - \text{lap}) \text{ Pallet}]} \\
 & \% [\text{No. of KC-10s}] - 1 \text{ Trip} \\
 & \times (\text{Time/lap}) \\
 & + (\text{Preparation Time} + \text{First One-way Trip})
 \end{aligned}$$

Again, using the mathematical relationships between the terms in the above equation, the sensitivity analysis is

very straight-forward. The following relationships exist between Closure Time and the terms in the equation:

Preparation Time--Additive. If Preparation Time is changed by 1 hour, Closure Time is also changed by 1 hour.

Time per Lap--Directly proportional. If lap time were increased by 4.5 hours (a 10% change), then the Total Lap Time would also increase by 10%. (Notice that, to get Closure Time, the Preparation Time term must be added to Total Lap Time.)

Average Cargo Weight--Inversely proportional (not including the additive term). It is very significant that the cargo load is uncertain within the range of 80,000 to 120,000 pounds per KC-10. This causes an uncertainty in Cargo Closure Time (and in apportioning between TTF and Airlifter roles!) of $\pm 20\%$.

Number of KC-10s--The number of trips to Europe required of the fleet of Airlifter-only KC-10s is clearly inversely proportional to the number of cargo-carrying KC-10s in the Airlifter-only mission. Figure 5.7 on the following page displays this relationship of Closure Time to the Total Number of Airlifter KC-10s.

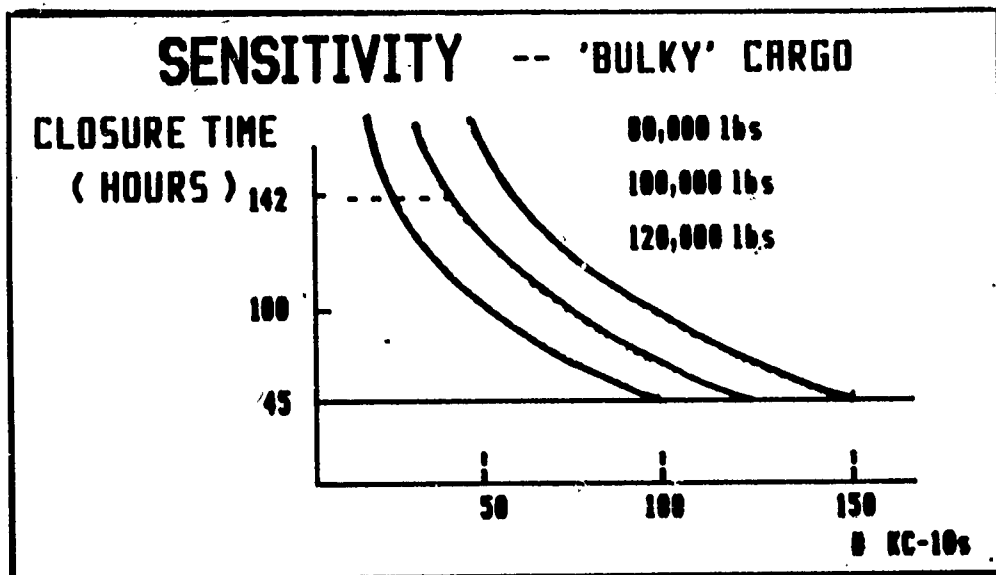


Figure 5.7. Sensitivity of Cargo Closure Time to the Number of KC-10s and the Cargo Weight

Apportionment of KC-10s between TTF and Airlifter Missions. The assignment of KC-10s to these two missions within the Distinct Roles concept is optimized when both have equal Closure Times. Figure 5.8 on the following page depicts the graphs of TTF and Airlifter "Closure Times vs. Number of KC-10s." It can be seen that the best overall Closure Time of 142 hours is achieved when 20 KC-10s are assigned to the TTF mission and 40 KC-10s are assigned to the Airlifter-only mission.

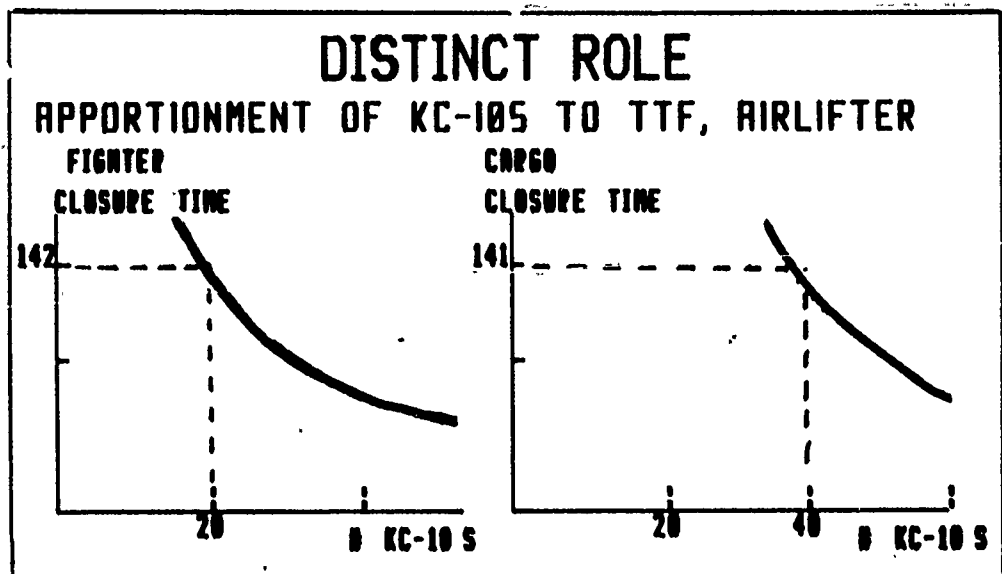


Figure 5.8. Apportionment of KC-10s between TTF, Airlifter Missions

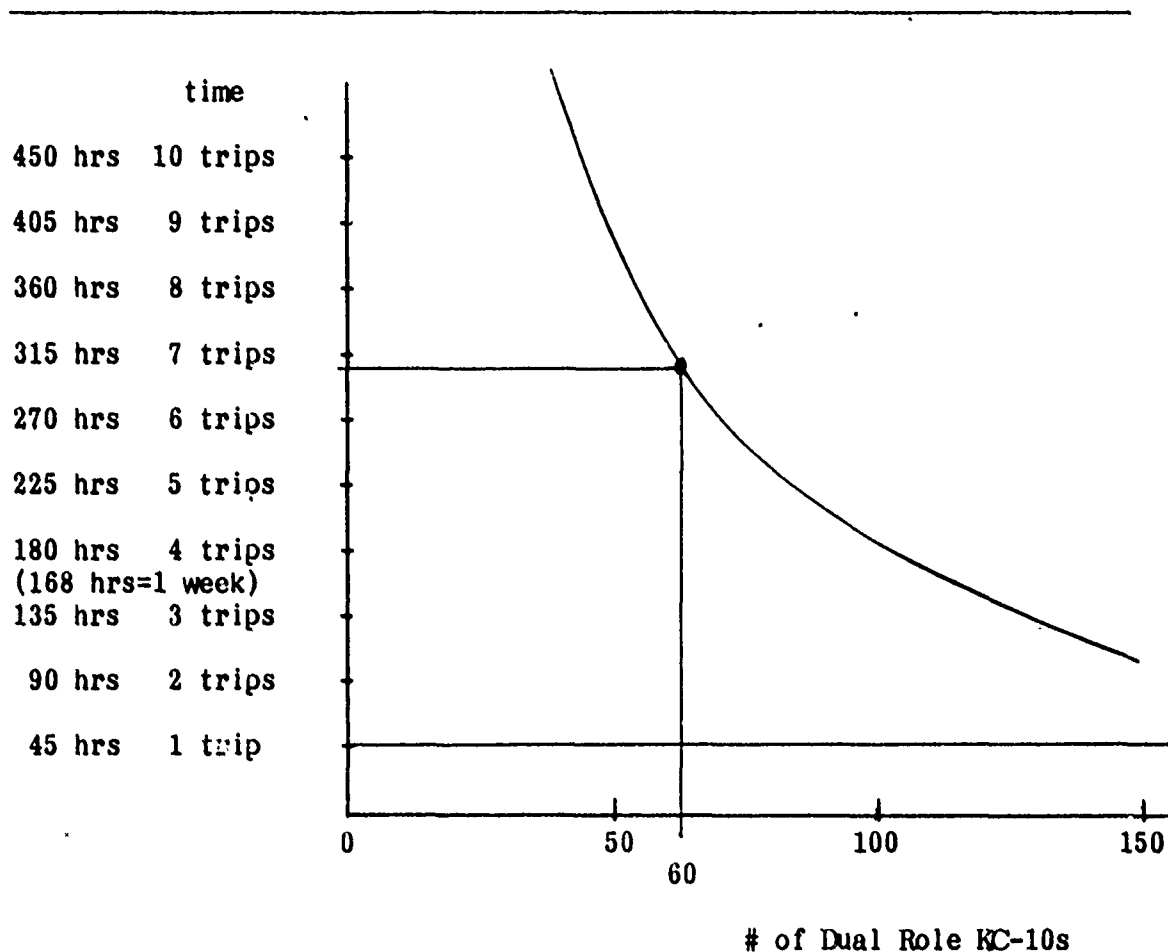
Analysis of Dual Role Closure Time Equations

Since the Dual Role Closure Time was calculated using the same equation as the Distinct Role Airlifter Closure Time, the sensitivity to uncertainty or to managerial changes is the same. Unlike the Airlifter-only KC-10s, the Dual Role KC-10s are not "bulked-out" (since the Dual Role KC-10s carry so little cargo). Because of this, Pallet Weight is not a consideration for the Dual Role KC-10s. The most important factor in the Dual Role operation is the Number of KC-10s assigned.

Figure 5.9 on the following page illustrates the sensitivity of Dual Role Closure Time to the number of KC-10s. On the graph, the number of KC-10s actually available, 60, is so small, compared to the number required to accomplish the deployment in one trip, as to place the Closure Time in the steeply increasing part of the

hyperbolic curve. In this part of the curve, sensitivity to all factors is more pronounced.

The following graph displays this relationship of Closure Time to Total KC-10s.



Note: This Figure assumes the KC-10s are not given additional air refuelings

Figure 5.9. Dual Role Closure Time vs. Total Number of KC-10s

Significance of the Difference Between Roles

The following Figure 5.10 charts the times of the the arrivals of fighters and cargo at the destination, as delivered by the two deployment concepts, Dual and Distinct Roles.

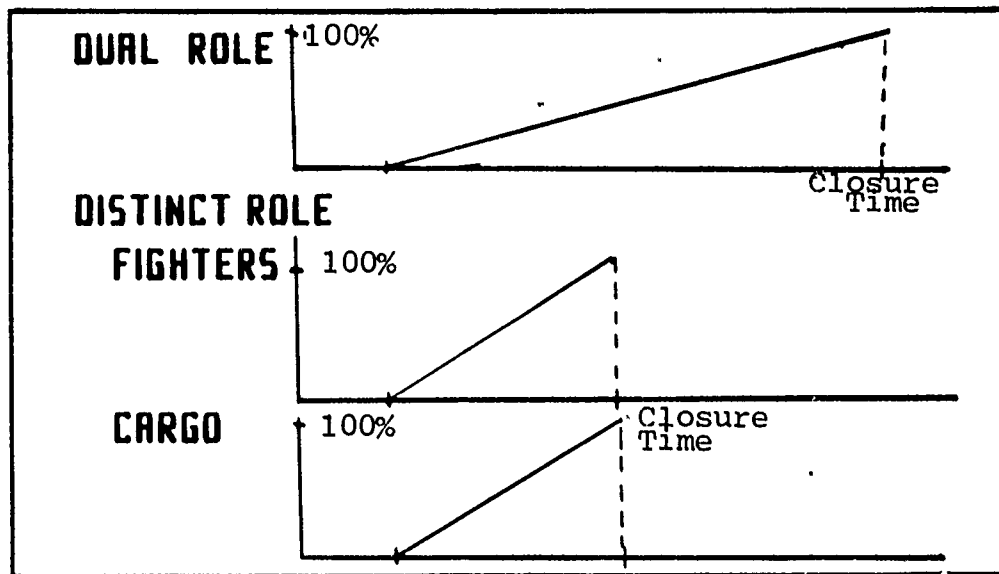


Figure 5.10. Cumulative Arrival of Fighters and Cargo for Dual and Distinct Role Deployment

The only parts of the chart that differ between the two concepts are:

1. slope of the cumulative arrivals (arrival rate)
2. horizontal displacement of the first arrival

In terms of this visual concept, the major sensitivity question that has to be asked then, is "is there sufficient uncertainty in the slope or in the horizontal displacement of the two Roles to doubt that Distinct Roles is better?"

In the above graphs, the horizontal displacement is the Set-up Time plus time to fly the first trip across the ocean. For the horizontal displacement to make up the difference between the Roles would require an error of incredible magnitude: 4 days!

The slope of the TTF deployment (ie: the rate of fighter refuelings) is the next part of the graph to be examined. The crux of the TTF is the ability of the KC-10s to rapidly and reliably "turn-around" for their next mission. In order for uncertainty in the slope to cause an uncertainty of greater than 4 days would require a doubling of the AR Interval (inverse of the rate). To do that would require "turn-around" times of about 12 hours. That would be ridiculously poor performance.

Another question that might be asked is--Would a combination of errors in the slope and displacement in the TTF deployment graph cause it to lose to the Dual Role concept? That would require, for example 2 days set-up and a 50% increase in sortie interval. Even that is not reasonable.

Next, the graph of the Airlifter-only deployment must be considered. Since Airlifter KC-10s and Dual Role KC-10s fly the same route, the set-up times (horizontal displacement) are identical. The slope of the Airlifter-only deployment (ie: cargo deployment rate) would also have to be examined. Indeed, there is significant question,

based on the "bulkiness" of the cargo, as to how much cargo each airlifter KC-10 can carry per trip. The difference, though great, would not be enough to make 40 Distinct Role Airlifter KC-10s perform worse than 60 Dual Role KC-10s.

Selection of the Best Factor Settings

Recall from chapter 1 that three factors were thought to have significant impact on the effectiveness of each KC-10s role:

1. reliability of the KC-10
2. ratio of fighters to KCs-10s for air refueling
3. location of the TTF (Distinct Role only)

For Dual Role KC-10s, the selections were straightforward. KC-10 reliability was always 100% because they waited on the ground until they were fixed. (The fighters simply waited until the KC-10 was fixed before they launched.) The ratio of fighters to KC-10s was the maximum feasible: 4 F-16s, 2 F-15s, 2 F-111s, or 2 RF4-Cs.

In the Distinct Role, reliability was directly impacted by the choice of ground turn-around time. Too short a turn-around time would cause missed ARs due to KC-10 maintenance. It was not possible, however, to choose a ground turn-around time without having information about the Maintenance Repair Time distribution. This therefore remains for future research.

The best ratio of fighters to KCS-10s was found to be six to one, for the overall deployment.

Of the three TTFs considered, only one was on the east side of the Atlantic Ocean, Mildenhall TTF was therefore mandatory to make the deployment feasible. On the west side of the Atlantic, a choice of two possible TTFs existed. Goose Bay, being closer to most of the AR tracks, was more effective than Loring AFB. It should be noted, however, that the use of two smaller TTFs, with some at Loring (refueling the AR tracks over New England) and some at Goose Bay (refueling the Atlantic AR tracks) would provide even better Closure Time.

Concept of Refueling the Dual Role KC-10s

The Air Force regularly uses the concept of air refueling the Dual Role KC-10s, usually by calling upon KC-135s to provide the extra fuel. A tanker, whether a KC-135 or a KC-10 which refuels the Dual Role KC-10 is, essentially, only helping it to carry more cargo--if the KC-10 takes off with less fuel (which is then provided by the other tanker), it can carry more cargo. To see how this might affect Closure Time, let us first consider the two main reasons why the Distinct Role concept was better than the unrefueled Dual Role concept:

1. TTF effectiveness. The 20 Distinct Role TTF KC-10s were able to deliver 30,114,100 pounds of fuel to the fighters in the same amount of time that it took 40 Distinct Role Airlifter KC-10s to deploy 12,000,000 pounds of cargo. This indicates that the KC-10 was twice as

effective in the TTF mission as it was in the Airlifter mission. In contrast to the TTF tankers which were able to provide ARs every few hours, the Dual Role KC-10s had to fly across the Atlantic and back (like the Distinct Role Airlifter) between ARs.

2. Reduced Dual Role Payload. The Dual Role KC-10s, having higher fuel consumption, had a lower payload capacity. Even worse, the Dual Role KC-10s often launched with much less than capacity payload because of the restriction that their cargo weight be in proportion to the number of fighters being refueled.

It is apparent that, if each of the Dual Role KC-10s were given an extra AR it would reduce the impact of item 2 above. That is, the Dual Role KC-10 could launch at Maximum Takeoff Gross Weight by carrying more cargo, but with inadequate fuel. Another tanker (preferably at a TTF base), would supply the difference in fuel. There, the Dual Role KC-10 would always be carrying a full payload.

Although the Dual role KC-10s would only be able to make 1 lap every 45 hours, they would be able to deploy with many more fighters each lap. The "Tanker" program was used to calculate that the following numbers of fighters could be refueled if the Dual Role KC-10s were provided an AR:
8 F-16s, 6 F-15s, 6 F-111s, 6 RF-4Cs. Using the Dual Role deterministic equation, the total deployment would require 172 KC-10 trips.

The air refueling support for these Dual Role KC-10s could be provided by 1 TTF KC-10 for each Dual Role KC-10s deploying with F-15s, F-111s, and RF-4Cs. F-16 deployments, being more fuel efficient, only require 1 TTF KC-10 for every 2 Dual Role KC-10s. The total TTF support would thus be 128 KC-10 sorties, each 6.5 hours long. The deterministic TTF equation, previously used to find Fighter Closure Time, was used to derive the graph of Closure Time (of fighters and cargo being deployed by Refueled Dual Role KC-10s) versus Number of TTF KC-10s. Then, using the same iterative procedure that was used for apportioning KC-10s between the Distinct Role TTF and Airlifter missions, the following apportionment was calculated between TTF and Refueled Dual Role KC-10s:

14 TTF KC-10s
46 Dual Role KC-10s

Notice that this is similar to the values calculated for the Distinct Role apportionment. Here, however, the Dual Role KC-10s were only carrying 60,000 to 80,000 pounds of cargo (the support equipment of 6 to 8 fighters), so more KC-10s were required in order to rapidly deploy all the cargo.

The expected value of the Refueled Dual Role Closure Time was calculated to be 3.74 laps = 168 hours. This was 26 hours (18%) longer than the Distinct Role deployment Closure Time, which was 142 hours.

Is Distinct Role Significantly Better than Refueled Dual Role? The difference of 26 hours between the Closure Times of the Distinct Role and Refueled Dual Role concepts lies within the range of uncertainty. Recall that the upper bound of Closure Time uncertainty for the Distinct Role Airlifters was 20% greater (170 hours), based on only 80,000 pounds of cargo being carried per trip. Notice that, at this point, the Refueled Dual Role KC-10s would be carrying nearly as much cargo as the "bulked out" Airlifter-only KC-10s. This deletes one of the main advantages of the Distinct Role concept over the Dual Role concept: that the Distinct Role airlifters carried more cargo per lap. If the Distinct Role airlifters carried as little as 80,000 pounds per lap, the Distinct Role would have an insignificant advantage over refueled KC-10s. Further data needs to be obtained to reduce the large range of uncertainty surrounding Distinct Role Airlifter Closure Time.

(It should also be pointed out that this argument is based on "expected" Closure time for the transAtlantic laps. In reality, 3.74 laps means that 35 of the Dual role KC-10s would stop after 3 laps, and 11 of them would return for a fourth lap. Compare that to the Distinct Role concept: although 20 of the Airlifter KC-10s had to return for the fourth lap, all the fighters had actually arrived by 142 hours. What this means is that, even if the refueled Dual Role had an "expected" Closure Time equal to the Distinct Role Closure Time, the Dual Role would have 66 fighters

arriving a half-lap (22 hours) later. Therefore, there is still a slight advantage to the Distinct Role concept.)

Summary

In conclusion, the sensitivity analysis of the two deployment concepts shows that, based on the mathematical relationships between terms, and the suspected uncertainty in those terms, the Distinct Roles concept is clearly superior to the unrefueled Dual Role concept.

It can be seen that most of the disparity in Closure Time can be explained by the fact that many of the unrefueled Dual Role KC-10s carried much less than their maximum payload. When deploying with F-111s or RF-4Cs, in this scenario the Dual Role KC-10s could only feasibly carry 20,000 pounds of cargo and air refuel 2 fighters on each trip. It was not quite feasible to refuel 3 fighters and carry their 30,000 pounds of cargo. That load inefficiency would account for a 33% loss of effectiveness for two of the four types of fighters. (The Dual Role deployments of the F-16s and F-15s were nearly optimal using Fighter-Tanker Ratios of 4, and 2, respectively.) It is obvious that, in any Dual Role deployment scenario, there are going to be some KC-10s with grossly inefficient payloads. It would be impossible to make all the Dual Role payloads 100% efficient.

One attempt to reduce this inefficiency has been the idea of air refueling the Dual Role KC-10s to allow them to

deploy with more fighters and their cargo. In this way, the extra cargo can be carried by the Dual Role KC-10s, and the extra fuel can be carried by another tanker. It was shown that providing the extra ARs for the Dual Role KC-10s did not improve the effectiveness beyond that of the Distinct role.

The following chapter will summarize conclusions and make recommendations.

VI. Conclusions and Recommendations

Conclusions

This research definitely shows that the Distinct Roles Concept of Operation is vastly superior to the "pure" Dual Role concept, that is, where the Dual Role KC-10s are not air refueled. By providing air refuelings to the Dual Role KC-10s, Closure Time could be reduced, but not sufficiently to equal the Distinct Role Closure Time. In reality, air refueling the Dual Role KC-10s provides a compromise, leaning toward separating the roles.

Recommendations

In light of the clear superiority of the Distinct Roles, largely due to the highly effective operations of the Tanker Task Force, the following recommendations are made.

1. Implement the Distinct Roles concept of operation.

The Air Force should not plan to use the KC-10 in the Dual Role, but to use the KC-10 in the Distinct Roles of Airlifter-only missions and Tanker-only missions.

2. Reduce uncertainty. Future research into the area of Distinct Role operations should also look more closely at the TTF operations to reduce the uncertainty surrounding the Closure Time resulting from TTF support of the fighter deployment. Three areas of TTF operation should be studied in depth:

a. KC-10 Maintainability/Reliability. In order

to determine the optimal refueling rate, the KC-10 ground turn-around time must be scheduled so as to reduce late take offs (which cause missed ARs), and at the same time, increase the sortie rate (more AR sorties means faster Closure Time). In order to make that decision, the calculation of the Distribution of Maintenance Repair Time is essential.

b. Fighter Abort Queueing? In order to optimize Closure Time, the TTF Operation is forced to select a non-zero abort rate. Thus, the aborting of fighters should be examined further. The time fighters spend on the ground should be closely examined to see whether queuing occurs for parking space or for services, including maintenance and Air Traffic Control.

c. TTF organization should be closely examined:

1. TTF Set-up Time. How long does it really take to set up the TTF?

2. TTF Size. Would a split into smaller TTFs be better or worse? For instance, the Goose Bay TTF of 15 KC-10s could have been split into two smaller forces, with some KC-10s operating out of Loring AFB. Since Loring AFB is closer to the western-most AR tracks, the sortie efficiency is

improved, causing a corresponding improvement in Closure Time. The issue is a matter of KC-10 sortie efficiency versus maintenance efficiency.

3. Consider the relative effectiveness of KC-10 and MAC airlifters. This recommendation deals with the relative inefficiency of the KC-10 as an airlifter, compared to its capability as a tanker. One way to ease the problem would be to reduce the scenario's demands for airlift. That would not be a very likely prospect. Therefore, if the Distinct Role KC-10s are required to move all the cargo and to supply all the necessary fuel for the deploying fighters, then the KC-10s will spend the majority of time doing that which they are least equipped to do--airlift. Why make two-thirds of the KC-10s carry cargo? Instead, the Air Force should seriously consider using the KC-10 to concentrate on what only it can do--provide air refuelings! That is not to say that the KC-10 should carry no cargo, but that, if other airlifters can do it better, they should do most of the airlifting. The final recommendation of this study then, is to further examine the whole deployment picture. If C-5s, C-141s and C-17s were used to transport fighter support equipment and personnel, then the Closure Time of fighter-squadrons would probably be greatly improved. In turn, the KC-10s freed from Airlifter duty would be able to increase the effectiveness of the MAC airlifters by providing them with extra air refuelings.

4. Consider the survivability of the KC-10. Attrition of the KC-10s was not studied in this thesis. Consideration should be given in future studies to the increased vulnerability of the KC-10 while on the ground unloading cargo at the destination. In contrast to the estimated KC-10 unloading duration of 3 hours, the MAC airlifters, with rear-opening cargo doors, can unload cargo in one sixth the time, which could greatly improve survivability at a fighter destination base. On the other hand, there is also a disadvantage to putting all the KC-10s into large TTFs, because they become very lucrative targets.

In summary, the KC-10s have been shown to be extremely effective in the Distinct Role Tanker Task Force mission, where they fly short, highly efficient, "round-robin" missions. This effectiveness in providing TTF air refuelings resulted in the Distinct Role concept of KC-10 operation being clearly superior to the Dual Role. Because the KC-10 is twice as effective in the TTF mission as it is in the Airlifter mission, further consideration should be given to reducing or eliminating the KC-10's cargo-carrying task.

APPENDIX A
ABBREVIATIONS AND DEFINITIONS

Abbreviations

AFB. Air Force Base.

AFIT. The Air Force Institute of Technology.

AR. Air refueling--the aerial transfer of jet fuel from a tanker (KC-10) to another aircraft, such as the deploying fighters.

ARCP. Air Refueling Control Point--the predetermined location where the tanker and receiver aircraft rendezvous. Once the rendezvous is complete, the air refueling operation begins immediately. On missions where the tankers and fighters are already flying together in formation, air refueling begins immediately upon arrival at the ARCP.

ARCT. Air Refueling Control Time--the predetermined time when both the tanker and the receiver aircraft will arrive at the AR Control Point.

CONUS. Acronym standing for Continental United States--all the deploying fighter aircraft and KC-10s are based in the CONUS.

C-141B, C-5. Two types of cargo aircraft operated by Military Airlift Command. Also called airlifters.

FORTTRAN. A math-oriented computer language, used in SLAM and in the deterministic model.

F-4, F-15, F-16, F-111. Four types of fighter aircraft which are studied in this thesis.

Hq. Headquarters.

IOCL Integral On-Board Cargo Loader. A proposed modification to the KC-10 which would make it self-

sufficient for cargo operations.

KC-10. A large tanker/cargo aircraft, operated by Strategic Air Command.

MAC. Military Airlift Command--Established by the Secretary of the Air Force as "the single manager operating agency for airlift service." As such, MAC is responsible for the C-5 and C-141 airlifter fleets.

Max. Maximum.

SLAM II The registered trademark of an advanced FORTRAN based computer language with which simulation models can be built. This acronym stands for Simulation Language for Alternative Modeling.

SAC. Strategic Air Command--The sole manager of all tanker resources, responsible for the KC-10 both in peacetime and in crisis fighter deployments.

TAC. Tactical Air Command--The USAF command responsible for the organizing, training, and equipping of tactical forces.

TGID. Thank Goodness It's Done!--An exclamation upon the occasion of the long-awaited completion of this Thesis.

TTF. Tanker Task Force--A temporary tanker organization which is formed to accomplish a specified refueling assignment.

USAF. The United States Air Force.

Definitions of Terms

Abort. The abnormal termination of a mission due to such events as a missed rendezvous or aircraft mechanical malfunction.

Airlifter. A cargo-carrying aircraft, such as the KC-10, C-5, C-141.

Augmented Aircrew. An aircrew which has extra pilots and other required personnel onboard the aircraft for the purpose of relieving the primary crew. Augmented aircrews are authorized to fly longer missions than normal.

Buddy. A buddy mission is one in which the tanker and receivers launch from the same base and fly together in formation to the subsequent air refueling. This is the type of mission flown under the Dual Role concept.

Closure Time. The time it takes for all of the fighter squadrons, including fighter aircraft and their support equipment and personnel, to arrive at their destination base in Europe.

Cochran Loader. The cargo loader required to load and unload the KC-10.

Concept of Operation. In this study, one of two possible master plans, Dual Role or Distinct Role, for use of the KC-10 in refueling fighters and carrying their support equipment and personnel.

Conceptual Model. A logical/descriptive representation of the deployment operation.

Computerized Model. The conceptual model implemented on a computer.

Deployment. The strategic movement of forces to another battle area. In this study, the movement of fighter squadrons to forward bases in Europe.

Duty Day. The aircrew duty day is the maximum allowable time period that the aircrew is allowed to perform flying duties. (Duty day limitations vary among aircraft types.) For example, the usual KC-10 crew duty day is 16 hours.

Operational Concept. See Concept of Operation.

Model. A representation of a real-life operation. In this thesis, the operation of KC-10s in the deployment of fighters to Europe is being modeled.

Offload. noun: A fuel offload is the fuel that a tanker has given away to a receiver. verb: To remove fuel from a tanker or cargo from an airlifter.

Onload. noun: The fuel that a receiver receives from a tanker. verb: To place fuel or cargo on an aircraft.

Palletized Cargo. Cargo that has been placed on pallets that can be quickly rolled on/off airlifters such as the KC-10, C-141, C-5.

Receiver Aircraft. An aircraft receiving fuel from a tanker. In this thesis, fighter aircraft such as the F-15 are the receivers.

Refueling Boom. The apparatus on the tanker aircraft by which fuel is transferred to the receiver aircraft during flight.

Refueling Receptacle. The apparatus on the receiver aircraft that enables it to receive fuel from a tanker refueling boom.

Reinforcement. The augmenting of forward-based military forces with units from the CONUS. In this study, specifically meaning the strategy which requires the deployment of fighter squadrons to Europe.

Rendezvous. In air refueling missions, the complex procedure whereby the tanker and receiver aircraft meet at a prearranged time and location for the purpose of accomplishing an aerial refueling.

Sortie. A single mission of any USAF aircraft, from takeoff to landing.

Support Equipment and Personnel. In this study, the equipment and personnel that are specifically required to deploy with the fighter squadrons as designated in the 4102 Plan.

Tanker. The KC-10. It carries extra fuel which it transfers to the receiver aircraft.

Track lap. Defined in this thesis as a reference to one of several trips each TTF KC-10 makes down the AR track.

Transferable fuel. The extra fuel in the tanker aircraft that is available to be offloaded to the receiver via air refueling.

