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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.
CAPTAIN, USAF

AFIT/GST/ENC/86J-1

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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.

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. 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

June 1986

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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 endebted to Mr M.E. Estes (AFCSA/SAGM), 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 endebted 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 sucessfully 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 intially 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.

<u>Deterministic Model</u> 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 reliablity 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 senitivities 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 theier 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 usuage 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.

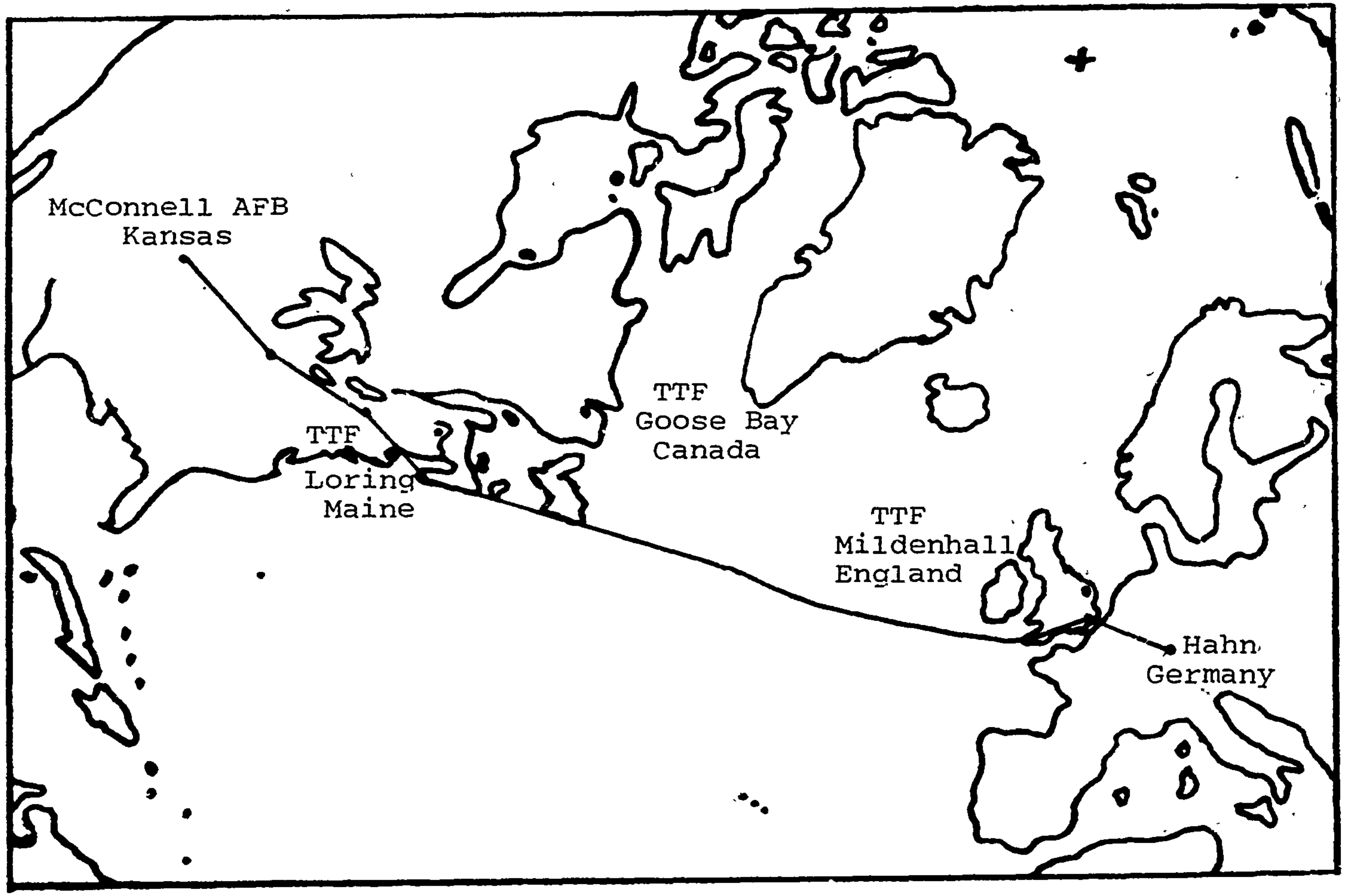


Figure 1.1. Map of TTF Locations relative to the Deployment Route.

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 alloted 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 availabl 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

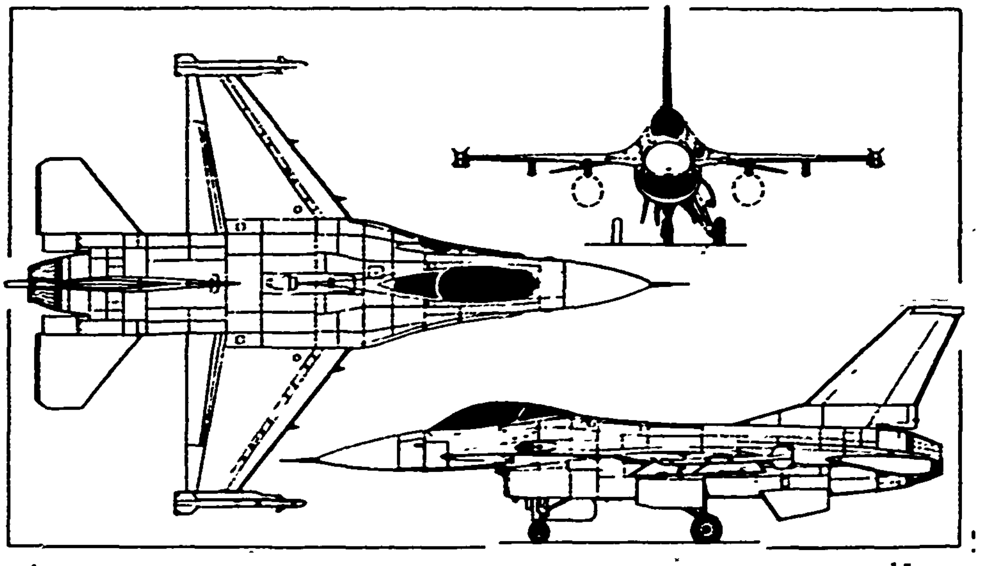
Introduction

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

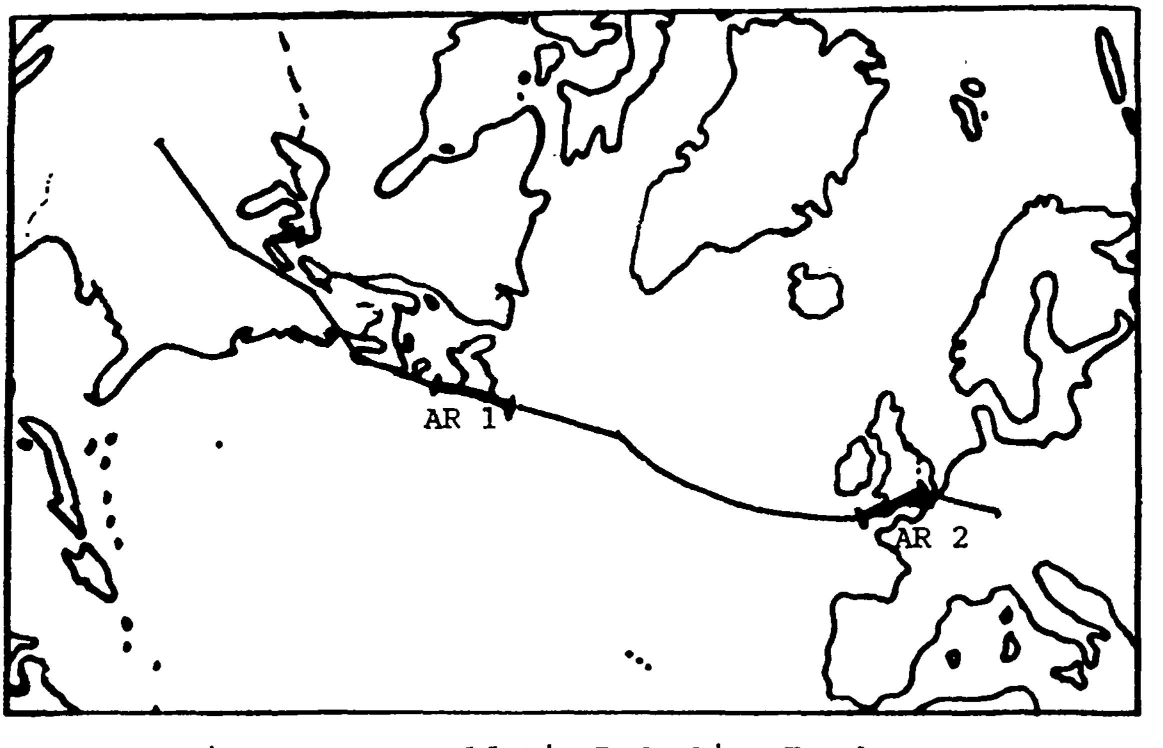
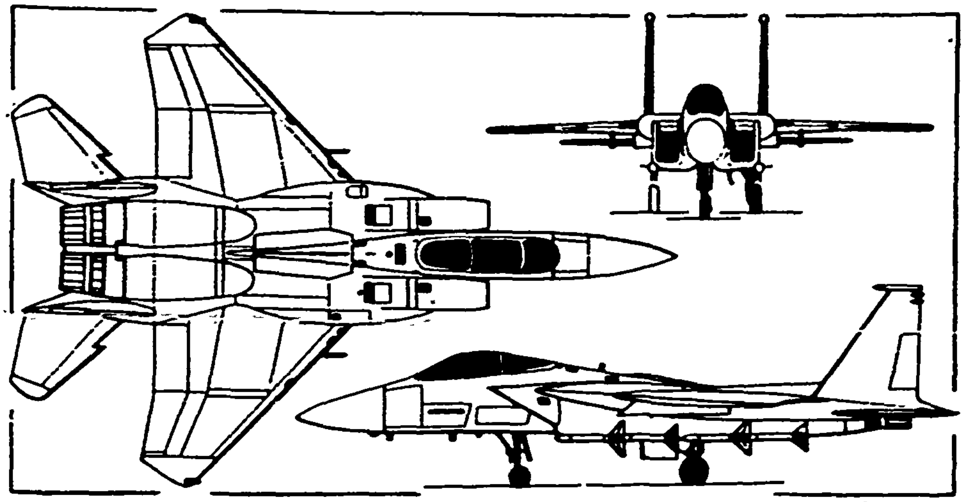


Figure 2.2. F-16 Air Refueling Tracks



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

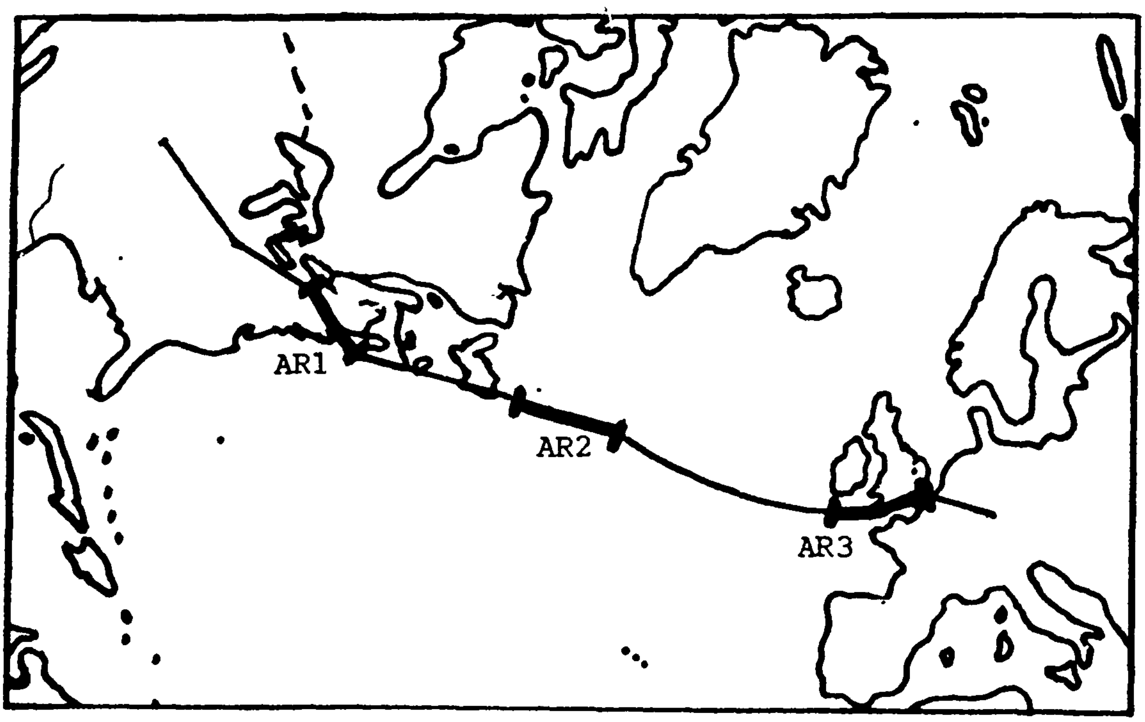
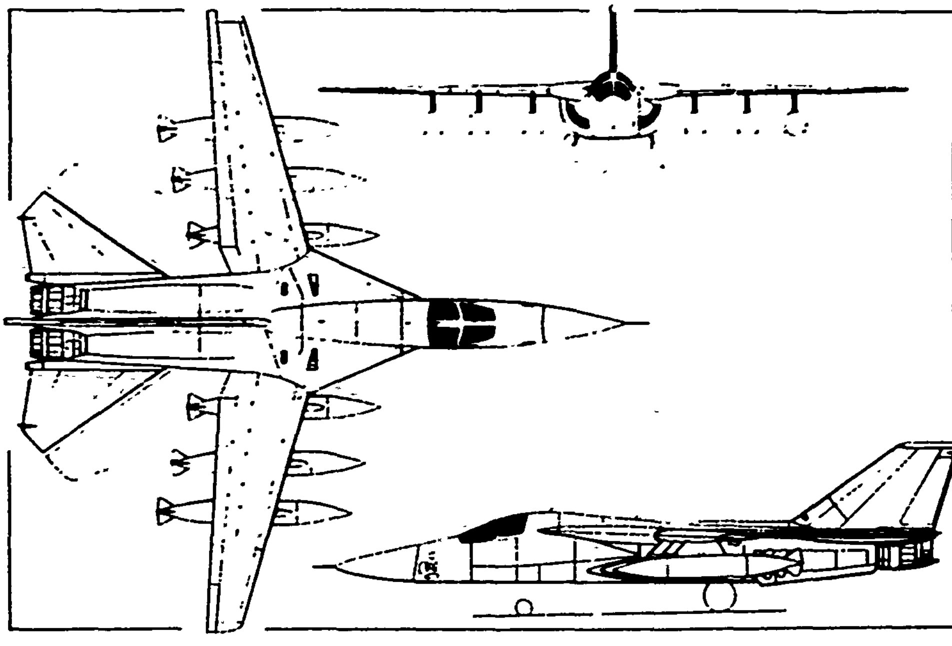


Figure 2.4. F-15 Air Refueling Tracks



Wingspan (spread) = 63 ft Max TO Weight = 91,500 lbs
(swept) = 32 ft Range (Max Internal Fuel) 2750 nm
Length = 73 ft
Height = 17 ft

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

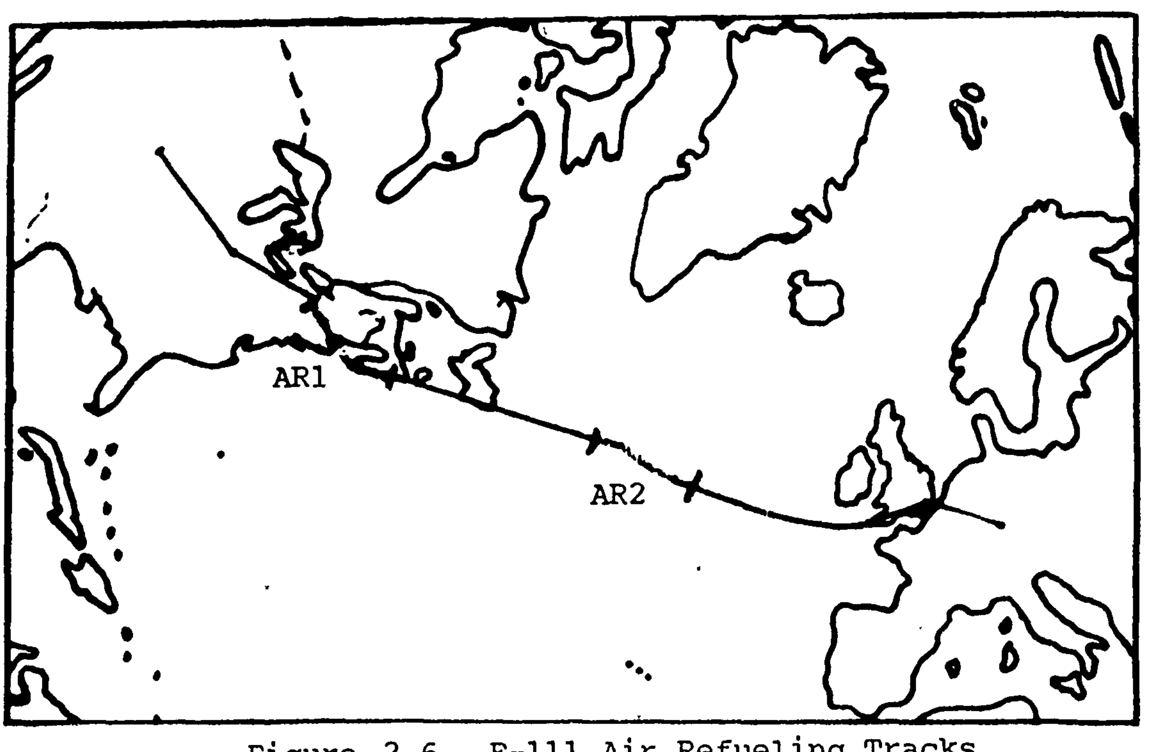
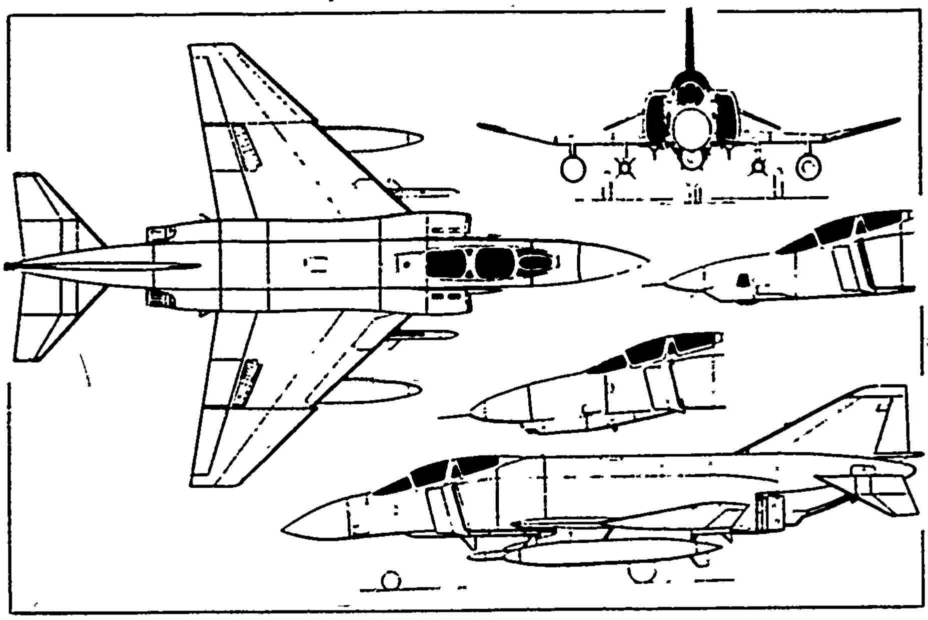


Figure 2.6. F-111 Air Refueling Tracks



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 <u>Janes All the World's Aircraft</u>

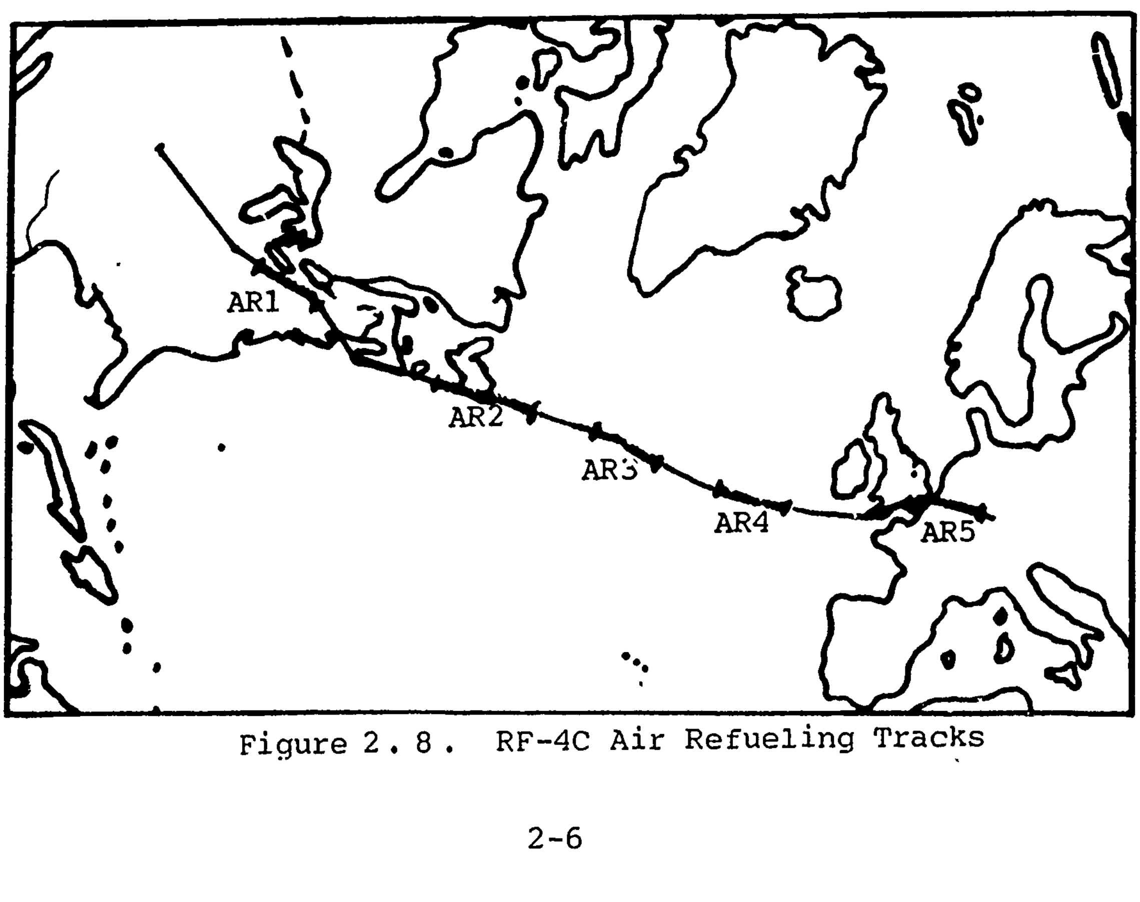
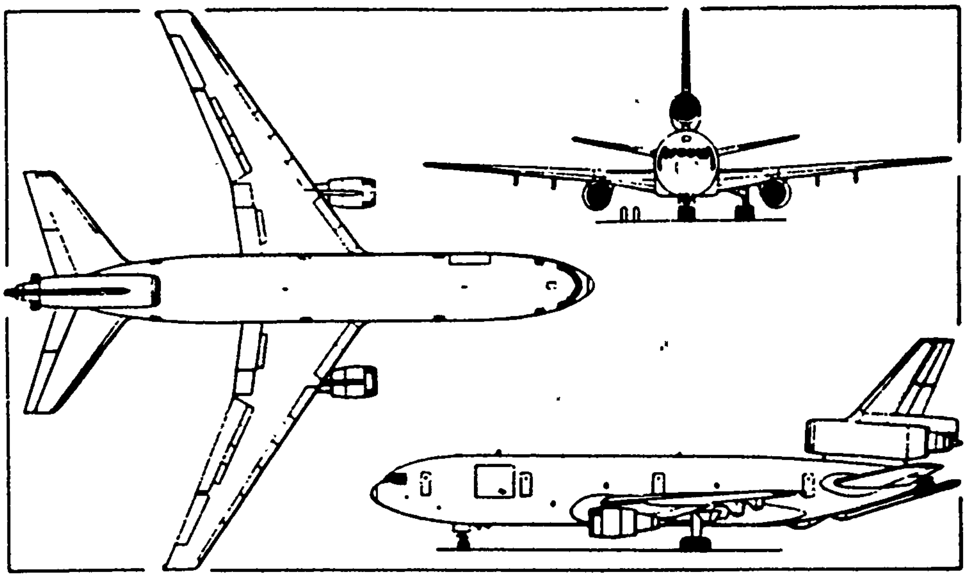


Figure 2. 8. RF-4C Air Refueling Tracks



Wingspan = 165 ft
Length = 181 ft
Height = 58 ft

Max TO Gross Wt = 588,200 lbs
Range w/Max Cargo = 3,797 nm.
w/No Cargo = 9,993 nm

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

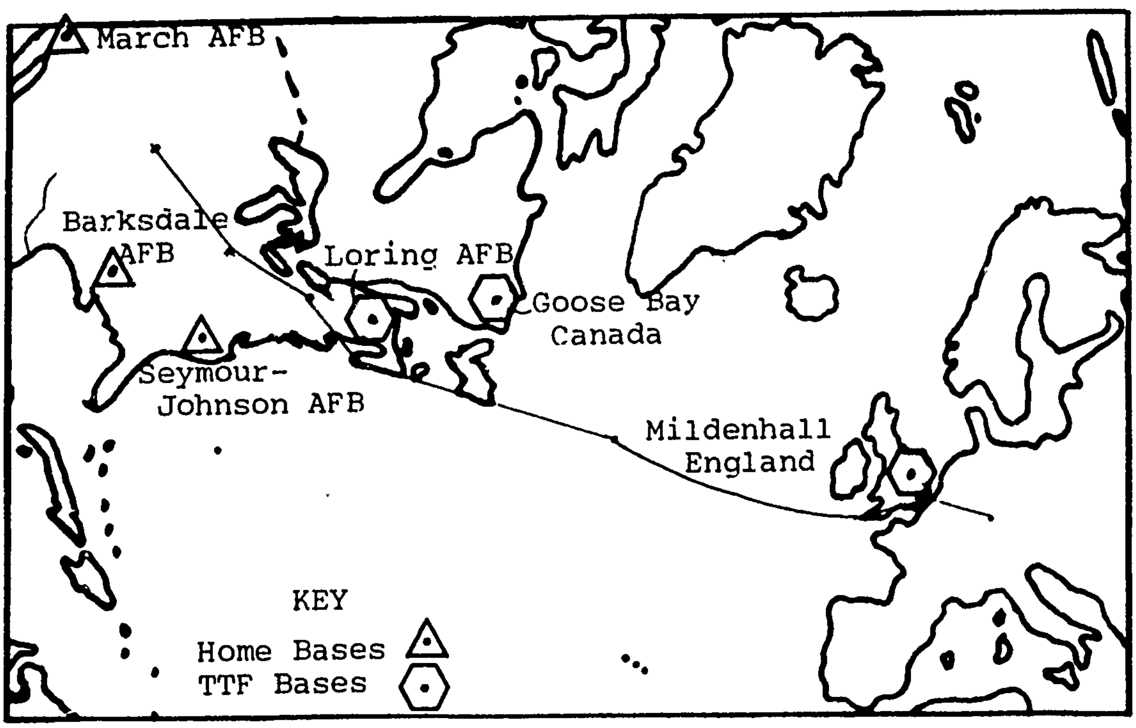


Figure 2.10. Map of KC-10 Home Bases and TTF Bases

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.)