APPENDIX B
DETERMINISTIC TTF PROGRAM

PROGRAM OUTPUT

Sensitivity of Fighter Closure Time
to Changes in TTF Ground Turn-Around Time

PRINTOUT FROM PROGRAM DETERMTTF.FOR

TURNTIME	IS	1.0	FIGHTER CLOSURE TIME IS	121.9 HOURS
TURNTIME	IS	1.5	FIGHTER CLOSURE TIME IS	127.0 HOURS
TURNTIME	IS	2.0	FIGHTER CLOSURE TIME IS	132.2 HOURS
TURNTIME	IS	2.5	FIGHTER CLOSURE TIME IS	137.3 HOURS
TURNTIME	IS	3.0	FIGHTER CLOSURE TIME IS	142.5 HOURS
TURNTIME	IS	3.5	FIGHTER CLOSURE TIME IS	147.7 HOURS
TURNTIME	IS	4.0	FIGHTER CLOSURE TIME IS	152.8 HOURS
TURNTIME	IS	4.5	FIGHTER CLOSURE TIME IS	158.0 HOURS
TURNTIME	IS	5.0	FIGHTER CLOSURE TIME IS	163.1 HOURS
TURNTIME	IS	5.5	FIGHTER CLOSURE TIME IS	168.3 HOURS
TURNTIME	IS	6.0	FIGHTER CLOSURE TIME IS	173.5 HOURS
TURNTIME	IS	6.5	FIGHTER CLOSURE TIME IS	178.6 HOURS
TURNTIME	IS	7.0	FIGHTER CLOSURE TIME IS	183.8 HOURS
TURNTIME	IS	7.5	FIGHTER CLOSURE TIME IS	188.9 HOURS
TURNTIME	IS	8.0	FIGHTER CLOSURE TIME IS	194.1 HOURS

APPORTIONMENTS TO AR TRACKS AND TO TTFS

--DATA FROM DETERMTTF PROGRAM

TURNTIME IS 3.0
GREEKETA= 365.56
100 TANKER, 1.00 RELIABILITY ADDEND3= 18.52
BASED ON 20. TANKERS, ADDEND3= 92.62
BASED ON 0.95 RELIABILITY, ADDEND3= 97.49
FIGHTER CLOSURE TIME IS 142.5 HOURS
GOOSE BAY APPORTIONMENT= 76.1 %
MILDENHALL APPORTIONMENT= 23.9 %
FOR F-16 , TRACK 1, KC-10 APPRT= 19.7 %
FOR F-16 , TRACK 2, KC-10 APPRT= 12.1 %
FOR F-15 , TRACK 1, KC-10 APPRT= 20.0 %
FOR F-15 , TRACK 2, KC-10 APPRT= 12.4 %
FOR F-15 , TRACK 3, KC-10 APPRT= 6.3 %
FOR F-111, TRACK 1, KC-10 APPRT= 7.3 %
FOR F-111, TRACK 2, KC-10 APPRT= 4.9 %
FOR RF-4C, TRACK 1, KC-10 APPRT= 4.9 %
FOR RF-4C, TRACK 2, KC-10 APPRT= 3.7 %
FOR RF-4C, TRACK 3, KC-10 APPRT= 3.1 %
FOR RF-4C, TRACK 4, KC-10 APPRT= 3.4 %
FOR RF-4C, TRACK 5, KC-10 APPRT= 2.2 %

PROGRAM DETERMTTF

*
*
* AUTHOR: JOHN DAVIS (DAVE) HUNSUCK, JR., CAPT, USAF
* 217 - 64 -7804.
*
*
* DATE: JUNE 5, 1986
*
*
*
* PURPOSE: THIS PROGRAM WAS DEVELOPED AS PART OF
* A MASTER'S THESIS RESEARCH AT THE AIR FORCE
* INSTITUTE OF TECHNOLOGY, WPAFB, OH.
* FURTHER EXPLANATION OF THE THEORY BEHIND
* THIS PROGRAM CAN BE FOUND IN THE
* ACCOMPANYING THESIS.
*
*
* USING A DETERMINISTIC MATHEMATICAL MODEL,
* THIS PROGRAM CALCULATES THE APPORTIONMENT
* OF TANKER TASK FORCE TANKERS (KC-10S)
* AMONG SEVERAL AIR REFUELING TRACKS.
* RECEIVER (FIGHTER) CLOSURE TIME IS ALSO
* CALCULATED.
*
*
* INPUT: CURRENTLY, THE INPUT ROUTINE CONSISTS OF
* A LIST OF INITIALIZING EQUATIONS IN THE
* PROGRAM. TO CHANGE DATA REQUIRES A
* RECOMPILATION OF THE PROGRAM.
* REQUIRED DATA INCLUDES ALL AR TRACK INFO,
* AS WELL AS INFO ABOUT THE TTFS.
*
*
* MAJOR FUNCTIONS: THIS PROGRAM DOES THE FOLLOWING:
* CALCULATE THE GREAT CIRCLE DISTANCES
* BETWEEN THE TTFS AND AR TRACKS.
* SEARCH FOR CLOSEST TTF BASE TO EACH AR TRACK
* CALL A MODIFIED 'TANKER' PROGRAM TO FIND:
* KC-10 SORTIE DURATION
* MAXIMUM FEASIBLE NUMBER OF 'TRACKLAPS'
* CALL THE DETERMINISTIC EQUATIONS TO:
* FIND KC-10 APPORTIONMENT AMONG TRACKS
* CALCULATE THE FIGHTER CLOSURE TIME

**** THE FOLLOWING COMMON IS USED AT THIS LEVEL OF THE PROGRAM:

COMMON /INPUT/
& ARCPLATT, ARCPLONG,
& EARLATT, EARLONG,
& TTFLATT, TTFLONG,
& ALTRAR, CASRAR, TIMERAR, DISTRAR, OFFRAR,
& TTFMAX70

real

```

&   ARCPLATT(4,5), ARCPLONG(4,5),
&   EARLATT(4,5),  EARLONG(4,5),
&   TTFLATT(3),   TTFLONG(3),
&   ALTRAR(4), CASRAR(4), TIMERAR(4,5), DISTRAR(4,5), OFFRAR(4,5),
&   TTFMAXTO(3)

```

```

COMMON /NAMES/ TTFNAME, FIGHTER
character TTFNAME(3)*10, FIGHTER(4)*5

```

```

COMMON/EQNS/ CLOSURE, SETUPM, FLYTOAR1, FLYTODST,
&   FTRCELL, TOTNOFTR, TURNTIME, KCFLTIME,
&   KCLAPS, GOOUT, GORTB,
&   TOTALTNK, TTFAPPRT, RELIBLTY, KCTRACK,

&   ITTFL, JFTRL, KTRAKL, NEARTTF,

&   DOMINATD

REAL CLOSURE, SETUPM, FLYTOAR1, FLYTODST,
&   FTRCELL(4), TOTNOFTR(4), TURNTIME(3), KCFLTIME(4,5),
&   KCLAPS(4,5), GOOUT(3,4,5), GORTB(3,4,5),
&   TOTALTNK, TTFAPPRT(3), RELIBLTY, KCTRACK(4,5)

REAL SORINTVL(4,5), AVGLAPINT(4,5)

INTEGER ITTFL, JFTRL, KTRAKL, NEARTTF(4,5)

LOGICAL DOMINATD(3,4,5)

```

```

* FOLLOWING COMMON LINES ADDED TO MAKE 'TANKER' WORK WITH
*   THIS DETERMTTF PROGRAM:

```

```

COMMON /HUNSUCK/ITANKR, IFULOP, NUMFAR, NUMFA1
COMMON /THESIS/FULSUB, TOWT, OPWT, FULLND, CRUDRG, RTBALT, RTBTIM, FLTWT
&   , CWT, DIST1S, FARCAS, DIST3, WT1T, TOTA, TIME
REAL TOTA, TIME
INTEGER ITANKER, IFULOP, NUMFAR, NUMFA1

INTEGER I, J, K, L, M

```

```

* THE FOLLOWING COMMON DATA ARE FOR SUBROUTINE TANKER
*****

```

```

COMMON /A      / DISTTA ,WT      ,AS(7) ,DAT
&             ,DAT1      ,LCAS    ,IPNT
REAL

```

```

&          DAT      (17,7,4)
&          ,DAT1     (17,5)
&          ,DISTTA
&          ,WT       (17)
      INTEGER IPNT    ,LCAS      (17,5)
      COMMON /B      / ALTX     ,CCCAS    ,CFUEL    ,CTIME
&          ,CDIST     ,TARTIME
      DOUBLE PRECISION CCCAS      (17)
&          ,CDIST     (17,7)
&          ,CFUEL     (17,7)
&          ,CTIME     (17,7)
      REAL TARTIME    ,ALTX(8)
      COMMON /C      / RFDRAg    ,ONLOAD   ,YTAB1    ,YTAB2
&          ,CCALT     ,CCNAM
      DOUBLE PRECISION CCALT      (17)
&          ,CCNAM     (17)
&          ,YTAB1     (17,7)
&          ,YTAB2     (17,7)
      REAL ONLOAD     ,RFDRAg
      COMMON /D      / FARDST    ,TIMELT    ,OFLOAD   ,NUMREC
&          ,FARALT    ,ALT1(5) ,FARTIM
      REAL
&          FARALT     (15)
&          ,FARDST    (15)
&          ,FARTIM    (15)
&          ,OFLOAD    (15)
&          ,TIMELT    (15)
      INTEGER NUMREC
      COMMON /E      / SPECIAL   ,ANUMRC
      DOUBLE PRECISION SPECIAL   (17)
      REAL ANUMRC      (15)
      COMMON /F      / NOPRNT
      COMMON /G      / DAT2      ,ICTAS
      REAL DAT2        (17,5)
      INTEGER NOPRNT   ,ICTAS    (17,5)

```

```
*      REAL KCFUELUS(3,4,5), KCFUELOF(3,4,5)
```

* *****

```
* First, tell the computer which type of tanker: 3 means KC-10.
```

```
      ITANKR = 3
```

```
* Next, open the appropriate data file.
```

```
      IF (ITANKR.EQ.1) OPEN(10,FILE='GST86J:[JHUNSUCK.FUELS]TKRW.DAT',
```

```
&      STATUS='OLD')
```

```
      IF (ITANKR.EQ.2) OPEN(10,FILE='GST86J:[JHUNSUCK.FUELS]TKRTT.DAT',
```

```
&      STATUS='OLD')
```

```
      IF (ITANKR.EQ.3) OPEN(10,FILE='GST86J:[JHUNSUCK.FUELS]TKRXA.DAT',
```

```

& STATUS='OLD')
IF(ITANKR.EQ.4) OPEN(10,FILE='GST86J:[JHUNSUCK.FUELS]KC135.DAT',
& STATUS='OLD')

* Next, open any output files that we desire to use.
* OPEN (UNIT=11, FILE='DISTANT.LIS',STATUS='NEW')
* OPEN (UNIT=12, FILE='FEASIBLE.LIS',STATUS='NEW')

* Establish the dimensions of the TTF, Fighter, Track Array.
* WRITE(*,*)'ENTER ITTF1, JFTR1, KTRAK1'
* READ(*,*) ITTF1,JFTR1,KTRAK1
* WRITE(*,*)'ENTER ITTFL,JFTRL,KTRAKL'
* READ(*,*) ITTFL,JFTRL,KTRAKL
* ITTF1 =1
* ITTFL =3
* JFTR1 =1
* JFTRL =4
* KTRAK1=1
* KTRAKL=5

* INITIALIZE ALL DATA CONCERNING TTFS, AR TRACKS:
* CALL INITIAL

* DATA FLYTOAR1/2./
* DATA FLYTODST/7./
* DATA SETUPTM/36./
* DATA TOTALTNK/20./
* DATA RELIBLTY/0.95/

* IF CALCULATIONS ARE NOT DESIRED FOR ANY PARTICULAR TTF,
* IT CAN BE SKIPPED BY SETTING ISKIPTTF TO THE TTF NUMBER.
* ISKIPTTF = 3

*NEXT, CALCULATE THE DISTANCES BETWEEN THE TTFS AND AR TRACKS:

* CALL CALCDISTANCE(ITTFL,ISKIPTTF,JFTRL,KTRAKL,ARCPLATT,
& ARCPLONG,EARLATT,EARLONG,TTFLATT,TTFLONG,TTFNAME,
& FIGHTER,GOOUT,GORTB)

* SEARCH FOR NEAREST TTF TO EACH TRACK:
* CALL NOTDOMINATED

* FOR EVERY AR TRACK, FOR EVERY FIGHTER TYPE, FOR EVERY TTF:
* DO 0100 I=1,ITTFL
* DO 0100 J=1,JFTRL
* DO 0100 K=1,KTRAKL

* IF (GOOUT(I,J,K).EQ.0.) GO TO 0100
* (IE: TRACK IS NON-EXISTANT, SO GO TO NEXT TRACK)

```

```

*      IF THIS IS NOT THE CLOSEST TTF TO THIS TRACK,
*      THEN SKIP THE CALCULATIONS,
*      ELSE $$ CALL TANKER $$ TO CALCULATE FUEL, FEASIBILITY:
*
      IF (NEARTTF(J,K).NE.1) GO TO 0100
      CONTINUE

*      THE FOLLOWING LINES LOAD VALUES INTO VARIABLES
*      USED BY TANKER:
          NUMFAR = 8
          {ie: attempt to put max of 8 tracklaps
              per KC-10 sortie}
          ANUMRC(1) = 6
          {ie: assign six fighters to the tracklap}

          DO 0003 L=2,NUMFAR
              ANUMRC(L)=ANUMRC(1)
0003      CONTINUE
          {ie: fill in the above matrix}

          DISTIS = GOOUT(I,J,K)
          FARALT(1)= ALTRAR(J)
          FARCAS = CASRAR(J)
          FARTIM(1)= TIMERAR(J,K)
          FARDST(1)= DISTRAR(J,K)
          OFLOAD(1)= OFFRAR(J,K)
          TIMELT(1)=?
          DIST3 = GORTB(I,J,K)

      CALL TANKER
      REWIND(10)

*      WRITE(12,1233) TIME
* 1233      FORMAT (1X,' TOTAL TIME=',F4.1)
*      WRITE(12,1234) OFLOAD(1),OFLOAD(1)*NUMFA1*ANUMRC(1)
* 1234      FORMAT(1X,'INDIV OFLOAD= ',F10.0,' TOTAL OFLOAD= ',F10.0)
*      WRITE(12,1600)WTTT,TOTA
* 1600      FORMAT(1X,'REMAINING FUEL= ',F7.0,', FUEL USED= ',F7.0)
*      WRITE(12,1605) NUMFA1
* 1605      FORMAT(1X,I3,' CELLS OF FIGHTERS')
*      WRITE(12,1610)(ANUMRC (M),M=1,NUMFA1)
* 1610      FORMAT(1X,'NUMBER OF RECEIVERS BY CELL',1X,8E12.2)

*      TRANSLATE THE 'TANKER' VALUES INTO VARIABLE NAMES USED BY
*      THIS PROGRAM:
          KCLAPS(J,K)=NUMFA1
          KCFLTIME(J,K)=TIME
          KCFUELUS(I,J,K)=TOTA
          KCFUELOF(I,J,K)=OFLOAD(1)*NUMFA1*ANUMRC(1)

```

0100 CONTINUE

```
*
*** DO APPORTIONMENT AND CLOSURE TIME EQUATIONS
*
* THE FOLLOWING LOOP WAS USED TO DO SENSITIVITY ANALYSIS
* OF CLOSURE TIME TO THE VARIABLE TURNTIME:
*   DO 120 I=6,6
*     TURNTIME(1)=0.5*I
*     TURNTIME(2)=0.5*I
*     TURNTIME(3)=0.5*I
*     WRITE(12,0101)TURNTIME(1)
* 0101  FORMAT(1X,'TURNTIME IS ',F4.1)

      CALL CLOSURETIME

      WRITE(12,0110) CLOSURE
0110  FORMAT(8X,' FIGHTER CLOSURE TIME IS ',F6.1,' HOURS')

*     WRITE(12,0111) (TTFNAME(K),TTFAPPRT(K),K=1,2)
* 0111  FORMAT(1X,' ',A10,' APPORTIONMENT= ',F5.1,' %')

* THE FOLLOWING LOOP WAS USED TO PRINT OUT THE APPORTIONMENT
* OF FIGHTERS TO ALL THE AR TRACKS:
*   DO 0120 J=1,JFTRL
*     DO 0120 K=1,KTRAKL
*       IF (KCTRACK(J,K).EQ.0) GO TO 120
*       WRITE(12,0112) FIGHTER(J),K,KCTRACK(J,K)
* 0112  FORMAT(1X,' FOR ',A5,', TRACK ',I1,
*    &      ', KC-10 APPRT=',F6.1,' %')
*
* 0120  CONTINUE

      STOP
      END
```

SUBROUTINE INITIAL

* PURPOSE: INITIALIZATION OF VARIABLES

```
COMMON /INPUT/
&   ARCPLATT, ARCPLONG,
&   EARLATT, EARLONG,
```

```

&    TTFLATT, TTFLONG,
&    ALTRAR, CASRAR, TIMERAR, DISTRAR, OFFRAR,
&    TTFMAXTO

```

```

real
&    ARCPLATT(4,5), ARCPLONG(4,5),
&    EARLATT(4,5), EARLONG(4,5),
&    TTFLATT(3), TTFLONG(3),
&    ALTRAR(4), CASRAR(4), TIMERAR(4,5), DISTRAR(4,5),
&    OFFRAR(4,5),
&    TTFMAXTO(3)

```

```

*****
COMMON /NAMES/ TTFNAME, FIGHTER
character TTFNAME(3)*10, FIGHTER(4)*5

```

```

*****

```

```

* The following are the Coords of ARCPs, EARs for the TTF refuelings of F-16s:

```

```

ARCPLATT(1,1)= 4621.
ARCPLONG(1,1)= 05908.
EARLATT(1,1)= 4745.
EARLONG(1,1)= 05128.
ARCPLATT(1,2)= 5050.
ARCPLONG(1,2)= 00315.
EARLATT(1,2)= 5018.
EARLONG(1,2)=-00433.

```

```

* name of fighter and AR altitude, AR calibrated air speed

```

```

FIGHTER(1) ='F-16'
ALTRAR(1) = 31000.
CASRAR(1) = 310.

```

```

* OFLOADs for the above AR tracks:

```

```

OFFRAR(1,1) = 11367.
OFFRAR(1,2) = 2114.

```

```

* times and distances for flying the above AR tracks:

```

```

TIMERAR(1,1) = 39.
TIMERAR(1,2) = 39.
DISTRAR(1,1) = 324.
DISTRAR(1,2) = 313.

```

```

* The following are the Coords of ARCPs for the TTF refuelings of F-15s:

```

```

ARCPLATT(2,1) = 4239.
ARCPLONG(2,1) = 07304.
EARLATT(2,1) = 4504.
EARLONG(2,1) = 06302.
ARCPLATT(2,2) = 4824.
ARCPLONG(2,2) = 04826.
EARLATT(2,2) = 5001.
EARLONG(2,2) = 03858.
ARCPLATT(2,3) = 5000.
ARCPLONG(2,3) = 00802.
EARLATT(2,3) = 5042.
EARLONG(2,3) = -00337.

```

```

*   name of fighter and AR altitude, AR calibrated air speed:
      FIGHTER(2)  = 'F-15'
      ALTRAR(2)   = 31000.
      CASRAR(2)   = 310.
*   OFLOADs for the above AR tracks:
      OFFRAR(2,1) = 20924.
      OFFRAR(2,2) = 14080.
      OFFRAR(2,3) = 3560.
*   times and distances for flying the above AR tracks:
      TIMERAR(2,1) = 57.
      TIMERAR(2,2) = 46.
      TIMERAR(2,3) = 56.
      DISTRAR(2,1) = 477.
      DISTRAR(2,2) = 384.
      DISTRAR(2,3) = 462.

*   The following are the Coords of ARCPs for the TTF refuelings of F-111s:
      ARCPLATT(3,1) = 4230.
      ARCPLONG(3,1) = 07628.
      EARLATT(3,1)  = 4522.
      EARLONG(3,1)  = 06214.
      ARCPLATT(3,2) = 4930.
      ARCPLONG(3,2) = 04312.
      EARLATT(3,2)  = 5001.
      EARLONG(3,2)  = 03057.
*   name of fighter and AR altitude, AR calibrated air speed:
      FIGHTER(3)  = 'F-111'
      ALTRAR(3)   = 24000.
      CASRAR(3)   = 305.
*   UFLUADs for the above AR tracks:
      OFFRAR(3,1) = 25804.
      OFFRAR(3,2) = 15423.
*   times and distances for flying the above AR tracks:
      TIMERAR(3,1) = 88.
      TIMERAR(3,2) = 64.
      DISTRAR(3,1) = 666.
      DISTRAR(3,2) = 477.

*   The following are the Coords of ARCPs for the TTF refuelings of RF-4Cs:
      ARCPLATT(4,1) = 4021.
      ARCPLONG(4,1) = 08351.
      EARLATT(4,1)  = 4237.
      EARLONG(4,1)  = 07517.
      ARCPLATT(4,2) = 4618.
      ARCPLONG(4,2) = 05923.
      EARLATT(4,2)  = 4806.
      EARLONG(4,2)  = 04936.
      ARCPLATT(4,3) = 4916.
      ARCPLONG(4,3) = 04426.
      EARLATT(4,3)  = 5001.
      EARLONG(4,3)  = 03630.

```

```

      ARCPLATT(4,4) = 5000.
      ARCPLONG(4,4) = 02949.
      EARLATT(4,4) = 5002.
      EARLONG(4,4) = 02152.
      ARCPLATT(4,5) = 5101.
      ARCPLONG(4,5) = 00213.
      EARLATT(4,5) = 4957.
      EARLONG(4,5) = -00715.
*   name of fighter and AR altitude, AR calibrated air speed:
      FIGHTER(4) = 'RF-4C'
      ALTRAR(4) = 29000.
      CASRAR(4) = 305.
*   OFLOADs for the above AR tracks:
      OFFRAR(4,1) = 15016.
      OFFRAR(4,2) = 15666.
      OFFRAR(4,3) = 8297.
      OFFRAR(4,4) = 8341.
      OFFRAR(4,5) = 2535.
*   times and distances for flying the above AR tracks:
      TIMERAR(4,1) = 51.
      TIMERAR(4,2) = 51.
      TIMERAR(4,3) = 39.
      TIMERAR(4,4) = 39.
      TIMERAR(4,5) = 51.
      DISTRAR(4,1) = 415.
      DISTRAR(4,2) = 413.
      DISTRAR(4,3) = 313.
      DISTRAR(4,4) = 307.
      DISTRAR(4,5) = 403.

*   Coords for TTF Base -- Goose Bay, Canada:
      TTFNAME(1)='GOOSEBAY'
      TTFLATT(1)= 5319.
      TTFLONG(1)= 06026.
      TTFMAXTO(1)= 588200.
*   Coords for TTF Base -- Mildenhall, England:
      TTFNAME(2)= 'MILDENHALL'
      TTFLATT(2)= 5222.
      TTFLONG(2)=-00029.
      TTFMAXTO(2)= 588200.
*   Coords for TTF Base -- Loring AFB, Maine, USA:
      TTFNAME(3)= 'LORING AFB'
      TTFLATT(3)= 4657.
      TTFLONG(3)= 06753.
      TTFMAXTO(3)= 588200.

      RETURN
      END
*   {OF INITIAL}

```

```

*****
SUBROUTINE CALCDISTANCE(ITTFI,IS,IPTTF,JFTRL,KTRAKL,ARCPLATT,

```

```

&          ARCPLONG,EARLATT,EARLONG,TTFLATT,TTFLONG,TTFNAME,
&          FIGHTER,GOOUT,GORTB)

*  PURPOSE: CALCULATE THE DISTANCES BETWEEN THE TTF AND AR TRACK
*           ARCP AND EAR POINT.  THIS IS DONE FOR EVERY TTF AND
*           FOR EVERY FIGHTER'S AR TRACKS.

      INTEGER ITTFL,ISKIPTTF,JFTRL,KTRAKL

      REAL ARCPLATT(4,5),ARCPLONG(4,5),EARLATT(4,5),EARLONG(4,5),
&         TTFLATT(3),TTFLONG(3),GOOUT(3,4,5),GORTB(3,4,5)

      CHARACTER TTFNAME(3)*10, FIGHTER(4)*5

*  Calculations of Distance from TTF to ARCPs
      DO 2222, I= ITTFL,ITTFL
*           {I is the TTF}
      IF (I.EQ.ISKIPTTF) GO TO 2222
      DO 2222, J=JFTR1,JFTRL
*           {J is the fighter type}
      DO 2222, K=KTRAK1,KTRAKL
*           {K is the track number for that fighter}

*  First, check if track exists (because matrix is not solid):
      IF((ARCPLATT(J,K) .EQ. 0.0) .AND. (EARLATT(J,K) .EQ. 0.0))
&  THEN
      GOOUT(I,J,K) = 0
      GO TO 2222
      ENDIF

      GOOUT(I,J,K) = GREATCIR( TTFLATT(I), TTFLONG(I),
&                             ARCPLATT(J,K), ARCPLONG(J,K))

      GORTB(I,J,K) = GREATCIR( EARLATT(J,K), EARLONG(J,K),
&                             TTFLATT(I), TTFLONG(I))

*           WRITE(11,1) TTFNAME(I),FIGHTER(J),K,GOOUT(I,J,K)
* 0001  FORMAT(15X,'THE DISTANCE FROM ',A10,' TO ',AS,' ARCP ',I1,
*           &' IS: ',F6.0)
*
*           WRITE(11,2) TTFNAME(I),FIGHTER(J),K,GORTB(I,J,K)
* 0002  FORMAT(15X,'',A10,'',AS,' EAR ',I1,
*           &' : ',F6.0)

2222  CONTINUE
      RETURN
      END

*           {OF SUBROUTINE CALCDISTANCE}

```

```

*****
function GreatCir (LattOrig,LongOrig,LattDest,LongDest)
  real    GreatCir, LattOrig,LongOrig,LattDest,LongDest

* This function calculates great-circle distance between two points,
* anywhere on the globe. The equations used based on the following
* geometry (which assumes a perfectly spherical earth):
*
*
*           North Pole of Earth
*           .
*           . . .
*           .   A   .
*           .       .
*       c .   .       .
*           .       .       b
*           .       .       .
* Origin > . B       .       .
*           .       .       .
*           ..... equator
*           . .
*           a .   .   .
*           .       .   C
*           .       .       .
*           .       .       < Destination
*           .
*
*           Thus, we have a triangle on the surface of a sphere
*           with sides a, b, c
*           and angles A, B, C.
*
*           We use positive coordinate values to indicate North Latt, West Long.
*           and negative values for South Latitude, East Longitude.
*
* It can therefore be seen that
*
*       c = distance from North Pole to Origin = 90 degrees - Origin Latitude
*       b = distance from North Pole to Dest.  = 90 degrees - Destination Latt.
*
*       A = angle at top of triangle = Origin Longitude - Destination Longitude.
*
* The law of cosines for sides of a spherical triangle states that:
*
*        $\cos a = \cos b \cos c + \sin b \sin c \cos A$ 
*
* Thus, the Great Circle Distance between the Origin and Destination is
*
*       a, the arccos of the above value.
*
* The distance is converted to nautical miles by multiplying a * 60,
* statute miles ..... a * 60 * 1.151,
* kilometers ..... a * 60 * 1.852.

```

```

*
*
*   NOTE:  This program assumes all lattitudes are North
*           and all longitudes are West.
*
*   To enter South Lattitudes or East Longitudes,
*           please use negative (-) values!
*
*   Examples:  3059 indicates 30 degrees, 59 minutes
*               -17900 indicates 179 degrees (east longitude)
*
*   Goose Bay :  5319N,  06026W.
*                 LattOrig=5319  LongOrig=6026
*
*   Loring AFB:  4657N,  06753W.
*                 LattOrig=4657  LongOrig=6753
*
*   Mildenhall:  5222N,  00029E.
*                 LattOrig=5222  LongOrig=-0029
*
*
* {variables}
*   Character
*   &   Answer
*   Real
*   &   cosa, smalla, smallb, smallc
*
*                                     {distances}
*   &   CapA
*
*                                     {angle}
*
* {begin GreatCir calculations:}
*
*   smallc= radian( 90 - DecDegrees(LattOrig))
*           {distance of Origin from the North Pole}
*   smallb= radian( 90 - DecDegrees(LattDest))
*           {distance of Destination from the North Pole}
*   CapA= radian( ( DecDegrees(LongOrig) - DecDegrees(LongDest) ) )
*           {a positive angle}
*
*   cosa= cos(smallb) * cos(smallc) +
*   &     sin(smallb) * sin(smallc) * cos(CapA)
*
*   smalla= deg( acos(cosa) )
*
*                                     { THIS IS THE GREAT CIRCLE DISTANCE
*                                     for a unit sphere }
*
* {Great Circle Distance =           (in nautical miles)}
*   GreatCir=smalla*60
*
*           *1.151      (in statute miles)
*           *1.852      (in kilometers)

```

```

*
*
    return
end
*   {of function GreatCir}

*****
    function DecDegrees(Coord)
        real DecDegrees,Coord

*   {This function separates minutes from the degrees in the coordinate.
*   The minutes are then converted to decimal fraction of degrees.
*   The output, DecDegrees, is a decimal representation of the coord.}

*   {variables}
    real
    &   Degrees, Minutes, DecMinutes

*   {begin}

        Degrees = real( int(Coord/ 100.))
*                               {truncates away the minutes}
        Minutes = ((Coord/100.) - real(int(Coord/ 100.))) * 100.
*                               {separates away the degrees, leaving the remainder}
*
        DecMinutes = Minutes / 60.
        DecDegrees = Degrees + DecMinutes
*   write(*,10)coord, degrees,minutes,decminutes,decdegrees
* 10   format(1x,'coord= ',f7.0,'degrees=',f5.1,', minutes= ',f5.1
*   &,' decmin= ',f7.5,', decdegrees= ',f11.5)
        return
    end
*   {function DecDegrees of function GreatCir}

*****
    function radian(xdegrees)
        real radian,xdegrees
*   {This function converts degrees to radians.}

        parameter pi= 3.141592653589793

*   {begin}
        radian=xdegrees * (2.0*pi/360.0)
        return
    end
*   {function radian of function GreatCir}

*****
    function deg(xradians)

```

```

      real deg,xradians
*   (This function converts radians back to degrees.)

      parameter pi = 3.141592653589793.

*   (begin)
      deg= xradians * (360.0/(2.0*pi))
      return
      end
*   (function deg of function GreatCir}

*****
SUBROUTINE NOTDOMINATED
*
*   PURPOSE:  THIS SUBROUTINE FINDS THE NEAREST TTF TO EACH
*             AR TRACK.
*   VALUES RETURNED:  ENTIRE MATRIX OF  NEARTTF
*
      COMMON/EQNS/ CLOSURE, SETUPTM, FLYTOAR1, FLYTODST,
&   FTRCELL, TOTNOFTR, TURNTIME, KCFLTIME,
&   KCLAPS, GOOUT, GORTB,
&   TOTALTNK, TTFAPRT, RELIBLTY, KCTRAK,

&   ITTFL, JFTRL, KTRAKL, NEARTTF,

&   TTFNAME, FIGHTER,

&   DOMINATD

      REAL CLOSURE, SETUPTM, FLYTOAR1, FLYTODST,
&   FTRCELL(4), TOTNOFTR(4), TURNTIME(3), KCFLTIME(4,5),
&   KCLAPS(4,5), GOOUT(3,4,5), GORTB(3,4,5),
&   TOTALTNK, TTFAPRT(3), RELIBLTY, KCTRAK(4,5)

      INTEGER I,J,K, ITTFL, JFTRL, KTRAKL, NEARTTF(4,5)

      CHARACTER TTFNAME(3)*10, FIGHTER(4)*5

      LOGICAL DOMINATD(3,4,5)

* SEARCH FOR DOMINATED SOLUTIONS (IE: WE ONLY WANT THE TTF CLOSEST TO
*   EACH TRACK):

      DO 0099 I=1,ITTFL-1
        DO 0099 J=1,JFTRL
          DO 0099 K=1,KTRAKL

```

```

      IF (GOOUT(I,J,K).EQ.0.) GO TO 0099

      IF ((GOOUT(I ,J,K)+GORTB(I ,J,K)).GT.
&      (GOOUT(I+1,J,K)+GORTB(I+1,J,K))) THEN
        DOMINATD(I ,J,K)= .TRUE.
        DOMINATD(I+1,J,K)= .FALSE.
      ELSE
        DOMINATD(I ,J,K)= .FALSE.
        DOMINATD(I+1,J,K)= .TRUE.
      END IF

0099 CONTINUE

      DO 0101 I=1,ITTFL
        DO 0101 J=1,JFTRL
          DO 0101 K=1,KTRAKL

            IF (.NOT.DOMINATD(I,J,K)) THEN
              NEARTTF(J,K) = 1

*              WRITE(12,0005)
*              WRITE(12,0006) TTFNAME(I), FIGHTER(J), K
* 0005      FORMAT(' ')
* 0006      FORMAT('      TTF:',A10,', FIGHTER: ',A5,', TRACK# ',I1)
*              WRITE(12,0007)
* 0007      FORMAT('      $$$BEST SOLUTION -- CLOSEST TO AR TRACK')

            ELSE
*              WRITE(12,0008)
* 0008      FORMAT('      * DOMINATED SOLUTION -- '
*      &      ',ANOTHER TTF IS CLOSER TO THIS TRACK.')
              GO TO 0101
            END IF

0101 CONTINUE

      RETURN
      END

*      ( OF SUBROUTINE NOTDOMINATED )
*      )i{~r
*****
      SUBROUTINE CLOSURETIME
*
*      (THIS SUBROUTINE APPORTIONS TANKERS AMONG SEVERAL TTFS,
*      AND CALCULATES THE RESULTING OPTIMAL CLOSURE TIME
*      FOR THE DEPLOYING RECEIVERS (FIGHTERS).)
*
      COMMON/EQNS/ CLOSURE, SETUPTM, FLYTOAR1, FLYTODST,
&      FTRCELL, TOTNOFTR, TURNTIME, KCFLTIME,
&      KCLAPS, GOOUT, GORTB,

```

```

&      TOTALTNK, TTFAPPRT, RELIBLTY, KCTRAK,
&      ITTFL, JFTRL, KTRAKL, NEARTTF,
&      TTFNAME, FIGHTER,
&      DOMINATD

      REAL CLOSURE, SETUPTM, FLYTOAR1, FLYTODST,
&      FTRCELL(4), TOTNOFTR(4), TURNTIME(3), KCFLTIME(4,5),
&      KCLAPS(4,5), GOOUT(3,4,5), GORTB(3,4,5),
&      TOTALTNK, TTFAPPRT(3), RELIBLTY, KCTRAK(4,5)

      REAL SORINTVL(4,5), AVGLAPINT(4,5),
&      GREEKETA, TRKRATIO(4), FTRRATIO(4)

      INTEGER I,J,K, ITTFL, JFTRL, KTRAKL, NEARTTF(4,5)

      LOGICAL DOMINATD(3,4,5)

*****
      COMMON /NAMES/ TTFNAME, FIGHTER
      character TTFNAME(3)*10, FIGHTER(4)*5

*****
***** START OF CALCULATIONS:
***** (REFER TO THESIS FOR MORE EXPLANATION OF THEORY.)

      GREEKETA=(TOTNOFTR(1)*(KCFLTIME(1,1) + TURNTIME(NEARTTF(1,1)))
&      /FTRCELL(1) ) /KCLAPS(1,1)

*      METHODOLOGY NOTE: FLOW RATES THROUGH ALL OTHER AR TRACKS
*      ARE ALSO EQUAL TO THE ABOVE FLOW RATE (GREEKETA).

*      WRITE(12,0101)GREEKETA
* 0101  FORMAT(1X,'GREEKETA=',F10.2)

      DO 0200 J=1,JFTRL
      DO 0200 K=1,KTRAKL

      IF (GOOUT(NEARTTF(J,K),J,K).EQ.0.) GO TO 0200
*      IE: THIS TRACK DOES NOT EXIST

      SORINTVL(J,K)= KCFLTIME(J,K) + TURNTIME(NEARTTF(J,K))
      AVGLAPINT(J,K)= SORINTVL(J,K) / KCLAPS(J,K)

*!!      METHODOLOGY NOTE: AVG LAP INTERVALS (IE: AVG HOURS PER TRACKLAP)
*!!      ARE DENOTED BY LOWER CASE a1,a2, b1,b2,b3,...IN THE THESIS:

      0200 CONTINUE

```

* INITIALIZATION:

DO 0210 J=1,JFTRL
TRKRATIO(J)=0.0
0210 CONTINUE

*!! THE FOLLOWING SECTION CALCULATES ALPHA, BETA, DELTA, GAMMA:

DO 0300 J=1,JFTRL
DO 0300 K=1, KTRAKL

IF (GDDOUT(NEARTTF(J,K),J,K).EQ.0.) GO TO 0300
* IE: THIS TRACK DOES NOT EXIST

TRKRATIO(J)= TRKRATIO(J)+ (AVGLAPINT(J,K)/AVGLAPINT(J,1))

*!! METHODOLOGY NOTE: THE "SUM OF TRACK RATIOS" FOR EACH FIGHTER ARE
*!! DENOTED BY THE FOLLOWING GREEK LETTERS IN THE THESIS EXPLANATION:
*!! [F-16] ALPHA = TRKRATIO(1)
*!! [F-15] BETA = TRKRATIO(2)
*!! [F-111] DELTA = TRKRATIO(3)
*!! [RF-4C] GAMMA = TRKRATIO(4)

0300 CONTINUE

* INITIALIZE THE DENOMINATOR BEFORE ENTERING LOOP:
DENOM=TRKRATIO(1)

DO 0400 J=2,JFTRL

FTRRATIO(J)=(TOTNOFTR(J)*SORINTVL(J,1)/(FTRCELL(J)*KCLAPS(J,1)))
& / (TOTNOFTR(1)*SORINTVL(1,1)/(FTRCELL(1)*KCLAPS(1,1)))

*!! METHODOLOGY NOTE: THE "RATIOS BETWEEN FIGHTERS FOR AR1"
*!! ARE DENOTED BY THE FOLLOWING GREEK LETTERS IN THE THESIS:
*!! [F-15/F-16] THETA = FTRRATIO(2)
*!! [F-111/F-16] PHI = FTRRATIO(3)
*!! [RF-4C/F-16] PSI = FTRRATIO(4)

DENOM = DENOM + (TRKRATIO(J) * FTRRATIO(J))

0400 CONTINUE

*!! METHODOLOGY NOTE: NEXT, SOLVE FOR KCTRACK(1,1) WHICH IS DENOTED BY
*!! THE FOLLOWING EQUATION IN THE THESIS EXPLANATION:

*!!
*!! $A1 = 100 / (\text{ALPHA} + \text{BETA} * \text{THETA} + \text{GAMMA} * \text{PHI} + \text{DELTA} * \text{PSI})$
*!!

*!! WHERE DENOM IS THE DENOMINATOR IN THE ABOVE EQUATION.

KCTRACK(1,1)= 100. / DENOM

```

*!! THEN SOLVE FOR THE APPORTIONMENT OF TANKERS
*!! TO THE REMAINING AR1 TRACKS:

      DO 0500 J=2,JFTRL

          KCTRACK(J,1) = KCTRACK(1,1) * FTTRATIO(J)

0500  CONTINUE

*!! FINALLY, BASED ON THE ABOVE APPORTIONMENT OF TANKERS TO EACH AR1,
*!! SOLVE FOR THE APPORTIONMENT OF TANKERS TO THE REMAINING TRACKS.

      DO 0600 J=1,JFTRL
      DO 0600 K=1,KTRAKL

          IF (GDOUT(NEARTTF(J,K),J,K).EQ.0.) GO TO 0600
*          IE: THIS TRACK DOES NOT EXIST

          KCTRACK(J,K)=KCTRACK(J,1)*AVGLAPINT(J,K)/AVGLAPINT(J,1)

*!! NEXT, SUM THE APPORTIONMENTS OF EACH TTF:

          TTFAPPRT(NEARTTF(J,K)) = TTFAPPRT(NEARTTF(J,K))
&                                  + KCTRACK(J,K)

0600  CONTINUE

*!! CALCULATE [ADDEND 3] BASED ON THE ABOVE APPORTIONMENTS
*!! NOTE THAT ALL TYPES OF RECEIVERS HAVE EQUAL [ADDEND 3],
*!! SO IT DOESN'T MATTER WHICH OF THE KCTRACK(J,K), THE
*!! FOLLOWING CALCULATION USES:

      ADDEND3 = GREEKETA/KCTRACK(1,1)

*      WRITE(12,0701)ADDEND3
* 0701  FORMAT(1X,'100 TANKER, 1.00 RELIABILITY ADDEND3= ',F6.2)

*!! THE FOLLOWING IS THE CORRECTION FOR THE
*!! ACTUAL SIZE OF TOTAL TTF FORCE:

      ADDEND3 = ADDEND3 / (TOTALTNK/100.)

*      WRITE(12,0702)TOTALTNK,ADDEND3
* 0702  FORMAT(1X,'BASED ON ',F3.0,' TANKERS,      ADDEND3= ',F6.2)

*!! THE FOLLOWING IS THE CORRECTION FOR THE LESS THAN PERFECT
*!! RELIABILITY OF THE TANKER FORCE.
*!! (IE: THIS ASSUMES THAT WHEN A TANKER CAUSES
*!! A MISSED AIR REFUELING, THE FIGHTERS THAT ABORTED
*!! MUST ALL BE SENT BACK THROUGH THAT AIR REFUELING.)

      ADDEND3 = ADDEND3 / RELIBLTY

```

```

*      WRITE(12,0703)RELIBTY, ADDEND3
* 0703  FORMAT(1X,'BASED ON ',F4.2,' RELIABILITY, ADDEND3= ',F6.2)

*!!   FINALLY, CLOSURE TIME OF THE ENTIRE DEPLOYMENT IS CALCULATED.

      CLOSURE = SETUPM + FLYTOAR1 + ADDEND3 + FLYTODST

      RETURN
      END
*      {OF SUBROUTINE CLOSURE TIME}

```

```

*****
***** SUBROUTINE TANKER *****
*****
      SUBROUTINE TANKER

```

```

*** NOTE:  THIS PROGRAM WAS SUPPLIED BY THE THESIS SPONSOR,
***        MR. M.E. ESTES, OF THE AIR FORCE CENTER FOR
***        STUDIES AND ANALYSIS, MOBILITY DIVISION.

***        SEVERAL MINOR MODIFICATIONS HAVE BEEN MADE TO MAKE IT A
***        NON-INTERACTIVE SUBROUTINE, AND TO CALCULATE THE MAXIMUM
***        FEASIBLE NUMBER OF 'FLIGHTS' OF FIGHTERS THAT CAN BE
***        REFUELED.  THIS NUMBER IS CALLED 'TRACKLAPS' IN THE
***        DETERMTTF PROGRAM.

***        ALL MODIFICATIONS ARE INDICATED BY THE '***' SYMBOLS.

```

```

      COMMON /A      / DISTTA ,WT      ,AS(7) ,DAT
&                  ,DAT1      ,LCAS      ,IPNT
      REAL
&                  DAT      (17,7,4)
&                  ,DAT1      (17,5)
&                  ,DISTTA
&                  ,WT      (17)
      INTEGER IPNT      ,LCAS      (17,5)
      COMMON /B      / ALTX      ,CCAS      ,CFUEL      ,CTIME
&                  ,CDIST      ,TARTIME
      DOUBLE PRECISION CCCAS      (17)
&                  ,CDIST      (17,7)
&                  ,CFUEL      (17,7)
&                  ,CTIME      (17,7)
      REAL      TARTIME ,ALTX(8)
      COMMON /C      / RFDRA8      ,ONLOAD      ,YTAB1      ,YTAB2
&                  ,CCALT      ,CCNAM
      DOUBLE PRECISION CCALT      (17)
&                  ,CCNAM      (17)
&                  ,YTAB1      (17,7)
&                  ,YTAB2      (17,7)
      REAL      ONLOAD      ,RFDRA8

```

```

COMMON /D          / FARDST ,TIMELT,OFLOAD ,NUMREC
&                  ,FARALT ,ALT1(5) ,FARTIM
REAL
&                  FARALT      (15)
&                  ,FARDST      (15)
&                  ,FARTIM      (15)
&                  ,OFLOAD      (15)
&                  ,TIMELT (15)
INTEGER NUMREC
COMMON /E          / SPECIAL ,ANUMRC
DOUBLE PRECISION SPECIAL (17)
REAL ANUMRC (15)
COMMON /F          / NOPRNT
COMMON /G          / DAT2      ,ICTAS
REAL DAT2 (17,5)
INTEGER NOPRNT ,ICTAS (17,5)
* FOLLOWING COMMON LINES ADDED TO WORK WITH TTF PROGRAM:
COMMON /HUNSUCK/ITANKR,IFULOP,NUMFAR,NUMFA1
COMMON /THESIS/FULSUB,TOWT,OPWT,FULLND,CRUDRG,RTBALT,RTBTIM,FLTWT
&                  ,CWT,DIST1S,FARCAS,DIST3,WTTT,TOTA,TIME
REAL TOTA
***
REAL ALT,CLDIST,CLUDGE,CRUDRG,CURRWT,DIFF,DIST,DIST1,DIST1S
&                  ,DIST2,DIST3
&                  ,DLEG (9)
&                  ,DLEGSV (9)
&                  ,DLEGTM (9)
REAL FARCAS,FLTWT,FULLND,FULRES,FULSUB,OPWT,RCVR
&                  ,RTBALT,RTBTIM,SGWT,STIME,TARALT,TARCAS,TEMP,TIME,TOWT
&                  ,CWT,TOWT1,WTTT,Y1,Y2,Y3,Y4
INTEGER I,IX
&                  ,ICELL,IDECRM,IEND,IERR,IFLAG,IFULOP,ITANKR
&                  ,ITEMP,J,JJ,K,LL,ML,NUMAAR,NUMLSV,NUMLEG,NUMFAR
&                  ,NUMFA1
C ptr DATA ALTX /15000.,20000.,25000.,30000.,35000.,40000.,45000./
C ptr DATA ALT1 /15000.,20000.,25000.,30000.,35000./
C ptr DATA AS /250.,260.,270.,280.,290.,300.,310./

*DATA PASSING ECHO CHECK:
* WRITE(*,2)ITANKR,CWT,DIST1S
* 2 FORMAT(1X,'TANKER= ',I5,' CARGO = ',F5.0,' DIST= ',F6.1)
* WRITE(*,3)NUMFAR,ANUMRC(NUMFAR)
* 3 FORMAT(1X,I5,' CELLS OF ',F5.0,' FIGHTERS')
* WRITE(*,4)FARALT(1),FARCAS
* 4 FORMAT(1X,'REFUELING AT ALT: ',F6.0,' AT CAS: ',F5.0)
* WRITE(*,5)FARTIM(1),FARDST(1),OFLOAD(1)
* 5 FORMAT(1X,'DURATION=',F5.0,', DIST=',F5.0,', OFLOAD=',F7.0)
* WRITE(*,6)DIST3
* 6 FORMAT(1X,'RTB DISTANCE =',F5.0)
* WRITE(*,7)IFULOP
* 7 FORMAT(1X,'THE FOLLOWING NUMBER IS A TWO FOR AAR: ',I5)

* 1 FORMAT(F12.4)

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0020 CONTINUE
* 0020 WRITE(*,0021) ITANKR
* 0021 FORMAT(1X,'ENTER TANKER (DEFAULT=',I4,')')
* READ(*,*) ITANKR
C INCLUDE DATA UNPACKING AND TABLE INITIALIZATION
GO TO 5000
0100 CONTINUE
C END INCLUDE
* CWT=0.0
* TOTFUL=0.
* FULTSF=0.
C FARALT(1) = 0.
* NUMFAR = 1
* NUMFA1 = 1
* WRITE(*,0101) TOWT
* 0101 FORMAT(1X,'ENTER T.O. WEIGHT (DEFAULT =',F12.0,')')
* READ(*,*) TOWT
TOWT1=TOWT
* WRITE(*,0402) CWT
* 0402 FORMAT(1X,'ENTER CARGO WT (DEFAULT =',F12.0,')')
* READ(*,*) CWT
OPWT=OPWT+CWT
TOTFUL=TOWT-OPWT
* WRITE(*,0102)TOTFUL
* 0102 FORMAT(1X,'T.O. FUEL =',F8.1)
TOWT = TOWT - FULSUB
TIME=0.
* WRITE(*,0800) CRUDRG,RFDRA
* 0800 FORMAT(1X,'ENTER CRUISE AND REFUEL DRAG FACTOR (DEFAULT = ',
* & F12.0,', ',F12.0,')')
C READ(*,*) CRUDRG,RFDRA
CRUDRG = 2. - CRUDRG
RFDRA = 2. - RFDRA
IPNT = 0
* WRITE(*,*) 'ENTER A 1 TO EXPAND PRINT (DEFAULT = 0)'
* READ(*,*) IPNT
* WRITE (*,0900) DIST1S
* 0900 FORMAT (1X,'DISTANCE TO FIRST TAR OR RAR OR AAR
* & (DEFAULT = ',F12.0,')')
* READ(*,*) DIST1S
DIST1 = DIST1S
* IF(DIST1.EQ.0.) GO TO 1020
C INCLUDE NORMAL CLIMB AND TAR OPTION
GO TO 6500
1000 CONTINUE
C END INCLUDE
GO TO 1050
C ELSE
C INCLUDE BUDDY REFUELING CLIMB
1020 ASSIGN 1050 TO IM
* GO TO 9700
1050 CONTINUE
C END INCLUDE

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C      ENDIF
*      IF(IFULOP.EQ.3) GO TO 1200
C      INCLUDE RAR
* THE FOLLOWING LINE ADDED BY HUNSUCK:
      GO TO 7000
*
1100  CONTINUE
C      END INCLUDE
      GO TO 1250
C      ELSE
C      INCLUDE AAR
1200  ASSIGN 1250 TO IM
*      GO TO 9000
1250  CONTINUE
C      END INCLUDE
C      ENDIF
*      IF(IFULOP.NE.1)
*      &      ONLOAD = 0.
C      OFLD2 = TTFLC - TTFLB
C      OFLD = OFLD1 + OFLD2
C      WRITE(*) 'OFLD=', OFLD
*      WRITE(*,1600)WTTT,TOTA,ONLOAD
* 1600  FORMAT(1X,'REMAINING FUEL= ',F7.0,', FUEL USED= ',
*      & F7.0,', ONLOAD USED= ',F7.0)
*      WRITE(*,1610)(ANUMRC(I),I=1,NUMFA1)
* 1610  FORMAT(1X,'RECEIVERS BY CELL',8E12.2)
*      GO TO 0020
* (NOTE:THE FOLLOWING LINE WAS ADDED BY HUNSUCK TO STOP INFINITE LOOP:)
      RETURN
*****DATA UNPACKING AND TABLE INITIALIZATION*****
5000  CONTINUE
$$$      WRITE(*,*) '*** LABEL 5000, DATA UNPACK'
* 5000  IF(ITANKR.EQ.1) OPEN(10,FILE='GST86J:[JHUNSUCK.FUELS]TKRW.DAT',
*      & STATUS='OLD')
*      IF(ITANKR.EQ.2) OPEN(10,FILE='GST86J:[JHUNSUCK.FUELS]TKRTT.DAT',
*      & STATUS='OLD')
*      IF(ITANKR.EQ.3) OPEN(10,FILE='GST86J:[JHUNSUCK.FUELS]TKRXA.DAT',
*      & STATUS='OLD')
*      IF(ITANKR.EQ.4) OPEN(10,FILE='GST86J:[JHUNSUCK.FUELS]KC135.DAT',
*      & STATUS='OLD')
      READ (10,*)FULSUB
      READ (10,*)TOWT,OPWT,FULLND,FULRES,CRUDRG,RFDRA,RTBALT,
& RTBTIM,FLTWT
      READ (10,*)((CTIME(I,J),I=1,17),J=1,7)
      READ (10,*)((CCNAM(I),I=1,17)
      READ (10,*)((SPECIAL(I),I=1,17)
      READ (10,*)((DAT(I,J,K),I=1,17),J=1,7),K=1,4)
      READ (10,*)((DAT1(I,J),I=1,17),J=1,5)
      READ (10,*)((DAT2(I,J),I=1,17),J=1,5)
      REWIND(10)
*      CLOSE(10)
      DO 5020 J=1,7
      DO 5020 I=1,17

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```

CTIME(I,J)=CTIME(I,J)*100000.
ITEMP=CTIME(I,J)/100000
CFUEL(I,J)=FLOAT(ITEMP)
CLUDGE=CFUEL(I,J)*100000.
TEMP=CTIME(I,J)-CLUDGE
ITEMP=TEMP/1000
CTIME(I,J)=ITEMP*1.
5020 CDIST(I,J)=TEMP-(ITEMP*1000.)
DO 5030 I=1,17
ITEMP=CCNAM(I)/1000.
CCALT(I)=ITEMP*100.
ITEMP1=IDINT(CCNAM(I))-(ITEMP*1000)
CCCAS(I)=FLOAT(ITEMP1)
TEMP=CCCAS(I)+(CCALT(I)*10.)
CCNAM(I)=CCNAM(I)-TEMP
5030 CONTINUE
DO 5040 I=1,17
DO 5040 J=1,5
LCAS(I,J)=DAT1(I,J)/1
DAT1(I,J)=DAT1(I,J)-1.*LCAS(I,J)
ICTAS(I,J)=DAT2(I,J)/1
5040 DAT2(I,J)=DAT2(I,J)-1.*ICTAS(I,J)
A = 950000.
IF(ITANKR.EQ.4)A=320000.
B=50000
IF(ITANKR.EQ.4)B=20000.
DO 5050 I=1,17
A = A - B
5050 WT(I) = A
GO TO 0100
9999 STOP
C*****SET YTAB1,YTAB2,DIFF SECTION*****
6000 IFLAG = 0
* $$ WRITE(*,*) 'LABEL 6000 SET YTAB1'
JJ = 4
C DOWHILE(ALT.LE.ALT1(JJ))
GO TO 6020
6010 JJ = JJ - 1
6020 IF(ALT.LT.ALT1(JJ)) GO TO 6010
C ENDDO
LL = JJ + 1
IF(ALT.EQ.ALT1(JJ))
& IFLAG = 1
C ENDF
DO 6030 I=1,17
DO 6030 J=1,7
YTAB1(I,J) = DAT(I,J,JJ)
IF(IFLAG.NE.1)
& YTAB2(I,J) = DAT(I,J,LL)
C ENDF
6030 CONTINUE
C ENDDO
IF(IFLAG.NE.1)

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      & DIFF = ((ALT - ALT1(JJ))/1000.)/5.
C      ENDIF
      GO TO IZ, (7110,8210,9130)
C*****PROLAT SECTION*****
6300 CONTINUE

$$$      WRITE(*,*) '**** LABEL 6300, PROLAT'
      IF(DIST.LE.250.) GO TO 6320
      Y1 = TNT1(CURRWT,17,WT,CCALT,2,IERR)
C      WRITE(*) 'Y1=',Y1,ALT
      IF(Y1.LE.ALT) GO TO 6310
C      CALL PROLAT TO GET CLIMB NUMBERS
C      WRITE(*) 'WT BEFORE PROLAT=',CURRWT
      CALL PROLAT(Y1,Y2,Y3,ALT,CURRWT)
      TIME = TIME + (Y3/60.)
      DIST = DIST - Y2
C      WRITE(*) 'TIME AFTER PROLAT=',TIME
C      WRITE(*) 'WT AFTER PROLAT=',CURRWT
      Y1 = TNT1(CURRWT,17,WT,CCALT,2,IERR)
C      WRITE(*) 'ALT AFTER PROLAT=',Y1
6310 CONTINUE
C      ENDIF
      CALL CRUCLM(TIME,DIST,CURRWT,CRUDRG)
      GO TO 6340
C      ELSE
6320 CALL CRUISE(ALT,DIST,CURRWT,TIME,CRUDRG)
6340 CONTINUE
C      ENDIF
      GO TO IZ, (7190,8220,9165)
C*****NORMAL CLIMB AND TAR OPTION*****
6500 CONTINUE

$$$      WRITE(*,*) '**** LABEL 6500, NORMAL CLIMB AND TAR'
      TOWT1 = TOWT
      DO 6510 I=1,7
      Y1 = TNT1(TOWT1,17,WT,CCALT,2,IERR)
C      Y1 CONTAINS A HACK AT CRUISE CLIMB ALT
      CALL CLIMB(TOWT1,TIME,Y1,Y2,Y3,Y4)
6510 TOWT1 = TOWT - (Y2*CRUDRG)
C      ENDDO
      CLDIST = Y3
      CURRWT = TOWT1
      TIME = TIME + Y4/60.
      IF(CLDIST.GE.DIST1) GO TO 6520
      DIST1 = DIST1 - CLDIST
      GO TO 6530
C      ELSE
6520 DIST1 = 0.
6530 CONTINUE
C      ENDIF
      CALL CRUCLM(TIME,DIST1,CURRWT,CRUDRG)
C      WRITE(*) 'TIME,CURRWT,CLDIST=',TIME,CURRWT,CLDIST
      CLDIST=0.

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*      WRITE(*,6541) IFULOP
* 6541  FORMAT(1X,'ENTER A 1 FOR A TAR OR A 2 FOR A RAR OR A 3 FOR AN
*      &  AAR (DEFAULT = ',I4)')
*      READ(*,'(I4)') IFULOP
C      IFULOP = 2
      IF(IFULOP.NE.1) GO TO 6550
C      INCLUDE TAR REFUELING NUMBER 1
      ASSIGN 6550 TO IX
      GO TO 8000
6550  CONTINUE
C      END INCLUDE
C      ENDIF
      GO TO 1000
C*****RECEIVER DECREMENT*****
*** THE FOLLOWING LINES ADDED BY HUNSUCK TO MAKE DECREMENT OCCUR BY CELL:
6600  NUMFAR = NUMFAR -1
      IF (NUMFAR.EQ.0) IEND = 1
      NUMFA1=NUMFAR

***      WRITE(*,*) '***$ LABEL 6600 DECRM'
* 6600  IF(RCVR.EQ..5) GO TO 6610
*      ANUMRC(ICELL) = ANUMRC(ICELL) - 1
*      IF(ANUMRC(ICELL).EQ.0.)
*      &      ICELL = ICELL + 1
*C      ENDIF
* 6610  CONTINUE
*C      ENDIF
*      IF(RCVR.NE..5) GO TO 6650
*      IF(ANUMRC(1).EQ..5) GO TO 6620
*      ANUMRC(1) = .5
*      GO TO 6650
*C      ELSE
* 6620  ANUMRC(NUMFAR) = 0.
*      NUMFAR = NUMFAR - 1
*      IF(NUMFAR.GT.0)
*      &      ANUMRC(1) = 1.
*C      ENDIF
*      IF(NUMFAR.EQ.0)
*      &      IEND = 1
*C      ENDIF
* 6650  CONTINUE
*C      ENDIF
      GO TO 7070
C*****LOITER AND LAND*****
C      IF(NOPRNT.EQ.0)WRITE(*,*) 'ENTER LOITER ALT,TIME OVER RTB BASE'
C      IF(NOPRNT.EQ.0)READ(*,*) RTBALT,RTBTIM
6700  FARALT(ML) = RTBALT

***      WRITE(*,*) '***$ LABEL 6700 LOITER AND LAND'
      TIMELT(ML) = RTBTIM
      TOTL=OPWT+TOTFUL-CURRWT
      CALL LOITER(TIME,CURRWT,ML,CRUDRG)
      TIME = TIME + .583

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*      IF(NOPRNT.EQ.0)
*      &      WRITE(*,6710)TIME
C      ENDIF
* 6710  FORMAT(1X,'TOTAL TIME ',F8.1)
C      WRITE(*,*) 'ENTER LANDING FUEL'
C      READ(*,*) FULLND
      CURRWT = CURRWT - FULLND
      TOTA=TOTA+FULLND
      WTTT = CURRWT - OPWT
      GO TO IX, (7050,9075)
*****RAR*****
7000  CONTINUE
***      WRITE(*,*) '*** LABEL 7000. RAR'
* 7000  WRITE(*,7001)NUMFAR,(ANUMRC(I),I=1,NUMFAR)
* 7001  FORMAT(1X,'ENTER CELL STRUCTURE' / 1X,'DEFAULT VALUES: ',
*      &  I4,(' ',F8.0))
*      READ(*,*)NUMFAR,(ANUMRC(I),I=1,NUMFAR)
      NUMFA1 = NUMFAR
*      WRITE(*,7002) FARALT(1),FARCAS
* 7002  FORMAT (1X,'ENTER RAR ALTITUDE AND CAS (DEFAULT = ',F12.0,',',
*      &  F12.0,')')
*      READ(*,*) FARALT(1),FARCAS
C      FARALT(1)=FARASAV
      TIMELT(1) = 15.
      TIMELT(2) = 15
      RCVR = 1.
      IF(ANUMRC(1).EQ.1.)
&      RCVR = .5
C      ENDIF
      IF(RCVR.EQ.1.) GO TO 7010
      WRITE(*,7005) TANKLT
7005  FORMAT(1X,'ENTER 2ND LOITER TIME (DEFAULT = ',F12.0,')')
      READ(*,*) TANKLT
      IF(TANKLT.EQ.0) RCVR = 1.
7010  CONTINUE
C      ENDIF
*      WRITE(*,*) ' ENTER TIME,DISTANCE AND OFLOAD FOR RAR'
*      WRITE(*,*) ' DEFAULTS ARE: '
*      WRITE(*,7015) FARTIM(1), FARDST(1), OFLOAD(1)
* 7015  FORMAT(10X,F8.0,', ',F8.0,', ',F8.0,/)
*      READ(*,*) FARTIM(1),FARDST(1),OFLOAD(1)
      DO 7020 I=1,NUMFAR-1
      FARTIM(I+1)=FARTIM(1)
      FARDST(I+1)=FARDST(1)
      OFLOAD(I+1)=OFLOAD(1)
      TIMELT(I+1)=TIMELT(2)
      FARALT(I+1)=FARALT(1)
7020  CONTINUE
C      ENDDO
*      WRITE(*,7021) DIST3
* 7021  FORMAT(1X,'WHAT IS DISTANCE TO RTB BASE OR TAR? (DEFAULT = ',
*      &  F12.0,')')
*      READ(*,*) DIST3

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*      WRITE(*,*) 'ENTER A 1 FOR TAR ON WAY HOME '
*      READ(*, '(I4)') IFULOP
C      IFULOP = 2
      IF(IFULOP.NE.1) GO TO 7026
*      WRITE(*,7022) DISTTA
* 7022  FORMAT(1X,'WHAT IS DISTANCE TO TAR (DEFAULT = ',F12.0,')')
*      READ(*,*) DISTTA
*      WRITE(*,7023) TARTIME
* 7023  FORMAT(1X,'ENTER TIME (MIN) FOR TAR (DEFAULT = ',F12.0,')')
*      READ(*,*) TARTIME
*      WRITE(*,7024) TARALT,TARCAS
* 7024  FORMAT(1X,'WHAT IS TAR ALTITUDE AND CAS? (DEFAULT = ',
*      & F12.0,', ',F12.0,')')
*      READ(*,*) TARALT,TARCAS
*      WRITE(*,7025) DIST2
* 7025  FORMAT(1X,'WHAT IS DISTANCE TO NEXT TAR OR RTB BASE? (DEFAULT =
*      & ',F12.0,')')
*      READ(*,*) DIST2
      7026  CONTINUE
C      ENDIF
      STIME = TIME
      SGWT = CURRWT
      STOTFUL=TOTFUL
      NOPRNT= 1
      IEND = 0
      ICELL = 1
C      DO UNTIL (IEND=1)
      7027  IF(NOPRNT.EQ.0)
      &      IEND = 1
C      ENDIF
      CURRWT = SGWT
      TIME = STIME
      TOTFUL=STOTFUL
      ML = ICELL
      IDECRM = 0
C      INCLUDE RAR REFUELING
      GO TO 7100
      7030  CONTINUE
C      END INCLUDE
      IF(IDECRM.EQ.1) GO TO 7060
      IF(IFULOP.NE.1) GO TO 7040
C      INCLUDE TAR NUMBER 2
      ASSIGN 7040 TO IX
      GO TO 8100
      7040  CONTINUE
C      END INCLUDE
C      ENDIF
C      INCLUDE LOITER AND LAND
      ASSIGN 7050 TO IX
      GO TO 6700
      7050  CONTINUE
C      END INCLUDE
      IF(IFULOP.NE.1)

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      & IDECRM = ICHEK(IFULOP,CURRWT,OPWT,FULRES)
C      ENDIF
      IF(IDECRM.EQ.0)
      & NOPRNT = 0
C      ENDIF
7060 CONTINUE
C      ENDIF
      IF(IDECRM.EQ.0) GO TO 7080
C      INCLUDE RECEIVER DECREMENT
      GO TO 6600
7070 CONTINUE
C      END INCLUDE
      IF(NOPRNT.EQ.0) GO TO 7080
*      WRITE(*,*) NOPRNT
      NOPRNT = NOPRNT + 1
7080 CONTINUE
C      ENDIF
C      ENDIF
      IF(IEND.NE.1) GO TO 7027
C      ENDDO
      GO TO 1100
C*****RAR REFUELING*****
7100 ALT = FARALT(1)
$$$      WRITE(*,*) '***$ LABEL 7100, RAR REFUELING'

C      INCLUDE SET YTAB1,YTAB2,DIFF
      ASSIGN 7110 TO IZ
      GO TO 6000
7110 CONTINUE
C      END INCLUDE
C      IF ((ML.GT.NUMFAR).OR.(IDECRM.EQ.1)) THEN
7120 CRUTIM = TIMELT(8)
      IF ((RCVR.EQ..5).AND.(ML.GT.1))
      &      TIMELT(ML) = TANKLT - CRUTIM - FARTIM(1)
      IF(TIMELT(ML).LT.0) WRITE(*,7130)
7130 FORMAT(1h,'TIMELT TO SMALL')

$$$ the following added by hunsuck:
*      idecrm=ichek(ifulop,currwt,opwt,fulres)
      if (totful.le.35000) idecrm=1
      if(idecrm.eq.1) go to 7030
$$$
      CALL LOITER(TIME,CURRWT,ML,CRUDRG)
      IDECRM = ICHEK(IFULOP,CURRWT,OPWT,FULRES)
$$$ the following added by hunsuck:
      if (totful.le.35000) idecrm=1
      if(idecrm.eq.1) go to 7030
$$$

*      IF(IDECRM.EQ.1) GO TO 7180
*      IF(NOPRNT.EQ.0)
*      &      WRITE(*,7140) TIME
* 7140 FORMAT(1H,'CUM TIME = ',F8.1)

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      TIME = TIME + FARTIM(ML)/60
      TOTFUL=TOTFUL-(OFLOAD(ML)*ANUMRC(ML))
*** the following added by hunsuck:
      idecrm=ichek(ifulop,currwt,opwt,fulres)
      if (totful.le.35000) idecrm=1
      if(idecrm.eq.1) go to 7030
***
      CALL LOAD(ML,CURRWT,FARCAS,IFLAG,DIFF,CRUDRG,2)
      IDECRM = ICHEK(IFULOP,CURRWT,OPWT,FULRES)
*      IF(IDECRM.EQ.1) GO TO 7180
*** the following added by hunsuck:
      if (totful.le.3500) idecrm=1
      if (idecrm.eq.1) go to 7030
      if (currwt.lt.(opwt+ofload(ml)*ANUMRC(ml)+30000)
& .and. (ml.lt.numfar)) then
          idecrm=1
          go to 7030
      end if
***      ie: if you can't refuel another flight, don't try!

      IF(ML.NE.NUMFAR)
&      CALL CRUISE(FARALT(ML),FARDST(ML),CURRWT,TIME,CRUDRG)
      ML = ML + 1
      IDECRM = ICHEK(IFULOP,CURRWT,OPWT,FULRES)

**** THE FOLLOWING LINE ADDED BY HUNSUCK:
      WRITE(*,7179)ML,CURRWT
7179  FORMAT(1X,'ML=',I2,' CURRWT=',F10.0)
      IF (IDECRM.EQ.1) GO TO 7180
***
7180  CONTINUE
      IF(ML.LE.NUMFAR.AND.IDECRM.NE.1) GO TO 7120
C      END IF
      IF(IDECRM.EQ.1) GO TO 7190
      DIST = DIST3
      ASSIGN 7190 TO IZ
* THE FOLLOWING LINE ADDED BY HUNSUCK:
*      WRITE(*,7181)IDECRM,NUMFAR
* 7181  FORMAT(1X,' 7181; IDECRM=',I3,' NUMFAR=',I3)
*
      GO TO 6300
7190  CONTINUE
      IDECRM = ICHEK(IFULOP,CURRWT,OPWT,FULRES)

* THE FOLLOWING LINE ADDED BY HUNSUCK:
*      WRITE(*,7191) IDECRM,NUMFAR
* 7191  FORMAT(1X,' 7191; IDECRM=',I3,' NUMFAR=',I3)
*
      GO TO 7030
C*****IAR REFUELING NUMBER 1*****
8000  WRITE(*,8005) DISTTA,ONLOAD
***      WRITE(*,*) '*$$$ LABEL 8000, TAR REFL 1'

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8005 FORMAT(1X,'ENTER DISTANCE AND ONLOAD FOR TAR (DEFAULT = ',
& F12.0,', ',F12.0,')')
READ(*,*) DISTTA,ONLOAD
WRITE(*,8008) TARTIME
8008 FORMAT(1X,'ENTER TIME (MIN) FOR TAR NUMBER 1 (DEFAULT = ',
& F12.0,')')
READ(*,*) TARTIME
WRITE(*,8020) TARALT,TARCAS
8020 FORMAT(1X,'WHAT IS TAR ALTITUDE AND CAS? (DEFAULT = ',
& F12.0,', ',F12.0,')')
READ(*,*) TARALT,TARCAS
WRITE(*,8030) DIST2
8030 FORMAT(1X,'DISTANCE TO AAR OR RAR (DEFAULT = ',
& F12.0,')')
READ(*,*) DIST2
WRITE(*,*) 'ENTER A 2 FOR A RAR OR A 3 FOR AN AAR'
READ(*, '(I4)') IFULOP
C IFULOP = 2
C INCLUDE TAR REFUELING
ASSIGN 8070 TO IY
GO TO 8200
8070 CONTINUE
C END INCLUDE
GO TO IX, (6550)
C*****TAR REFUELING NUMBER 2*****
8100 ONLOAD = FLTWT - CURRWT
*$$ WRITE(*,*) '***$ LABEL 8100. TAR 2'
IF(NOPRNT.NE.0) GO TO 8160
IF(ONLOAD.LE.WTTT)
& ONLOAD = 0.
C ENDIF
IF(ONLOAD.GT.WTTT.AND.WTTT.GT.0.)
& ONLOAD = ONLOAD - WTTT
C ENDIF
8160 CONTINUE
C ENDIF
C INCLUDE TAR REFUELING
ASSIGN 8170 TO IY
GO TO 8200
8170 CONTINUE
C END INCLUDE
GO TO IX, (7040,9070)
C*****TAR REFUELING*****
8200 ALT = TARALT
*$$ WRITE(*,*) '***$ LABEL 8200, TAR REFUELING'
C INCLUDE SET YTAB1,YTAB2,DIFF
ASSIGN 8210 TO IZ
GO TO 6000
8210 CONTINUE
C END INCLUDE
TOTFUL=TOTFUL+ONLOAD
CALL LOAD(1,CURRWT,TARCAS,IFLAG,DIFF,CRUDRG,1)

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      TIME = TIME + TARTIME/60.
C      WRITE(*,*) 'TIME AFTER TARTIME',TIME
      DIST = DIST2
C      INCLUDE PROLAT SECTION
      ASSIGN 8220 TO IZ
      GO TO 6300
8220  CONTINUE
C      END INCLUDE
C      WRITE(*,*) 'TIME AFTER CRU TO NEXT TAR',TIME
      GO TO IY, (8070,8170)
C*****AAR*****
9000  DO 9010 I=1,8
C      DLEG(I) = 0.
C      FARTIM(I) = 0.
C      FARDST(I) = 0.
C      OFLOAD(I) = 0.
9010  CONTINUE
$$$      WRITE(*,*) '$$$ LABEL 9010, AAR'
C      ENDDO
      TIMELT(1) = 15.
      WRITE(*,9012) ANMRCS
9012  FORMAT(1X,'ENTER NUMBER OF RECEIVERS (DEFAULT = ',
& F12.0,')')
      READ(*,*) ANMRCS
      ANUMRC(1)=ANMRCS
      IF(FARALT(1).NE.0.) GO TO 9014
      WRITE(*,9013) FARALT(1),FARCAS
9013  FORMAT(1X,'ENTER REFUEL ALTITUDE AND CAS (DEFAULT = ',
& F8.0,', ',F8.0,')')
      READ(*,*) FARALT(1),FARCAS
C      FARALT(1)=FARASAV
      CALL LOITER(TIME,CURRWT,1,CRUDRG)
9014  CONTINUE
C      ENDIF
      WRITE(*,9015) NUMLSV,NUMAAR
9015  FORMAT(1X,'ENTER NUMBER OF LEGS AND NUMBER OF AARs (DEFAULT = ',
& I4,', ',I4,')')
      READ(*,*) NUMLSV,NUMAAR
      NUMLEG=NUMLSV
      ICHG=0
      WRITE(*,*) 'TYPE A 1 TO ENTER NEW CRUISE DISTANCES & TIMES'
      READ(*, '(I4)') ICHG
      IF(ICHG.NE.1) GO TO 9017
      WRITE(*,*) ' ENTER ALL CRUISE DISTANCES AND TIMES IN ORDER'
      WRITE(*,*) ' DEFAULTS ARE:'
      WRITE(*,9016) (DLEGSV(I),DLEGTM(I),I = 1,NUMLEG)
9016  FORMAT(10X,F9.0,5X,F9.0,/)
      READ(*,*) (DLEGSV(I),DLEGTM(I), I = 1,NUMLEG)
      DO 9027 I = 1,NUMLEG
9027  DLEG(I)=DLEGSV(I)
      IF(DLEG(1).LE.CLDIST)
& DLEG(1) = 0.
C      ENDIF