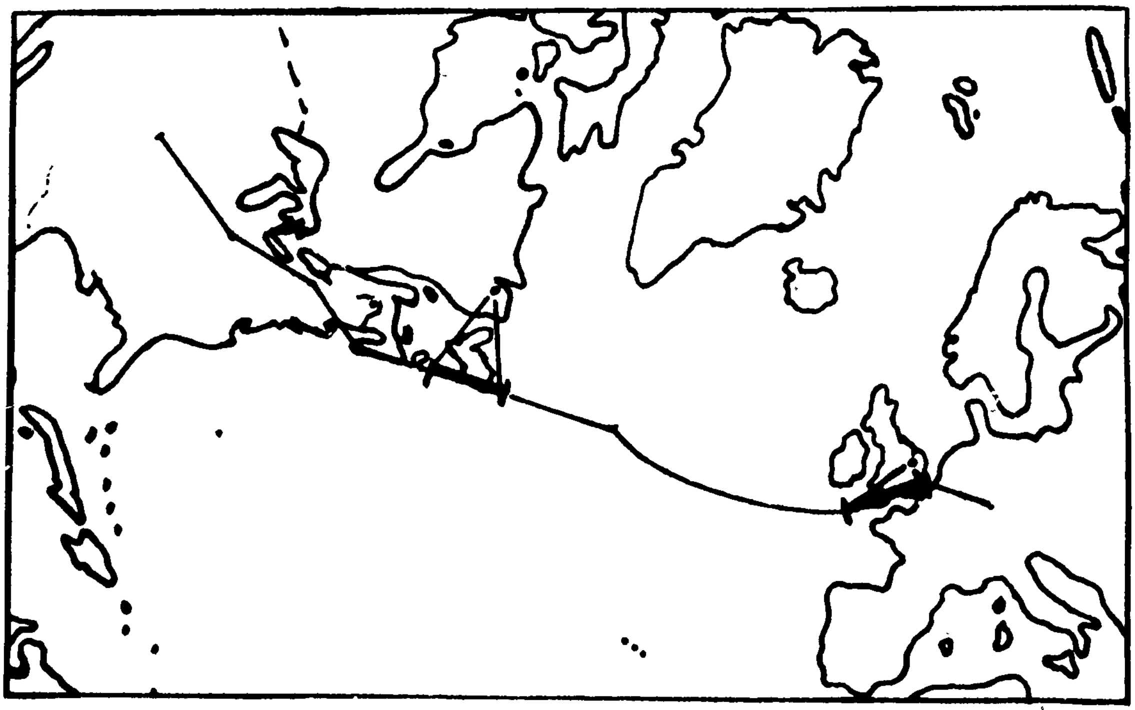


Figure 2.11. Fighters being refueled by TTF KC-10s.

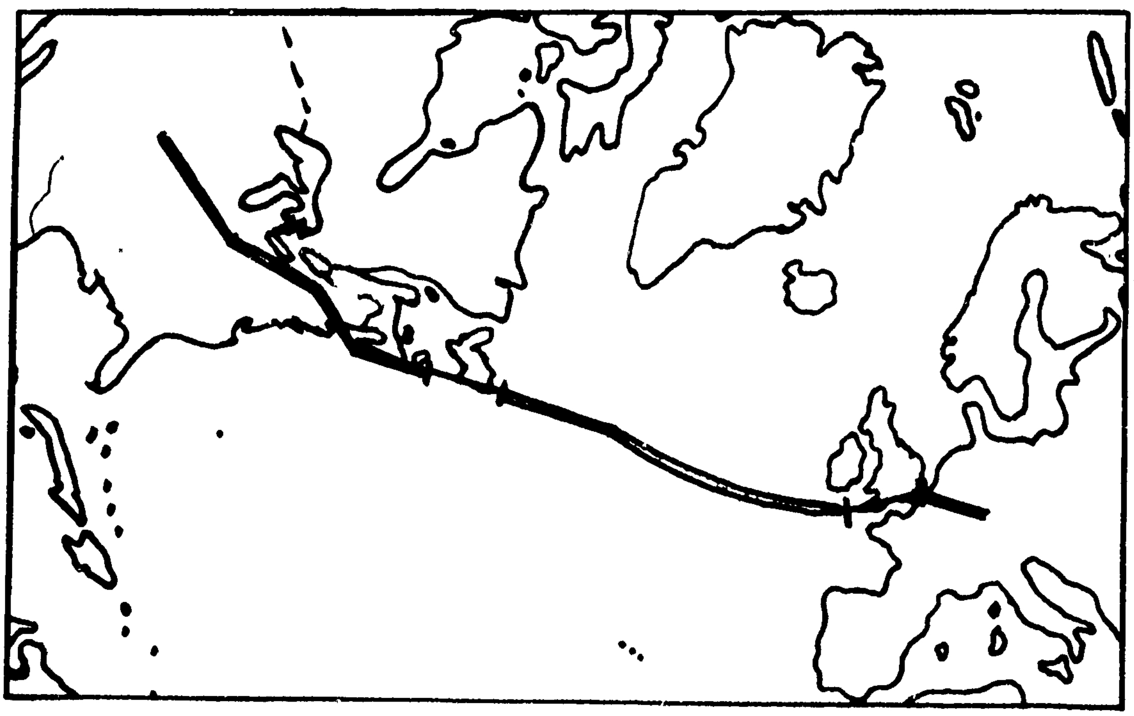


Figure 2.12. Fighters being refueled by Dual Role KC-10s.

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 be deems fit.

3. Abort due to Failed Refueling after a Successful Rendebzvous. 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 is 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 transfered).

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

Max fuel Wt = Max TO Gross Wt - Cargo Wt - Aircraft Empty Wt

= 588,200 - 0 - 243,209 = 344,991 pounds, 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):

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

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.

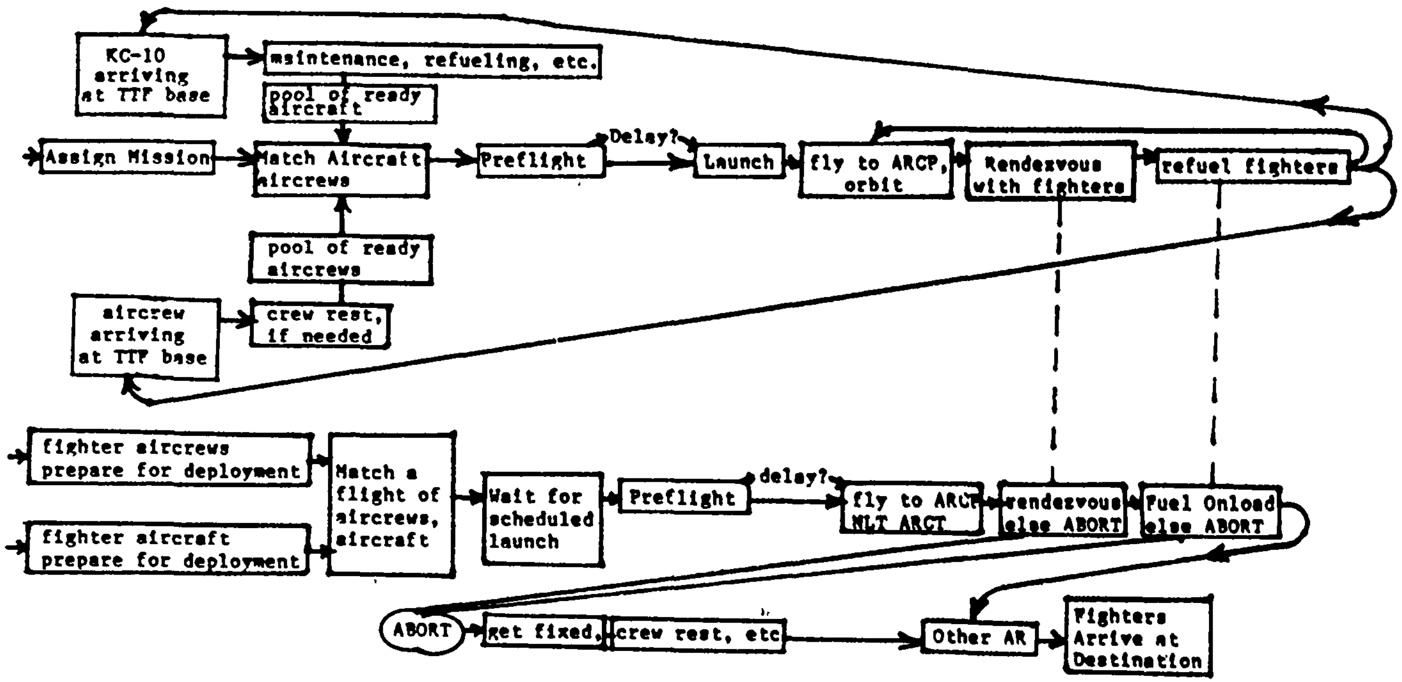
There are two opposing influences that act upon the proper choice of KC-10 Sortie Interval:

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 undesireable! This means that the possiblity 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:
Figure2.13 Flowplan of Tanker Task Force Operation and Fighter Mission Simulation
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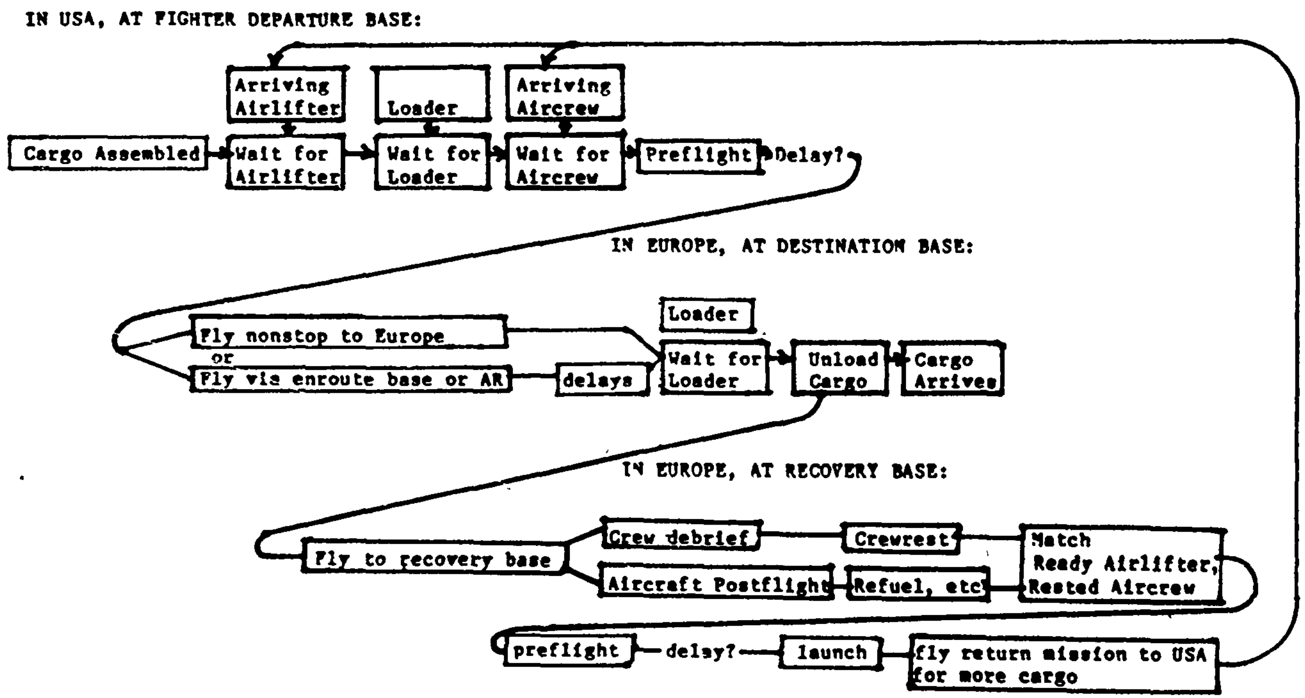