```

```

      IF(DLEG(1).GT.CLDIST)
      &      DLEG(1) = DLEG(1) - CLDIST
C      ENDIF
9017  CONTINUE
      ICHG=0
      WRITE(*,*) 'TYPE 1 TO ENTER NEW TIME,DISTANCE & OFLOAD FOR AAR'
      READ(*,'(I4)') ICHG
      IF(ICHG.NE.1) GO TO 9019
      WRITE(*,*) ' ENTER TIME,DISTANCE & OFLOAD FOR AARS IN ORDER'
      WRITE(*,*) ' DEFAULTS ARE:'
      WRITE(*,9018) (FARTIM(I),FARDST(I),OFLOAD(I),I = 1,NUMAAR)
9018  FORMAT(10X,F8.0,3X,F8.0,3X,F8.0,/)
      READ(*,*) (FARTIM(I),FARDST(I),OFLOAD(I), I=1,NUMAAR)
9019  CONTINUE
      WRITE(*,9020) DIST3
9020  FORMAT(1X,'WHAT IS DISTANCE TO RTB BASE OR TAR? (DEFAULT = ',
      &  F12.0,')')
      READ(*,*) DIST3
      IFULOP = 0
      IF(DIST3.EQ.0.) GO TO 9030
      WRITE(*,*) 'ENTER A 1 FOR TAR ON WAY HOME '
      READ(*,'(I4)') IFULOP
C      IFULOP = 2
      IF(IFULOP.NE.1) GO TO 9030
      WRITE (6,9021)DISTTA
9021  FORMAT(1X,'WHAT IS DISTANCE FOR TAR NUMBER 2 (DEFAULT = ',
      &  F12.0,')')
      READ(*,*) DISTTA
      WRITE(*,9022)TARTIME
9022  FORMAT(1X,'ENTER TIME (MIN) FOR TAR (DEFAULT = ',F12.0,')')
      READ(*,*) TARTIME
      WRITE(*,9023)TARALT,TARCAS
9023  FORMAT(1X,'WHAT IS TAR ALTITUDE AND CAS (DEFAULT = ',
      &  F12.0,', ',F12.0,')')
      READ(*,*) TARALT,TARCAS
      WRITE(*,9024) DIST2
9024  FORMAT(1X,'DISTANCE TO NEXT TAR OR RTB (DEFAULT = ',
      &  F12.0,', ',F12.0,')')
      READ(*,*) DIST2
9030  CONTINUE
C      ENDIF
C      ENDIF
      STIME = TIME
      SGWT = CURRWT
      STOTFUL=TOTFUL
      NOPRNT = 1
      IEND = 0
C      DO UNTIL (IEND=1)
9045  IF(NOPRNT.EQ.0)
      &      IEND = 1
C      ENDIF
      CURRWT = SGWT
      TIME = STIME

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```

      TOTFUL=STOTFUL
      IDECRM = 0
C      INCLUDE AAR REFUELING
      ASSIGN 9050 TO IX
      GO TO 9100
9050  CONTINUE
C      END INCLUDE
      IDECRM = ICHEK(IFULOP,CURRWT,OPWT,FULRES)
      IF(IDECRM.EQ.1) GO TO 9080
      IF(IFULOP.NE.1) GO TO 9070
C      INCLUDE TAR NUMBER 2
      ASSIGN 9070 TO IX
      GO TO 8100
9070  CONTINUE
C      END INCLUDE
C      ENDIF
      ML=8
C      INCLUDE LOITER AND LAND
      ASSIGN 9075 TO IX
      GO TO 6700
9075  CONTINUE
C      END INCLUDE
      IF(IFULOP.NE.1)
&      IDECRM = ICHEK(IFULOP,CURRWT,OPWT,FULRES)
C      ENDIF
      IF(IDECRM.EQ.0)
&      NOPRNT = 0
C      ENDIF
9080  CONTINUE
C      ENDIF
      IF(IDECRM.NE.1) GO TO 9090
      ANUMRC(1) = ANUMRC(1) - 1
      IF(ANUMRC(1).EQ. 0)
&      IEND = 1
C      ENDIF
      IF(NOPRNT.EQ.0) GO TO 9090
      WRITE(*,*) NOPRNT
      NOPRNT = NOPRNT + 1
9090  CONTINUE
C      ENDIF
C      ENDIF
      IF(IEND.EQ.0) GO TO 9045
      GO TO IM, (1250)
C*****AAR REFUELING*****
9100  ALT = FARALT(1)
      WRITE(*,*) '***$ LABEL 9100, AAR REFUELING'
C      INCLUDE SET YTAB1,YTAB2,DIFF
      ASSIGN 9130 TO IZ
      GO TO 6000
9130  CONTINUE
C      END INCLUDE
      ML = 1
C      DO UNTIL (IDECRM.EQ.1.OR.(ML.GT.NUMLEG.AND.ML.GT.NUMAAR))

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```

C      INCLUDE CRUISE LEG
9135  ASSIGN 9140 TO IY
      GO TO 9500
9140  CONTINUE
C      END INCLUDE
      IF(IDECRM.EQ.1) GO TO 9160
C      INCLUDE AARLEG
      ASSIGN 9150 TO IY
      GO TO 9600
9150      CONTINUE
C      END INCLUDE
      ML = ML + 1
9160      CONTINUE
C      ENDIF
      IF(IDECRM.NE.1.AND.(ML.LE.NUMLEG.OR.ML.LE.NUMAAR)) GO TO 9135
C      ENDDO
      IF(IDECRM.EQ.1) GO TO 9180
      IF(DIST3.EQ.0) GO TO 9180
      DIST = DIST3
C      INCLUDE PROLAT SECTION
      ASSIGN 9165 TO IZ
      GO TO 6300
9165      CONTINUE
C      END INCLUDE
9180      CONTINUE
C      ENDIF
C      ENDIF
      GO TO IX, (9050)
*****CRUISE LEG*****
9500  CONTINUE
      WRITE(*,*) '***$ LABEL 9500, CRUISE LEG'

      IF(ML.GT.NUMLEG) GO TO 9550
      TIME = TIME + DLEGT(ML)/60.
      DIST = DLEG(ML)/10.
      DO 9545 I=1,10
          Y1 = TNT2(CURRWT,FARCAS,17,7,WT,AS,YTAB1,IERR1,IERR2,17,0)
          IF(IFLAG.EQ.1) GO TO 9530
          Y2 = TNT2(CURRWT,FARCAS,17,7,WT,AS,YTAB2,IERR1,IERR2,17,0)
          Y1 = Y1 + (DIFF*(Y2 - Y1))
9530      CONTINUE
C      ENDIF
      A = FUEL(Y1,DIST,CRUDRG)
      CURRWT = CURRWT - A
      IDECRM = ICHEK(IFULOP,CURRWT,OPWT,FULRES)
      IF(NOPENT.EQ.0.AND.IPNT.EQ.1)
          &      WRITE(*,9540)ML,1,DIST,A,CURRWT
9540      &      FORMAT(1H,'CRUISE LEG ',I2,' SUBLEG ',I2,' DIST= ',F5.1,
          &      ' FUEL USED= ',F8.0,' GWT=',F8.0)
C      ENDIF
9545      CONTINUE
C      ENDDO
9550      CONTINUE

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C      ENDIF
      GO TO IY, (9140)
C*****AARLEG*****
9600 CONTINUE
***      WRITE(*,*) '*** LABEL 9600, AARLEG'
      IF (ML.GT.NUMAAR) GO TO 9650
      ANUMRC(ML) = ANUMRC(1)
      TIME = TIME + FARTIM(ML)/60.
C      TTFLC=TOTFUL
      IF (OFLOAD(ML).GT.0)
&      TOTFUL=TOTFUL-(OFLOAD(ML)*ANUMRC(1))
C      TTFLD=TOTFUL
C      ENDIF
      IF (OFLOAD(ML) .LT.0)
&      TOTFUL=TOTFUL-OFLOAD(ML)
C      ENDIF
      CALL LOAD(ML,CURRWT,FARCAS,IFLAG,DIFF,CRUDRG,2)
      IDECRM = ICHEK(IFULOP,CURRWT,OPWT,FULRES)
9650 CONTINUE
C      ENDIF
      GO TO IY, (9150)
C*****BUDDY REFUELING CLIMB*****
9700 CONTINUE
***      WRITE(*,*) '*** LABEL 9700, BUDDY REFL CLIMB'

      WRITE(*,9710) FARALT(1),FARCAS
9710 FORMAT(1X,'ENTER REFUEL ALTITUDE AND CAS (DEFAULT = ',
& F12.0,', ',F12.0,')')
      READ(*,*) FARALT(1),FARCAS
C      FARALT(1)=FARASAV
      Y1 = FARALT(1)
      TOWT1 = TOWT
      CALL CLIMB(TOWT1,TIME,Y1,Y2,Y3,Y4)
      CURRWT = TOWT - Y2
      CLDIST = Y3
C      TIME = TIME + Y4/60.
      IFULOP = 3
      GO TO IM, (1050)
      END
C *****
      SUBROUTINE PROLAT(Y1,Y2,Y3,ALTOLD,CURRWT)
      COMMON/A/DISTTA,WT(17),AS(7),DAT(17,7,4),DAT1(17,5),LCAS(17,5),
& INPNT
      COMMON/B/ALT(8),CCAS(17),CFUEL(17,7),CTIME(17,7),CDIST(17,7),
& TARTIME
      COMMON/C/RFDRAG,ONLOAD,YTAB1(17,7),YTAB2(17,7),CCALT(17),
& CCNAM(17)
      COMMON/D/FARDST(15),TIMELT(15),OFLOAD(15),NUMREC,FARALT(15),
& ALT1(5),FARTIM(15)
      DOUBLE PRECISION CTIME,CCNAM,CCAS
      DOUBLE PRECISION CFUEL,CDIST,CCALT
      DOUBLE PRECISION YTAB1,YTAB2
      WTT=CURRWT

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DO 10 L=1,5
ALTNEW=TNT1(WTT,17,WT,CCALT,2,IERR)
DO 1 I=1,2
IF(I.EQ.1)AALT=ALTOLD
IF(I.EQ.2)AALT=ALTNEW
IF(I.EQ.2)GO TO 3
Y1=TNT2(WTT,AALT,17,7,WT,ALT,X,CFUEL,IERR1,IERR2,17,0)
C WRITE(*,*) 'Y1=',Y1
Y2=TNT2(WTT,AALT,17,7,WT,ALT,X,CDIST,IERR1,IERR2,17,0)
C WRITE(*,*) 'Y2=',Y2
Y3=TNT2(WTT,AALT,17,7,WT,ALT,X,CTIME,IERR1,IERR2,17,0)
C WRITE(*,*) 'Y3=',Y3
GO TO 1
3 CONTINUE
Y4=TNT2(WTT,AALT,17,7,WT,ALT,X,CFUEL,IERR1,IERR2,17,0)
C WRITE(*,*) 'Y4=',Y4
Y5=TNT2(WTT,AALT,17,7,WT,ALT,X,CDIST,IERR1,IERR2,17,0)
C WRITE(*,*) 'Y5=',Y5
Y6=TNT2(WTT,AALT,17,7,WT,ALT,X,CTIME,IERR1,IERR2,17,0)
C WRITE(*,*) 'Y6=',Y6
1 CONTINUE
Y1=(Y4-Y1)
Y2=(Y5-Y2)
Y3=(Y6-Y3)
C WRITE(*,*) 'FUEL,DIST AND TIME=',Y1,Y2,Y3
GO TO 6
6 CONTINUE
WTT=CURRWT-Y1
C WRITE(*,*) 'WTT=',WTT
10 CONTINUE
CURRWT=WTT
RETURN
END
C*****
SUBROUTINE CRUCLM(TIME,DISTER,WTT,DRAG)
COMMON/A/DISTTA,WT(17),AS(7),DAT(17,7,4),DAT1(17,5),LCAS(17,5),
& IPNT
COMMON/B/ALT(X),CCAS(17),CFUEL(17,7),CTIME(17,7),CDIST(17,7),
& TARTIME
COMMON/C/RFDRA,UNLOAD,YTAB1(17,7),YTAB2(17,7),CCALT(17),
& CCNAM(17)
COMMON/D/FARDST(15),TIMELT(15),OFLOAD(15),NUMREC,FARALT(15),
& ALT1(5),FARTIM(15)
COMMON/F/NOFRT
DOUBLE PRECISION CCNAM,CCAS,CCALT
DOUBLE PRECISION CDIST,CFUEL,CTIME
DOUBLE PRECISION YTAB1,YTAB2
WRITE(*,*) '*** SUBROUTINE CRUISECLIMB '
DO 10 I=1,10
DIST=DISTER/10.
Y1=TNT1(WTT,17,WT,CCNAM,2,IERR)
Y2=TNT1(WTT,17,WT,CCAS,2,IERR)
A = FUEL(Y1,DIST,DRAG)

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WTT = WTT - A
Y3=TNT1(WTT,17,WT,CCALT,2,IERR)
IF(Y3.EQ.0)WTT=0
TIME=TIME+(DIST/Y2)
IF(IPNT.EQ.1.AND.NOPRNT.EQ.0)WRITE(*,100)I,DIST,Y2,Y3,WTT
100  FORMAT(1X,'ON CC SUBLEG ',I2,' , DIST =',F4.0,' , TAS= ',
&  F8.1,' ALT= ',F6.0,' , AND WT= ',F8.0)
10  CONTINUE
RETURN
END
C*****
SUBROUTINE LOAD(M,CURRWT,TARCAS,IFLAG,DIFF,CRUDRG,MM)
COMMON/A/DISTTA,WT(17),AS(7),DAT(17,7,4),DAT1(17,5),LCAS(17,5),
&  IPNT
COMMON/B/ALT(8),CCAS(17),CFUEL(17,7),CTIME(17,7),CDIST(17,7),
&  TARTIME
COMMON/C/RFDRA,ONLOAD,YTAB1(17,7),YTAB2(17,7),CCALT(17),
&  CCNAM(17)
COMMON/D/FARDST(15),TIMELT(15),OFLOAD(15),NUMREC,FARALT(15),
&  ALT1(5),FARTIM(15)
COMMON/E/SPECIAL(17),ANUMRC(15)
COMMON/F/NOPRNT
DOUBLE PRECISION CTIME,CCNAM,CCAS
DOUBLE PRECISION CFUEL,CDIST,CCALT
DOUBLE PRECISION YTAB1,YTAB2
DOUBLE PRECISION SPECIAL
$$$  WRITE(*,*) '$$$$ SUBROUTINE LOAD'
IF(MM.EQ.1)DIST=DISTTA/5.
IF(MM.EQ.2)DIST=FARDST(M)/5.
A=ANUMRC(M)
IF(OFLOAD(M).LT.0) A=1
IF(MM.EQ.2)LOADD=OFLOAD(M)*A
IFLAGG=0
IF(FARALT(1).NE.35000.)GO TO 1
IF(TARCAS.NE.260.)GO TO 1
Y1=TNT1(CURRWT,17,WT,SPECIAL,2,IERR)
WRITE(*,*) 'SPECIAL AIRCRAFT'
IFLAGG=1
1  DO 16 J=1,5
    IF(IFLAGG.EQ.1)GO TO 2
    Y1=TNT2(CURRWT,TARCAS,17,7,WT,AS,YTAB1,IERR1,IERR2,17,0)
    IF(IFLAG.NE.1)Y2=TNT2(CURRWT,TARCAS,17,7,WT,AS,YTAB2,IERR1,IERR2,
&  17,0)
    IF(IFLAG.NE.1)Y1=Y1+(DIFF*(Y2-Y1))
2  A=FUEL(Y1,DIST,CRUDRG)
    IF(MM.EQ.1)CURRWT = CURRWT - A + ONLOAD/5.
    A=FUEL(Y1,DIST,RFDRA)
    IF(MM.EQ.2)CURRWT = CURRWT - A - LOADD/5.
    IF(CURRWT.LE.100000) CURRWT = 100000
C  WRITE(*,100) J,DIST,CURRWT
    IF(IPNT.EQ.1.AND.NOPRNT.EQ.0)WRITE(*,100)J,DIST,CURRWT
100  FORMAT(1X,'ON TAR OR RAR SUBLEG ',I2,' DIST= ',F5.0,
&  ' CURRWT= ',F8.0)

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16    CONTINUE
C    WRITE(*,105) CURRWT,M
*    IF(NOPRNT.EQ.0)WRITE(*,105)CURRWT,M
* 105  FORMAT(1X,'CURRENT WT= ',F7.0,' AFTER TAR OR RAR NUM ',I1)
      RETURN
      END
C*****
      SUBROUTINE CLIMB(TOWT1,TIME,Y1,Y2,Y3,Y4)
      COMMON/A/DISTTA,WT(17),AS(7),DAF(17,7,4),DAF1(17,5),LCAS(17,5),
&  IPNT
      COMMON/B/ALT(8),CCAS(17),CFUEL(17,7),CTIME(17,7),CDIST(17,7),
&  TARTIME
      COMMON/C/RFDRAG,ONLOAD,YTAB1(17,7),YTAB2(17,7),CCALT(17),
&  CCNAM(17)
      COMMON/D/FARDST(15),TIMELT(15),OFLOAD(15),NUMREC,FARALT(15),
&  ALT1(5),FARTIM(15)
      DOUBLE PRECISION CTIME,CCNAM,CCAS
      DOUBLE PRECISION CFUEL,CDIST,CCALT
      DOUBLE PRECISION YTAB1,YTAB2
      WRITE(*,*) '**** SUBROUTINE CLIMB '
      Y2=TNT2(TOWT1,Y1,17,7,WT,ALT,CFUEL,IERR1,IERR2,17,0)
      Y3=TNT2(TOWT1,Y1,17,7,WT,ALT,CDIST,IERR1,IERR2,17,0)
      Y4=TNT2(TOWT1,Y1,17,7,WT,ALT,CTIME,IERR1,IERR2,17,1)
C    WRITE(*,100)Y1,Y2,Y3,Y4
      100  FORMAT(2X,'FINAL ALT,WT,DIST,TIME=',
&  2X,F7.1,2X,F7.1,2X,F5.1,2X,F4.1)
      RETURN
      END
C*****
      FUNCTION TNT1(XARG,NTBARG,XTBARG,YTBARG,NPTARG,NERR)
      DIMENSION XTBARG(NTBARG),YTBARG(NTBARG)
      DOUBLE PRECISION YTBARG
*$    WRITE(*,*) '**** FUNCTION TNT1'
      1    NTAB=NTBARG
      X=XARG
      NPT=MIN0(NTAB,NPTARG)
C    *****TABLE SEARCH*****J1)
      CALL TLU1(X,NTAB,XTBARG,J,NERR)
      IF(NERR.NE.0) GOTO 901
      JMIN=MAX0(1,J-(NPT-1)/2)
      JMAX=JMIN+(NPT-1)
      N1=NTAB-JMAX
      IF(N1.GE.0)GO TO 21
      JMAX=JMAX+N1
      JMIN=JMIN+N1
      21    Y=0
      DO 91 J1=JMIN,JMAX
      TEMP=YTBARG(J1)
      DO 41 J2=JMIN,JMAX
      IF(J1.EQ.J2)GO TO 41
      TEMP=TEMP*(X-XTBARG(J2))/(XTBARG(J1)-XTBARG(J2))
      41    CONTINUE
      Y=Y+TEMP

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91    CONTINUE
      GO TO 1001
C    ***** X OUT OF RANGE OF TABLE *****
901    Y = 0.0
1001   TNT1=Y
5001   RETURN
      END
      FUNCTION TNT2(X1ARG,X2ARG,N1ARG,N2ARG,X1TARG,X2TARG,YTBARG,
&      J1ARG,J2ARG,IDIM,II)
      DIMENSION X1TARG(N1ARG),X2TARG(N2ARG),YTBARG(IDIM,N2ARG)
      DIMENSION N(2),X(2),Y(2),X1TAB(2),X2TAB(2),YTAB(2,2),TEMP(2)
      DOUBLE PRECISION YTBARG
1      N(1)=N1ARG
      N(2)=N2ARG
21     X(1)=X1ARG
C     *****SEARCH FIRST INDEPENDENT TABLE*****
      KK=1
      CALL TLUI(X(1),N(1),X1TARG,N1,J1ARG)
      X(2)=X2ARG
C     *****SEARCH SECOND INDEPENDENT TABLE*****
      CALL TLUI(X(2),N(2),X2TARG,N2,J2ARG)
      IF(J1ARG.NE.0.OR.J2ARG.NE.0) GO TO 901
      N1=MAX(1,MIN(N1,N(1)-1))
      N2=MAX(1,MIN(N2,N(2)-1))
C     *****STORE TABLE VALUES IN TEMPORARY LOCATION
101    DO 121 J1=1,2
        M1=J1+N1-1
        M2=J1+N2-1
        X1TAB(J1)=X1TARG(M1)
        X2TAB(J1)=X2TARG(M2)
        DO 121 J2=1,2
          M2=J2+N2-1
121    YTAB(J1,J2)=YTBARG(M1,M2)
C     *****PERFORM INTERPOLATION*****
201    IF(N(1).GT.1) GO TO 241
        IF(N(2).GT.1) GO TO 231
221    Y(1)=YTAB(1,1)
231    Y(1)=YTAB(1,1)+(X(2)-X2TAB(1))*(YTAB(1,2)-YTAB(1,1))/
&      (X2TAB(2)-X2TAB(1))
        GO TO 1001
241    TEMP(1)=X(1)-X1TAB(1)
        TEMP(2)=X1TAB(2)-X1TAB(1)
        DO 251 J1=1,2
          Y(J1)=YTAB(1,J1)+TEMP(1)*(YTAB(2,J1)-YTAB(1,J1))/TEMP(2)
          IF(N(2).EQ.1) GO TO 1001
251    CONTINUE
        Y(1)=Y(1)+(X(2)-X2TAB(1))*(Y(2)-Y(1))/(X2TAB(2)-X2TAB(1))
        GO TO 1001
901    Y(1)=0.0
1001   TNT2=Y(1)
5001   RETURN
      END
      SUBROUTINE TLUI(ARG,NTAB,TAB,J,IERR)

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      DIMENSION TAB(NTAB)
1     IERR=0
      DO 21 J1=1,NTAB
      IF(TAB(1).GT.TAB(2))VAR=TAB(J1)-ARG
      IF(TAB(1).LE.TAB(2))VAR=ARG-TAB(J1)
      IF(VAR)41,61,21
21    CONTINUE
      IERR=1
      J=NTAB
      GO TO 5001
41    IF(J1.GT.1) GO TO 101
      IERR=-1
      J=1
      GO TO 5001
61    J1=J1+1
101   J=J1-1
5001  RETURN
      END
*****
      SUBROUTINE LOITER (TIME,CURRWT,ML,CRUDRG)
      COMMON/A/DIST1A,WT(17),AS(7),DAT(17,7,4),DAT1(17,5),LCAS(17,5),
&  IFNT
      COMMON/B/ALT(8),CCAS(17),CFUEL(17,7),CTIME(17,7),CDIST(17,7),
&  TARTIME
      COMMON/C/RFDRA,ONLOAD,YTAB1(17,7),YTAB2(17,7),CCALT(17),
&  CCNAM(17)
      COMMON/D/FARDST(15),TIMELT(15),DFLOAD(15),NUMREC,FARALT(15),
&  ALT1(5),FARTIM(15)
      COMMON/F/NOFRT
      DOUBLE PRECISION CTIME,CCNAM,CCAS
      DOUBLE PRECISION CFUEL,CDIST,CCALT
      DOUBLE PRECISION YTAB1,YTAB2
      DIMENSION YTAB3(17),YTAB4(17),YTAB5(17),YTAB6(17)
      DOUBLE PRECISION YTAB3,YTAB4,YTAB5,YTAB6
$$$    WRITE(*,*) '**** SUBROUTINE LOITER !! !!'
      IFLAG=0
      IF(IFNT.EQ.1.AND.NOFRT.EQ.0)WRITE(*,100)ML,TIME,CURRWT
      DO 1 I=1,4
      IF(FARALT(ML).EQ.ALT1(I))IFLAG=1
      IF(FARALT(ML).GT.ALT1(I))JJ=I
      IF(FARALT(ML).EQ.ALT1(I))JJ=I
1     CONTINUE
      LL=JJ+1
      TIME=TIME+(TIMELT(ML)/60.)
      TIME1=TIMELT(ML)/5.
      DO 2 I=1,17
      YTAB3(I)=DAT1(I,JJ)
      IF(IFLAG.NE.1)YTAB4(I)=DAT1(I,LL)
      YTAB5(I)=LCAS(I,JJ)
2     IF(IFLAG.NE.1)YTAB6(I)=LCAS(I,LL)
      IF(IFLAG.NE.1)DIFF=((FARALT(ML)-ALT1(JJ))/1000.)/5.
      DO 3 I=1,5
      Y1=TNT1(CURRWT,17,WT,YTAB3,2,IERR)

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      IF (IFLAG.NE.1) Y2=TNT1(CURRWT,17,WT,YTAB4,2,IERR)
      Y3=TNT1(CURRWT,17,WT,YTAB5,2,IERR)
      IF (IFLAG.NE.1) Y4=TNT1(CURRWT,17,WT,YTAB6,2,IERR)
      IF (IFLAG.NE.1) Y1=Y1+(DIFF*(Y2-Y1))
      A1=Y3
      IF (IFLAG.NE.1) A1=Y3+(DIFF*(Y4-Y3))
      DISTER=TIME1/60.*A1
**      WRITE(*,200) Y1,DISTER,CRUDRG,TIME1,A1
** 200  FORMAT(1X,'Y1:',F7.0,' DISTER:',F7.0,' CRUDRG:',F7.0,
**      &' TIME1:',F7.0,' A1:',F7.0)
      A=FUEL(Y1,DISTER,CRUDRG)
      CURRWT = CURRWT - A
      TAS=A1
      IF (IPNT.EQ.1.AND.NOPRNT.EQ.0) WRITE(*,101) ML,1,TAS,DISTER
C      WRITE(*,102) TIME1,A,CURRWT
      3      IF (IPNT.EQ.1.AND.NOPRNT.EQ.0) WRITE(*,102) TIME1,A,CURRWT
      100  FORMAT(1H,'ON LOITER LEG ',I1,' THE TIME= ',F8.1,' CURRWT= ',
      &      F8.0)
      101  FORMAT(1H,'LOITER LEG',I2,' SUBLEG',I2,' TAS=',F8.2,
      &      ' DIST= ',F6.1)
      102  FORMAT(1H,'TIME= ',F8.0,' FUEL USED=',F8.0,' GWT= ',F8.0)
      RETURN
      END
C*****
      SUBROUTINE CRUISE (Y,Z,CURRWT,CUMTIME,CRUDRG)
      COMMON/A/DISTTA,WT(17),AS(7),DAT(17,7,4),DAT1(17,5),LCAS(17,5),
      &      IPNT
C *** Y = ALTITUDE , Z = DISTANCE , CURRWT = CURRENT WEIGHT ,
C *** CUMTIME = CUMMULATIVE FLIGHT TIME , CRUDRG = CRUISE DRAG FACTOR
      COMMON/D/FARDST(15),TIMELT(15),OFLOAD(15),NUMREC,FARALT(15),
      &      ALT1(5),FARTIM(15)
      COMMON/F/NOPRNT
      COMMON /G/ DAT2(17,5),ICTAS(17,5)
C *** DAT2 = NAM/LD & ICTAS = TAS FOR FIXED ALT CRUISE
      DIMENSION YTAB3(17),YTAB4(17),YTAB5(17),YTAB6(17)
      DOUBLE PRECISION YTAB3,YTAB4,YTAB5,YTAB6
**$ WRITE(*,3) '$$$$ SUBROUTINE CRUISE '
      TIMER=0.
      IFLAG=0
      NPT=2
      DO 12 I=1,5
      IF(Y.EQ.ALT1(I)) IFLAG=1
      IF(Y.GT.ALT1(I)) JJ=1
      IF(Y.EQ.ALT1(I)) JJ=1
      12  CONTINUE
C      WRITE(*,4) 'CRUISE ALT & DIST = ',Y,Z
      LL=JJ+1
      DIST=Z/5.
      DO 2 I=1,17
      YTAB3(I)=DAT2(I,JJ)
      IF (IFLAG.NE.1) YTAB4(I)=DAT2(I,LL)
      YTAB5(I)=ICTAS(I,JJ)
C      WRITE(*,4) 'CRUISE TABLES DAT2 & ICTAS = ',YTAB3(I),YTAB5(I)

```

```

2      IF(IFLAG.NE.1)YTABG(I)=ICTAS(I,LL)
      IF(IFLAG.NE.1)DIFF=CALT1(JJ)/1000./75.
      DO 3 I=1,5
      Y1=TNT1(CURRWT,17,WT,YTABG,2,IERR)
      IF(IFLAG.NE.1)Y2=TNT1(CURRWT,17,WT,YTAB4,2,IERR)
C      WRITE(*,*) 'NAM/LB = ',Y1
      IF(IFLAG.NE.1)Y1=Y1+(DIFF*(Y2-Y1))
      A = FUEL(Y1,DIST,CRUDRG)
      Y1=TNT1(CURRWT,17,WT,YTAB5,2,IERR)
      IF(IFLAG.NE.1)Y2=TNT1(CURRWT,17,WT,YTAB6,2,IERR)
      CURRWT = CURRWT - A
C      WRITE(*,*) 'TAS = ',Y1
      A1=Y1
      IF(IFLAG.NE.1)A1=Y1+(DIFF*(Y2-Y1))
      TIME=DIST/A1
      TIMER=TIMER+TIME
      CUMTIME=CUMTIME+TIME
      IF(IPNT.EQ.1.AND.NOPRNT.EQ.0)WRITE(*,102)1,DIST,A,CURRWT
3      IF(IPNT.EQ.1.AND.NOPRNT.EQ.0)WRITE(*,103)DIST,A1,TIME,TIMER,Y
      TIMELT(8) = TIMER*60.
      IF(IPNT.EQ.1.AND.NOPRNT.EQ.0)WRITE(*,105)TIMER
      IF(IPNT.EQ.1.AND.NOPRNT.EQ.0)WRITE(*,106)TIMER
102  FORMAT(1H,'CRUISE LEG ',I2,' DIST= ',F6.1,
& ' FUEL USED= ',F8.0,' GWI=',F8.0)
103  FORMAT(1H,'DIST= ',F6.1,' TAS= ',F8.1,' TIME FOR LEG= ',
& F6.2,' CUM TIME= ',F6.2,' ALT= ',F6.0)
C104  FORMAT(1H,'CLIMBING FROM ',F6.0,' TO ',F6.0,' TOOK ',*** BUG TEST ***
C    & F6.1,' #'S OF FUEL, LEVEL OFF WT= ',F8.0)
105  FORMAT(1H,'CUM TIME TO CRUISE OUT TO 1ST URB1=' ,F6.2)
106  FORMAT(1H,'CUM TIME TO RETURN FROM LAST AAR=' ,F6.2)
      RETURN
      END
C*****
C      FUEL USED FUNCTION
      FUNCTION FUEL(FARG1,FARG2,FARG3)
      $$$      WRITE(*,*) '**** FUNCTION FUEL '

C      CALL %FXOPT(69,1,1,0)  ** ERROR MESSAGE ***
C      CALL %FXOPT(71,1,1,0)  ** FOR DIVIDE ERROR ***
      FUEL = 1./FARG1*FARG2*FARG3
C      CALL %FXOPT(69,1,0,0)
C      CALL %FXOPT(71,1,0,0)
      RETURN
      END
C*****
C      ICHEK FUNCTION
      FUNCTION ICHEK(IFULOP,CURRWT,OPWT,FULRES)

      *      WRITE(*,*) '**** FUNCTION ICHEK '
      *      M = 0
      *      IF(IFULOP.EQ.1.AND.CURRWT.LE.(OPWT+FULRES))
      *      & M = 1

```


INTEGER ITTFL, JFTRL, KTRAKL, NEARTTF(4,5)

LOGICAL DOMINATD(3,4,5)

* FOLLOWING COMMON LINES ADDED TO MAKE 'TANKER' WORK WITH
* THIS DETERMTTF PROGRAM:

```
COMMON /HUNSUCK/ITANKER, IFULOP, NUMFAR, NUMFA1
COMMON /THESIS/FULSUB, TOWT, OPWT, FULLND, CRUDRG, RTBALT, RTBTIM, FLTWT
&      , CWT, DISTIS, FARCAS, DISTIS, WTTT, TOTA, TIME
REAL TOTA, TIME
INTEGER ITANKER, IFULOP, NUMFAR, NUMFA1

INTEGER I, J, K, L, M
```

* THE FOLLOWING COMMON DATA ARE FOR SUBROUTINE TANKER

```
COMMON /A      / DISTTA , WT      , AS(7) , DAT
&              , DAT1      , LCAS      , IPNT
REAL
&      DAT      (17,7,4)
&      , DAT1    (17,5)
&      , DISTTA
&      , WT      (17)
INTEGER IPNT      , LCAS      (17,5)
COMMON /B      / ALTX      , OCCAS      , CFUEL      , CTIME
&              , CDIST1
DOUBLE PRECISION OCCAS      (17)
&              , CDIST1      (17,7)
&              , CFULL      (17,7)
&              , CTIME      (17,7)
REAL      TARTIME , ALTX(8)
COMMON /C      / RFDRAW , ONLOAD , YTAB1 , YTAB2
&              , CCALT      , CCNAM
DOUBLE PRECISION CCALT      (17)
&              , CCNAM      (17)
&              , YTAB1      (17,7)
&              , YTAB2      (17,7)
REAL      ONLOAD , RFDRAW
COMMON /D      / FARDST , TIMELT, OFLOAD , NUMREC
&              , FARALT , ALT1(5) , FARTIM
REAL
&      FARALT      (15)
&      , FARDST      (15)
&      , FARTIM      (15)
&      , OFLOAD      (15)
&      , TIMELT      (15)
INTEGER NUMREC
```

```

COMMON /E      / SPECIAL ,ANUMRC
DOUBLE PRECISION SPECIAL (17)
REAL  ANUMRC      (15)
COMMON /F      / NOPRNT
COMMON /G      / DAT2      , ICTAS
REAL  DAT2      (17,5)
INTEGER NOPRNT      , ICTAS      (17,5)

```

```

DATA  ALT1      /15000.,20000.,25000.,30000.,35000.
&      ,40000.,45000.,0./
DATA  ALT1      /15000.,20000.,25000.,30000.,35000./
DATA  AS      /250.,260.,270.,280.,290.,300.,310./

```

C

END

Appendix C

Explanation of Tanker Program Sample Output of Tanker Program

COMMAND/EXPLANATION OF TANKER UTILITY PROGRAM

1. ENTER TANKER 2 KC-135E
Select tanker eg. 1 = KC-135A, 3 = KC-135R, 4 = KC-10A.
2. ENTER T.O. WEIGHT
Enter "Unstick" (liftoff) weight in pounds. Note: Carriage return (CR) defaults to Max gross to weight shown in data file.
3. ENTER CARGO WEIGHT
Enter weight of cargo carried by tanker---in pounds.
4. ENTER A 1 TO EXPAND PRINT
"1" gives long print, anything else, including carriage return, gives summary print.
5. DISTANCE TO FIRST TAR OR RAR OR AAR
TAR is Refuel Tanker, RAR is Orbit Refuel, AAR is Buddy Refuel.
6. ENTER A 1 FOR A TAR OR A 2 FOR A RAR OR A 3 FOR AN AAR.
Selects type of mission if you enter a "1" continue below if you enter a "2" go to 12 if you enter a "3" go to 22.
7. ENTER DISTANCE AND ONLOAD FOR TAR
Enter distance run during TAR in nm and fuel onload in pounds.
8. ENTER TIME (MIN) FOR TAR NUMBER 1
Enter time to cover distance shown above.
9. WHAT IS TAR ALTITUDE AND CAS
Enter Tanker aerial refueling altitude in feet and airspeed in CAS (KTS).
10. DISTANCE TO AAR OR RAR
Enter distance to next event. If RAR, distance to ARCP. If AAR, distance to joinup.
11. ENTER A 2 FOR RAR OR A 3 FOR AN AAR
Enter a "2" for an orbit refuel and continue below--or a "3" to join a formation for a buddy refueling then go to 22.
12. ENTER CELL STRUCTURE
For Orbit Refuel - 1st number is number of cells of receivers followed by the number of receivers in each cell eg. 3,1,1,1 means 3 cells consisting of one receiver in each cell.
13. ENTER RAR ALTITUDE AND CAS
Enter altitude in feet and CAS in knots for refueling operation eg., 25000, 252.