DISTINCT ROLES:
Figure 2.14 Flowplan of Cargo Movement and KC-10 Transport Operation

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

Passengers	Cargo Pallets
0	27
6	25
20	23
75	17

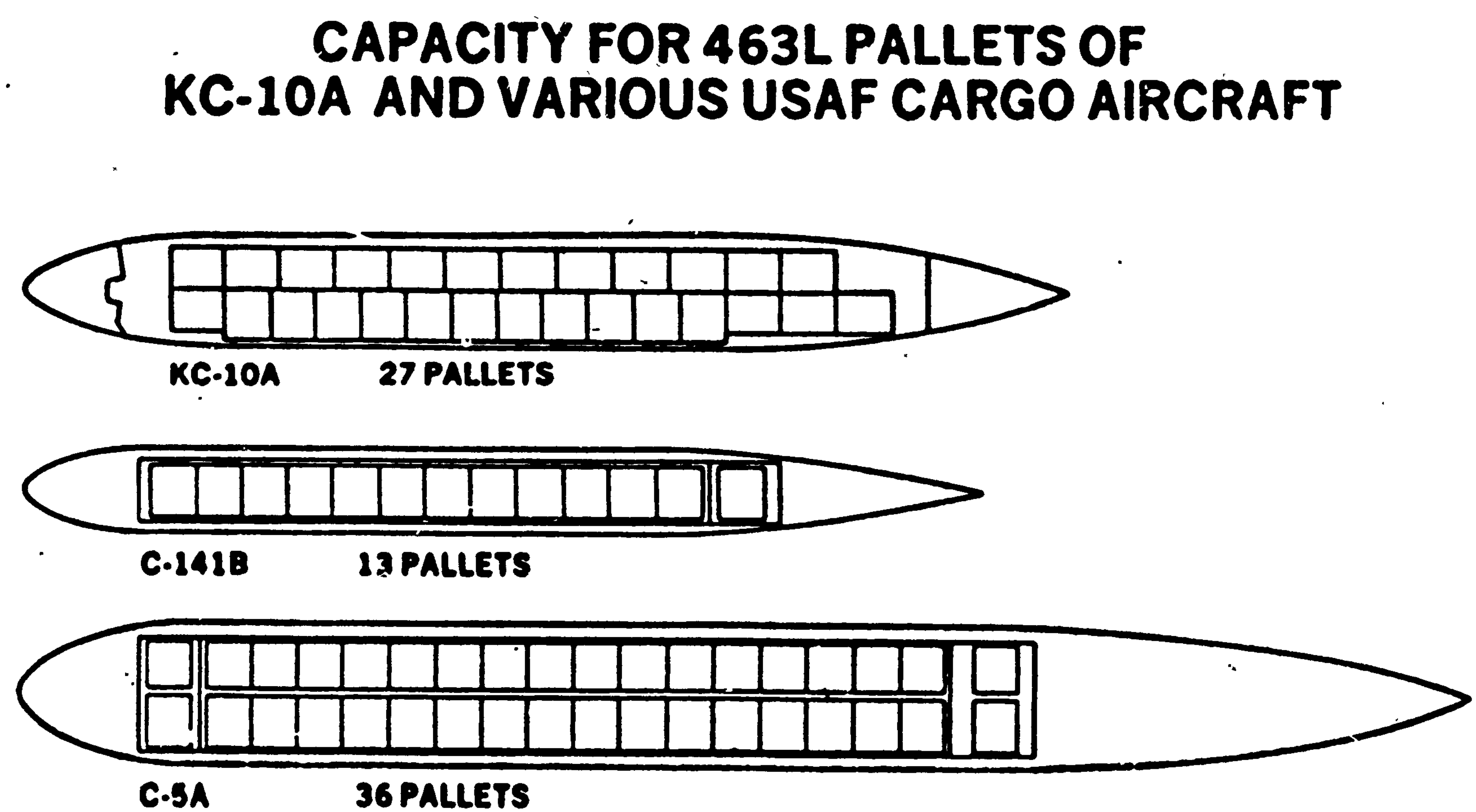

Figure 2.15. Comparison of Airlifter Pallet Capabilities (14:13).

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)

	Fuel	Cargo
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.

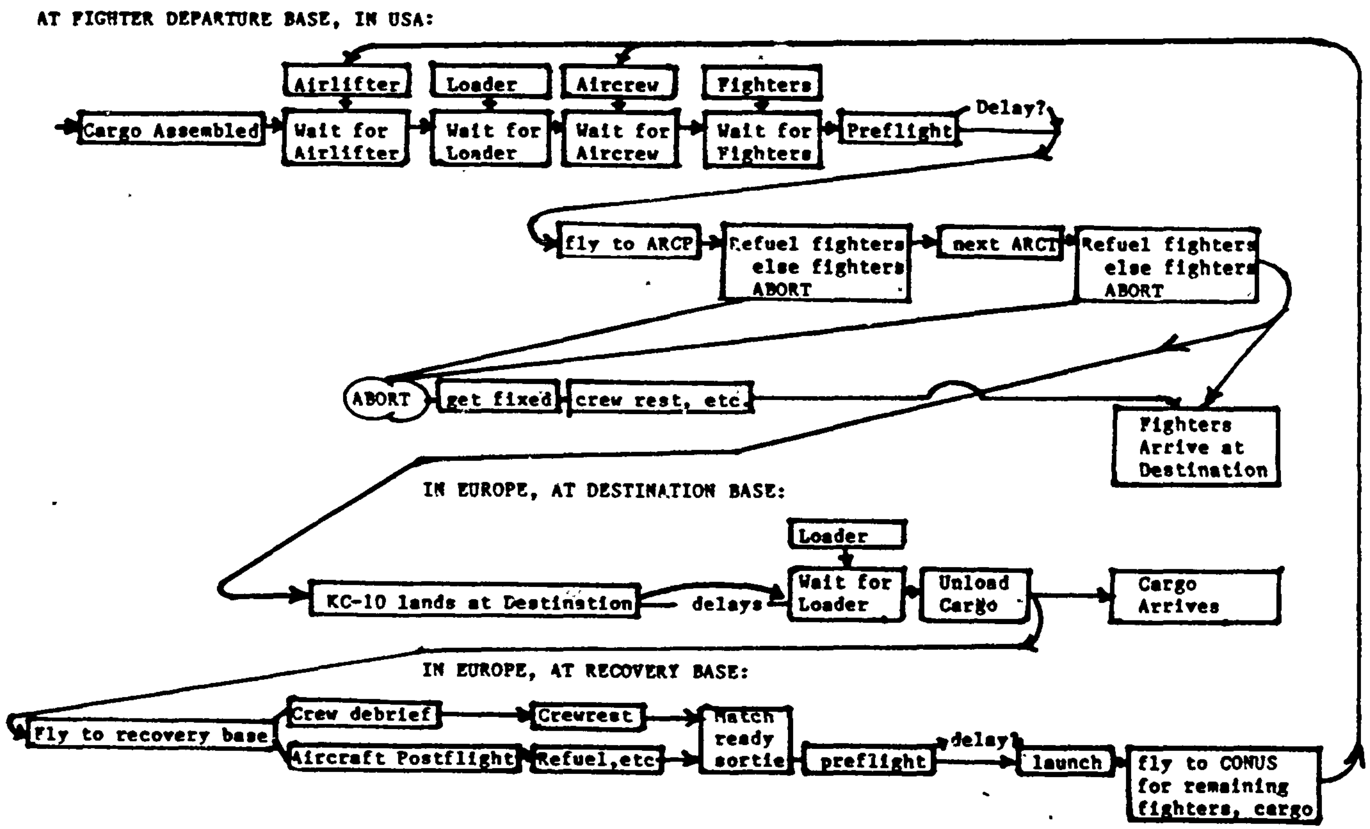

Figure 2.13 Flowplan of Dual-Role Concept of Operation

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 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 <u>number</u> of KC-10s. Since my thesis searches for the best <u>way</u> 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.

<u>Minimizing fuel consumption when refueling airlifters</u>. 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 desireable 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 disertation (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 Embarcation, 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 flexibilty 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 (refernce 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 sucessful 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 ± 10 minutes (Uniform)

Penetration ™ Uniform(7,10) minutes

Final Approach ™ 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 ™ 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, intial 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 determinstic 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 determinstic 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 interdepedent 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.

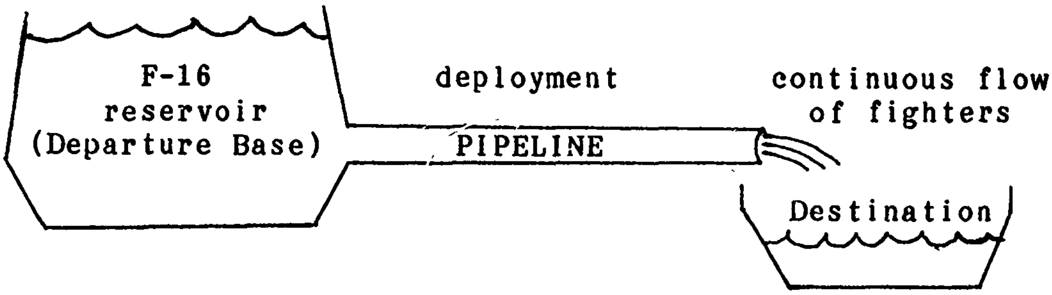

Figure 4.1 Flow Illustration

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 developes 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.

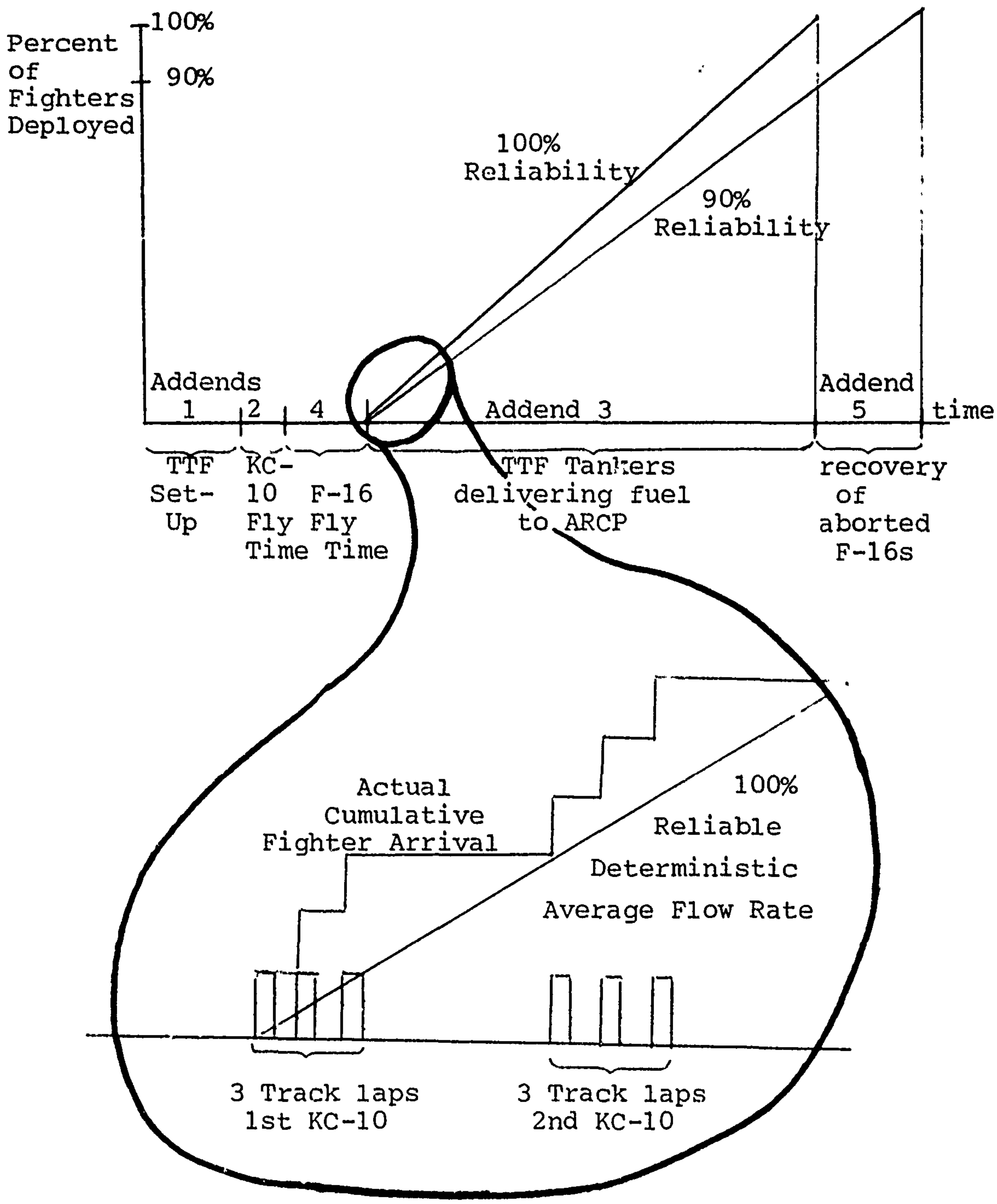

Figure 4.2. Graphical Illustration of Fighter Arrivals, related to Deterministic TTF Closure Time Equations.

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.)

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

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 <u>fighters</u> and the <u>refueling</u> <u>sorties</u> 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.)

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

= (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."

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

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:

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

$$= \frac{\text{Airborne Mission Time} + \text{Ground turn-around time}}{\text{KC-10 sortie}}$$

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

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

$$Rate_{AR\ track\ 1} = Rate_{AR\ track\ 2}$$

$$\frac{(2\ \text{Fighters/hr})}{(\text{KC-10})} \times (\#\ \text{of KC-10s at Goose Bay})$$

$$= \frac{(4\ \text{Fighters/hr})}{(\text{KC-10})} \times (\#\ \text{of KC-10s at Mildenhall})$$

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

$\alpha = 1 + a_2/a_1$

$\beta = 1 + b_2/b_1 + b_3/b_1$

$\gamma = 1 + c_2/c_1$

$\delta = 1 + d_2/d_1 + d_3/d_1 + d_4/d_1 + d_5/d_1$

Proportionality between Fighter Types

$\theta = B_1/A_1$

$\phi = C_1/A_1$

$\psi = D_1/A_1$

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

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

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

Note that this is equivalent to:

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

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:

$$\begin{array}{ccc} [Goose\ Bay] & & [Mildenhall] \\ (F\text{-}16\ Addend\ 3)_{TRACK\ 1} & = & (F\text{-}16\ Addend\ 3)_{TRACK\ 2} \end{array}$$

or

$$\frac{a_1}{A_1} = \frac{a_2}{A_2}$$

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:

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

[Goose Bay]

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

[Mildenhall]

(Note: For computationaly 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:

$$A_2 = \frac{a_2}{a_1} A_1$$

$$= .697\ A_1$$

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

$B_2 = (b_2/b_1)B_1$
$B_3 = (b_3/b_1)B_1$

$C_2 = (c_2/c_1)C_1$

$D_2 = (d_2/d_1)D_1$
$D_2 = (d_2/d_1)D_1$
$D_4 = (d_4/d_1)D_1$
$D_5 = (d_5/d_1)D_1$

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 contraint 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,

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

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.)

$$\text{time}_{F-16} = \frac{(700 \text{ Total F-16s}) \times (6.4 + 3.0 \text{ hrs/sortie})_1}{(6 \text{ F-16s/tracklap})(3 \text{ tracklaps/sortie})(A_1)}$$

$$= \text{time}_{F-15} = \frac{(300 \text{ Total F-15s}) \times (4.4 + 3.0 \text{ hrs/sortie})_1}{(6 \text{ F-15s/tracklap})(1 \text{ tracklap/sortie})(B_1)}$$

Solving for the relationship between A_1 and B_1,

$$B_1 = A_1 \frac{(300 \text{ F-15s})(4.4 + 3 \text{ hrs/sortie})_{F-15}}{(700 \text{ F-16s})(6.4 + 3 \text{ hrs/sortie})_{F-16}}$$

$$\frac{(6 \text{ F-16s/tracklap})}{(6 \text{ F-15s/tracklap})} \times \frac{(3 \text{ tracklaps/sortie})_{F-16}}{(1 \text{ tracklaps/sortie})_{F-15}}$$

$$= \theta A_1$$

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:

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

$$= \frac{365.55}{A_1}$$

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:

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

[F-15] $$\beta = 1 + (b_2/b_1) + (b_3/b_1)$$

$$= 1 + \frac{[(6.2 + 3)/2]}{[(4.4 + 3)/1]} + \frac{[(8.6 + 3)/5]}{[(4.4 + 3)/1]} = 1.935$$

[F-111] $$\gamma = 1 + (c_2/c_1)$$

$$= 1 + \frac{[(7.9 + 3)/2]}{[(5.1 + 3)/1]} = 1.673$$

[RF-4C] $$\delta = 1 + (d_2/d_1) + (d_3/d_1) + (d_4/d_1) + (d_5/d_1)$$

$$= 1 + \frac{[(5.3 + 3)/2]}{[(7.8 + 3)/2]} + \frac{[(7.5 + 3)/3]}{[(7.8 + 3)/2]} +$$

$$+ \frac{[(8.4 + 3)/3]}{[(7.8 + 3)/2]} + \frac{[(11.7 + 3)/6]}{[(7.8 + 3)/2]} = 3.574$$

The ratios between fighter AR_1 tracks were as follows:

$[F\text{-}15s/F\text{-}16s]_1$

$$\theta = \frac{(300\ F15s)(4.4 + 3\ hours/sortie)_{F15}}{(700\ F16s)(6.4 + 3\ hours/sortie)_{F16}}$$

$$\times \frac{(6\ F16s/tracklap)(3\ tracklaps/sortie)_{F16}}{(6\ F15s/tracklap)(1\ tracklap/sortie)_{F15}} = 1.012$$

$[F\text{-}111s/F\text{-}16s]_1$

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

$[RF\text{-}4Cs/F\text{-}16s]_1$

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

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

$$A_1 = 100\% \ / \ [(1.611) + (1.935)(1.012) + (1.673)(0.369) + (3.574)(0.246)]$$

$$= 100\% \ / \ 5.066$$

$$= 19.74\% \text{ of the Total KC-10s}$$

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:

$B_1 = \theta A_1 = (1.012)(19.74) = 19.977\%$ 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:

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

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

For the RF-4C AR Tracks:

$D_1 = \psi A_1 = (0.246)(19.74) = 4.856\%$ 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:

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

$$\text{Mildenhall TTF} = A_2 + B_3 + (D_4 + D_5) = 23.945\%$$

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

time = 365.55 / 19.74 = 18.52 hours (if 100 TTF tankers)

time = 18.52/.60 = 30.86 hours (if 60 TTF tankers)

time = 18.52/.20 = 92.60 hours (if 20 TTF tankers)

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

[1st Addend] = TTF Set-up Time = 3 hours notification
+ 5 hours preparation
+ 3 hours cargo loading
+ 2 hours preflight
+ 5 hours flight time
+ 3 hours unloading
+ 13 hours crew rest
+ 2 hours preflight
= 36 hours

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

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

$$[3rd\ Addend] + [5th\ Addend] = \frac{[3rd\ Addend]}{KC\text{-}10\ AR\ reliability}$$

= 92.6 hours, 100% reliable

or = 97.5 hours, 95% reliable

or = 102.9 hours, 90% reliable

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 = <u>142.5 hours</u>

(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:

Input	Major Functions	Output
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 (Lattitude, 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 (lattitude, 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:

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

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:

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

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:

$$\text{Total Cargo} = \frac{\text{(pounds of Cargo)}}{\text{(Fighter)}} \times \text{(Number of Fighters)}$$

$$\frac{\text{Cargo}}{\text{KC-10 - lap}} = \frac{\text{(No. of Pallets)}}{\text{(KC-10 - lap)}} \times \frac{\text{(Pounds of Cargo)}}{\text{Pallet}}$$

Therefore, Closure Time becomes:

$$\text{Cargo Closure Time} = \frac{\text{(pounds of Cargo)}}{\text{(Fighter)}} \times \text{(Number of Fighters)}$$

$$\div \left[\frac{\text{(No. of Pallets)}}{\text{(KC-10 - lap)}} \; \frac{\text{(Pounds of Cargo)}}{\text{Pallet}}\right]$$

$$\div \; [\text{No. of KC-10s}] \quad -1 \text{ Trip}$$

$$\times \quad \text{(Time/lap)}$$

$$+ \quad \text{(Preparation Time + First One-way Trip)}$$

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

(1200 Fighters) x (10,000 lbs cargo/fighter)

= 12,000,000 lbs cargo

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:

Cargo Closure Time =

$$\frac{12{,}000{,}000 \text{ lbs}}{(80{,}000 \text{ pounds/(KC-10 lap)}} \times \frac{1}{\text{(No. of KC-10s)}} - 1 \text{ trip}$$

x 45 hrs/lap

\+ 45 hrs for Preparation and 1st One-way Trip

= 168 hours (ie: 1 week)

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

$$= 150 \text{ KC-10 laps} \times \frac{1}{(\text{No. of KC-10s})} - 1$$

$$\times \; 45 \text{ hours/lap}$$

$$+ \; 45 \text{ hours for Preparation and 1st Trip}$$

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:

$$\text{KC-10 trips}_{(\text{F-16s})} = \frac{10{,}000 \text{ lbs}}{\text{Fighter}} \times 700 \text{ F-16s}$$

$$\times \frac{1 \text{ KC-10 trip}}{40{,}000 \text{ lbs}}$$

$$= 175 \text{ trips}$$

$$\text{KC-10 trips}_{(F\text{-}15s)} = \frac{10{,}000\ \text{lbs}}{\text{Fighter}} \times 300\ \text{F-15s}$$

$$\times \frac{1\ \text{KC-10 trip}}{20{,}000\ \text{lbs}}$$

$$= 150\ \text{trips}$$

$$\text{KC-10 trips}_{(F\text{-}111s)} = \frac{10{,}000\ \text{lbs}}{\text{Fighter}} \times 100\ \text{F-111s}$$

$$\times \frac{1\ \text{KC-10 trip}}{20{,}000\ \text{lbs}}$$

$$= 50\ \text{KC-10 trips}$$

$$\text{KC-10 trips}_{(RF\text{-}4Cs)} = \frac{10{,}000\ \text{lbs}}{\text{Fighter}} \times 100\ \text{RF-4Cs}$$

$$\times \frac{1\ \text{KC-10 trip}}{20{,}000\ \text{lbs}}$$

$$= 50\ \text{KC-10s trips}$$

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,

$$\text{C.T.} = \left[\frac{425\ \text{KC-10 trips}}{\text{No. of KC-10s (ie: 60)}} - 1\ \text{trip}\right] \text{laps} \times 45\ \text{hrs/lap}$$

$$+ \text{ set up time (ie: 36 hrs)}$$

$$+ \text{ flight time for 1st one-way trip (ie: 9 hrs)}$$

$$\text{C.T.} = [(7.08) - 1] \times 45 + 36 + 9$$

$$= 319\ \text{hrs}$$

$$= 1\ \text{week, } 6\ \text{days, } 7\ \text{hours}$$

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

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

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

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:

<u>First Addend:</u> <u>Time to set-up TTF</u>. Any error in this term is directly <u>added</u> 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:

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

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).

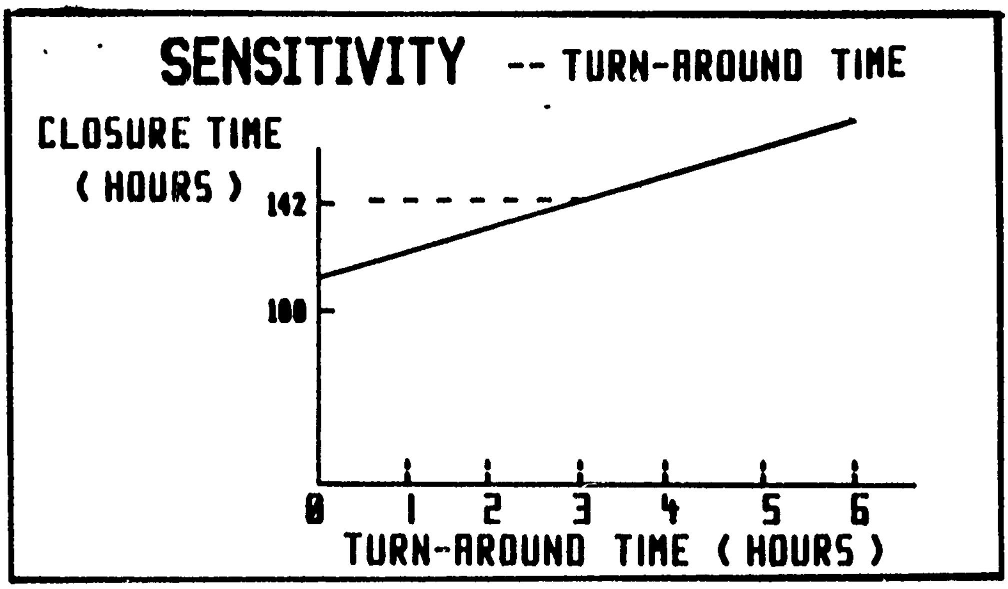

Figure 5.2 Sensitivity of Closure Time to changes in TTF Ground Time

2. <u>Number of consecutive sorties required.</u> 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:

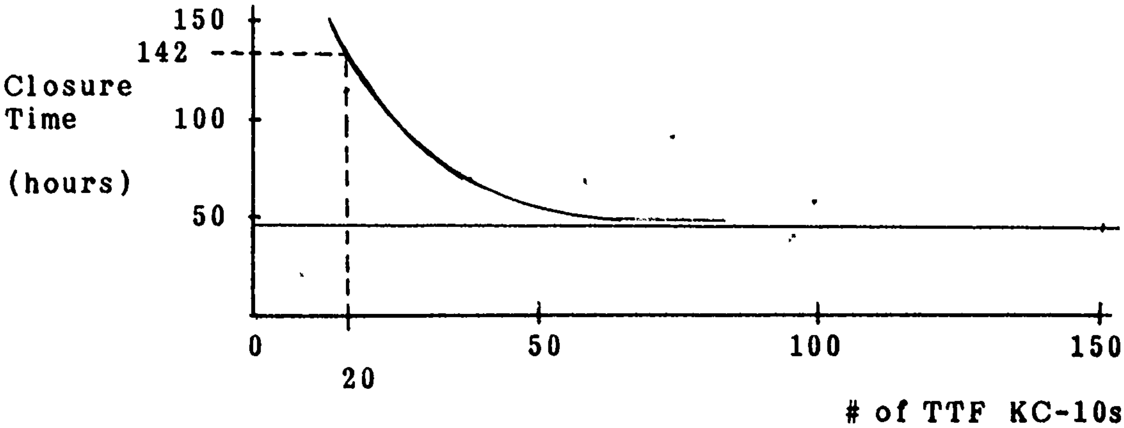

Figure 5.3. Sensitivity of Closure Time to Number of TTF KC-10s

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:

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

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 Reliablity 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.