14. ENTER 2ND LOITER TIME
Enter time (in minutes) between cells.
15. ENTER TIME, DISTANCE, AND OFFLOAD FOR RAR
Describes aerial refueling run. Enter time in minutes, distance in nautical miles, and offload in pounds. eg., 45,300,95000.
16. WHAT IS THE DISTANCE TO RTB BASE OR TAR?
Distance from last aerial refueling to landing base or tanker aerial refueling--as appropriate.
17. ENTER A 1 FOR TAR ON WAY HOME
Entering CR ends profile and begins solution and printout. Entering a "1" brings additional queries eg:
18. WHAT IS DISTANCE FOR TAR?
Enter length of aerial refueling in nm.
19. ENTER TIME (MIN) FOR TAR
Enter length of time of aerial refueling
20. WHAT IS TAR ALTITUDE AND CAS?
Enter altitude (in feet) and calibrate airspeed of refueling.
21. WHAT IS DISTANCE TO RTB BASE?
Enter distance in nm to home base. Upon entering data, computation begins.
22. ENTER NUMBER OF RECEIVERS
Number of receivers in the cell accompanying the tanker.
23. ENTER REFUELING ALTITUDE AND CAS
Enter altitude in feet and cruising airspeed in knots CAS.
24. ENTER NUMBER OF LEGS AND NUMBERS OF AAR's
Enter the number of legs not counting aerial air refuelings and enter the number of aerial refuelings - Note: The number of legs must be one greater than the number of AARs eg., 3,2.
25. ENTER ALL CRUISE DISTANCES AND TIMES IN ORDER
Enter the distance in nm and the time of flight in minutes for each leg listed above eg., 1000, 125, 500, 63, 750, 94.
26. ENTER TIME, DISTANCE AND OFFLOAD FOR AARs IN ORDER
List data requested in order of AARs eg., 35, 175, 21000, 42, 850, 40000.
P4, 1-11
27. WHAT IS DISTANCE TO RTB OR TAR
If you are at destination, enter 0. If not go to 16.

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AFCSA/SAGM
Wash DC 20330-5420

Sample Tanker Data

Dual Role KC-10 refueling Four F-16s

```

A>> tank1
ENTER TANKER (DEFAULT= 0)
3
ENTER T.O. WEIGHT (DEFAULT = 588200.)
588200
ENTER CARGO WT (DEFAULT = 0.)
40000
T.O. FUEL =304991.0
ENTER A 1 TO EXPAND PRINT (DEFAULT = 0)
0
DISTANCE TO FIRST TAR OR RAR OR AAR (DEFAULT = 0.)
0
ENTER REFUEL ALTITUDE AND CAS (DEFAULT = 0., 0.)
31000,310
ENTER NUMBER OF RECEIVERS (DEFAULT = 0.)
4
ENTER NUMBER OF LEGS AND NUMBER OF AARs (DEFAULT = 0, 0)
3,2
TYPE A 1 TO ENTER NEW CRUISE DISTANCES & TIMES
1
ENTER ALL CRUISE DISTANCES AND TIMES IN ORDER
DEFAULTS ARE:
0. 0.
0. 0.
0. 0.

1805,216
1829,223
243, 35
TYPE 1 TO ENTER NEW TIME,DISTANCE & OFLOAD FOR AAR
1
ENTER TIME,DISTANCE & OFLOAD FOR AARS IN ORDER
DEFAULTS ARE:
0. 0. 0.
0. 0. 0.

36,300,11578
36,288,2755
WHAT IS DISTANCE TO RTB BASE OR TAR? (DEFAULT = 0.)
0
CURRENT WT= 417595. AFTER TAR OR RAR NUM 1
CURRENT WT= 309562. AFTER TAR OR RAR NUM 2
TOTAL TIME 9.5
REMAINING FUEL= 4296., FUEL USED= 232527., ONLOAD USED= 0.
RECEIVERS BY CELL .40E+01
ENTER TANKER (DEFAULT= 3)

```

Airlifter Only KC-10
Carrying 120,000 pounds of cargo

```

3
ENTER T.O. WEIGHT (DEFAULT =      588200.)
88200  588200
ENTER CARGO WT (DEFAULT =      0.)
120000
T.O. FUEL =224991.0
ENTER A 1 TO EXPAND PRINT (DEFAULT = 0)
0
DISTANCE TO FIRST TAR OR RAR OR AAR                (DEFAULT =      4465.)
4465
ENTER A 1 FOR A TAR OR A 2 FOR A RAR OR A 3 FOR AN  AAR (DEFAULT =      0)
3
ENTER NUMBER OF RECEIVERS (DEFAULT =      0.)
0
ENTER NUMBER OF LEGS AND NUMBER OF AARs (DEFAULT =      2,      1)
2,1
TYPE A 1 TO ENTER NEW CRUISE DISTANCES & TIMES
0
TYPE 1 TO ENTER NEW TIME, DISTANCE & OFLOAD FOR AAR
0
WHAT IS DISTANCE TO RTB BASE OR TAR? (DEFAULT =      0.)
0
CURRENT WT= 393963. AFTER TAR OR RAR NUM 1
TOTAL TIME      9.9
REMAINING FUEL= 15415., FUEL USED= 195237., ONLOAD USED=      0.
RECEIVERS BY CELL      .00E+00
ENTER TANKER (DEFAULT=      3)

```

Goose Bay TTF KC-10
Refueling F-16s on AR Track 1

3
ENTER T.O. WEIGHT (DEFAULT = 588200.)
588200
ENTER CARGO WT (DEFAULT = 0.)
0
T.O. FUEL =344991.0
ENTER A 1 TO EXPAND PRINT (DEFAULT = 0)
0
DISTANCE TO FIRST TAR OR RAR OR AAR (DEFAULT = 0.)
421
ENTER A 1 FOR A TAR OR A 2 FOR A RAR OR A 3 FOR AN AAR (DEFAULT = 0)
2
ENTER CELL STRUCTURE
DEFAULT VALUES: 1, 0.
3,6,6,6
ENTER RAR ALTITUDE AND CAS (DEFAULT = 0., 0.)
31000,310
ENTER TIME,DISTANCE AND OFLOAD FOR RAR
DEFAULTS ARE:
0., 0., 0.

39,324,11367
WHAT IS DISTANCE TO RTB BASE OR TAR? (DEFAULT = 0.)
477
ENTER A 1 FOR TAR ON WAY HOME
0

CUM TIME = 1.2
CURRENT WT= 467870. AFTER TAR OR RAR NUM 1
CUM TIME = 2.8
CURRENT WT= 365803. AFTER TAR OR RAR NUM 2
CUM TIME = 4.3
CURRENT WT= 272051. AFTER TAR OR RAR NUM 3
TOTAL TIME 6.4
REMAINING FUEL= 6254., FUEL USED= 124578., ONLOAD USED= 0.
RECEIVERS BY CELL .60E+01 .60E+01 .60E+01
ENTER TANKER (DEFAULT= 3)

Appendix D

"TACAP" Data

This Appendix consists of the TAC Air Profiler computer printouts which dictated the locations of the air refueling tracks and the fuel requirements of the fighters.

The TACAP fighter flight plans are in the following order:

Flight Plans for refuelings by TTFs (they include time for rendezvous)

plane	page
F-16	D-2
F-15	D-5
F-111	D-9
RF-4C	D-12

Flight Plans for "buddy" refuelings (Dual Role KC-10s)

plane	page
F-16	D-16
F-15	D-19
F-111	D-22
RF-4C	D-25

UNCLASSIFIED

12-02-86 2336Z ROUTE										ROUTE JND FACTOR +J13									
F-16A										TOTAL FUEL ONLOAD BY RECEIVER									
233700Z: 300CLT																			
F-16A																			
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12-32-86	23352	ROUTE	TRUE VBR	DATA POINT	COORDINATES	TIME CRS	HAS JAR	DISTANCE LEG	TOTAL LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
21	NO.2 ABORT,OFF	3 ON	4656N 75515W	074	+7	12	1047	01	03445	73	58	13425	2722	3129	11010	503
22	NO.3 ABORT,OFF	4 ON	4778N 75502W	075	+27	53	1997	06	03451	307	243	13118	2492	3122	11250	503
23	NO.4 ABORT,OFF	5 ON	4727N 75350W	075	+27	53	2047	05	03457	304	243	12814	2242	3392	11490	503
24	ST JONAS		4723N 75251W	076	+27	41	2088	05	04402	246	194	12558	2048	3375		503
25	NO.5 ABORT,OFF	6 ON	4731N 75339W	073	+27	9	2197	01	04403	51	43	12517	2038	3360	11724	499
26	NO. 6 ABORT,OFF	EAR	4724N 75128W	074	+27	47	2144	06	04409	296	234	12221	13732	3062	11958	499

27	LEVELOFF	FL360	4747N 75114W	074	+23	13	2156	01	04410	93	93	12123	13659	4550		499
28	CR PT		4830N 75030W	074	+23	51	2207	05	04416	295	308	11833	13331	3132		517
29	CR PT		4910N 74500W	058	+23	213	2417	25	04441	1205	1257	10628	12074	3078		514
30	CR PT		5000N 74000W	073	+27	231	2518	25	04404	1106	1152	9522	13922	2357		517
31	CR PT		5030N 73500W	058	+25	123	2311	23	05427	1043	1054	9479	9415	2878		511
32			5000N 73200W	058	+24	123	3304	23	05450	1009	1045	7473	8722	2789		513
33	CR PT		5000N 73000W	058	+22	123	3197	23	04413	994	1027	6476	7755	2715		508
34	CR PT		5114N 72700W	058	+21	123	3300	23	04434	971	1033	5535	6755	2343		508
35	CR PT		5000N 71500W	058	+17	125	3543	23	04450	957	985	4545	5779	2583		505
36	CR PT		5000N 71000W	058	+14	123	3776	23	07422	933	953	3613	4810	2526		506
37	CR PT		5000N 70700W	039	+12	77	3853	03	07431	367	377	3245	4442	2486		506
38	DESCEND		5007N 70553W	034	+11	82	3735	12	07441	389	433	2857	4047	2474		505
39	LAVDS FUD	FL300	5009N 70533W	034	+10	9	3544	02	07443	24	24	2833	4018	960		487
40	AIR REFUELLING CTL PT	5050N 70315W	764	+17	123	4344	12	07455	501	514	2332	3504	2597			487
41	START AAR 02		5100N 70239W	056	+9	25	4369	03	07459	122	125	2213	3379	2500		487
42	YEDVILTON		5100N 70239W	071	+9	3	4370	03	07459	4	4	2235	3375	2400		487
43	NO.1 ABORT,OFF	2 ON	5104N 70124W	054	+9	47	4117	05	08404	230	235	4625	3140	2474	2719	488
44	NO.2 ABORT,OFF	3 ON	5107N 70007W	085	+9	49	4165	05	08410	250	243	4445	2897	2542	2472	488

AVERAGE ONLOAD FOR AAR 1 11367

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ROUTE

PAGE 02

UNCLASSIFIED

12-02-84 22357 ROUTE			ROUTE AND FACTOR +113										
LINE VBR	DATA POINT	CORRELATES	TRUE CRS	WAS JAB	DISTANCE LEG	TOTAL LEG	FUEL 1	USED 5	FUEL 1	REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
45	NO.3 ABORT-OFF, 4 ON	5112V 77700E	036	+ 7	43	03:15	249	242	4135	2655	2532	2231	488
46	OVER	5112V 77712E	037	+ 7	7	01:20	34	33	4152	2622	2550		488
47	ENBU	5178V 77720E	024	+ 7	25	03:20	127	122	4035	2570	2540		488
48	NO.4 ABORT-OFF, 5 ON	5107V 77725E	074	+ 5	14	02:22	80	77	3955	2423	2526	1090	487
49	KORSEY	5106V 77725E	094	+ 5	7	01:23	46	45	3929	2378	2509		487
50	NO.5 ABORT-OFF, 6 ON	5065V 77731E	123	+ 5	37	05:20	200	193	3737	2133	2500	1754	487
51	NO. 6 ABORT-OFF, 6 ON	5071V 77731E	123	+ 5	43	05:37	246	239	3453	3453	2502	1519	487

AVERAGE ONLOAD FOR AIR 2													
2114													

52	FLORENES	5015V 77430E	124	+ 5	5	01:02	46	45	3417	3417	4600		502
53	LEVFLORF	FL340	130	+ 5	5	01:07	47	47	3370	3370	4700		497
54	DESCEND	5075V 77500E	170	+ 5	42	05:42	237	232	3135	3135	2400		505
55	NATTENHEIM	5001V 77532E	130	+ 5	20	04:45	64	64	3074	3074	893		281
56	HAHN	FL000	027	+ 4	22	04:53	94	94	2930	2930	831		487

ABORT BASES RECEIVED 1

*** AIR 1 ***

ABORT POINT	4642V 75723E	1927	03+10	2955		
19A STEPHENVILLE	4833V 75833E	337	+23 127	16 03+55	633	2332 2450 464
19A BINGO FUEL	2000					
19B GANDER	4855V 75434E	039	+23 175	21 04+00	854	2171 2445 494
19B BINGO FUEL	2420					
19C ST JOHNS	4737V 75245E	072	+23 195	24 04+03	961	2034 2443 498
19C BINGO FUEL	2426					

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ROUTE

PAGE 03

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12-72-85 22452 ROUTE

F-15C/D 355104K5

FLY LEVEL 1 2 3 4 5
 ALT UPPER 250 320 380
 TAS LOWER 250 300 350
 450 485 510

CAS
 MSN-TEMP-REV +25C
 WY ELIMATOLOGICAL FINDS ON WORST PROB FACTOR

ROUTE JVD FACTOR +314

TOTAL FUEL ONLOAD BY RECEIVER

RECVR 1 RECVR 2 RECVR 3 RECVR 4
 35774 37117 39050 38822
 RECVR 5 RECVR 6
 39684 40543

LINE	DATA POINT	COORDINATES	TRUE WGS CRS	DISTANCE	TIME	FUEL USED	FUEL REMAIN	FUEL FLOW	WIND OR ONLOAD	GS
1	MCCONNELL	3737N 09716W	074	- 3	52	2500	2500	25800		
2	START-TAXI-TAKEOFF	3737N 09716W				2500	2500	23300		
3	LEVELOFF POINT FL190	3755N 09401W	074	- 3	52	2112	2112	21198	14080	528
4	BUTLER VORTAC	3815N 09429W	073	- 7	75	977	977	20211	7053	536
5	ST LOUIS VORTAC	3852N 09029W	077	- 5	121	2234	2234	17977	6293	538
6	INDIANAPOLIS	3949N 08422W	072	- 3	102	2216	2216	15751	5980	537
7	DAYTON	4001N 08424W	071	+ 0	71	990	990	14771	5931	538
8	DRYER	4122N 08310W	050	+ 0	130	1411	1411	13350	5799	533
9	JAMESTOWN	4211N 07907W	059	+ 4	145	1523	1523	11837	5676	539
10	DESCEND	4233N 07557W	079	+ 8	142	1091	1091	9856	7420	531
11	LEVELOFF	FL300 4237N 07518W	032	+11	20	138	133	9713	1382	506
12	ALBANY	4245N 07348W	082	+12	47	849	849	8859	6448	513
13	AIR REFUELING CTL PT	4239N 07304W	100	+13	33	429	429	8460	6774	513
14	START AAR 01	4234N 07232W	100	+14	25	328	328	8112	6786	513
15	ROSTON	4221N 07100W	100	+15	58	891	891	7221	5757	501
16	NO.1 ABORT-OFF, 2 ON	4225N 07349W	066	+16	2	99	99	25800	18678	501
17	NO.2 ABORT-OFF, 3 ON	4254N 06715W	066	+15	75	1361	878	24739	6244	501
18	NO.3 ABORT-OFF, 4 ON	4323N 06740W	057	+17	75	1036	895	23633	7119	501
19	YARMOUTH	4340N 06505W	058	+19	74	1011	907	22652	4442	501
20	NO.4 ABORT-OFF, 5 ON	4357N 06504W	059	+20	1	12	10	22647	4432	502

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ROUTE

PAGE 01

JNC_ASSIFIED

12-72-85 2235Z 00JTE

ROUTE WIND FACTOR 0714

IVE NBR	DATA	TIME	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LES	TIME LFG TOTAL	FUEL 1	USED 5	FUEL REMAIN		FUEL FLOW	WIND OR ONLOAD	GS			
										1	6						
21	NO. 5 ABORT, OFF, 6 0V	44274	754334	050	+20	75	1566	09	03+01	1033	917	21607	3515	6964	22285	502	
22	HALIFAX	44554	755244	050	+22	57	1623	07	03+08	785	701	20821	2814	6935		502	
23	NO. 6 ABORT, OFF.	45144	755724	051	+23	13	1541	02	23+10	243	217	20578	25870	5943	23203	505	

									AVERAGE ONLOAD FOR AAR 1		20024						
24	LEVEL OFF	FL390	45144	062364	051	+23	21	1567	03	03+13	312	312	20266	25438	7499	505	
25	SYDNEY		46094	050034	051	+23	120	1792	14	03+27	1445	3750	19821	21738	16667	530	
26	CHECK PT		45524	755304	072	+25	153	1935	17	03+44	1765	2077	17055	19651	7152	525	
27	ST JOHNS		47294	752514	074	+27	153	2788	17	04+01	1715	1778	15341	17283	6166	528	
28	DESCEND		44444	051304	073	+27	57	2145	07	04+08	633	655	14778	17228	6346	524	
29	LEVEL OFF	FL370	47524	052484	074	+29	20	2174	04	04+12	138	139	14570	17070	1892	499	
30	CC PT		48794	757004	074	+23	33	2207	04	04+16	431	435	14132	16655	5592	499	
31	AIR REFUELING CTL PT	48244	753764	050	+23	47	2274	08	04+24	899	903	13251	15752	6689		496	
32	START AAR 02		48324	757514	059	+23	25	2209	03	04+27	327	334	12024	15418	6680	496	
33	NO. 1 ABORT, OFF, 2 0V	48514	756704	070	+28	57	2356	07	04+34	743	751	25877	14667	6626	13619	496	
34	NO. 2 ABORT, OFF, 3 0V	49294	755064	071	+23	57	2413	07	04+41	811	751	24939	13916	7156	13518	496	
35	CC PT		49194	755004	072	+27	4	2417	00	04+41	48	44	24041	13872	7200	496	
36	NO. 3 ABORT, OFF, 4 0V	49244	754324	073	+27	53	2470	06	04+47	751	689	24170	13182	7152	13725	498	
37	NO. 4 ABORT, OFF, 5 0V	49304	754174	074	+27	57	2527	07	04+54	970	763	23370	12440	7059	14099	498	
38	NO. 5 ABORT, OFF, 6 0V	49404	7540514	075	+27	57	2584	07	05+01	797	733	22593	11702	7332	14470	498	
39	RP PT		50094	047004	076	+27	34	2519	04	05+05	467	432	22125	11270	7005	498	
40	NO. 6 ABORT, OFF.		50014	038584	088	+25	47	2458	05	05+10	555	519	21571	25870	6938	15049	492

									AVERAGE ONLOAD FOR AAR 2		14080						
41	LEVEL OFF	FL387	50014	038254	088	+25	21	2570	03	05+13	312	312	21257	25489	7498	492	
42	CC PT		50004	035704	088	+25	132	2811	15	05+28	1750	4021	19579	21467	15769	517	
43			50004	030004	088	+24	193	3004	22	05+50	2277	2499	17232	18998	6724	519	

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ROUTE

PAGE 02

JMC-CLASSIFIED

LINE NR	DATA POINT	ROUTE	COORDINATES	TRUE CRS	MAG JAR	DISTANCE LES	TIME LES	FUEL TOTAL	ROUTE USED	FUEL REMAIN	FUEL FLOW	WIND OR OVLAD	GS
44	CC PT		50000 015000	098	+22	193	23	3197	2291	15035	16637	5033	514
45	RP PT		50000 015000	098	+21	193	22	06+35	2159	12845	14455	5898	515
46	CC PT		50000 015000	098	+17	193	23	06+58	2165	10538	12319	6207	512
47	DESCEND		50000 015000	098	+14	141	17	07+15	1072	5535	10594	7171	513
48	LEVELOFF	FL380	50000 015000	090	+13	23	76	27+19	138	8323	12455	1982	488
49	RP PT		50000 015000	090	+12	23	03	07+22	377	8071	10145	6766	488
50	AIR REFUELING CTL PT		50000 015000	089	+12	75	09	07+31	1023	997	7018	9148	488
51	RP PT		50000 015000	090	+11	1	00	07+31	10	11	7038	9137	488
52	START AAR 73		50000 015000	084	+11	26	03	07+34	286	317	6752	8820	487
53	LANDS END		50000 015000	084	+11	57	08	07+42	907	925	5943	7874	487
54	NO.1 ABORT-OFF, 2 ON		50000 015000	064	+10	5	01	07+43	60	68	10350	7826	488
55	NO.2 ABORT-OFF, 3 ON		50000 015000	064	+10	72	09	07+52	953	953	9407	6873	488
56	YEDWILTON		50000 015000	055	+9	43	05	07+52	640	583	8757	5277	488
57	NO.3 ABORT-OFF, 4 ON		50000 015000	084	+9	25	03	08+01	338	295	8429	5924	489
58	NO.4 ABORT-OFF, 5 ON		50000 015000	085	+8	73	00	08+10	1074	905	7425	5088	489
59	DOVER		50000 015000	086	+7	52	06	08+15	645	647	6750	4439	489
60	NO.5 ABORT-OFF, 6 ON		50000 015000	074	+7	21	03	08+19	246	253	6534	4181	489
61	EBRU		50000 015000	074	+5	1	00	08+19	39	47	6475	4139	489
62	KORSEY		50000 015000	074	+5	25	03	08+22	295	317	6200	3879	487
63	NO. 6 ABORT-OFF.		50000 015000	123	+5	44	05	08+27	536	554	5654	5178	487

AVERAGE													
54	LEVELOFF	FL380	50000 015000	123	+5	21	03	08+30	312	312	5352	5352	487
65	FLORENNES		50000 015000	123	+5	27	03	08+33	264	264	5088	5088	512
66	DESCEND		50000 015000	100	+5	33	04	08+37	328	328	4755	4755	513
67	VATTENHEIM		50000 015000	100	+5	41	08	08+45	302	302	4453	4453	322

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ROUTE

PAGE 03

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12-02-86 2352 ROUTE
 -IVE DATA POINT
 NBR COORDINATES TRUE WAS DISTANCE TIME FUEL USED FUEL REMAIN FUEL WIND OR
 65 HAIN FLOOD 4957N 77716E 027 + 4 27 4605 05 09:50 213 213 4250 4250 2367 488
 GS

ABORT BASES RECEIVER 1

*** AAR 1 ***

ABORT POINT 4225N 77040E 1246 02:25 7122
 16A PEASE 4305N 77349E 000 +15 47 13:06 05 02:37 484 6638 5927 485
 16A BINGO FUEL 2584
 16B BANGOR 4448N 76850E 030 +10 147 14:38 20 02:45 2027 5172 6000 496
 16C BINGO FUEL 4170
 16C SWEAPWATER 4488N 76330E 064 +23 364 16:10 41 03:16 4173 2949 6092 502
 16C BINGO FUEL 6273

*** AAR 2 ***

ABORT POINT 4351N 76520E 2356 74:14 12131
 33A ST JOHNS 4727N 75245E 255 +23 251 25:17 37 05:11 3972 8209 6511 427
 33A BINGO FUEL 6072

*** AAR 3 ***

ABORT POINT 5010N 77531E 3949 07:43 5853
 54A ST MARYS 5025N 77500E 051 +17 25 39:24 03 07:46 304 5579 5080 486
 54A BINGO FUEL 2474
 54B BOSCOWEN-DOWN 5110N 77144E 065 + 3 155 41:04 19 03:02 1962 3921 6163 486
 54B BINGO FUEL 4062

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PAGE 04

ROUTE

12-02-86 2237Z ROUTE										ROUTE WIND FACTOR +311													
FLY LEVEL		1	2	3	4	5	F-111D		4 PYLONS		FROM MCCONNELL		TOTAL FUEL ONLOAD BY RECEIVER		RECVR 1		RECVR 2		RECVR 3		RECVR 4		
ALT UPPER		100	260	255	255	255	5				TIF		41780		41692		41692		41313		41134		
IAS		193	423	451					TO 44MM														
CAS									ROOM TYPE REFUELING				RECVR 5		RECVR 5		40925		40719				
MSH-TEMP-DEV +05C		WAY CLIMATOLOGICAL WINDS		90		Worst PROR FACTOR																	
LINE	DATA POINT	COORDINATES		TRUE CRS		WAS DISTANCE		TIME		FUEL		USED		FUEL REMAIN		FUEL FLOW		WIND OR					
9R						VAR		LEG		TOTAL		1		5		1		6		GS			
1	MCCONNELL	3737N	30716W									3830	3830	30500	30500								
2	START, TAXI, TAKEOFF	3737N	30716W																				
3	LEVELOFF POINT FL250	3735N	30602W	074	- 8	51	61	09	09+00			1745	1745	24925	24925	11633						469	
4	BUTLER VORTAC	3815N	30629W	073	- 7	75	137	10	09+10			1098	1098	23827	23827	5792						469	
5	ST LOUIS VORTAC	3852N	30700W	077	- 5	191	328	24	00+43			2712	2712	21115	21115	5559						469	
6	INDIANAPOLIS	3940N	30622W	072	- 3	190	527	25	01+08			2740	2740	18375	18375	6498						471	
7	DAYTON	4001N	30624W	081	+ 0	21	518	12	01+20			1223	1223	17152	17152	5381						471	
8	DRYER	4122N	30210W	050	+ 0	150	748	17	01+37			1752	1752	15400	15400	5333						468	
9	JAMESTOWN	4211N	30707W	059	+ 5	155	303	18	01+55			1932	1932	13458	13458	6300						472	
10	DESCEND	4213N	30748W	079	+ 8	16	907	02	01+57			189	189	13279	13279	6300						467	
11	LEVELOFF	4214N	30842W	080	+ 3	5	912	01	01+53			15	15	13256	13256	900						459	
12	AIR REFUELING CIL DT	4230N	30628W	080	+ 3	170	1310	13	02+11			1296	1296	11970	11970	5972						459	
13	START AAR 31	4233N	30554W	081	+10	25	1737	03	02+14			340	340	11630	11630	6375						459	
14	ALBANY	4245N	30748W	082	+11	03	1130	12	02+26			1260	1260	10370	10370	6248						459	
15	W-1 ABORT-OFF, 2 ON	4243N	30732W	100	+13	16	1144	02	02+23			159	159	32785	10211	5300						464	
16	W-2 ABORT-OFF, 3 ON	4222N	30705W	170	+16	178	1252	14	02+42			1509	1230	31135	8092	5902						464	
17	30500Y	4221N	30709W	101	+15	6	1256	01	02+43			59	43	31123	8924	6960						464	
18	W-3 ABORT-OFF, 4 ON	4322N	30650W	056	+15	106	1360	14	02+57			1542	1297	29535	7627	5803						456	
19	W-4 ABORT-OFF, 5 ON	4341N	30634W	057	+13	105	1466	14	03+11			1558	1311	28028	6316	6725						456	
20	VARVJUTH	4360N	30605W	059	+20	23	1689	03	03+14			365	281	27633	60150	4970						456	

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LINE NO	DATA POINT	ROUTE	TRUE CRS	MAG VAR	DISTANCE LES	TIME LES	TOTAL	ROUTE FUEL FACTOR +011				FUEL FLOW	WIND OR ONLOAD	GS
								FUEL 1	USED 5	FUEL- 1	REMAIN- 5			
21	NO.5 ABORT-OFF, 6 ON		059	+20	93	1572	11 03+25	1190	1012	26433	5023	6511	27762	457
22	HALIFAX		050	+20	50	1522	07 03+32	713	605	25787	4417	6582		457
23	NO. 6 ABORT-OFF.		051	+23	55	1678	07 03+10	794	680	24985	32785	6526	29048	459

24	LEVELOFF	FL255	051	+20	3	1581	01 03+40	95	95	24821	32670	5700		459
25	SYDNEY		051	+20	107	1731	13 03+53	1444	1537	23447	31153	7205		467
26	CHECK PT		072	+25	153	1734	20 04+13	2198	2328	21259	28825	7090		465
27	ST JOHN'S		074	+27	153	2037	20 04+13	2136	2274	19123	26551	5951		467
28	CC PT		073	+27	110	2206	15 04+48	1647	1750	17475	24722	6853		463
29	DESCEND		058	+28	178	2334	23 05+11	2447	2604	15029	22188	5734		460
30	LEVELOFF	FL240	071	+23	5	2190	01 05+12	15	15	15014	22173	900		452
31	CC PT		071	+23	27	2416	04 05+16	351	353	14653	21805	5309		452
32	AIR REFUELLING CTL PT	FL212	073	+27	74	2490	17 05+26	763	1004	13700	20801	6275		455
33	START AAR 72		075	+27	25	2514	03 05+20	319	332	13331	20459	6225		455
34	NO.1 ABORT-OFF, 2 ON		075	+27	75	2500	10 05+10	889	1037	31598	19432	6222	19206	455
35	RP PT		076	+25	27	2517	04 05+43	402	361	31175	19071	5891		455
36	NO.2 ABORT-OFF, 3 ON		058	+25	40	2466	07 05+50	738	671	30433	18400	6812	17679	450
37	NO.3 ABORT-OFF, 4 ON		059	+25	75	2741	10 04+00	1132	1025	29335	17374	6792	16155	450
38	CC PT		059	+25	50	2810	08 06+00	1027	941	23299	16433	6698		450
39	NO.4 ABORT-OFF, 5 ON		058	+26	5	2816	01 06+10	78	72	28321	16351	5585	14665	452
40	NO.5 ABORT-OFF, 6 ON		058	+26	75	2891	10 06+20	1038	1003	27123	15358	6655	13164	452
41	NO. 6 ABORT-OFF.		059	+25	75	2866	10 06+30	1090	995	26033	26033	6606	11671	452

42	LEVELOFF	FL255	051	+22	3	2969	01 06+31	95	95	25938	25938	5700		452
43			051	+22	36	3703	04 06+35	501	501	25437	25437	6832		460

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ROUTE

PAGE 02

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LINE VBR	12-22-86	2237Z	ROUTE	COORDINATES	TRUE CRS	VAR	DISTANCE LEG	TIME LEG	FUEL 1	USED 5	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS	
44	CK PT			50704 075004	038	+22	173	3126	25	07+00	2860	22577	22577	5756	455
45	RP PT			50704 075004	038	+20	173	3380	25	07+25	2775	19799	19799	6588	456
46	CC PT			50704 075004	038	+17	173	3582	25	07+51	2227	17072	17072	5416	453
47	RP PT			50704 075004	038	+14	173	3775	25	08+17	2685	14334	14334	6325	453
48	RP PT			50704 009004	039	+12	77	3852	10	08+27	1956	13328	13328	6273	453
49	LANDS END			50704 005384	034	+11	71	3943	12	08+37	1245	12033	12033	6225	452
50	YEDVILTON			51004 077384	044	+17	125	4069	17	08+55	1711	10372	10372	5147	452
51	DOVER			51104 07121E	034	+2	150	4210	20	09+15	2009	8333	8333	6057	452
52	ERBU			51004 07200F	034	+7	25	4244	03	09+17	337	8033	8033	6000	452
53	KOKSEY			51004 07239E	034	+5	25	4269	03	09+22	328	7705	7705	5964	452
54	FLORENES			50154 07439E	123	+5	22	4361	12	09+34	1213	6472	6472	5966	452
55	DESCEND			50704 07513E	100	+3	51	4422	08	09+42	790	5702	5702	5925	452
56	MATTHEWHEIM			50004 07632E	100	+4	13	4435	02	09+44	46	5656	5656	1533	434
57	HAHN			49574 07716E	027	+4	29	4464	04	09+48	104	5550	5550	1551	444

ABORT BASES RECEIVED 1

*** AAR 1 ***

ABORT POINT	42434 073294	1144	02+29	10211	398
15A GRIFFIS	43144 075244	291	+12	37	1233
15A BINGO FUEL	3941				
15B PEASE	43054 073404	078	+15	117	1263
15B BINGO FUEL	4141				
15C BAYGOR	44484 055504	056	+17	237	1391
15C BINGO FUEL	5616				

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13-02-86 0140Z ROUTE

FLY LEVEL 1 2 3 4 5
 ALT UPPER 230 300 285
 TAS LOWER 230 280 285
 437 470 475
 CAS

REF-CC 243700Z UNCL PYLONS FORM
 FROM MCCONNELL
 TO 44HN
 ROOM TYPE REFUELING

ROUTE JIND FACTOR +J12

TOTAL FUEL ONLOAD BY RECEIVER

RECVR 1 RECVR 2 RECVR 3 RECVR 4
 50023 49276 49927 49867

RECVR 5 RECVR 6
 49753 49569

MSV-TEAP-DEV +JSC MAY CLIMATOLOGICAL JINDS OF WPOST PROB FACTOR

LIVE VBR	DATA POINT	COORDINATES	TRUE CRS	WAS VFR	DISTANCE LES	TIME TOTAL	FUEL USED	FUEL REMAIN	FUEL FLOW	WIND OR ONLOAD	GS
1 MCCONNELL	2717N 09716W						2215	17035	17955		
2 START, TAXI, TAKEOFF	3717N 09716W						2215	17035	17955		
3 LEVFLUFF PRJHT FL280	3755N 09559W	074	- 3	54	64	00 00+00	2020	15935	13333		501
4 RJTLER VORTAC	3915N 09420W	073	- 7	73	137	19 00+18	1027	14953	14958	7002	495
5 ST LOUIS VORTAC	3852N 09029W	077	- 5	191	228	23 00+41	2601	12337	12337	6756	495
6 INDIANAPOLIS	3940N 08622W	072	- 3	192	527	24 01+05	2599	0738	0738	6498	496
7 RESCEND	3952N 08556W	081	+ 0	20	547	02 01+07	254	9434	9434	5359	497
8 LEVFLUFF	FL280	3955N 08552W	08	1	550	01 01+08	10	7474	9474	1200	492
9 DAYTON	4001N 08424W	082	+ 0	58	518	00 01+15	838	8435	8636	6132	492
10 AIP REFUELING CTL PT	4021N 08351W	050	+ 0	32	550	04 01+20	397	8239	8239	6108	489
11 START AAR 01	4037N 08326W	051	+ 1	25	575	03 01+23	303	7935	7935	5350	489
12 NO. 1 ABORT, OFF, 2 ON	4117N 08218W	051	+ 2	55	740	00 01+31	798	2020	7138	6361	489
13 DRYER	4122N 08210W	052	+ 3	5	748	01 01+32	113	20027	7027	7533	489
14 NO. 2 ABORT, OFF, 3 ON	4142N 08059W	059	+ 4	57	805	07 01+37	869	19218	6354	7557	494
15 NO. 3 ABORT, OFF, 4 ON	4204N 07936W	070	+ 5	63	870	00 01+47	978	19240	5573	7523	494
16 JAMESTOWN	4211N 07907W	070	+ 7	23	893	03 01+50	322	17913	5322	7156	494
17 NO. 4 ABORT, OFF, 5 ON	4218N 07811W	079	+ 8	42	935	05 01+55	608	17310	4798	7153	487
18 NO. 5 ABORT, OFF, 6 ON	4224N 07644W	080	+ 9	55	1000	08 02+03	950	16350	4028	7125	487
19 NO. 5 ABORT, OFF, 6 ON	4237N 07517W	081	+10	55	1065	08 02+11	929	15431	20277	5958	487
AVERAGE ONLOAD FOR AAR 1											15016