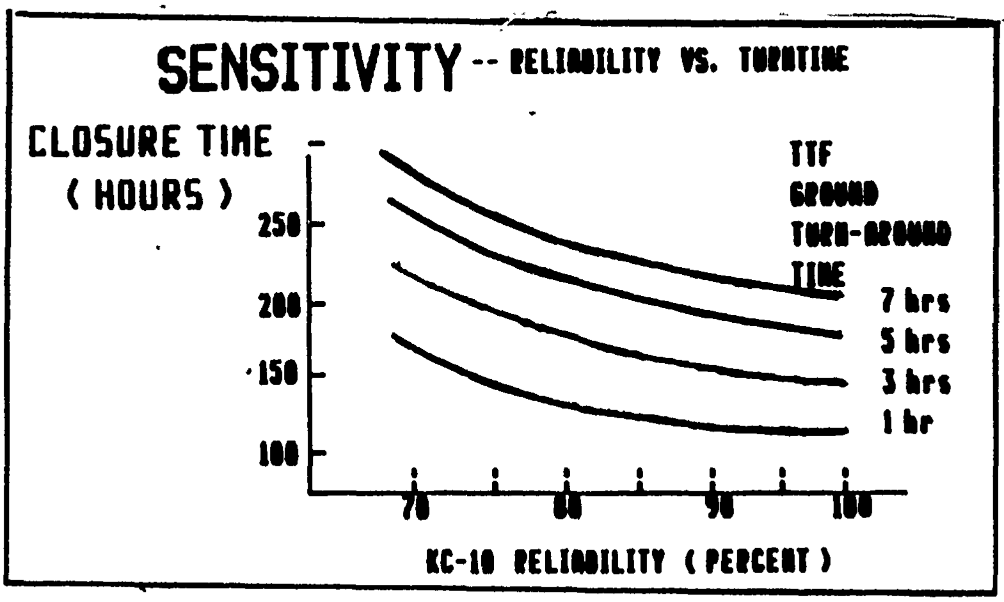

Figure 5.5. Sensitivity of Closure Time to TTF AR Reliability.

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.)

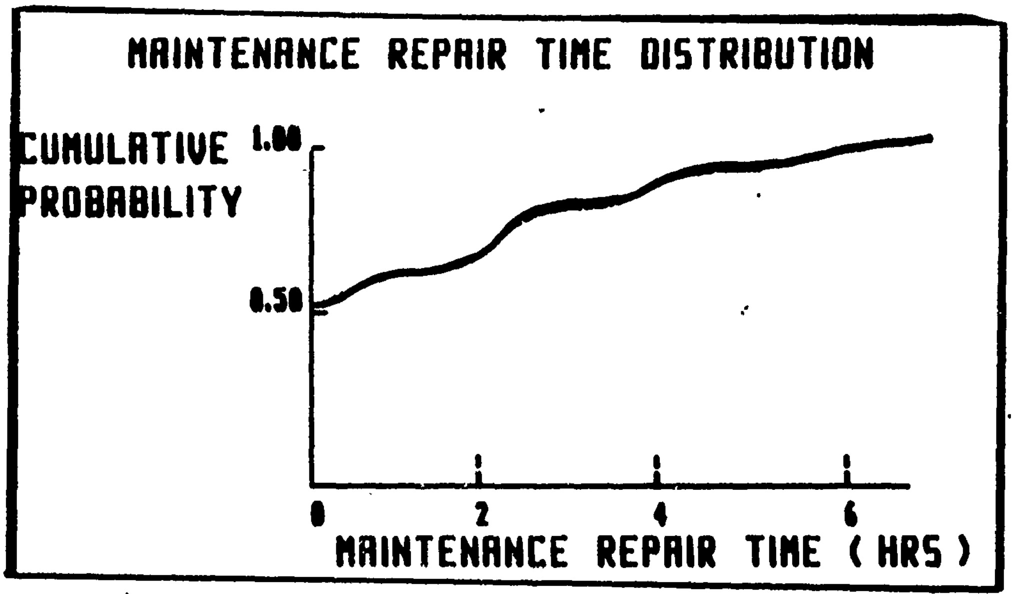

Figure 5.6. Hypothetical Maintenance Repair Time Distribution

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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:

$$\text{Cargo Closure Time} = \frac{(\text{pounds of Cargo})}{(\text{Fighter})}(\text{Number of Fighters})$$

$$\% \quad \left[\frac{(\text{No. of Pallets})}{(\text{KC-10 - lap})}\ \frac{(\text{Pounds of Cargo})}{\text{Pallet}}\right]$$

$$\% \quad [\text{No. of KC-10s}] \quad -1 \text{ Trip}$$

$$\times \quad (\text{Time/lap})$$

$$+ \quad (\text{Preparation Time + First One-way Trip})$$

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 ± 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.

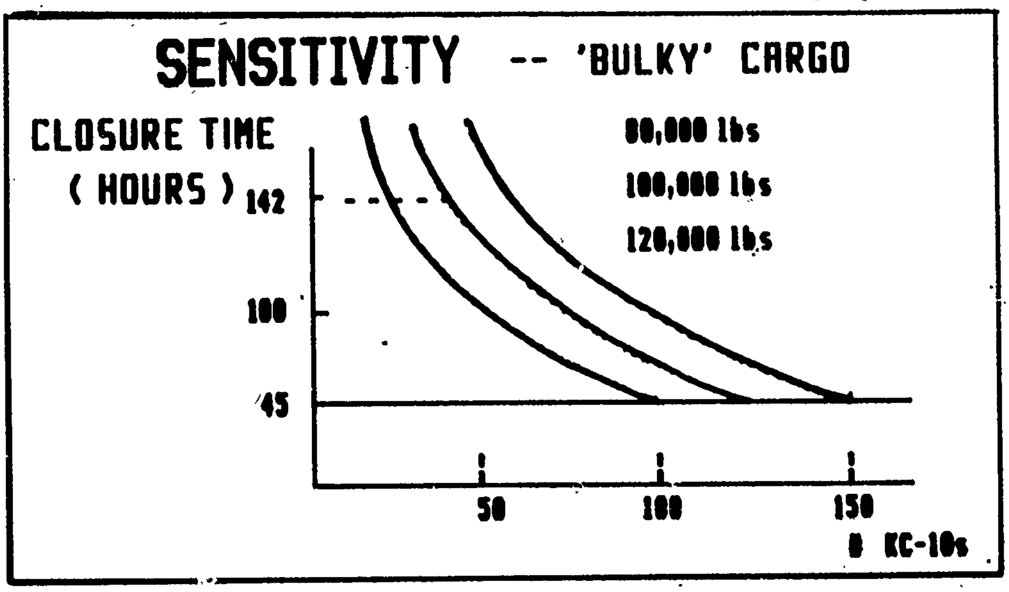

Figure 5.7. Sensitivity of Cargo Closure Time to the Number of KC-10s and the Cargo Weight

<u>Apportionment of KC-10s between TTF and Airlifter Missions.</u> 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 dipicts 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.

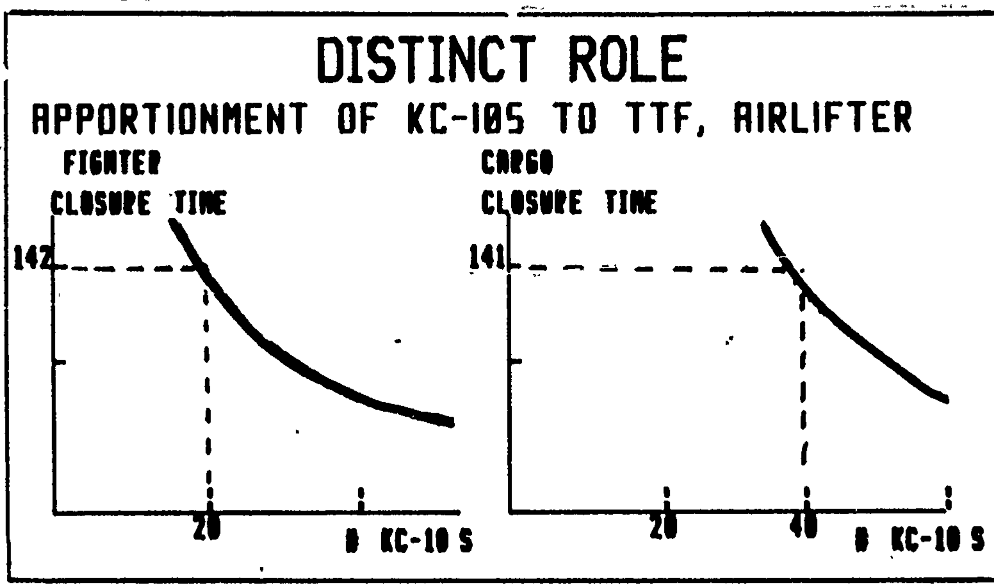

Figure 5.8. Apportionment of KC-10s between TTF, Airlifter Missions

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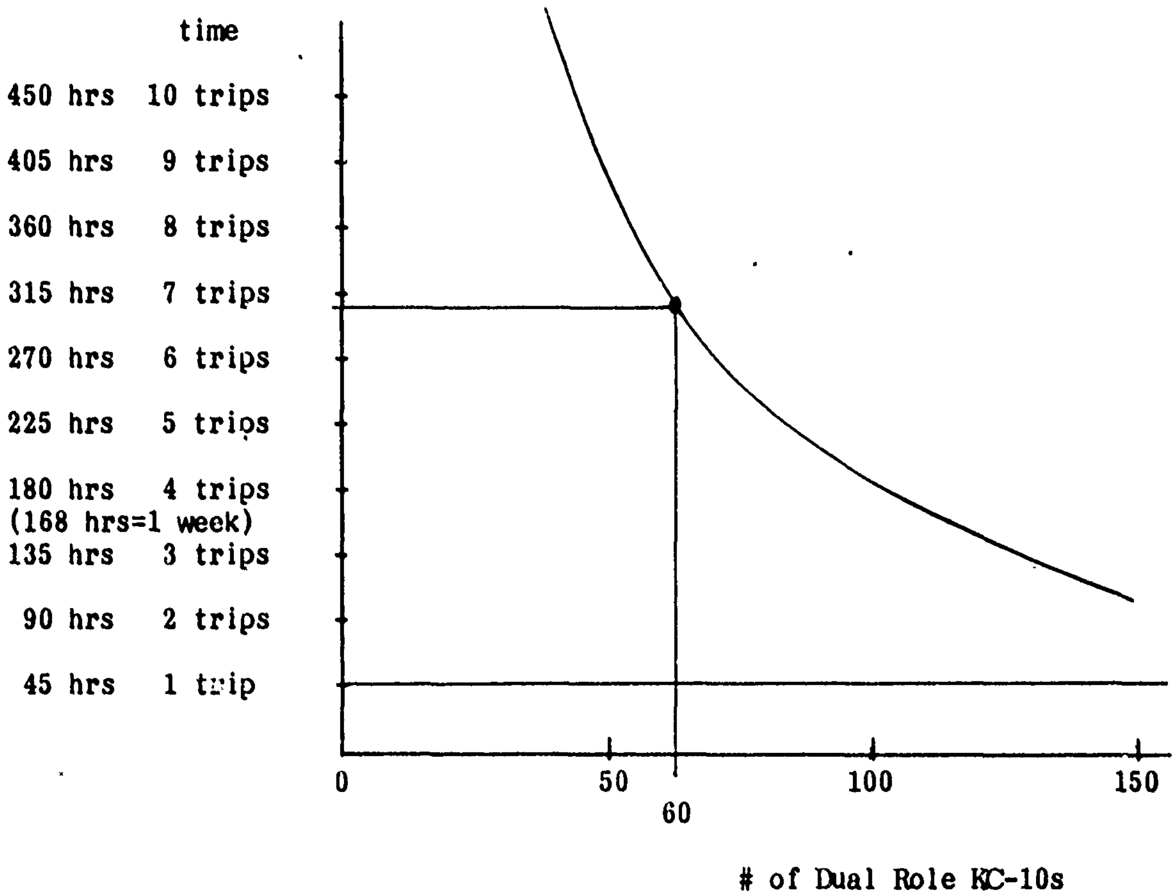
Analysis of Dual Role Closure Time Equations

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.