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ROUTE

PAGE 01

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13-72-85 71472		ROUTE		ROUTE AND FACTOR x12									
LIVE NR	DATA POINT	COORDINATES	TRUE CRS	WAS VAR	DISTANCE LES	TIME LEG	TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL 5	WIND OR ONLOAD	GS
20	LEVELOFF	FL285 4237N 07513W	082	+12	3	1268	01 02+12	150	152	15231 20050	18000		487
21	ALARMY	4245N 07348W	082	+12	53	1131	08 72+20	876	954	14405 19076	7532		492
22	ROSTON	4221N 07100W	100	+13	125	1257	15 02+35	1700	1553	12735 17243	7353		495
23	YARMOUTH	4349N 06505W	056	+15	233	1490	29 03+04	3089	3325	7615 13919	7000		490
24	HALIFAX	4455N 06324W	059	+20	133	1523	16 03+20	1700	1809	7015 12110	6696		490
25	DESCEND	4535N 06138W	061	+23	95	1709	10 03+30	1074	1134	5942 10976	6542		492
26	LEVELOFF	FL287 4517N 06134W	052	+24	3	1711	01 03+31	10	11	6932 10955	1200		497
27	SYDNEY	4607N 06003W	052	+24	71	1782	09 03+40	871	917	5751 10049	6324		487
28	AIR REFUELING CIL PT 4618N 05223W												
29	STADT AAR 02	4505N 05948W	072	+25	25	1836	03 03+47	301	305	5339 9380	6120		485
30	NO. 1 ABORT-OFF, 2 W	4503N 05718W	073	+25	55	1901	08 03+55	721	813	20277 8562	5135	15682	485
31	CHECK PT	4552N 05530W	074	+24	34	1935	04 03+59	529	427	19671 8135	7557		485
32	NO. 2 ABORT-OFF, 3 W	4707N 05546W	074	+27	31	1966	04 04+03	479	384	19133 7731	7547	15685	488
33	NO. 3 ABORT-OFF, 4 W	4716N 05413W	075	+27	45	2031	08 04+11	959	799	18234 6952	7511	15684	488
34	ST JOHNS	4729N 05251W	076	+27	57	2089	07 04+19	834	702	17370 6250	7149	488	
35	NO. 4 ABORT-OFF, 5 W	4731N 05240W	073	+27	3	2096	01 04+19	107	91	17253 5150	7133	15688	484
36	NO. 5 ABORT-OFF, 6 W	4748N 05103W	074	+27	54	2160	09 04+27	936	791	16327 5359	7109	15646	484
37	CK PT	4800N 05000W	075	+28	47	2207	06 04+34	673	574	15654 4795	6962		484
38	NO. 6 ABORT-OFF-EAR	4826N 04936W	058	+24	17	2224	02 04+35	244	207	15410 20200	6971	15612	481

AVERAGE UNLOAD FOR AIR 2													
39	LEVELOFF	FL285 4907N 04932W	059	+23	3	2227	01 04+36	150	150	15250 20050	18000		481
40	DESCEND	4845N 04656W	059	+23	117	2337	14 04+50	1555	1707	13735 18363	7531		486
41	LEVELOFF	FL290 4844N 04552W	071	+23	3	2340	01 04+51	10	10	13625 18333	1200		481
42	CK PT	4910N 04500W	071	+23	77	2417	10 05+01	1064	1145	12639 17139	7156		481
43	AIR REFUELING CIL PT	4715N 04426W	073	+27	23	2440	03 05+04	306	334	12323 16854	7157		484

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ROUTE

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JHC CLASSIFIED													X	
13-02-85 0140Z 00JTE														
LINE	DATA POINT	COORDINATES	TRUE CRS	NAC	DISTANCE	TIME	FUEL	USED	FUEL REMAIN	FUEL	WIND OR	GS		
YBR				WAS	LES	LEG	TOTAL				ONLOAD			
44	START AAR 03	4023N 0636E	074	+27	25	03	05+27	323	357	11025	16437	7140	484	
45	NO.1 ABORT-OFF, 2 0W	4023N 0623E	074	+27	48	06	05+13	639	685	20230	15811	6976	8844	484
46	NO.2 ABORT-OFF, 3 0W	4023N 0612E	075	+27	52	06	05+19	743	685	19457	15125	7556	9626	484
47	NO.3 ABORT-OFF, 4 0W	4023N 0601E	076	+27	53	06	05+25	743	675	18714	14453	7556	8403	484
48	RP PT	5000N 0600E	077	+25	7	01	05+26	140	124	19574	14326	7636	484	
49	NO.4 ABORT-OFF, 5 0W	5000N 0559E	098	+25	37	05	05+31	587	541	17987	13785	7338	8194	479
50	NO.5 ABORT-OFF, 6 0W	5000N 0545E	098	+25	53	05	05+37	715	675	17272	13139	7150	7969	479
51	NO. 6 ABORT-OFF. <u>EAR</u>	5000N 0530E	099	+25	53	05	05+43	716	654	16555	20230	7160	7745	479

AVERAGE ONLOAD FOR AAR 3													8297	
52	LEVELOFF	FL285	5000N 0535E	090	+25	3	05+44	150	150	16435	20050	18000	479	
53	CL PT	5000N 0530E	090	+25	55	07	05+51	794	854	15612	19125	7535	484	
54	DESCEND	5000N 0522E	098	+24	77	12	06+03	1385	1483	14227	17713	7415	486	
55	LEVELOFF	FL280	5000N 0522E	090	+23	3	06+04	10	10	14217	17733	1200	481	
56		5000N 0520E	090	+24	33	12	06+15	1301	1377	12015	16325	7122	481	
57	AIR REFUELING CIL PT	5000N 0520E	098	+22	7	01	06+17	95	93	12823	16243	6975	475	
58	START AAR 24	5000N 0520E	098	+22	25	03	06+20	339	350	12420	15823	6768	475	
59	NO.1 ABORT-OFF, 2 0W	5000N 0515E	098	+22	57	05	06+26	642	685	20230	15159	6966	8352	475
60	NO.2 ABORT-OFF, 3 0W	5000N 0504E	099	+21	67	06	06+32	743	677	19457	14511	7556	8350	475
61	NO.3 ABORT-OFF, 4 0W	5000N 0501E	090	+21	57	06	06+39	743	665	18714	13846	7556	9358	475
62	CL PT	5000N 0500E	091	+21	20	03	06+41	316	282	18329	13564	7594	475	
63	NO.4 ABORT-OFF, 5 0W	5000N 0451E	098	+20	27	03	06+44	410	383	17933	13131	7235	9349	476
64	NO.5 ABORT-OFF, 6 0W	5000N 0440E	098	+19	57	05	06+50	704	645	17234	12536	7159	8331	476
65	NO. 6 ABORT-OFF. <u>EAR</u>	5000N 0435E	099	+19	47	05	06+56	704	643	16530	20230	7159	8307	476

AVERAGE ONLOAD FOR AAR 4													8341	
66	LEVELOFF	FL285	5000N 0434E	090	+13	3	06+57	150	150	16430	20050	18000	476	

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13-02-86 01472 ROUTE		UNCLASSIFIED										ROUTE JND FACTOR +012		X	
LINE	DATA POINT	COORDINATES	TRUE CRS	MAS	DISTANCE	TIME	FUEL	JSED	FUEL REMAIN	FUEL	WIND OR				
NR					LES	-EG	TOTAL		5	1	ONLOAD				
57	RP PT	50204 020000	020	+18	52	09	07+05	1004	1081	15625	18970	7535		481	
58	CK PT	50204 015000	020	+17	191	24	07+30	2750	2932	12675	16038	7269		477	
59	RP PT	50204 010000	088	+16	133	24	07+54	2450	2772	10045	13259	6890		478	
77	RP PT	50204 008000	032	+10	77	10	08+04	1016	1053	9030	12195	5544		478	
71	LANDS END	50204 005000	084	+01	91	11	08+15	1123	1244	7837	10952	6547		476	
72	DESCEND	50144 005000	064	+10	13	02	08+17	166	173	7671	10779	6489		476	
73	LEVELOFF	50154 005154	064	+10	3	01	08+18	10	10	7651	10759	1200		471	
74	AIR REFUELING CTL PT	50554 002524	064	+10	170	13	08+31	1279	1324	6332	9445	5253		471	
75	REDVILTON	51074 002334	067	+7	2	01	08+32	110	113	6272	9332	5164		471	
76	START AAR 75	51074 002134	084	+7	14	02	08+34	201	205	6071	9127	6150		472	
77	NO.1 ABORT,OFF, 2 ON	51054 007334	034	+8	53	08	08+42	900	817	9354	5310	6128	4083	472	
78	NO.2 ABORT,OFF, 3 ON	51104 00103E	036	+3	43	03	08+50	917	803	9537	7502	5128	3467	472	
79	DOVER	51104 00121E	087	+7	8	01	08+51	102	101	9435	7431	6120		472	
80	ERBU	51054 00200E	074	+7	25	03	08+54	314	313	8121	7038	6077		472	
81	KAKSEY	51044 00233E	094	+5	25	03	08+57	313	313	7838	6775	6058		471	
82	NO.3 ABORT,OFF, 4 ON	51034 00246E	123	+5	5	01	08+58	51	40	7747	5715	6100	2855	471	
83	NO.4 ABORT,OFF, 5 ON	50284 00100E	123	+5	53	03	09+06	807	801	6940	5914	6053	2234	471	
94	FLORENES	50154 00439E	124	+5	24	03	09+07	301	301	6639	5613	6020		471	
85	NO.5 ABORT,OFF, 6 ON	50284 00532E	100	+5	32	05	09+14	490	488	6142	5125	6000	1616	472	
86	VATTENHEIM	50314 00532E	100	+5	35	04	09+18	440	433	5732	4630	5000		472	
87	NO. 5 ABORT,OFF. EAR	50574 00715E	077	+4	28	04	09+22	349	345	5350	5350	5983	1016	472	

88	HAHN	49574 00716E	077	+4	1	00	09+22	10	10	5350	5350	6000		472	

AVERAGE ONLOAD FOR AAR 5															2545

ABORT PAGES RECEIVER 1

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ROUTE 1100 FAX 133 413

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12-72-86		22412	ROUTE		ROUTE AND FACTOR +013												
LINE	VER	DATA	POINT	COORDINATES	TRUE CRS	XFS JAR	DISTANCE LES	TOTAL	TIME	TOTAL	FUEL 1	USED 5	FUEL REMAIN 4	FUEL FLOW	WIND OR ONLOAD	SS	
21	VO-5	ABORT, OFF,	6 ON	47224 253394	076	+27	50	2055	05	04+06	302	238	12515	1777	3071	11935	503
22	ST	JOHNS		47204 252514	076	+27	31	2798	04	04+10	100	157	12317	1640	3062		503
23	NO.	6	ABORT, OFF.	47344 052274	073	+27	17	2105	02	04+12	102	81	12215	13732	3060	12173	500

AVERAGE UNLOAD FOR AIR 1											11578						
24	CC	PT		48744 750004	074	+23	102	2207	12	04+24	612	634	11611	13028	3118		500
25	CC	PT		49104 045004	058	+28	210	2417	25	04+40	1239	1287	10354	11811	3052		497
26	RP	PT		50004 040004	073	+27	271	2519	24	05+13	1147	1189	9217	10622	2960		500
27	CC	PT		50744 735004	088	+23	123	2311	23	05+34	1042	1112	9133	9523	2959		494
28				50704 337004	098	+24	171	3704	23	05+59	1052	1085	7033	9417	2797		496
29	CC	PT		50704 025004	098	+22	193	3197	24	06+23	1038	1067	6015	7350	2724		491
30	RP	PT		50704 027004	098	+20	193	3320	24	06+47	1017	1043	5028	6327	2663		491
31	CC	PT		50704 715004	098	+17	193	3533	24	07+11	1006	1032	4022	5275	2413		488
32	RP	PT		50744 717004	098	+14	193	3776	24	07+35	995	1022	3037	4256	2554		488
33	RP	PT		50704 722004	099	+12	77	3853	29	07+44	996	395	2651	3872	2528		488
34			START AIR 2	50744 005544	094	+11	91	3934	13	07+54	406	417	2245	3453	2502		486
35	LANDS	END		50784 205384	085	+10	10	3744	01	07+55	49	51	2175	3423	2500		485
36	VO-1	ABORT, OFF,	2 ON	50244 204444	064	+10	33	3782	05	08+00	186	170	5322	3213	2478	3382	486
37	NO-2	ABORT, OFF,	3 ON	50444 203354	065	+7	49	4730	05	08+06	254	243	5118	2970	2583	3127	486
38	YEDVILTON			51004 022384	065	+7	47	4770	05	08+11	270	202	4029	2758	2559		486
39	NO-3	ABORT, OFF,	4 ON	51714 202254	084	+7	8	4378	01	08+12	35	37	4821	2731	2533	2885	487
40	VO-4	ABORT, OFF,	5 ON	51354 201094	084	+3	43	4126	05	08+13	252	241	4339	2491	2563	2628	487
41	NO-5	ABORT, OFF,	6 ON	51744 200075	085	+5	64	4174	05	08+24	249	247	4390	2251	2532	2379	487
42	DOVER			51104 201215	096	+7	45	4220	05	08+30	236	227	4154	2024	2529		487
43	NO.	6	ABORT, OFF.	51104 711245	094	+7	2	4222	00	08+30	8	3	4115	4145	2470	2130	487

AVERAGE UNLOAD FOR AIR 2											2755						

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LINE NR	DATA POINT	COORDINATES	TRUE CRS	MAG JAR	DISTANCE LES	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL FLOW 6	WIND OR ONLOAD	GS
12-02-86	22412	ROUTE										
44	EBBU	5138N 00200E	094	+ 7	23	03 09+33	113	113	4023	4023	2529	487
45	KOKSEY	5136N 00230E	094	+ 5	25	03 09+36	126	126	3932	3932	2520	487
46	FLDRENNES	5015N 00630E	123	+ 5	72	11 08+47	471	471	3431	3431	2501	485
47	DESCEND	5033N 00616E	170	+ 5	53	08 08+55	318	318	3113	3113	2478	487
48	MATTHEMEIM	5001N 00532E	100	+ 6	11	05 09+58	36	36	3077	3077	864	266
49	HANN	FL000 4957N 00716E	097	+ 6	22	07 09+05	97	97	2930	2930	859	487

ABORT BASES RECEIVER 1

*** AAR 1 ***

ABORT POINT	COORDINATES	TRUE CRS	MAG JAR	DISTANCE LES	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL FLOW 6	WIND OR ONLOAD	GS
15A STEPHENVILLE	4851N 05922E			1955	03+42			2750			
15A BINGO FUEL 2070	4833N 05933E	356	+23	122	15 03+57		616	2135	2460		493
15B GANDER	4856N 05636E	065	+29	211	26 04+08		1033	1717	2431		495
15B BINGO FUEL 2408	4737N 05245E	071	+23	239	29 04+11		1157	1593	2427		498
15C ST JOHNS											
15C BINGO FUEL 2622											

*** AAR 2 ***

ABORT POINT	COORDINATES	TRUE CRS	MAG JAR	DISTANCE LES	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL FLOW 6	WIND OR ONLOAD	GS
36A ST MARGARYS	5024N 00444E			3982	09+07			2010			
36A BINGO FUEL 1518	5026N 00500E	280	+10	10	01 09+01		53	1957	2446		443
36B BOSCUMBE-004N											
36B BINGO FUEL 2069	5112N 00144E	056	+ 3	122	15 09+15		603	1417	2412		486

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ROUTE 2C762 98-20-21

ROUTE 11VD FAC139 +J13

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MS4-TEMP-DEV +JSC 4147 CLIMATOLOGICAL FINDS 07 WORST PROB FACTOR

LINE NUMBER	DATA POINT	COORDINATES	TRUE CRS	MAS VAR	DISTANCE LES	TIME LEG	FUEL TOTAL	FUEL 1	USED 5	FUEL REMAIN 1 6	FUEL FLOW	WIND OR ONLOAD
1	MCCONNELL	37374 707164								25800 25800		
2	STAPITAXI, TAKEOFF	37374 707164								23300 23300		
3	LEVELOFF POINT FL300	37404 705264	074	- 3	41	07	00+07	2500	2500	21500 21500	16615	518
4	BUTLER VORTAC	38164 094294	073	- 3	75	11	00+19	1315	1315	20195 20195	6921	505
5	ST LOUIS VORTAC	39524 003204	077	- 5	191	23	00+41	2570	2570	17615 17615	6823	506
6	INDIANAPOLIS	39604 085224	072	- 3	192	24	01+05	2619	2619	14975 14975	5587	507
7	DARTON	40014 084244	081	+ 0	21	11	01+16	1182	1182	13814 13814	5528	508
8	DRYER	41024 092104	050	+ 0	150	15	01+31	1681	1681	12133 12133	6549	505
9	JAMESTOWN	42114 070014	069	+ 4	165	17	01+48	1834	1834	10299 10299	6473	510
10	START AAP 1	42254 072084	070	+ 8	22	11	01+52	1136	1136	9153 9153	5410	503
11	NO.1 ABORT-OFF, 2 ON	42364 075284	081	+10	75	09	02+09	992	992	25800 25800	6688	503
12	ALBANY	42454 073494	082	+12	74	00	02+17	1049	987	24751 24751	7152	503
13	NO.2 ABORT-OFF, 3 ON	42454 073474	100	+13	1	00	02+17	13	10	24738 24738	7800	509
14	NO.3 ABORT-OFF, 4 ON	42314 072054	100	+14	75	09	02+25	1055	873	23433 23433	7112	509
15	BOSTON	42214 071004	101	+15	50	06	02+32	668	564	23015 23015	7032	509
16	NO.4 ABORT-OFF, 5 ON	42324 073264	066	+16	27	03	02+35	370	330	22640 22640	7031	500
17	NO.5 ABORT-OFF, 6 ON	43014 068524	066	+16	75	09	02+44	1045	927	21595 21595	6967	500
18	NO. 5 ABORT-OFF.	43204 067174	057	+18	75	09	02+53	1041	927	20554 20554	5940	500
***** AVERAGE ONLOAD FOR AAP 1 *****												
19	YARMOUTH	43494 066054	058	+19	55	07	03+03	763	799	19786 19786	7155	500

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ROJTE

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LINE NR	12-02-86	22472	ROUTE	DATA POINT	COORDINATES	TRUE CRS	WAS FAR	DISTANCE LES	TOTAL LES	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL 5	WIND OR ONLOAD	GS	
44	NO.2	ABORT-OFF	3	DN	5030N 00424E	054	+13	32	3206	05	08+03	685	10112	6953	5441	6774	485
45	NO.3	ABORT-OFF	4	DN	5059N 00240E	055	+7	72	4268	09	08+12	943	0175	6025	5430	5819	486
46	YESVILTON				5100N 00238E	056	+2	2	4770	00	08+12	21	9155	6074	6300		486
47	NO.4	ABORT-OFF	5	DN	5106N 00247E	054	+9	70	4140	09	08+21	958	872	5272	6494	4838	487
48	NO.5	ABORT-OFF	6	DN	5110N 00108E	056	+3	72	4212	09	08+17	989	905	4295	5743	3831	487
49	POWER				5110N 00121E	057	+7	8	4220	01	08+31	98	88	4208	5867		487
50	EBBU				5108N 00200E	054	+7	25	4245	03	08+34	206	309	3899	6180		487
51	KOKSEY				5105N 00239E	054	+5	25	4270	03	08+37	205	302	3528	6180		487
52	NO. 5	ABORT-OFF			5052N 00258E	123	+5	14	4234	02	08+39	167	175	6351	5176	2945	485

AVERAGE ONLOAD FOR AAR 3 5323																	
53	FLORENES				5015N 00430E	123	+5	78	4362	10	08+49	961	961	5430	6006		486
54	DESCEND				5004N 00413E	100	+5	51	4423	08	08+57	772	772	4628	6176		487
55	MATTENHEIM				5001N 00432E	100	+5	13	4436	03	09+00	114	114	4514	2533		291
56	HAHN				4957N 00716E	027	+5	22	4465	05	09+06	264	264	4250	2555		487

ABORT BASES RECEIVED 1

LINE NR	12-02-86	22472	ROUTE	DATA POINT	COORDINATES	TRUE CRS	WAS FAR	DISTANCE LES	TOTAL LES	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL 5	WIND OR ONLOAD	GS
*** AAR 1 ***																
ABORT POINT																
11A	STIFFS				4234N 07524E	003	+12	33	1395	05	02+13	520	7651	5783		486
11A	BINGO FUEL	2620														
11B	PEASE				4305N 07349E	080	+15	275	1263	24	02+32	2530	5641	6221		505
11B	BINGO FUEL	4630														
11C	BANGOR				4448N 05550E	053	+12	315	1373	38	02+46	3890	4231	6237		504
11C	BINGO FUEL	5990														

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LINE VBR	17-22-86	DATE POINT	ROUTE	COORDINATES	TRUE CRS	MAS ZAR	DISTANCE LES	TIME LEG TOTAL	FUEL USED	FUEL REMAIN	FUEL FLOW	WIND OR ONLOAD	GS
20	HALIFAX			4455N 6532W	050	+23	133	1623	1403	17975	23121	7094	501
21	STONY			4570N 6537W	051	+25	152	1742	2115	15852	20025	5971	503
22	CHICK PT			4552N 6553W	072	+25	153	1745	2021	13839	18027	6870	501
23	ST JOHNS			4770N 6525W	074	+27	153	2783	1084	2042	11855	16778	503
24	START ARR 2			4752N 6516W	073	+27	85	2123	1102	1136	10753	15612	500
25	CC PT			4970N 6510W	075	+27	34	2207	431	441	10322	15178	500
26	NO.1 ABORT-OFF, 2 ON			4915N 6630W	058	+23	51	2248	526	541	25830	14657	497
27	NO.2 ABORT-OFF, 3 ON			4940N 6471W	059	+25	74	2327	1761	24739	13676	7153	497
28	NO.3 ABORT-OFF, 4 ON			4940N 6453W	070	+25	74	2306	1056	972	23683	12734	497
29	CC PT			4910N 6450W	072	+27	21	2417	294	274	23339	12430	497
30	NO.4 ABORT-OFF, 5 ON			4940N 6434W	073	+27	53	2470	738	684	22651	11746	500
31	NO.5 ABORT-OFF, 6 ON			4943N 6415W	074	+27	75	2545	1045	972	21636	10774	500
32	RP PT			5000N 6400W	076	+27	73	2418	1006	934	20630	9850	500
33	NO. 6 ABORT-OFF.			5000N 6355W	055	+25	2	2520	24	22	20575	25870	494

34	CC PT			5000N 6350W	058	+25	101	2811	2633	2735	17943	23054	494
35				5000N 6300W	058	+24	103	3004	2604	2701	15339	20353	496
36	CC PT			5000N 6250W	058	+22	128	3107	2582	2674	12737	17639	491
37	RP PT			5000N 6200W	058	+20	123	3190	2542	2621	10215	15068	491
38	CC PT			5000N 6150W	058	+17	193	3583	2606	2601	7639	12457	488
39	RP PT			5000N 6100W	058	+14	123	3776	2408	2559	5201	9978	488
40	START ARR 7			5000N 6050W	059	+12	75	3851	948	983	4253	8925	488
41	CC PT			5000N 6000W	059	+11	2	3853	21	23	4232	8932	488
42	NO.1 ABORT-OFF, 2 ON			5000N 6050W	054	+11	71	3924	896	983	11054	7919	486
43	LANDS END			5000N 6050W	055	+10	20	3944	258	272	10836	7657	486

AVERAGE ONLOAD FOR ARR 2 15998

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ROUTE

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12-02-86 22412 ROUTE

ROUTE JND FACTOR +010

F-111D 4 PYLONS

TOTAL FUEL ON/DAS BY RECEIVER

FROM MCCONNELL

RECVR 1 RECVR 2 RECVR 3 RECVR 4

TO 44HH 84004

40677 40159 40208 40018

R004 TYPE REFUELING

RECVR 5 RECVR 6

30835 39532

CAS 305

MSN-TEMP-DEV +052 WY CLIMATOLOGICAL JINDS 97 WORST PROB FACTOR

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	WGS VAR	DISTANCE LES	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
1	MCCONNELL	3737N 09716W					3831	3830	26670	26670		
2	START, TAXI, TAKEOFF	3737N 09716W										
3	LEVELOFF POINT FL240	3756N 09506W	074	- 3	58	08	1650	1650	25020	25020	12375	467
4	BUTLER VORTAC	3815N 09629W	073	- 7	70	187	1112	1112	23903	23903	5678	460
5	ST LOUIS VORTAC	3652N 09229W	077	- 5	121	323	2637	2637	21271	21271	5354	460
6	INDIANAPOLIS	3940N 08622W	072	- 3	109	527	2672	2672	18599	18599	5214	462
7	DAYTON	4031N 08624W	081	+ 7	71	418	1212	1212	17397	17397	6153	462
8	DRYER	4123N 08210W	050	+ 0	150	748	1720	1720	15657	15657	5107	459
9	JAMESTOWN	4211N 07907W	050	+ 4	145	398	1881	1881	13735	13735	6335	463
10	STAPT AIR 1	4235N 07538W	070	+ 8	156	3740	2043	2043	11743	11743	6009	458
11	ALBANY	4265N 07343W	082	+ 11	82	1131	1134	1134	10609	10609	6359	458
12	NO. 1 ABORT, OFF, 2 ON	4241N 07315W	130	+ 13	25	1156	304	304	32735	32735	5700	464
13	BOSTON	4221N 07100W	100	+ 14	171	1257	1625	1625	31220	31220	9153	464
14	NO. 2 ABORT, OFF, 3 ON	4224N 07051W	056	+ 15	7	1264	105	85	31135	31135	9077	456
15	NO. 3 ABORT, OFF, 4 ON	4305N 06838W	066	+ 15	176	1370	1578	1337	29607	29607	7750	456
16	NO. 4 ABORT, OFF, 5 ON	4344N 06623W	057	+ 13	135	1676	1558	1313	28047	28047	5437	456
17	YARMOUTH	4369N 06505W	059	+ 20	14	1490	207	170	27847	27847	6257	456
18	NO. 5 ABORT, OFF, 6 ON	4435N 06414W	059	+ 20	92	1582	1336	1134	26511	26511	5133	456
19	HALIFAX	4455N 06324W	050	+ 22	41	1423	583	494	25028	25028	4639	456
20	NO. 6 ABORT, OFF.	4525N 06203W	051	+ 23	65	1538	924	791	25004	25004	5522	458

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12-02-86 22412 ROUTE

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LINE NR	DATA POINT	COORDINATES	TRUE CRS	WAS JAR	DISTANCE LES	TOTAL LES	TIME TOTAL	FUEL 1	USED 5	FUEL REMAINING 1	FUEL FLOW 5	WIND OR OVLAD	GS

21	SYDNEY	4570Y 350034	052	+24	24	1782	12 03+53	1326	1414	23678	31371	6898	458
22	CHECK PT	4552Y 056304	072	+25	153	1735	20 04+13	2129	2279	21569	29032	6803	456
23	ST JONVS	4720Y 352514	074	+27	153	2388	20 04+33	2080	2224	19459	26898	6572	458
24	CK PT	4530Y 057004	073	+27	117	2307	15 04+40	1618	1719	17831	25169	6560	454
25	CK PT	4910Y 045004	068	+23	210	2417	28 05+17	2828	2975	15023	22174	6421	452
26	START AAR 2	4942Y 041554	073	+27	124	2541	16 05+33	1642	1715	13331	20459	6274	455
27	NO.1 ABORT,OFF, 2	5070Y 043014	076	+27	75	2617	10 05+43	989	1037	30539	19422	5222	455
28	RP PT	5070Y 043014	076	+25	1	2618	00 05+43	11	11	37578	19411	6500	455
29	NO.2 ABORT,OFF, 3	5072Y 035034	089	+25	75	2599	10 05+53	1133	1032	29445	15370	6798	449
30	NO.3 ABORT,OFF, 4	5071Y 035074	089	+25	75	2768	10 05+03	1110	1025	28325	17353	6714	449
31	CK PT	5070Y 035004	081	+25	53	2811	05 06+09	637	554	27639	16759	5735	449
32	NO.4 ABORT,OFF, 5	5071Y 034104	039	+24	37	2843	04 06+13	483	423	27225	16341	6614	452
33	NO.5 ABORT,OFF, 6	5072Y 032144	039	+24	75	2919	10 06+23	1091	1003	26135	15338	6612	452
34	NO. 6 ABORT,OFF.	5070Y 030174	030	+23	75	2923	10 06+33	1078	994	25057	25057	6533	452

35		5070Y 030034	021	+22	11	3104	01 06+34	152	152	24935	24935	5514	452
36	CK PT	5070Y 025034	088	+22	193	3197	25 07+07	2767	2767	22138	22138	6410	447
37	RP PT	5070Y 025034	035	+20	193	3330	25 07+26	2688	2688	19450	19450	6251	448
38	CK PT	5070Y 015004	085	+17	193	3583	25 07+52	2671	2671	16779	16779	5154	445
39	RP PT	5070Y 010004	088	+15	193	3776	25 08+18	2626	2626	14153	14153	6060	445
40	RP PT	5070Y 009004	089	+12	77	3353	10 08+23	1027	1027	13126	13126	5953	445
41	LANDS END	5070Y 005334	084	+11	91	3744	12 08+40	1218	1218	11908	11908	5990	444
42	YEDVILTON	5107Y 002334	054	+10	125	4070	17 09+57	1737	1737	10171	10171	5131	444
43	DOVER	5110Y 002121E	084	+7	150	4220	20 09+17	1841	1841	9330	8330	5468	444

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ROUTE

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LIVE NBR	DATA POINT	COORDINATES	TRUE CRS	WAS JAR	DISTANCE LEG	TOTAL LEG	TIME TOTAL	ROUTE AND FACTOR +310				FUEL FLOW	WIND OR ONLOAD	GS
								FUEL 1	USED 6	FUEL 1	REMAIN 5			
44	EBBU	5178V 07200F	074	+ 7	25	4245	03 09+20	314	314	8015	8016	5700	444	
45	KOKSEY	5176V 07210F	074	+ 5	25	4270	03 09+23	314	314	7732	7732	5709	444	
46	FLOREYVES	5015V 07430E	123	+ 5	32	4362	12 30+35	1170	1170	6532	6532	5651	444	
47	DESCEND	5073V 07522E	100	+ 5	57	4420	09 37+44	844	844	5638	5638	5627	444	
48	NATTERHEIM	5071V 07612E	100	+ 4	7	4436	01 09+45	26	26	5652	5652	1733	468	
49	HAHH	4957V 07714E	097	+ 4	20	4465	04 09+49	112	112	5550	5550	1690	444	

ABORT MISSFS RECEIVER 1

*** AAR 1 ***

ABORT POINT	COORDINATES	TRUE CRS	WAS JAR	DISTANCE LEG	TOTAL LEG	TIME TOTAL	FUEL 1	USED 6	FUEL 1	REMAIN 5	FUEL FLOW	WIND OR ONLOAD	GS
12A PEASE	4241V 07315W	076	+15	100	1265	14 07+45	10335	1259	9046	5320	460		
12A BINGO FUEL	4375V 07740W	054	+17	220	1385	33 33+41	2753	5353	4955	5583	457		
12B BINGO FUEL	4423V 06350W	071	+23	418	1504	58 03+29	12392	7553	4839	5716	396		
12C SHEARWATER	4438V 06330W	259	+28	522	3139	1 19 07+02	10979	1413	5650	447			
12C BINGO FUEL	4438V 06330W	071	+23	418	1504	58 03+29	10979	1413	5650	447			

*** AAR 2 ***

ABORT POINT	COORDINATES	TRUE CRS	WAS JAR	DISTANCE LEG	TOTAL LEG	TIME TOTAL	FUEL 1	USED 6	FUEL 1	REMAIN 5	FUEL FLOW	WIND OR ONLOAD	GS
27A ST JOHNS	5007V 05001W	259	+28	522	3139	1 19 07+02	10979	1413	5650	447			
27A BINGO FUEL	4737V 05245W	259	+28	522	3139	1 19 07+02	10979	1413	5650	447			
27B LAJES	3846V 07706W	135	+17	859	3486	1 57 07+40	10979	1413	5650	447			
27B BINGO FUEL	13729						10979	1413	5650	447			

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ROUTE

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12-02-86 2739Z ROUTE						ROUTE JIND FACTOR +012									
FLY LEVEL		1	2	3	4	5	DE-AC		2X370WIS00CL OYLOHS FOAM		TOTAL FUEL ONLOAD BY RECEIVER				
ALT JOPER	TAS						FROM	TO	HAHH	RECVR 1	RECVR 2	RECVR 3	RECVR 4		
CAS 305										42661	49532	49613	49573		
MSGN-TESP-DEV +0SC MAY CLIMATOLOGICAL WINDS QZ WORST PROB FACTOP															
LIVE	DATA POINT	COORDINATES	TRUE WAS DISTANCE	CSS	JAR LES	TOTAL LES	TIME TOTAL	FUEL	USED	FUE--REMAIN	JFEL	WIND OR			
1 MCCONNELL		3737N 77716W													
2 START,TAXI-TAKEOFF		3737N 77716W													
3 LEVELOFF POINT FL280		3755N 79502W	074 - 3	51	61	09	00+00	1870	1A70	16115	16115	13062	500		
4 BUTLER VORTAC		3915N 79420W	073 - 7	75	137	07	00+18	1080	1080	15035	15035	5958	489		
5 ST LOUIS VORTAC		3852N 79229W	077 - 5	121	328	23	00+41	2608	2608	12427	12427	5716	490		
6 INDIANAPOLIS		3957N 78422W	072 - 3	129	527	24	01+05	2580	2580	08358	08358	5393	491		
7 DAYTON		4021N 78424W	081 + 0	71	518	11	01+15	1124	1124	8714	8714	6131	492		
8 START ARR 1		4730N 73323W	050 + 0	50	528	07	01+23	752	752	7952	7952	5397	489		
9 NO.1 ABORT,OFF.	2 ON	4119N 73715W	051 + 2	55	743	08	01+31	770	770	20270	20270	6368	489		
10 DRYER		4122N 73210W	052 + 4	5	748	01	01+32	76	61	20124	20124	7600	489		
11 NO.2 ABORT,OFF.	3 ON	4143N 73355W	069 + 4	57	508	07	01+30	920	733	19274	6350	7562	493		
12 NO.3 ABORT,OFF.	4 ON	4235N 73933W	070 + 5	55	873	03	01+47	080	791	19215	5578	7511	493		
13 JAMESTOWN		4211N 73907W	070 + 7	27	508	02	01+49	286	244	17929	5334	7150	493		
14 NO.4 ABORT,OFF.	5 ON	4219N 73807W	079 + 8	55	938	05	01+55	656	543	17273	4791	7156	487		
15 NO.5 ABORT,OFF.	6 ON	4229N 07640W	080 + 2	55	1703	03	02+03	949	790	16324	4071	7118	487		
16 NO. 6 ABORT,OFF.		4237N 07513W	081 +10	55	1268	03	02+11	929	773	15375	20270	5958	487		

AVERAGE ONLOAD FOR ARR 1 15013															
17 ALBANY		4245N 07348W	082 +12	63	1131	08	02+19	886	970	14539	19230	7558	487		
18 BOSTON		4221N 07100W	100 +13	126	1257	15	02+34	1713	1873	12796	17357	7345	493		
19 YARMOUTH		4349N 73605W	066 +15	233	1400	20	03+03	3071	3341	9723	14015	5960	485		

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LINE NR	DATA POINT	ROUTE	TRUE CRS	TRUE FAR	DISTANCE LES	TIME LES	TIME TOTAL	FUEL 1	FUEL USED	FUEL REMAIN	FUEL FLOW	WIND OR OVERLOAD	GS
20	HALIFAX		059	+21	133	1623	16 03+19	1672	1817	9053	12199	6668	485
21	SYDNEY		061	+23	159	1782	20 03+39	1962	2078	5091	10121	6394	487
22	START AAP 2	4524V 75364V	072	+25	55	1338	07 03+45	691	712	5470	9409	6191	485
23	NO.1 ABORT,OFF.	2 ON 4646V 05715V	073	+25	55	1703	08 03+54	791	813	20230	5591	6135	15591
24	CHECK PT	4652V 75530V	074	+25	55	1735	06 03+58	491	397	17739	8174	7554	485
25	NO.2 ABORT,OFF.	3 ON 4771V 75563V	074	+27	33	1968	04 04+02	504	405	19235	7799	7560	15594
26	NO.3 ABORT,OFF.	4 ON 4717V 05419V	075	+27	55	2033	08 04+10	1002	809	19233	6990	7515	15603
27	ST JOHNS	4720V 75251V	076	+27	55	2038	07 04+17	799	672	17434	5378	7155	487
28	NO.4 ABORT,OFF.	5 ON 4732V 05237V	073	+27	17	2078	01 04+18	144	127	17250	6188	7200	15602
29	NO.5 ABORT,OFF.	6 ON 4769V 05105V	074	+27	54	2162	08 04+25	937	791	16323	5327	7116	15593
30	CK PT	4800V 05000V	075	+23	45	2207	05 04+32	639	544	15684	4853	6971	483
31	NO. 6 ABORT,OFF.	4377V 74333V	058	+23	17	2226	02 04+34	267	223	15417	20230	5955	15575
32	CK PT	4910V 04500V	059	+23	191	2417	04 04+58	2687	2937	12730	17253	7474	481
33	START AAP 3	4924V 04363V	073	+27	52	2460	06 04+04	697	762	12033	16531	7144	484
34	NO.1 ABORT,OFF.	2 ON 4937V 04232V	074	+27	53	2517	05 05+10	640	685	20230	15814	5766	8807
35	NO.2 ABORT,OFF.	3 ON 4969V 74120V	075	+27	53	2565	05 05+15	743	635	19437	15139	7556	8590
36	NO.3 ABORT,OFF.	4 ON 4959V 74007V	076	+27	55	2513	05 05+22	743	675	18714	14454	7556	8363
37	RP PT	5000V 04000V	077	+25	5	2518	01 05+23	77	68	18637	14386	7700	484
38	NO.4 ABORT,OFF.	5 ON 5001V 03853V	093	+25	53	2561	05 05+28	450	597	17937	13739	7358	8146
39	NO.5 ABORT,OFF.	6 ON 5024V 03738V	098	+25	55	2707	06 05+34	715	675	17272	13113	7150	7941
40	NO. 6 ABORT,OFF.	5001V 03624V	099	+25	55	2757	06 05+40	716	655	16556	20230	7160	7742
41	CK PT	5000V 03500V	090	+25	54	2811	07 05+47	779	844	15777	19356	7558	478
42		5000V 03400V	088	+24	193	3004	24 06+11	2742	2925	13035	16430	7285	480
AVERAGE OVERLOAD FOR AAR 2													15593
AVERAGE OVERLOAD FOR AAR 3													8265

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ROUTE

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12-02-86 2239Z ROUTE

LINE NO.	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LES	TIME LEG TOTAL	ROUTE 4100 FACTOR 4112				FUEL FLCM	WIND OR ONLOAD	GS
							FUEL 1	USED 5	FUEL 1	REMAIN 6			
43	START AAR 4 5001N 22850E	088	+22	30	3243	05	06+16	534	569	12531	15851	6967	475
44	NO.1 ABORT-OFF, 2 ON 5002N 22746E	088	+22	27	3090	05	06+22	643	685	20270	15175	6976	475
45	NO.2 ABORT-OFF, 3 ON 5001N 22633E	089	+21	27	3137	05	06+28	743	677	19437	14498	7556	475
46	NO.3 ABORT-OFF, 4 ON 5000N 22520E	090	+20	27	3184	05	06+34	743	655	18714	13833	7556	475
47	CR PT 5000N 22500E	091	+20	13	3197	02	06+36	203	180	18511	13653	7613	475
48	NO.4 ABORT-OFF, 5 ON 5001N 22407E	088	+20	36	3231	04	06+40	512	473	17089	13180	7814	476
49	NO.5 ABORT-OFF, 6 ON 5002N 22254E	088	+19	27	3278	05	06+45	703	665	17275	12534	7149	476
50	NO. 6 ABORT-OFF. 5001N 22141E	089	+18	27	3325	06	06+52	703	643	16533	20200	7149	476

							AVERAGE ONLOAD FOR AAR 4				8331		
51	RP PT 5000N 22000E	090	+18	55	3390	08	07+03	943	1020	15650	19180	7556	476
52	CR PT 5000N 21500E	088	+17	103	3583	25	07+25	2777	2953	12873	15222	7244	472
53	RP PT 5000N 21000E	088	+16	103	3776	24	07+49	2615	2791	10353	13431	6863	473
54	RP PT 5000N 20500E	089	+12	77	3953	10	07+50	1002	1067	9256	12364	6600	473
55	LANDS END 5000N 20500E	084	+11	71	3944	12	08+11	1172	1241	9094	11123	6475	471
56	YE3VILTOY 5000N 20238E	084	+10	125	4070	15	08+27	1613	1672	6471	9451	5270	471
57	START AAR 5 5001N 20213E	084	+7	15	4086	02	08+29	200	204	6271	9247	6120	472
58	NO.1 ABORT-OFF, 2 ON 5000N 20033E	084	+5	53	4149	08	08+37	501	817	9354	8430	6128	472
59	NO.2 ABORT-OFF, 3 ON 5000N 20009E	086	+3	53	4212	08	08+45	917	809	9537	7621	6128	472
60	DNVER 5000N 20012E	087	+7	3	4220	01	08+46	102	101	9435	7520	5120	472
61	ER3U 5000N 20000E	084	+7	25	4245	03	08+49	314	313	8121	7207	6777	472
62	KOKSEY 5000N 20039E	094	+5	25	4270	03	08+52	313	313	7808	6894	5058	471
63	NO.3 ABORT-OFF, 4 ON 5000N 20045E	123	+5	5	4275	01	08+53	61	59	7747	6835	6100	471
64	NO.4 ABORT-OFF, 5 ON 5000N 20009E	123	+5	53	4338	08	09+01	807	800	5940	5035	5053	471
65	FLORANNES 5001N 200439E	124	+5	24	4362	03	09+04	301	301	6639	5734	6020	471
66	NO.5 ABORT-OFF, 6 ON 5000N 200539E	100	+5	39	4401	05	09+09	490	490	6149	5244	5000	472

D-27

UNCLASSIFIED

ROUTE

PAGE 03

JNC-CLASSIFIED

12-02-86 2239Z ROUTE

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAS VAR	DISTANCE LEG	TOTAL LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
67	WATTERHEIM	5001N 00532E	100	+ 5	35	4436	04 09+13	440	435	5739	4839	6000	472
53	NO. 5 ABORT, OFF.	4757N 77715E	097	+ 5	24	4464	04 09+17	340	345	5353	5953	897	472
								AVERAGE ONLOAD FOR AAR 5					
								10	13	5353	5350	6000	472

ABORT BASES RECEIVER 1

*** AAR 1 ***

ABORT POINT

4119N 38215N 743 01+31

9A RICKENBACHER

3949N 73256N 100 + 2 35 338 13 01+44

9A BINGO FUEL 4025

4314N 37524N 067 +12 325 1368 40 02+11

9B GRIFFIS

4314N 37524N 067 +12 325 1368 40 02+11

9B BINGO FUEL 6713

4314N 37524N 067 +12 325 1368 40 02+11

*** AAR 2 ***

ABORT POINT

4544N 75715N 1703 03+54

23A STEPHENVILLE

4933N 75833N 334 +24 121 2724 16 04+10

23A BINGO FUEL 4333

4933N 75833N 334 +24 121 2724 16 04+10

23B ST JOHNS

4737N 35245N 072 +23 107 2093 24 04+19

23B BINGO FUEL 5047

4737N 35245N 072 +23 107 2093 24 04+19

*** AAR 3 ***

ABORT POINT

4937N 36232N 2517 05+10

34A ST JOHNS

4737N 35245N 257 +23 423 2930 1 01 06+11

34A BINGO FUEL 8972

4737N 35245N 257 +23 423 2930 1 01 06+11

JNC-CLASSIFIED

ROUTE

PAGE 04

Appendix E

MODAS Maintenance/Reliability Data

AFIT/LSMA

The Maintenance and Operational Data Access System (MODAS) is a valuable source of Air Force wide maintenance and operational information. Requirements to access this system are a computer and modem, with an identification number and password. Capt Jim Smith, AFIT/LSMA, has attended the course on MODAS and has the user identification number and password for this department. The password can be used from any location. It is restricted to office personnel.

USER IDENTIFICATION: AFTLSMA

PASSWORD: MAKE.POW

To access the system, call 257-5207 (local), 1-800-648-7381 (Ohio ONLY) or 1-800-435-7549 (outside state of Ohio). This avenue of access is "LOGNET", and is restricted to MILITARY ONLY. The following sequence will follow:

PROMPTS

CONNECT: <CR>
SYSTEM?: CHOICE 2
USERNAME: AFTLSMA
PASSWORD: MAKE.POW
TERMINAL: <CR> PRESS RETURN <CR>
ENTER MODAS SYSTEM REQUIRED: "A", "B", OR "Q"

Entering a "system" puts a user into a set of ALCs, as described in the operations manual. There are few copies of this manual available (in reprint) at this time. The ONLY copy in AFIT is maintained by Capt Smith, room 302, building 641 (School of Systems and Logistics).

Modas is also accessible by the following commercial numbers:

SYSTEM "A": (513) 257-5672/73/74/75/76/77
SYSTEM "B": (513) 257 2179, 5667/68/69/70/71

AT THE PROMPT ("_"), ENTER: LOGON_AFTLSMA_ON_SYS(A or B)
(pay attention to the spaces (_))
PASSWORD:MAKE.POW
(the password DOES NOT echo, get it right)

PAY ATTENTION TO THE MESSAGES ON THE OPENING MENU!! They tell you if a particular ALC is unaccessible because of update or if a particular MDS is being updated and not accessible at that time.

SEARCHES CAN TAKE A LONG TIME. If you begin a dat intensive search and can not stay with the system, YOU MUST CALL MR. FRANK MAGUIRE, 513-257-6906 (AV 787-6906), FOR A DISCONNECT!! To just turn your system off and hang up leaves the line connected and denies other users access. A search once started, must be completed.

00
L2
Modas

KC010A - Maintainability Report #4
For Nov 85

05 MAR 1986

G063

* All Systems *

Ranked by

Latest 3 Month MH/PH (Unscheduled Manhours) *M. J. / 12,000*

Rank	Wuc	Noun	# Failures	3 Month Manhours	3 Month MH/PH	Ranking Factor	
1	46***	System	46	187	4198.1	22.616 0.64927	100.00
2	23***	System	23	124	2392.9	18.126 0.37008	57.00
3	71***	System	71	111	1556.7	11.040 0.24076	37.08
4	14***	System	14	57	1308.0	22.441 0.20229	31.16
5	13***	System	13	82	1034.8	11.111 0.16004	24.65
6	52***	System	52	70	896.0	7.444 0.13857	21.34
7	24***	System	24	57	876.6	22.571 0.13557	20.88
8	44***	System	44	111	832.3	7.498 0.12872	19.83
9	45***	System	45	41	761.8	15.547 0.11782	18.15
10	41***	System	41	57	549.2	14.543 0.08494	13.08
11	64***	System	64	77	459.2	5.344 0.07102	10.94
12	51***	System	51	55	459.0	6.525 0.07099	10.93
13	68***	System	68	17	372.8	21.721 0.05766	8.88
14	11***	System	11	24	364.2	15.175 0.05633	8.68
15	63***	System	63	15	346.1	23.070 0.05353	8.24
16	72***	System	72	10	341.9	11.247 0.05288	8.14

For Nov 85

17	12***	System	12	17	334.2	17.627 0.05169	7.96
18	42***	System	42	21	331.2	15.771 0.05122	7.89
19	47***	System	47	55	282.3	5.133 0.04366	6.72
20	49***	System	49	21	174.7	7.279 0.02702	4.16
21	65***	System	65	9	97.0	10.776 0.01500	2.31
22	61***	System	61	10	72.0	7.200 0.01114	1.72
23	64***	System	64	9	72.0	8.000	

05 MAR 1986

Modas

LZ
KC010A - Reliability Report #4
For Nov 85

05 MAR 1986

G063

* All Systems *

Ranked by

Latest 3 Month MTBM (Type 1 Failures)

Rank	Wuc	Noun	3 Month Failures	3 Month MTBM	Ranking Factor
1	46***	System 46	184	35.14075	100.00
2	71***	System 71	141	45.85741	76.63
3	23***	System 23	132	48.98407	71.74
4	44***	System 44	111	58.25133	60.33
5	52***	System 52	90	71.84328	48.91
6	13***	System 13	83	77.90236	45.11
7	64***	System 64	77	83.97269	41.85
8	14***	System 14	57	113.43677	30.98
9	47***	System 47	55	117.56177	29.89
10	51***	System 51	55	117.56177	29.89
11	45***	System 45	49	131.95703	26.63
12	24***	System 24	37	174.75397	20.11
13	41***	System 41	37	174.75397	20.11
14	72***	System 72	30	215.52991	16.30
15	11***	System 11	24	269.41229	13.04
16	49***	System 49	24	269.41229	13.04

*

Latest 3 Month MTBM (Type 1 Failures)

Rank	Wuc	Noun	3 Month Failures	3 Month MTBM	Ranking Factor
17	42***	System 42	21	307.89978	11.41
18	12***	System 12	17	380.34680	9.24
19	68***	System 68	17	380.34680	9.24
20	63***	System 63	15	431.05975	8.15
21	61***	System 61	10	646.58960	5.43
22	65***	System 65	9	718.43286	4.89
23	69***	System 69	9	718.43286	4.89

LI200 RELIABILITY STATUS REPORT

PAGE 1 OF 2 PAGES
PREPARED: 05 MAR 1988 LI300

END ART DESIG: KC010A

BASE: ****

FLEET SUMMARY

WORK UNIT CODE: 46*** = FUEL SYSTEM

TYPE FAILURE: 1

LI500

DATE	FLIGHT HOURS		TOTAL MEAN TIME BETWEEN MAINTENANCE			
	ACTUAL	CUM.	FAILURE COUNT	MONTHLY	3 MONTH	CUM.
84 1	1124.3	1124.3	50	22.49	0.00	22.49
84 2	1289.3	2413.6	60	21.49	0.00	21.94
84 3	1630.8	4044.4	28	58.24	29.31	29.31
84 4	1426.7	5471.1	59	24.18	29.57	27.77
84 5	1616.4	7087.5	44	36.74	35.68	29.41
84 6	1690.2	8777.7	65	26.00	28.17	28.69
84 7	1722.2	10499.9	70	24.60	28.09	27.93
84 8	1952.3	12452.2	49	39.84	29.16	29.30
84 9	1784.8	14237.0	48	37.18	32.69	30.10
84 10	2036.6	16273.6	61	33.39	36.54	30.47
84 11	1869.0	18142.6	71	26.32	31.61	29.99
84 12	1391.4	19534.0	61	22.81	27.45	29.33
85 1	1642.7	21176.7	76	21.61	23.57	28.54
85 2	1909.7	23086.4	74	25.81	23.43	28.29
85 3	2366.7	25453.1	77	30.74	26.08	28.50
85 4	2264.3	27717.4	94	24.09	26.70	28.08
85 5	2113.6	29831.0	39	54.19	32.12	29.08

LI500LZ DSD G063

*** M O D A S ***

VERSIO

DATE	ACTUAL	CUM.	COUNT	MONTHLY	3 MONTH	CUM.
85 6	1815.7	31646.7	111	16.36	25.38	27.83
85 7	2012.2	33658.9	103	19.54	23.48	27.14
85 8	2543.6	36202.5	67	37.96	22.67	27.70
85 9	1899.6	38102.1	53	35.84	28.95	28.02
85 10	2442.0	40544.1	61	40.03	38.04	28.53
85 11	2124.3	42668.4	70	30.35	35.14	28.62
85 12	0.0	42668.4	55	0.00	24.55	27.60
TOTAL	42668.4		1546			

Latest 3 month Flying hours = 6465.9

3 month
Total
184 failures

LI500LZDSD G063
 LI2000 OPERATIONAL STATUS REPORT
 LI500
 MDS: KCO10A
 COMMAND: ***
 LI500

*** M O D A S ***

VERSION 1.01
 PAGE 1 OF 2 PAGES
 PREPARED: 05 MAR 1986L1
 FLEET SUMMARY

DATE	TOTAL FLIGHT HOURS	SORTIES	AVERAGE AIRCRAFT INVENTORY	TOTAL POSSESSED HOURS	FULLY MISSION CAPABLE	NOT MISSION CAPABLE	PARTLY MISSION CAPABLE
8312	888.9	206	18	13435	12297	957	181
8401	1124.3	265	18	13595	12332	975	288
8402	1289.3	308	19	13297	12446	668	183
8403	1630.8	347	20	14888	13676	1091	121
8404	1426.7	318	20	14574	13281	1135	158
8405	1616.4	343	21	15456	14411	986	59
8406	1690.2	346	20	14304	12264	1056	984
8407	1722.2	361	23	16991	15186	1488	317
8408	1952.3	408	23	16786	15119	1592	75
8409	1784.8	364	24	17130	15225	1643	262
8410	2036.6	434	23	17520	15837	1274	409
8411	1869.0	463	25	18186	15497	1785	904
8412	1391.4	338	27	19903	18638	945	320
8501	1642.7	388	27	20162	17851	2147	164
8502	1909.7	426	27	18354	15251	2630	473
8503	2366.7	516	28	20832	18916	1648	268
8504	2264.3	491	29	20510	18853	1584	73

LI500LZDSD G063

*** M O D A S ***

VERSION 1.01

	TOTAL FLIGHT HOURS	SORTIES	AVERAGE AIRCRAFT INVENTORY	TOTAL POSSESSED HOURS	FULLY MISSION CAPABLE	NOT MISSION CAPABLE	PARTLY MISSION CAPABLE
8505	2113.6	472	29	21613	20147	1370	96
8506	1815.7	413	30	21859	20664	1073	122
8507	2012.2	467	31	23118	21032	1897	189
8508	2543.6	553	33	24108	21867	1699	542
8509	1899.6	439	33	23596	21468	1794	334
8510	2442.0	581	35	25990	23687	1683	620
8511	2124.3	487	36	25976	23745	1685	546
TOTAL	43557.3	9734		452183	409690	34805	7688
MONTHLY AVERAGE	1814.9	405	25	18840	17070	1450	320

APPENDIX F

DISTANCES BETWEEN TTF BASES AND THE AR TRACKS (As calculated by the Great Circle routine)

THE DISTANCE FROM GOOSEBAY	TO F-16	ARCP 1 IS:	421.
GOOSEBAY	F-16	EAR 1 :	477.
THE DISTANCE FROM GOOSEBAY	TO F-16	ARCP 2 IS:	2057.
GOOSEBAY	F-16	EAR 2 :	2333.
THE DISTANCE FROM GOOSEBAY	TO F-15	ARCP 1 IS:	814.
GOOSEBAY	F-15	EAR 1 :	505.
THE DISTANCE FROM GOOSEBAY	TO F-15	ARCP 2 IS:	541.
GOOSEBAY	F-15	EAR 2 :	820.
THE DISTANCE FROM GOOSEBAY	TO F-15	ARCP 3 IS:	1916.
GOOSEBAY	F-15	EAR 3 :	2290.
THE DISTANCE FROM GOOSEBAY	TO F-111	ARCP 1 IS:	911.
GOOSEBAY	F-111	EAR 1 :	482.
THE DISTANCE FROM GOOSEBAY	TO F-111	ARCP 2 IS:	682.
GOOSEBAY	F-111	EAR 2 :	1107.
THE DISTANCE FROM GOOSEBAY	TO RF-4C	ARCP 1 IS:	1227.
GOOSEBAY	RF-4C	EAR 1 :	873.
THE DISTANCE FROM GOOSEBAY	TO RF-4C	ARCP 2 IS:	423.
GOOSEBAY	RF-4C	EAR 2 :	516.
THE DISTANCE FROM GOOSEBAY	TO RF-4C	ARCP 3 IS:	646.
GOOSEBAY	RF-4C	EAR 3 :	908.
THE DISTANCE FROM GOOSEBAY	TO RF-4C	ARCP 4 IS:	1148.
GOOSEBAY	RF-4C	EAR 4 :	1431.
THE DISTANCE FROM GOOSEBAY	TO RF-4C	ARCP 5 IS:	2087.
GOOSEBAY	RF-4C	EAR 5 :	2433.

THE DISTANCE FROM MILDENHALL TO F-16 ARCP 1 IS: 2290.
MILDENHALL F-16 EAR 1 : 1976.

THE DISTANCE FROM MILDENHALL TO F-16 ARCP 2 IS: 167.
MILDENHALL F-16 EAR 2 : 196.

THE DISTANCE FROM MILDENHALL TO F-15 ARCP 1 IS: 2905.
MILDENHALL F-15 EAR 1 : 2469.

THE DISTANCE FROM MILDENHALL TO F-15 ARCP 2 IS: 1850.
MILDENHALL F-15 EAR 2 : 1472.

THE DISTANCE FROM MILDENHALL TO F-15 ARCP 3 IS: 350.
MILDENHALL F-15 EAR 3 : 154.

THE DISTANCE FROM MILDENHALL TO F-111 ARCP 1 IS: 3027.
MILDENHALL F-111 EAR 1 : 2431.

THE DISTANCE FROM MILDENHALL TO F-111 ARCP 2 IS: 1635.
MILDENHALL F-111 EAR 2 : 1181.

THE DISTANCE FROM MILDENHALL TO RF-4C ARCP 1 IS: 3362.
MILDENHALL RF-4C EAR 1 : 2982.

THE DISTANCE FROM MILDENHALL TO RF-4C ARCP 2 IS: 2301.
MILDENHALL RF-4C EAR 2 : 1900.

THE DISTANCE FROM MILDENHALL TO RF-4C ARCP 3 IS: 1685.
MILDENHALL RF-4C EAR 3 : 1382.

THE DISTANCE FROM MILDENHALL TO RF-4C ARCP 4 IS: 1140.
MILDENHALL RF-4C EAR 4 : 848.

THE DISTANCE FROM MILDENHALL TO RF-4C ARCP 5 IS: 129.
MILDENHALL RF-4C EAR 5 : 293.

THE DISTANCE FROM LORING AFB TO F-16 ARCP 1 IS: 362.
LORING AFB F-16 EAR 1 : 668.

THE DISTANCE FROM LORING AFB TO F-16 ARCP 2 IS: 2478.
LORING AFB F-16 EAR 2 : 2764.

THE DISTANCE FROM LORING AFB TO F-15 ARCP 1 IS: 339.
LORING AFB F-15 EAR 1 : 232.

THE DISTANCE FROM LORING AFB TO F-15 ARCP 2 IS: 788.
LORING AFB F-15 EAR 2 : 1157.

THE DISTANCE FROM LORING AFB TO F-15 ARCP 3 IS: 2323.
LORING AFB F-15 EAR 3 : 2721.

THE DISTANCE FROM LORING AFB TO F-111 ARCP 1 IS: 453.
LORING AFB F-111 EAR 1 : 253.

THE DISTANCE FROM LORING AFB TO F-111 ARCP 2 IS: 994.
LORING AFB F-111 EAR 2 : 1465.

THE DISTANCE FROM LORING AFB TO RF-4C ARCP 1 IS: 796.
LORING AFB RF-4C EAR 1 : 408.

THE DISTANCE FROM LORING AFB TO RF-4C ARCP 2 IS: 352.
LORING AFB RF-4C EAR 2 : 742.

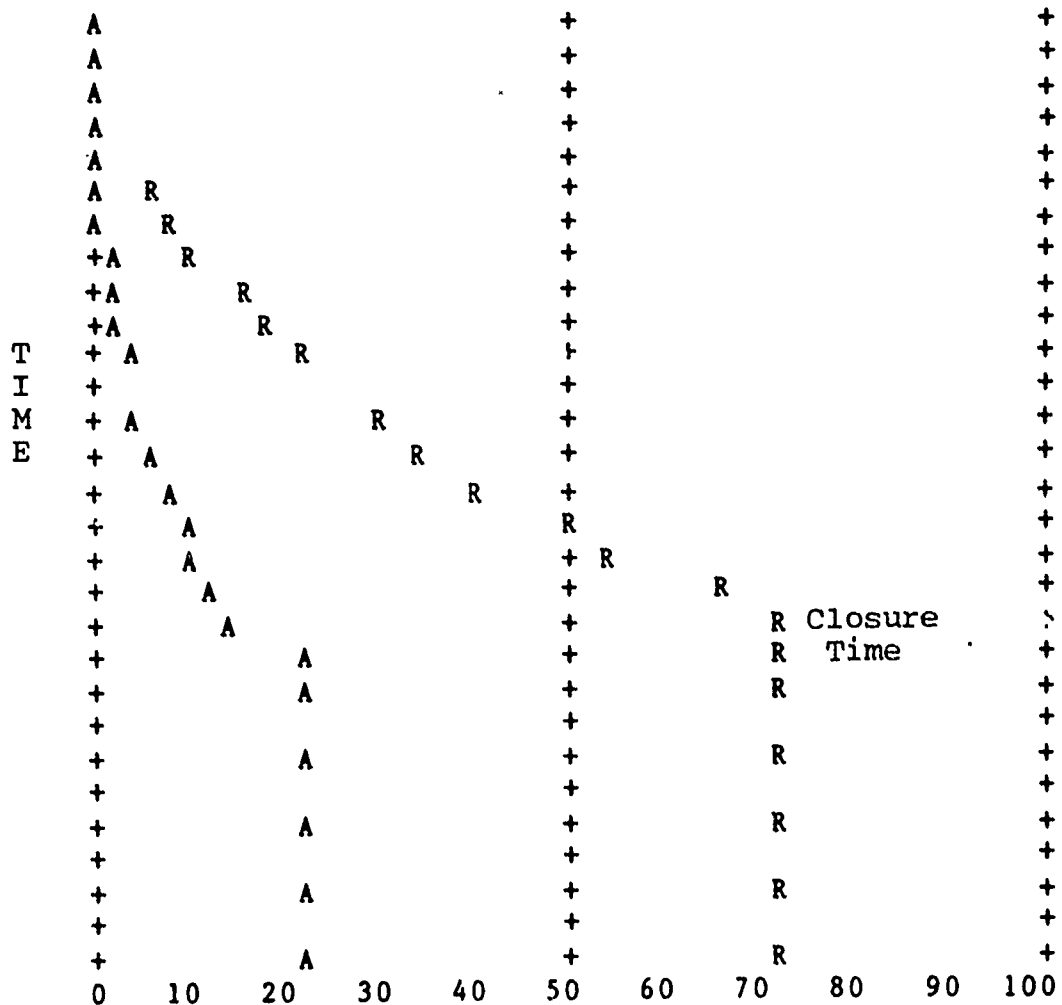
THE DISTANCE FROM LORING AFB TO RF-4C ARCP 3 IS: 946.
LORING AFB RF-4C EAR 3 : 1252.

THE DISTANCE FROM LORING AFB TO RF-4C ARCP 4 IS: 1509.
LORING AFB RF-4C EAR 4 : 1810.

THE DISTANCE FROM LORING AFB TO RF-4C ARCP 5 IS: 2511.
LORING AFB RF-4C EAR 5 : 2866.

SLAM TTF Output

Plot of Cumulative Fighters Refueled (R)
and Aborted Fighters due to Missed ARs (A)
VS. Time.



Cumulative Refuelings and Aborts


```

PROGRAM MAIN
  DIMENSION NSET(50000)
  COMMON/SCOM1/ATTRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
  COMMON QSET(50000)
  EQUIVALENCE(NSET(1),QSET(1))
  NNSET=50000
  NCRDR=5
  NPRNT=6
  NTAPE=7
  NPLOT=2
  CALL SLAM
  STOP
  END
  SUBROUTINE INTLC
  COMMON/SCOM1/ATTRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
  RETURN
  END
  SUBROUTINE OUTFUT
  COMMON/SCOM1/ATTRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
  RETURN
  END

```

```

  SUBROUTINE EVENT(I)
  COMMON/SCOM1/ATTRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
  DIMENSION NSET(50000)
  COMMON QSET(50000)
  EQUIVALENCE(NSET(1),QSET(1))
  EQUIVALENCE (ATTRIB(1),FLYHRS),(ATTRIB(4),MXTIME)
  REAL PROBFAIL,MTBF,MTTR,STDEV,MXTIME

```

```

  GO TO (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22
1,23) I

```

- C Events 1-23 are used to determine Maintenance Time for the 23 Sub-
- C systems of the KC-10 aircraft. First, a probability of failure is
- C calculated using the exponential distribution as a model (the
- C parameter of the exponential distribution depends on the subsystem).
- C A random number is then drawn to see if the subsystem fails. If not,
- C then Maintenance Time (MXTIME) is set to zero. Otherwise, a random
- C value is drawn from the Lognormal distribution with the parameters
- C for the Maintenance Time for that particular subsystem.
- C NOTE: These values are based on MODAS (Maintenance and Operational
- C Data Access System) values for the three months Sep - Nov 85.
- C The value for MTTR is calculated using Manhours per failure,
- C ie: Total Manhours/ Total Failures. All values for Manhours are divided
- C by the average number of men per repair, 2.7188, to get MTTR in hours.
- C Subsystems are listed in descending order by failure rate (First is

C Worst).

C Event 1 calculates MXTIME for the 46*** subsystem.
 1 MTBF = 35.14075
 MTTR = 22.816 / 2.7188
 GO TO 98

C Event 2 calculates MXTIME for the 71*** subsystem.
 2 MTBF = 45.85741
 MTTR = 11.040 / 2.7188
 GO TO 98

C Event 3 calculates MXTIME for the 23*** subsystem.
 3 MTBF = 48.98407
 MTTR = 18.128 / 2.7188
 GO TO 98

C Event 4 calculates MXTIME for the 44*** subsystem.
 4 MTBF = 58.25133
 MTTR = 7.498 / 2.7188
 GO TO 98

C Event 5 calculates MXTIME for the 52*** subsystem.
 5 MTBF = 71.84328
 MTTR = 9.956 / 2.7188
 GO TO 98

C Event 6 calculates MXTIME for the 13*** subsystem.
 6 MTBF = 77.90236
 MTTR = 12.467 / 2.7188
 GO TO 98

C Event 7 calculates MXTIME for the 64*** subsystem.
 7 MTBF = 83.97269
 MTTR = 5.964 / 2.7188
 GO TO 98

C Event 8 calculates MXTIME for the 14*** subsystem.
 8 MTBF = 113.43677
 MTTR = 22.947 / 2.7188
 GO TO 98

C Event 9 calculates MXTIME for the 47*** subsystem.
 9 MTBF = 117.56177
 MTTR = 5.133 / 2.7188
 GO TO 98

C Event 10 calculates MXTIME for the 51*** subsystem.
 10 MTBF = 117.56177
 MTTR = 8.345 / 2.7188
 GO TO 98

C Event 11 calculates MXTIME for the 45*** subsystem.