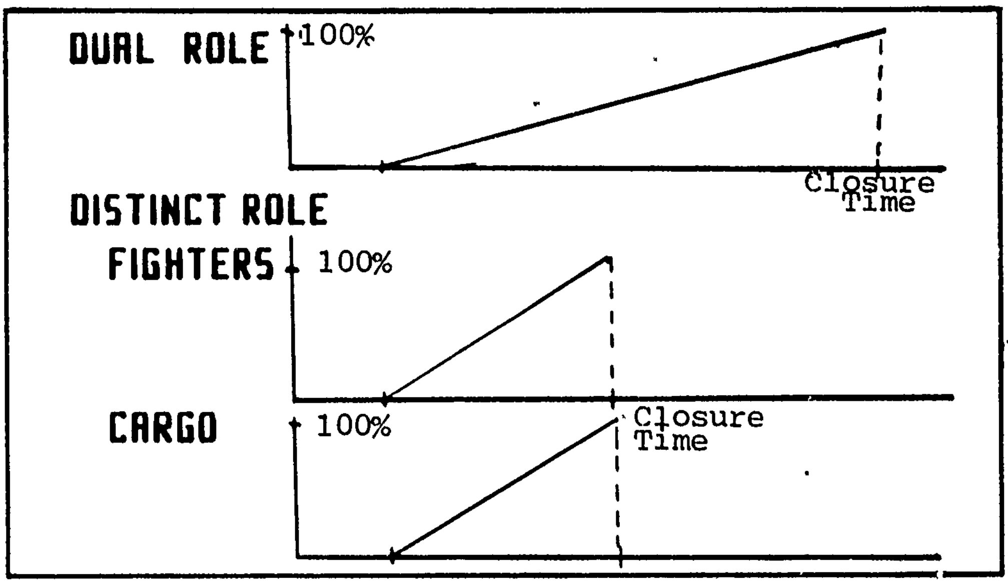


Figure 5.10. Cummulative Arrival of Fighters and Cargo for Dual and Distinct Role Deployment

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 I 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, ho ever, 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. Aother 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 <u>any</u> 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 Maintainance 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 maintainance 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. <u>Consider the survivability of the KC-10.</u> 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 condsideration 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 predeterined 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.

FORTRAN. 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, resposible 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 transfered 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, SETUPTM, FLYTOAR1, FLYTODST,
     &      FTRCELL, TOTNOFTR, TURNTIME, KCFLTIME,
     &      KCLAPS, GOOUT, GORTB,
     &      TOTALTNK, TTFAPPRT, RELIBLTY, KCTRACK,

     &      ITTFL, JFTRL, KTRAKL, NEARTTF,

     &      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, 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,OFWT,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        ,IFNT
      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, FEASIBLITY:
*
        IF (NEARTTF(J,K).NE.I) 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)

            DIST1S   = 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)
C           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.
*     OFLOADs 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(ITTFL,ISKIPTTF,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= ITTF1,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 ',A5,' ARCP ',I1,
*     &' IS: ',F6.0)
*
*       WRITE(11,2) TTFNAME(I),FIGHTER(J),K,GORTB(I,J,K)
* 0002   FORMAT(15X,'                   ',A10,'    ',A5,'  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 Lattitude, East Longitude.
*
* It can therefore be seen that
*
*     c = distance from North Pole to Origin = 90 degrees - Origin Lattitude
*     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, TTFAPPRT, RELIBLTY, KCTRACK,

     &      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, KCTRACK(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) = I

*          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, KCTRACK,

     &       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, KCTRACK(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 (GOOUT(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 / (ALPHA + BETA*THETA + GAMMA*PHI + DELTA*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) * FTRRATIO(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 (GOOUT(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 [ADDDEND 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)RELIBLTY, ADDEND3
* 0703  FORMAT(1X,'BASED ON ',F4.2,' RELIABILITY, ADDEND3= ',F6.2)

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

      CLOSURE = SETUPTM + 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     ,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)
* 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)
```

```
 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,RFDRAG
* 0800  FORMAT(1X,'ENTER CRUISE AND REFUEL DRAG FACTOR (DEFAULT = ',
*     &  F12.0,', ',F12.0,')')
C      READ(*,*),CRUDRG,RFDRAG
       CRUDRG = 2. - CRUDRG
       RFDRAG  = 2. - RFDRAG
       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
```

```
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(*) 'OFLOAD=',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
C**********************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,RFDRAG,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
```

```
      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     ENDIF
      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      ENDIF
 6030 CONTINUE
C     ENDDO
      IF(IFLAG.NE.1)
```

```
     &   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.
```

```
*       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
       TOTA=OPWT+TOTFUL-CURRWT
       CALL LOITER(TIME,CURRWT,ML,CRUDRG)
       TIME = TIME - .583
```

```
*       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)
C***************************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
```

```
*       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)
```

```
     &  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)
```

```
      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*********************************TAR REFUELING NUMBER 1***********
 8000 WRITE(*,8005) DISTTA,ONLOAD
*$$       WRITE(*,*) '*$$$ LABEL  8000, TAR REFL 1'
```

```
 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)
```

```
      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
```

```
      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))
```

```
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)
C**********************************CRUISE LEG**************
 9500  CONTINUE
        WRITE(*,*) '*$$$ LABEL  9500, CRUISE LEG'

        IF(ML.GT.NUMLEG) GO TO 9550
        TIME = TIME + DLEGTM(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(NOPRNT.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
```

```
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/ALTX(8),CCCAS(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,CCCAS
        DOUBLE PRECISION CFUEL,CDIST,CCALT
        DOUBLE PRECISION YTAB1,YTAB2
        WTT=CURRWT
```

```
      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,ALTX,CFUEL,IERR1,IERR2,17,0)
C     WRITE(*,*) 'Y1=',Y1
      Y2=TNT2(WTT,AALT,17,7,WT,ALTX,CDIST,IERR1,IERR2,17,0)
C     WRITE(*,*) 'Y2=',Y2
      Y3=TNT2(WTT,AALT,17,7,WT,ALTX,CTIME,IERR1,IERR2,17,0)
C     WRITE(*,*) 'Y3=',Y3
      GO TO 1
  3   CONTINUE
      Y4=TNT2(WTT,AALT,17,7,WT,ALTX,CFUEL,IERR1,IERR2,17,0)
C     WRITE(*,*) 'Y4=',Y4
      Y5=TNT2(WTT,AALT,17,7,WT,ALTX,CDIST,IERR1,IERR2,17,0)
C     WRITE(*,*) 'Y5=',Y5
      Y6=TNT2(WTT,AALT,17,7,WT,ALTX,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/ALTX(8),CCCAS(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)
      COMMON/F/NOPRNT
      DOUBLE PRECISION CCNAM,CCCAS,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,CCCAS,2,IERR)
      A = FUEL(Y1,DIST,DRAG)
```

```
      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/ALTX(8),CCCAS(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)
      COMMON/E/SPECIAL(17),ANUMRC(15)
      COMMON/F/NOPRNT
      DOUBLE PRECISION CTIME,CCNAM,CCCAS
      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,RFDRAG)
      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)
```

```
 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),DAT(17,7,4),DAT1(17,5),LCAS(17,5),
     &  IPNT
        COMMON/B/ALTX(8),CCCAS(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,CCCAS
        DOUBLE PRECISION CFUEL,CDIST,CCALT
        DOUBLE PRECISION YTAB1,YTAB2
         WRITE(*,*) '*$$$ SUBROUTINE CLIMB  '
        Y2=TNT2(TOWT1,Y1,17,7,WT,ALTX,CFUEL,IERR1,IERR2,17,0)
        Y3=TNT2(TOWT1,Y1,17,7,WT,ALTX,CDIST,IERR1,IERR2,17,0)
        Y4=TNT2(TOWT1,Y1,17,7,WT,ALTX,CTIME,IERR1,IERR2,17,1)
C       WRITE(*,100)Y1,Y2,Y3,Y4
 100    FORMAT(2X,'FINAL ALT,WT,DIST,TIME=',
     &  2X,F7.1,2X,F7.1,2X,F5.1,2X,F4.1)
        RETURN
        END
C**********************************************************************
        FUNCTION TNT1(XARG,NTBARG,XTBARG,YTBARG,NPTARG,NERR)
        DIMENSION XTBARG(NTBARG),YTBARG(NTBARG)
        DOUBLE PRECISION YTBARG
*$         WRITE(*,*) '*$$$ 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
```

```
 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 TLU1(X(1),N(1),X1TARG,N1,J1ARG)
        X(2)=X2ARG
C       **************SEARCH SECOND INDEPENDENT TABLE********
       CALL TLU1(X(2),N(2),X2TARG,N2,J2ARG)
       IF(J1ARG.NE.0.OR.J2ARG.NE.0) GO TO 901
       N1=MAX0(1,MIN0(N1,N(1)-1))
       N2=MAX0(1,MIN0(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 TLU1(ARG,NTAB,TAB,J,IERR)
```

```
      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
C***********************************************************************
      SUBROUTINE LOITER (TIME,CURRWT,ML,CRUDRG)
      COMMON/A/DISTTA,WT(17),AS(7),DAT(17,7,4),DAT1(17,5),LCAS(17,5),
     & IPNT
      COMMON/B/ALTX(8),CCCAS(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)
      COMMON/F/NOPRNT
      DOUBLE PRECISION CTIME,CCNAM,CCCAS
      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(IPNT.EQ.1.AND.NOPRNT.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)-ALTX(JJ))/1000.)/5.
      DO 3 I=1,5
      Y1=TNT1(CURRWT,17,WT,YTAB3,2,IERR)
```

```
      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,I,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
*$$  WRITE(*,*) '*$$$ 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=I
      IF(Y.EQ.ALT1(I))JJ=I
 12   CONTINUE
C     WRITE(*,*)  '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(*,*)  'CRUISE TABLES DAT2 & ICTAS = ',YTAB3(I),YTAB5(I)
```

```
 2      IF(IFLAG.NE.1)YTAB6(I)=ICTAS(I,LL)
        IF(IFLAG.NE.1)DIFF=(ALT1(JJ)/1000.)/5.
        DO 3 I=1,5
        Y1=TNT1(CURRWT,17,WT,YTAB3,2,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)I,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,' GWT=',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 ORBIT=',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
```

```
C       ENDIF
*        IF(IFULOP.NE.1.AND.CURRWT.LE.OPWT)
*$$$ THE FOLLOWING ADDED BY HUNSUCK: $$$
         IF (CURRWT.LE.(OPWT+5000))
      & M = 1
C       ENDIF
        ICHEK = M
        RETURN
        END
C*****************************************************************************
C***  BLOCK DATA PORTION
C**
      BLOCK DATA
C
C

****
        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

*******
         COMMON/EQNS/ CLOSURE, SETUPTM, FLYTOAR1, FLYTODST,
     &        FTRCELL, TOTNOFTR, TURNTIME, KCFLTIME,
     &        KCLAPS, GOOUT, GORTB,
     &        TOTALTNK, TTFAPP  , RELIBLTY, KCTRACK,

     &        ITTFL, JFTRL, KTRAKL, NEARTTF,

     &        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, 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,DIST15,FARCAS,DIST3,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     ,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       / NOFRNT
      COMMON /G       / DAT2        ,ICTAS
      REAL    DAT2      (17,5)
      INTEGER NOFRNT   ,ICTAS       (17,5)

*******
      DATA    ALTX        /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/EXPLAINATION 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.

27. WHAT IS DISTANCE TO RTB OR TAR
If you are at destination, enter 0. If not go to 16.

Tel (202) 697-9315
Autovon 227-9315

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AFCSA/SAGM
Wash DC 20330-5420