11 MTBF = 131.95703
 MTTR = 15.547 / 2.7188
 GO TO 98

C Event 12 calculates MXTIME for the 24*** subsystem.
 12 MTBF = 174.75397
 MTTR = 8.345 / 2.7188
 GO TO 98

C Event 13 calculates MXTIME for the 41*** subsystem.
 13 MTBF = 174.75397
 MTTR = 14.843 / 2.7188
 GO TO 98

C Event 14 calculates MXTIME for the 72*** subsystem.
 14 MTBF = 215.52991
 MTTR = 11.397 / 2.7188
 GO TO 98

C Event 15 calculates MXTIME for the 11*** subsystem.
 15 MTBF = 269.41229
 MTTR = 15.175 / 2.7188
 GO TO 98

C Event 16 calculates MXTIME for the 49*** subsystem.
 16 MTBF = 269.41229
 MTTR = 7.279 / 2.7188
 GO TO 98

C Event 17 calculates MXTIME for the 42*** subsystem.
 17 MTBF = 307.89978
 MTTR = 15.771 / 2.7188
 GO TO 98

C Event 18 calculates MXTIME for the 12*** subsystem.
 18 MTBF = 380.34680
 MTTR = 19.659 / 2.7188
 GO TO 98

C Event 19 calculates MXTIME for the 68*** subsystem.
 19 MTBF = 380.34680
 MTTR = 21.929 / 2.7188
 GO TO 98

C Event 20 calculates MXTIME for the 63*** subsystem.
 20 MTBF = 431.05975
 MTTR = 23.073 / 2.7188
 GO TO 98

C Event 21 calculates MXTIME for the 61*** subsystem.
 21 MTBF = 646.58960
 MTTR = 7.200 / 2.7188
 GO TO 98

```

C   Event 22 calculates MXTIME for the 65*** subsystem.
22  MTBF = 718.43286
    MTTR = 10.778 / 2.7188
    GO TO 98

C   Event 23 calculates MXTIME for the 69*** subsystem.
23  MTBF = 718.43286
    MTTR = 8.000 / 2.7188
    GO TO 98

C   These are the calculations for probability of subsystem failure,
C   and for Maintenance Time, if the subsystem does fail.

98  PROBFAIL = 1 - EXP(-FLYHRS/MTBF)
    IF (DRAND(1) .LE. PROBFAIL) THEN
        GO TO 99
    ELSE
        MXTIME = 0
C        WRITE(NPRNT,*)'FOR SUB = ',I,' 0 XXTIME = ',XX(10)
        RETURN
    ENDIF

99  STDEV = 0.29 * MTTR
    MXTIME = RLOGN(MTTR,STDEV,2)
C    WRITE(NPRNT,*)'FOR SUB = ',I,'  MX TIME = ',MXTIME
    RETURN
END

```

GEN,HUNSUCK,TTF 2HR 4RATIO,4/1/1986,1,NO,NO,YES,NO,YES,72;
 LIMITS,35,8,2500;
 TIMST,XX(1),CREWREST;
 TIMST,XX(2),KCCREWDD;
 TIMST,XX(3),F16ARCT1;
 TIMST,XX(4),F16ARCT2;
 TIMST,XX(5),TRACK161;
 TIMST,XX(6),RTB16_1;
 TIMST,XX(7),GNDINTVL;
 TIMST,XX(8),KCAR16_1;
 TIMST,XX(9),ABORTS;
 TIMST,XX(10),F16PERLAP;
 TIMST,XX(11),TOT_F16S;
 TIMST,XX(12),ORBITTM;
 TIMST,XX(13),MAXCRWDD;
 TIMST,XX(14),LAPS161;
 TIMST,XX(15),LAUNCH1;
 TIMST,XX(16),REFUELED;
 EQUIVALENCE /XX(1),CREWREST/ XX(2),KCCREWDD/ XX(3),F16ARCT1;
 EQUIVALENCE /XX(4),F16ARCT2/ XX(5),TRACK161/ XX(6),RTB16_1;
 EQUIVALENCE /XX(7),GNDINTVL/ XX(8),KCAR16_1/XX(9),ABORTS;
 EQUIVALENCE /XX(10),F16PERLAP/XX(11),TOT_F16S/XX(12),ORBITTM;
 EQUIVALENCE /XX(13),MAXCRWDD/ XX(14),LAPS161 /XX(15),LAUNCH1;
 EQUIVALENCE /XX(16),REFUELED;
 EQUIVALENCE /ATTRIB(1),FLYHRS/ ATTRIB(2),STCREWDD/ ATTRIB(3),STARTMX;
 EQUIVALENCE /ATTRIB(4),MXTIME/ ATTRIB(5),MYLAPS / ATTRIB(6),CREWDUTY;
 EQUIVALENCE /ATTRIB(7),SCHEDTO;
 EQUIVALENCE /UNFRM(2,4),UNLOAD;
 INTLC,CREWREST=13;; includes 1 hour transportation
 INTLC,F16ARCT1=3.55;; this is the time from F-16 launch to ARCT1
 INTLC,F16ARCT2=7.97;; " " " " " " " " " " 2
 INTLC,TRACK161=0.65;; time down track for the 1st AR for F-16s
 ; = 39 minutes
 INTLC,GNDINTVL=2.0;; scheduled interval between KC-10 landing and T.O.
 INTLC,RTB16_1 =1.3;; the time it takes the KC-10 to RTB after F-16 EAR1
 INTLC,KCAR16_1=1.2;; the time it takes the KC10 to fly from TTF to
 ; F-16 ARCT1
 INTLC,ABORTS =0.0;; accumulates number of fighter aborts
 INTLC,F16PERLAP=4.0;; fighter to tanker ratio (also, fighters per
 ; track lap)
 INTLC,TOT_F16S=700.0;; total number of F-16s to be deployed / remaining
 INTLC,ORBITTM =0.1666;; air refueling orbit is a 10 minute delay
 INTLC,LAPS161 =4.0;; number of laps of F-16 AR track 1,
 ; to be flown by KC10
 INTLC,LAUNCH1 =24.0;; time of the first scheduled TTF KC10
 ; launch for AR
 INTLC,MAXCRWDD=16.0;; max allowable KC-10 crew duty day *****
 INTLC,REFUELED=0.0;; the number of fighters refueled by the TTF

 RECORD,TNOW,TIME OF DEPLOY,0,P,6,0,168,YES;
 VAR,TOT_F16S,T,TOT F16S REMAIN,0,1000;
 VAR,ABORTS, A,CUM F16S ABORT, 0,1000;
 VAR,REFUELED,R,REFUELINGS ,0,1000;

```

NETWORK;
    RESOURCE,CREWGOODS(0),30;; Initially, there are no KC-10 crews
;                               at Goose.
    RESOURCE,F16_1RZ(4),33,32,31;; Only 4 KC-10s are allowed on track

KCGOOD CREATE,0.01,6,,4,2;; Make 4 KC-10s instantly at Goose Bay,
;                               starting at time =6 hrs. Entity goes to 2 nodes.
    ACT,CREWREST,,NEWCR; newly arrived crews must rest
;                               before flying
    ACT,,,FLYHR;
NEWCR ALTER,CREWGOODS/+3; Landing tankers bring extra aircrews, who
    TERM;                     become available after completing crew rest.
FLYHR ASSIGN, FLYHRS=6.0; Duration of mission flying to TTF from Home.
    ACT,UNLOAD,,MAINT;Plane is unloaded.
;                               (ALL crews already resting)

TIRED GOON,1;
    ACT,CREWREST,,RESTD;
RESTD    FREE,CREWGOODS/1; this tired crew gets freed after
;                               13 hours rest
    TERM;

MAINT ASSIGN, STARTMX=TNOW; Plane enters maintenance.
GOON,23;;      KC-10 is divided into its 23 subsystems for
    ACT,,,EV1;      repair as necessary.
    ACT,,,EV2;
    ACT,,,EV3;
    ACT,,,EV4;
    ACT,,,EV5;
    ACT,,,EV6;
    ACT,,,EV7;
    ACT,,,EV8;
    ACT,,,EV9;
    ACT,,,EV10;
    ACT,,,EV11;
    ACT,,,EV12;
    ACT,,,EV13;
    ACT,,,EV14;
    ACT,,,EV15;
    ACT,,,EV16;
    ACT,,,EV17;
    ACT,,,EV18;
    ACT,,,EV19;
    ACT,,,EV20;
    ACT,,,EV21;
    ACT,,,EV22;
    ACT,,,EV23;

EV1    EVENT,1,1;;      Calculates MXTIME (Atrib(4) of the entity)
    ACT,MXTIME,,Q1;
EV2    EVENT,2,1;;

```

```

      ACT,MXTIME,,Q2;
EV3  EVENT,3,1;;
      ACT,MXTIME,,Q3;
EV4  EVENT,4,1;;
      ACT,MXTIME,,Q4;
EV5  EVENT,5,1;;
      ACT,MXTIME,,Q5;
EV6  EVENT,6,1;;
      ACT,MXTIME,,Q6;
EV7  EVENT,7,1;;
      ACT,MXTIME,,Q7;
EV8  EVENT,8,1;;
      ACT,MXTIME,,Q8;
EV9  EVENT,9,1;;
      ACT,MXTIME,,Q9;
EV10 EVENT,10,1;;
      ACT,MXTIME,,Q10;
EV11 EVENT,11,1;;
      ACT,MXTIME,,Q11;
EV12 EVENT,12,1;;
      ACT,MXTIME,,Q12 ;
EV13 EVENT,13,1;;
      ACT,MXTIME,,Q13;
EV14 EVENT,14,1;;
      ACT,MXTIME,,Q14;
EV15 EVENT,15,1;;
      ACT,MXTIME,,Q15 ;
EV16 EVENT,16,1;;
      ACT,MXTIME,,Q16;
EV17 EVENT,17,1;;
      ACT,MXTIME,,Q17;
EV18 EVENT,18,1;;
      ACT,MXTIME,,Q18;
EV19 EVENT,19,1;;
      ACT,MXTIME,,Q19;
EV20 EVENT,20,1;;
      ACT,MXTIME,,Q20;
EV21 EVENT,21,1;;
      ACT,MXTIME,,Q21;
EV22 EVENT,22,1;;
      ACT,MXTIME,,Q22;
EV23 EVENT,23,1;;
      ACT,MXTIME,,Q23;

```

```

;      Now we wait (in Queues 1-23) until completion of Maintenance
;      on all subsystems (MATCH). Then we ACCUMULATE all the
;      subsystems into one KC-10 entity again:

```

```

Q1   QUEUE(1),,,MATC;
Q2   QUEUE(2),,,MATC;
Q3   QUEUE(3),,,MATC;
Q4   QUEUE(4),,,MATC;
Q5   QUEUE(5),,,MATC;

```

```

Q6   QUEUE(6),,,,MATC;
Q7   QUEUE(7),,,,MATC;
Q8   QUEUE(8),,,,MATC;
Q9   QUEUE(9),,,,MATC;
Q10  QUEUE(10),,,,MATC;
Q11  QUEUE(11),,,,MATC;
Q12  QUEUE(12),,,,MATC;
Q13  QUEUE(13),,,,MATC;
Q14  QUEUE(14),,,,MATC;
Q15  QUEUE(15),,,,MATC;
Q16  QUEUE(16),,,,MATC;
Q17  QUEUE(17),,,,MATC;
Q18  QUEUE(18),,,,MATC;
Q19  QUEUE(19),,,,MATC;
Q20  QUEUE(20),,,,MATC;
Q21  QUEUE(21),,,,MATC;
Q22  QUEUE(22),,,,MATC;
Q23  QUEUE(23),,,,MATC;

```

```

;   The aircraft subsystems are matched by the fact that they all have
;   a common Atrib(3)=STARTMX time. When all maintenance is
;   completed, the 23 subsystems of the KC-10 proceed together to A1,
;   where they are ACCUMULATED into a single KC-10 entity again.

```

```

MATC MATCH,3,Q1/A1,Q2/A1,Q3/A1,Q4/A1,Q5/A1,Q6/A1,Q7/A1,Q8/A1,Q9/A1,
      Q10/A1,Q11/A1,Q12/A1,Q13/A1,Q14/A1,Q15/A1,Q16/A1,Q17/A1,Q18/A1,
      Q19/A1,Q20/A1,Q21/A1,Q22/A1,Q23/A1;

```

```

A1   ACCUMULATE,23,23,HIGH(4),1; Save attribute set of entity with
;                               highest value of MXTIME= ATRIB(4).
;   COLCT,INTVL(3),MAINTENANCE TIME,40,0.0,0.25,1;
;   ACT,0,STCREWDD.NE.0.,CKDAY; already have a crew, but check
;                               if tired
;   ACT,0,,KCREW;               if no crew, wait to get a
;                               new crew
CKDAY ASSIGN,CREWDUTY=TNOW-STCREWDD,1; update the crew duty day
;   ACT,0,CREWDUTY.LT.12,SCHED; plenty of day left for
;                               another flt
;   ACT,0,,LONG;               not enough duty day left,
;                               go rest

```

```

LONG GOON,2;
      ACT,CREWREST-GNDINTVL,,RESTD; old aircrew is sent into
;                               crew rest before maintenance
;                               actions started!
      ACT,0,,KCREW; must get new aircrew

```

```

KCREW AWAIT(30),CREWGOOS; if no crews are available, wait for one
      ASSIGN,STCREWDD=TNOW-1.5; this time includes briefing of
;                               new crew and aircrew preflight
;                               of the KC-10
SCHED GOON,1; assigns scheduled launch time,
; and flight plan route

```

```

ACT,0,TNOW.LE.LAUNCH1,FIRST; ie: this is a "no earlier than"
; time. NOTE: independent of crew or mx.
ACT,0,TNOW.GT.LAUNCH1,LATER; later launches are scheduled
; based on a pre-planned
; ground mx time.

FIRST ASSIGN,SCHEDTO=LAUNCH1, MYLAPS = LAPS161;
ACT,0,,MISSN;
LATER ASSIGN,SCHEDTO=STARTMX + GNDINTVL, MYLAPS = LAPS161;
ACT,0,,MISSN;
; *** This is the key to the TTF operation: KC-10 launches are
; scheduled on a regular interval, which is based on the
; reliability and maintainability of the KC-10. Every KC-10 is
; planned to fly a closely scheduled mission, followed by a
; specified time on the ground, in which maintenance is performed.
; If the KC-10 breaks and cannot be repaired prior the end of
; the specified time on the ground (GNDINTVL), the KC-10 misses
; an AR! If the KC-10 misses an AR, the maintenance is continued,
; with the hope of being able to make the next scheduled AR for
; that KC-10. If all ARs are missed, due to very long repair
; time, then the KC-10 must wait until its next scheduled takeoff
; (but it has 100% reliability for that launch).
;
MISSN GOON,1;; Choose one of the following three actions:
ACT/1,SCHEDTO-TNOW,SCHEDTO.GE.TNOW.AND.MYLAPS.EQ.LAPS161,LAUNC;
; On-Time TO! ie: takeoff intvl .GT. mxtime
ACT/2,0,SCHEDTO.LT.TNOW,MSSRZ; Missed RZ!
; caused by excessive delay

ACT/3,SCHEDTO-TNOW,SCHEDTO.GE.TNOW.AND.MYLAPS.LT.LAPS161,LAUNC;
; Delayed TO!
ACT/4,,,LAUN;SCREWED UP LOGIC
; (programming note: SCHEDTO is required to be an ATRIB
; since it will be changed by subsequent entities.)

; Note: if KC10 aircrew not available,
; or if Maintenance delayed, (one long MXTIME can cause
; several missed rendezvous'!) this program
; calls it MSSRZ.

; *** put fighter abort actions here (ie:entity to abort, colct,etc)

MSSRZ ASSIGN,MYLAPS = MYLAPS-1; this ensures that KC10 only flies
; its own (preplanned) ARCTs (ie: if it launches late,
; it does NOT fly the same number of track laps).
; The following test ensures that a delay causes
; the KC10 to miss ONLY its scheduled ARCTs:
ACT,0,MYLAPS.EQ.0,MSALL; missed all laps--wait till next
; sched mission but, obviously, no further mx needed.
ACT,0,MYLAPS.GT.0,MORE; still have at least one sched ARCT
; to try achieve.
MSALL ASSIGN,FLYHRS=0;
ACT,SCHEDTO+KCAR16_1+TRACK161+RTB16_1+GNDINTVL - TNOW;

```

```

;           ie: to get proper interval, wait out the remainder
;           of the planned mission plus unneeded subsequent
;           maintenance (GNDINTVL)
;           ASSIGN,STARTMX=TNOW-GNDINTVL;; this tells scheduler when
;           to launch
ACT,0,,CKDAY;; check if crew is still fresh, then fly next mission
MORE   ASSIGN,SCHEDTO=SCHEDTO + 2*TRACK161 + ORBITTM; to make
;           next ARCT
;           ASSIGN,ABORTS = ABORTS + F16PERLAP;
;           ACT,0,,MISSN;

LAUNC GOON;
      ACT,KCAR16_1;
RZ161 AWAIT(33),F16_1RZ;
      ACT,TRACK161;
      ASSIGN,TOT_F16S=TOT_F16S - F16PERLAP, MYLAPS= MYLAPS - 1,2;
      ASSIGN,REFUELED=REFUELED + F16PERLAP;
      ACT,,,FRE1; this KC-10 entity will free the track for subseq. RZ
      ACT,,,FIGHT; this entity will become a fighter

FRE1. FREE,F16_1RZ/1,1;
      ACT,TRACK161+ORBITTM, MYLAPS.GT.0, RZ161;; Take another lap
;                                           vax RZ
;           ACT,0                      , MYLAPS.LE.0, RTB;; KC-10 Returns
;                                           To Base

RTB   GOON,1;;
      ACT,RTB16_1;; fly back to the TTF base from this track
      ASSIGN,FLYHRS=TNOW-SCHEDTO,1;
LAND  ASSIGN,CREWDUTY=TNOW-STCREWDD,1;
      COLCT,FLYHRS,MISSION LENGTH,24,0.0,1;
      COLCT,CREWDUTY,CREW DUTY DAY,24,0.0,1;
      ACT,0,CREWDUTY.GT.MAXCRWDD,NOCRW; too close to max DD,
;                                           get rid of crew

;***      Need to modify this for realistic test!
;           (ie: make atrib=actual DD) ***
;           ACT,0,,MAINT; otherwise, the crew stays with the aircraft
;*** considering the large GNDINTVL (?) should I keep crew with acft?

NOCRW ASSIGN,STCREWDD=0;
      ACT,0,,TIRED; this is the aircrew going back to the barracks
      ACT,0,,MAINT; this is the KC10 aircraft going back to
;           maintenance

FIGHT GOON,1;
      ACT,,,TOT_F16S.LE.0,STP; ***could also terminate
;                               by setting STOP=1***
      ACT,,,TOT_F16S.GT.0,CONT;
CONT  TERM,200; fighters continue on their merry way, and so do KC-10s
; *** the above term number is only applicable for 700 F-16s by 4s
STP   ALTER,F16_1RZ/-2; prevent any more KC-10s from flying missions

```

COLCT,TNOW,TIME OF TERMINATION;
TERM;

STATS CREATE,12,0;
COLCT,TOT_F16S,F16s REMAINING;
COLCT,ABORTS, F16s ABORTING;
TERM;

** NECESSARY? **

ENDNETWORK;
INIT,0,168;
;MONTR,TRACE,0,50;
;MONTR,SUMRY,168;
FIN;

```

PROGRAM MAIN
DIMENSION NSET(10000)
COMMON/SCOM1/ATTRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
COMMON QSET(10000)
EQUIVALENCE(NSET(1),QSET(1))
NNSET=10000
NCRDR=5
NPRNT=6
NTAPE=7
NPLDT=2
CALL SLAM
STOP
END

```

```

*****
SUBROUTINE EVENT(I)
COMMON/SCOM1/ATTRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
IF(I.GT.3) CALL ERROR(1)
GO TO (1,2,3) I
*****

```

***EVENT (1) loads the aircraft to capacity with fuel/cargo and assigns
 *** fighters, depending on what remains to be deployed.

```

1 IF(ATTRIB(1).EQ.1)THEN
    GO TO 11
ELSE
    CALL ERROR(11)
ENDIF

```

***Acft is a KC-10

***RULE: Assign optimum # fighters to acft, then assign fuel for
 *** KC-10, offload, then assign cargo load (as attributes to entity).

```

11 IF (XX(14).LE.(XX(12)-XX(13)))THEN
    ATTRIB(7)=1
    ATTRIB(8)=XX(14)
    XX(13)=XX(13)+XX(14)

```

```

***           An entire flight of fighters is
***           assigned to the KC-10.
***           NOTE: ATTRIB(7) indicates 1=AR,0=No Air Refl
***           ATTRIB(8) is # fighters assigned to KC-10
***           XX(14) is optimal # of fighters per KC-10
***           XX(12)-XX(13) is remaining fighters

```

```

ELSE
    IF (XX(12)-XX(13).EQ.0) THEN
        ATTRIB(7)=0
        ATTRIB(8)=XX(12)-XX(13)
    ENDIF
    IF (ATTRIB(8).GE.1) THEN
        ATTRIB(7)=1
        XX(13)=XX(12)
    ENDIF

```

```

***          Any remaining fighters were assigned to KC-10
      ENDIF
***          Next assign fuel to KC-10
      ATRIB(5)=200+25*ATLIB(8)
***          Next assign any remaining payload to cargo
***          if any cargo remains!
      IF((XX(1)-XX(2)).GT.(ATLIB(4)-ATLIB(5))) THEN
          ATRIB(6)=ATLIB(4)-ATLIB(5)
          XX(2)=XX(2)+ATLIB(6)
      ELSE
          ATRIB(6)=XX(1)-XX(2)
          XX(2)=XX(1)
      ENDIF

*          NOTE:ATLIB(4) is max payload=(max GW-ramp wt)
*          ATRIB(5) is fuel load
*          ATRIB(6) is cargo load
*          XX(2) is cumulative cargo deploying
      RETURN

*****
*****EVENT 2 CALCULATES FUEL CONSUMED ON THE GROUND
*          (Not yet modified to include delay time TNOW-ATLIB(2))
2      IF (ATLIB(1).EQ.1) THEN
*          Aircraft is a KC-10
          XX(3)=XX(3)+3.0
          ATRIB(5)=ATLIB(5)-3.0
      ENDIF

      IF (ATLIB(1).GT.1) CALL ERROR(2)
      RETURN

*****
*****          EVENT 3 CALCULATES INFLIGHT FUEL CONSUMPTION
3      DURATION=TNOW-ATLIB(2)
      IF (ATLIB(1).EQ.1) THEN
*          Aircraft is a KC-10
          XX(3)=XX(3)+15*DURATION
          ATRIB(5)=ATLIB(5)-15*DURATION
      ENDIF

      IF (ATLIB(1).GT.1) CALL ERROR(3)
      RETURN
      END

*****
SUBROUTINE INTLC
COMMON/SCOM1/ATLIB(100), DD(100), DDL(100), DTNOW, II, MFA, MSTOP, NCLNR
1, NCRDR, NPRNT, NNRUN, NNSSET, NTAPE, SS(100), SSL(100), TNEXT, TNOW, XX(100)
RETURN
END
SUBROUTINE OTPUT
COMMON/SCOM1/ATLIB(100), DD(100), DDL(100), DTNOW, II, MFA, MSTOP, NCLNR

```

```

1, NCRDR, NPRNT, NNRUN, NNSET, NTAPE, SS(100), SSL(100), TNEXT, TNOW, XX(100)
RETURN
END

```

```

*****
SUBROUTINE ALLOC (I, IFLAG)
DIMENSION A(13)
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)
IFLAG=0
RETURN
END

```

```

*****+*****
FUNCTION USERF (I)
COMMON/SCOM1/ATRIB(100), DD(100), DDL(100), DTNOW, II, MFA, MSTOP, NCLNR
1, NCRDR, NPRNT, NNRUN, NNSET, NTAPE, SS(100), SSL(100), TNEXT, TNOW, XX(100)

```

```

IF (I.GT.3) CALL ERROR(5)
GO TO (1,2,3), I

```

```

*****

```

```

***USERF(1) determines cargo loading/unloading time
1 GO TO (11), ATRIB(1)

```

```

***ACFT is a KC-10
11 USERF=RNORM(4.0, .5, 1)
RETURN

```

```

*****

```

```

***USERF(2) determines KC-10 fuel consumption in thousands
*** of pounds (very coarse!)
2 USERF=(TNOW-ATRIB(3))*12.0
RETURN

```

```

*****

```

```

***USERF(3) calculates expected major maintenance
3 USERF=3
*** (For lack of an exact formula)
RETURN
END

```

Bibliography

Cited Articles

Books

1. Jane's All the World's Aircraft, 1985 - 86. New York: Jane's Publishing Co., Inc., 1986.
2. Selby, Samuel M. Ed. Standard Mathematical Tables, 20th Edition. Cleveland, OH: The Chemical Rubber Company, 1972.

Articles and Periodicals

3. Mehrez, Abraham and Helman Stern. "Vehicle Fleet Refueling Strategies to Maximize Operational Range," Naval Research Logistics Quarterly, 30,: 319-342 (1983).

Official Documents

4. Air Force Regulation 60-1, SAC Supplement 1, change 84-2.
5. Air Force Regulation 60-16.
6. IFR Supplement, DOD Flight Information Publication (Enroute). St Louis Air Force Station, MO: The Defense Mapping Agency Aerospace Center, 1986.
7. Quatromani, Anthony F. Catalog of Wargaming and Military Simulation Models, 9th Ed. SAGAM 120-82. Organization of the Joint Chiefs of Staff Studies Analysis and Gaming Agency, Washington D.C. (AD A115 950).

Unpublished Materials

8. Blamey, Maj John T. "Extract from Strategic Mobility, Theater Warfare Lesson, Air Command and Staff College Vol 12." as quoted in the ACSC Readings Book, Lesson 41. Maxwell AFB, AL: Air University, 1984.

9. Bordelon, Capt Vernon P. and Major John C. Marcotte, Jr. Optimization of Strategic Airlift In-Flight Refueling. MS Thesis, GST/OS/81M-3. School of Engineering, AFIT (AU), Wright-Patterson AFB, OH, March 1981.
10. Carroll, Maj Jason D., Project Coordinator. Analysis of the Simulated Deployment of the 2d Armored Division to Europe. (SECRET) Military Traffic Management Command Report No. OA 79-8a-13 Vol. I. Transportation Engineering Agency, Newport News, VA, August 1980. (AD C024 248)
11. Carroll, Maj Jason D., Project Coordinator. Analysis of the Simulated Deployment of the 6th Cavalry Brigade (Air Combat) to Europe. (SECRET) Military Traffic Management Command Report No. OA 79-8a-13 Vol. II. Transportation Engineering Agency, Newport News, VA, August 1980. (AD C023 671)
12. Dietz, Capt Dennis C. An Analytical Methodology for Predicting Repair Time Distributions of Advanced Technology Aircraft. MS Thesis, GOR/OS/85D-3, School of Engineering, AFIT (AU), Wright-Patterson AFB, OH, Dec 1985.
13. Estes, Mr Milburn E. TACAIR Deployment Alternatives (SN:22993). Air Force Center for Studies and Analysis, Mobility Division (AFCSA/SAGM), Washington DC, Sep 1985.
14. Foley, LTC Jack O. The KC-10--Concept, Capabilities, and Future. Air War College Report No. 84-073. Maxwell AFB, AL, March 1984.
15. Harp, Maj Tilford W. "M-14: A Model to Estimate the Wartime Capability of Strategic Airlift." Student Report 83-1010. Air Command and Staff College, Maxwell AFB, AL. June 1983.
16. Holck, Capt Eric K. and Capt Robert W. Ticknor. Strategic Airlift: US to Europe. MS Thesis, GST/OS/81M-7. School of Engineering, AFIT (AU), Wright-Patterson AFB, OH, March 1981. (AD A101 139)
17. Lindholm, Capt Tenny A. An Aerial Refueling Optimization Model Applied to Strategic Airlift. MS Thesis, GST/OS/82M-7. School of Engineering, AFIT (AU), Wright-Patterson AFB, OH, March 1982.

18. Reynolds, Capt Robert D. Optimum Utilization of the KC-10 for Fighter Aircraft Deployments. MS Thesis, GSM/SM/79S-12. School of Engineering, AFIT (AU), Wright-Patterson AFB OH, 1979.
19. Sargent, R.G. "Verification and Validation of Simulation Models," Progress in Modelling and Simulation, pp 159-167. New York: Academic Press, Inc., 1982.
20. Shaw, LTC Christopher C., Jr. The Effect of System Operation Duration on Failure Rate: A Study of Strategic Airlift. PhD Dissertation, University of Nebraska at Lincoln, December 1982.
21. Stanberry, Capt Wayne P. An Improved Maintenance Model for the Simulation of Strategic Airlift Capability. MS Thesis, GST/OS/82M-13, School of Engineering, AFIT (AU), Wright-Patterson AFB, OH, March 1982.
22. _____. US Air Force Airlift Master Plan (unclassified version). Action memorandum. Washington: Hq USAF, 29 Sep 1983.

Interviews

23. Coppler, LTC Tom, TACAP Expert. Telephone Interviews (AV-432-3391), Hq TAC/DOXD, Langley AFB, VA, Jan 1986
24. Dutelle, Capt Gary, Telephone Interviews. Hq Strategic Air Command Tanker Operations (SAC/DO8X), Offutt AFB, NE. Sep-Oct 1985.
25. Estes, Mr. Milburn E., Mobility Analyst. Telephone Interviews (AV-227-9315), AFCSA/SAGM, The Pentagon, Sep 1985 - May 1986.
26. Jeffcoat, Maj George, KC-135A Instructor Instructor Pilot. Telephone Interview. Central Flight Instructor Course, Castle AFB, CA. 29 April 1985.
27. Kline, TSgt Mark, 2nd Bombardment Wing Inflight Refueling Manager. Telephone interview (AV-781-3334). Barksdale AFB, LA, 10 Apr 1986.

28. Lee, CMSgt Randy, Chief ALCE, HqMAC/DOCSA. Telephone Interviews (AV-576-3570). Scott AFB, IL, Jan 1986.
29. Moses, Maj Glenn, "M-14" Program Expert. Telephone Interviews. Headquarters Military Airlift Command, Operations Research Branch (MAC/XPSR), Scott AFB, IL. Sep-Oct 1985.
30. Poggi, Maj Bill, KC-10 Training Flight Instructor Pilot. Telephone Interview. 32d Air Refueling Squadron, Barksdale AFB, LA. 29 April 1985.
31. Pugh, Maj Jim, KC-10 Instructor Pilot and Deployment Planner. Telephone Interviews. Hq Eighth Air Force (SAC) Tanker Task Force Branch (8AF/DOOK), Barksdale AFB, LA, Sep-Oct 1985.
32. Smith, Capt Jim, AFIT expert on how to access "MODAS." Personal Interviews (255-4149). AFIT/LSMA, Wright-Patterson AFB, OH, Feb-Mar 1986.

Other

33. "MODAS," Maintenance and Operational Data Access System. Computerized database including fleetwide KC-10 Reliability and Maintainability Reports summarizing Sep, Oct, Nov 1985. Database Accesses: March 1986.

Additional References

Books

- Banks, Jerry and John S. Carson, II. Discrete Event System Simulation. New Jersey: Prentice-Hall, Inc., 1984.
- Gibbons, Jean and Ingram Olkin, and Milton Sobel. Selecting and Ordering Populations: A New Statistical Methodology. New York: John Wiley and Sons, Inc., 1977.
- Kleijnen, J.P.C. "Experimentation with Models: Statistical Design and Analysis Techniques," Progress in Modelling and Simulation, pp 173-183. New York: Academic Press, Inc., 1982.
- Montgomery, Douglas C. Design and Analysis of Experiments, 2nd Edition. New York: John Wiley and Sons, Inc., 1984.
- Pritsker, A. Alan B. Introduction to Simulation and SLAM II. New York: John Wiley and Sons, Inc., 1984.

Articles and Periodicals

- Alder, Konrad. "Aerial Refueling--A Growing Need," Armada International, 6: 90-102 (March/April 1982).
- Berent, Mark E. "Aerial Refueling in NATO," NATO's Sixteen Nations, 28: 52-55 (October/November 1983).
- Bracken, J. and J.D. Longhill. "Note on a Model for Minimizing Cost of Aerial Tankers' Support of a Practice Bomber Mission," Naval Research Logistics Quarterly, 11 (4): 359-364 (December 1964).
- Hoyt, Brig Gen Ross G., "Reflections of an Early Refueler," Air Force Magazine, 1: 55-59 (January 1974).
- Jester, Lt Col Clifton J. "Air Refueling--the Need," Combat Crew Magazine 6: 20,21 (June 1980).
- Poe, Bruce. "Tomorrow's Tanker," Flight International, 112: 1673-1676 (December 3, 1977).

Ullman, Capt Robert P., and Capt Myhre E. Paulson, Jr.
"Refueling Behind the KC-10," Combat Crew Magazine, 7:
34-36 (July 1981).

Official Documents

✓ CINCENR OPLAN 4102-84. (SECRET)

Joint Staff Officer's Guide, Armed Forces Staff College
Pub 1. Norfolk, VA: National Defense University,
July 1984.

KC-10 Minimum Equipment List and Procedures, Technical Order
1C-10(K)A-1-2, 1 July 1985.

"WMP-4" USAF War and Mobilization Plan, Volume 4, 1 Oct
1984. (TOP SECRET)

"WMP-5" Basic Planning Factors and Data, Volume 5, 1 Oct
1985. (SECRET)

Unpublished Materials

Bailey, Maj Charles E. Strategic Mobility and the KC-10:
A Pilot's Perspective. Air Command and Staff College
Report No. 83-120. Maxwell AFB, AL, April 1983. (For
Official/Operational Use Only).

Benson, Maj Donald R. KC-10 Maintenance Organization
Structure. Air Command and Staff College Report No.
82-0240, Maxwell AFB, AL, March 1982. (For
Official/Operational Use Only) (AD B066 745L)

Del Mar, Major General H.R. "Total Systems Approach to
Strategic Mobility." Address to the Worldwide Strategic
Mobility Conference. Fort McNair, Washington, DC,
4 May 1977.

Head, Capt Elbert B. and Capt Leslie R. VanHeeswyk. Better
Utilization of Tankers for Refueling Bombers in the
SIOP. MS thesis, GST/OS/83M-4 (SECRET). School of
Engineering, Air Force Institute of Technology (AU),
Wright-Patterson AFB, OH, 1983.

✓ Fought, Major Stephen O. Air Refueling: The Linchpin to our Continental Strategy. (SECRET NOFORN) Naval War College, Newport, RI, June, 1981. (AD C025 677)

Kuehner, LTC Gregory A. Air Refueling: The KC-10 Connection. Industrial College of the Armed Forces Report No. IR27-83. Ft McNair, Washington, DC, May 1983. (For Official/Operational Use Only) (AD-B093 713L)

Tapleshay, Major Thomas N. TC-10A--The SIOP Tanker (SECRET NOFORN) Air Command and Staff College, Report No. 2355-81. Maxwell AFB, AL, May 1981. (AD C027 245)

Interviews

Chapman, TSgt Mary Kay, analyst. Telephone Interview (AV-271-2892). HQ SAC/LGY, Offutt AFB, NE, Feb 1986.

Citing:

LGCM 271 Maintenance Man Hours/Flying Hour Report
LGCM 273 Standard Reliability and Maintenance Report
LGCM 275 On-Equipment Summary.

Cole, SMSgt Thomas, Squadron Chief Inflight Refueling Operator. Telephone Interview. 42nd Air Refueling Squadron, Loring AFB, ME, 26 April 1985.

Coulter, Major Dennis, F-111 pilot. Personal Interviews while assigned to AFIT. Currently at Hq AF/XOXFM, Washington DC, Jan 1986.

Englert, Capt Marvin, United States Army Officer. Telephone Interview. Air Force Institute of Technology, Wright-Patterson AFB, OH, 29 April 1985, citing
United States Army Infantry School, Infantry Reference Tactics Data Book ST7-176 FY83,
Washington: US Government Printing Office, 1984.

Ewing, Major William, former C-5A Navigator. Personal Interviews. Air Force Institute of Technology, Wright-Patterson AFB, OH. 1 April - 2 May 1985.

Federinko, Major John, "4102 Plan" expert. Personal Interviews (AV-257-5648). AFLC Logistics Operations Center/XOXR, Wright-Patterson AFB, OH, Nov 1985 - Apr 1986.

Tom, Maintenance Information Services Manager.
Telephone Interviews (213-593-5511). Douglas Aircraft
Corporation, Long Beach, CA, Feb 1986.

Gross, Mr Chuck, MODAS expert. Telephone Interviews (257-
6906). KC-10 Special Program Office, Wright-Patterson
AFB, OH, Feb 1986.

Phillips, Col, Chief of KC-10 Special Project Officer.
Telephone Interviews (255-5624). Wright-Patterson AFB,
OH, Feb 1986.

Rochelle, Mr Pete, "TANKER" program expert. Telephone
Interviews (AV-225-0685). AFCSA/SAGM The Pentagon.
January - March 1986.

Selva, Capt Mike, Operations Analyst. Telephone Interview
(AV-271-5836). Hq SAC/XOS, Offut AFB, NE, Nov 1985.

Welch, SMSGT Mike, designer for Strategic Airlift.
Telephone Interviews (255-7533). Aeronautical Systems
Division, Wright-Patterson AFB, OH March 1986.