Sample Tanker Data

Dual Role KC-10 refueling Four F-16s

```
A>b:tankl
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)

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

12-02-86 2236Z ROUTE — ROUTE WIND FACTOR +013

F-16A 2X370GAL: 300CLT — TOTAL FUEL ONLOAD BY RECEIVER

FLT LEVEL	1	2	3	4	5
ALT UPPER	250	320	340		
LOWER	250	300	340		
TAS	449	485	503		
CAS					

FROM MCCONNELL
TO HAHN
TTF
BOOM TYPE REFUELING

RECVR 1	RECVR 2	RECVR 3	RECVR 4	RECVR 5	RECVR 6
13485	13482	13481	13480	13479	13477

MSN-TEMP-DEV +05C MAY CLIMATOLOGICAL WINDS 90 WORST PROB FACTOR

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 6	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
1	MCCONNELL	3737N 09716W									13732	13732			
2	START,TAXI,TAKEOFF	3737N 09716W							592	592	13140	13140			
3	LEVELOFF POINT FL340	3751N 09516W	074	- 3	48	48	07	00+07	724	724	12415	12415	5592		523
4	BUTLER VORTAC	3816N 09429W	073	- 3	89	137	10	00+17	509	509	11907	11907	3024		526
5	ST LOUIS VORTAC	3852N 09029W	077	- 5	191	328	22	00+39	1071	1071	10836	10836	2961		527
6	INDIANAPOLIS	3949N 08622W	077	- 3	199	527	23	01+02	1081	1081	9755	9755	2870		528
7	DAYTON	4001N 08424W	081	+ 0	91	618	10	01+12	483	483	9272	9272	2814		529
8	DRYER	4122N 08210W	050	+ 1	130	748	15	01+27	683	683	8589	8589	2769		525
9	JAMESTOWN	4211N 07907W	069	+ 4	145	893	16	01+43	740	740	7849	7849	2707		530
10	ALBANY	4245N 07349W	079	+ 8	238	1131	27	02+10	1202	1202	6647	6647	2642		523
11	BOSTON	4221N 07100W	100	+13	126	1257	14	02+24	612	612	6035	6035	2586		529
12	YARMOUTH	4349N 06605W	066	+15	233	1490	27	02+51	1137	1137	4898	4898	2536		519
13	HALIFAX	4455N 06324W	059	+20	133	1623	15	03+06	634	634	4264	4264	2486		519
14	DESCEND	4538N 06131W	061	+23	90	1713	10	03+16	421	421	3843	3843	2452		522
15	LEVELOFF FL300	4542N 06120W	062	+24	9	1722	02	03+18	24	24	3819	3819	960		504
16	SYDNEY	4609N 06003W	062	+24	60	1782	07	03+25	296	296	3523	3523	2501		504
17	AIR REFUELING CTL PT	4621N 05908W	072	+25	40	1822	05	03+30	196	196	3327	3327	2502		501
18	START AAR 01	4628N 05833W	072	+25	25	1847	03	03+33	119	119	3208	3208	2462		501
19	NO.1 ABORT,OFF, 2 ON	4642N 05723W	073	+25	50	1897	06	03+39	243	243	13732	2965	2471	13767	501
20	CHECK PT	4652N 05630W	074	+25	38	1935	05	03+44	234	185	13498	2780	3120		501

12-02-86 22352 ROUTE

ROUTE WIND FACTOR +013

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
21	NO.2 ABORT,OFF, 3 ON	4656N 05613W	074	+27	12	1947	01	03+45	73	58	13425	2722	3129	11010	503
22	NO.3 ABORT,OFF, 4 ON	4708N 05502W	075	+27	50	1997	06	03+51	307	243	13118	2482	3122	11250	503
23	NO.4 ABORT,OFF, 5 ON	4720N 05350W	075	+27	50	2047	06	03+57	304	243	12814	2242	3092	11490	503
24	ST JOHNS	4729N 05251W	076	+27	41	2088	05	04+02	246	194	12558	2048	3075		503
25	NO.5 ABORT,OFF, 6 ON	4731N 05238W	073	+27	9	2097	01	04+03	51	40	12517	2008	3060	11724	499
26	NO. 6 ABORT,OFF. EAR	4745N 05128W	074	+27	49	2146	06	04+09	296	234	12221	13732	3062	11958	499
*****************										AVERAGE ONLOAD FOR AAR 1				11367	
27	LEVELOFF FL340	4747N 05114W	074	+23	10	2156	01	04+10	93	93	12128	13639	4650		499
28	CK PT	4800N 05000W	074	+23	51	2207	05	04+16	295	308	11833	13331	3132		517
29	CK PT	4910N 04500W	068	+23	210	2417	25	04+41	1205	1257	10628	12074	3078		514
30	RP PT	5000N 04000W	073	+22	201	2618	23	05+04	1106	1152	9522	10922	2957		517
31	CK PT	5000N 03500W	088	+25	193	2811	23	05+27	1043	1084	8479	9845	2878		511
32		5000N 03000W	088	+24	193	3004	23	05+50	1009	1045	7470	8792	2789		513
33	CK PT	5000N 02500W	088	+22	193	3197	23	06+13	994	1027	6476	7765	2715		508
34	RP PT	5000N 02000W	088	+21	193	3390	23	06+36	971	1000	5505	6755	2643		508
35	CK PT	5000N 01500W	088	+17	193	3583	23	06+59	952	986	4546	5779	2583		505
36	RP PT	5000N 01000W	083	+14	193	3776	23	07+22	933	960	3613	4819	2526		506
37	RP PT	5000N 00800W	039	+12	77	3853	09	07+31	367	377	3246	4442	2486		506
38	DESCEND	5037N 00553W	034	+11	82	3935	10	07+41	389	400	2857	4042	2474		505
39	LANDS END FL300	5039N 00539W	034	+10	9	3944	02	07+43	24	24	2833	4018	960		487
40	AIR REFUELING CTL PT	5050N 00315W	064	+10	100	4044	12	07+55	501	514	2332	3504	2597		487
41	START AAR 02	5100N 00239W	056	+ 9	25	4069	03	07+58	122	125	2210	3379	2500		487
42	YEOVILTON	5100N 00238W	071	+ 9	1	4070	00	07+58	4	4	2205	3375	2400		487
43	NO.1 ABORT,OFF, 2 ON	5104N 00124W	094	+ 9	47	4117	06	08+04	230	235	4695	3140	2474	2719	488
44	NO.2 ABORT,OFF, 3 ON	5107N 00007W	085	+ 8	48	4165	05	08+10	250	243	4445	2897	2542	2472	488

12-02-85 22357 ROUTE

ROUTE WIND FACTOR +013

LINE NBR	DATA POINT		COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL 1	REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
45	NO.3 ABORT,OFF, 4 ON		5110N 00109E	036	+7	43	4213	06	08+15	249	242	4195	2655	2532	2231	488
46	DOVER		5110N 00121E	037	+7	7	4220	01	08+17	34	33	4152	2622	2550		488
47	EBBU		5108N 00220E	094	+7	25	4245	03	08+20	127	122	4035	2500	2540		488
48	NO.4 ABORT,OFF, 5 ON		5107N 00225E	094	+5	16	4261	02	08+22	80	77	3955	2423	2526	1990	487
49	KOKSEY		5106N 00232E	094	+5	9	4270	01	08+23	46	45	3909	2378	2509		487
50	NO.5 ABORT,OFF, 6 ON		5045N 00331E	123	+5	39	4309	05	08+28	200	195	3709	2133	2500	1754	487
51	NO. 6 ABORT,OFF. EAR		5018N 00433E	123	+5	48	4357	05	08+34	246	239	3453	3453	2502	1519	487
******************										AVERAGE ONLOAD FOR AAR 2					2114	
52	FLORENNES		5015N 00439E	124	+5	5	4362	01	08+35	46	45	3417	3417	4600		502
53	LEVFLOFF	FL340	5014N 00447E	100	+5	5	4367	01	08+36	47	47	3370	3370	4700		487
54	DESCEND		5005N 00509E	100	+5	49	4416	06	08+42	237	232	3138	3138	2400		505
55	NATTENHEIM		5001N 00632E	100	+4	20	4436	04	08+46	64	64	3074	3074	893		281
56	HAHN	FL000	4957N 00716E	097	+4	29	4465	06	08+52	94	94	2980	2980	881		487

ABORT BASES RECEIVED 1

*** AAR 1 ***

	DATA POINT		COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL 1	REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
	ABORT POINT		4642N 05723W				1897		03+39				2955			
19A	STEPHENVILLE		4833N 05833W	337	+23	120	2017	16	03+55		633		2332	2450		464
19A	BINGO FUEL	2098														
19B	GANDER		4855N 05434W	059	+23	175	2072	21	04+00		854		2101	2445		494
19B	BINGO FUEL	2329														
19C	ST JOHNS		4737N 05245W	072	+23	196	2093	24	04+03		961		2004	2443		498
19C	BINGO FUEL	2425														

12-02-86 22352 ROUTE

ROUTE WIND FACTOR +014

F-15C/D 3X510TNKS

FROM MCCONNELL

TO HAHN

TTF

BOOM TYPE REFUELING

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

TOTAL FUEL ONLOAD BY RECEIVER

RECVR 1	RECVR 2	RECVR 3	RECVR 4	RECVR 5	RECVR 6
35774	37411	38050	38822	39684	40543

MSN-TEMP-DEV +05C   MAX CLIMATOLOGICAL WINDS   90 WORST PROB FACTOR

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 5	FUEL FLOW	WIND OR OVLOAD	GS
1	MCCONNELL	3737N 09716W									25800	25800			
2	START,TAXI,TAKEOFF	3737N 09716W							2500	2500	23300	23300			
3	LEVELOFF POINT FL390	3755N 09601W	074	-8	52	52	09	00+09	2112	2112	21188	21188	14080		528
4	BUTLER VORTAC	3815N 09429W	073	-7	75	137	08	00+17	977	977	20211	20211	7063		536
5	ST LOUIS VORTAC	3852N 09029W	077	-6	191	328	21	00+38	2234	2234	17977	17977	6293		538
6	INDIANAPOLIS	3949N 08622W	072	-3	199	527	22	01+00	2216	2216	15761	15761	5989		537
7	DAYTON	4001N 08424W	081	+0	91	618	10	01+10	990	990	14771	14771	5931		538
8	DRYER	4122N 08210W	050	+0	130	748	15	01+25	1411	1411	13360	13360	5799		533
9	JAMESTOWN	4211N 07907W	069	+4	145	893	16	01+41	1523	1523	11837	11837	5676		539
10	DESCEND	4233N 07557W	079	+8	142	1035	16	01+57	1981	1981	9856	9856	7429		531
11	LEVELOFF FL390	4237N 07518W	032	+11	29	1064	04	02+01	138	138	9718	9718	1882		536
12	ALBANY	4245N 07348W	082	+12	67	1131	08	02+09	849	849	8869	8869	6448		506
13	AIR REFUELING CTL PT	4239N 07304W	100	+13	33	1164	04	02+13	429	429	8440	8440	6774		513
14	START AAR 01	4234N 07230W	100	+14	25	1189	03	02+16	328	328	8112	8112	6786		513
15	BOSTON	4221N 07100W	100	+14	68	1257	08	02+24	891	891	7221	7221	5757		513
16	NO.1 ABORT,OFF, 2 ON	4225N 07049W	056	+15	9	1266	01	02+25	99	99	25800	7122	5940	18678	501
17	NO.2 ABORT,OFF, 3 ON	4254N 06915W	066	+16	75	1341	09	02+34	1061	878	24739	6244	7153	19556	501
18	NO.3 ABORT,OFF, 4 ON	4323N 06740W	067	+17	75	1416	09	02+43	1056	895	23683	5349	7119	20451	501
19	YARMOUTH	4349N 06505W	058	+19	74	1490	09	02+52	1031	907	22652	4442	7030		501
20	NO.4 ABORT,OFF, 5 ON	4350N 06504W	059	+20	1	1491	00	02+52	12	10	22640	4432	7200	21368	502

12-02-85 2235Z ROUTE

ROUTE WIND FACTOR +014

LINE NBR	DATA POINT		COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
21	NO.5 ABORT,OFF, 6 ON		4427N 064334W	059	+20	75	1566	09	03+01	1033	917	21607	3515	6964	22285	502
22	HALIFAX		4455N 063324W	060	+22	57	1623	07	03+08	786	701	20821	2814	6935		502
23	NO. 6 ABORT,OFF.		4504N 063092W	061	+23	18	1641	02	03+10	243	217	20578	25800	5943	23203	505
******************										AVERAGE ONLOAD FOR AAR			1		20924	
24	LEVELOFF	FL380	4514N 062364W	061	+23	21	1662	03	03+13	312	312	20266	25488	7498		505
25	SYDNEY		4609N 060034W	061	+23	120	1782	14	03+27	1445	3750	18821	21738	16667		530
26	CHECK PT		4652N 055304W	072	+25	153	1935	17	03+44	1765	2077	17055	19651	7162		525
27	ST JOHNS		4729N 052514W	074	+27	153	2088	17	04+01	1715	1778	15341	17883	6166		528
28	DESCEND		4.44N 051304W	073	+27	57	2145	07	04+08	633	655	14708	17228	6046		524
29	LEVELOFF	FL300	4752N 050484W	074	+28	29	2174	04	04+12	138	139	14570	17090	1892		499
30	CK PT		4800N 050004W	074	+23	33	2207	04	04+16	431	435	14139	16655	5592		499
31	AIR REFUELING CTL PT		4824N 043264W	059	+23	67	2274	08	04+24	888	903	13251	15752	6689		496
32	START AAR 02		4832N 047514W	069	+23	25	2299	03	04+27	327	334	12924	15418	6680		496
33	NO.1 ABORT,OFF, 2 ON		4851N 046294W	070	+28	57	2356	07	04+34	743	751	25800	14667	6626	13619	496
34	NO.2 ABORT,OFF, 3 ON		4909N 045064W	071	+23	57	2413	07	04+41	811	751	24939	13916	7156	13518	496
35	CK PT		4910N 045004W	072	+27	4	2417	00	04+41	48	44	24941	13872	7200		496
36	NO.3 ABORT,OFF, 4 ON		4924N 043424W	073	+27	53	2470	06	04+47	751	689	24120	13183	7152	13725	498
37	NO.4 ABORT,OFF, 5 ON		4939N 042174W	074	+27	57	2527	07	04+54	800	743	23320	12440	7359	14099	498
38	NO.5 ABORT,OFF, 6 ON		4952N 040514W	075	+27	57	2584	07	05+01	797	733	22523	11702	7332	14470	498
39	RP PT		5000N 040004W	076	+27	34	2618	04	05+05	467	432	22135	11270	7005		498
40	NO. 6 ABORT,OFF.		5001N 038558W	088	+25	40	2658	05	05+10	555	519	21571	25800	6938	15049	492
******************										AVERAGE ONLOAD FOR AAR			2		14080	
41	LEVELOFF	FL380	5001N 038254W	088	+25	21	2679	03	05+13	312	312	21259	25488	7488		492
42	CK PT		5000N 035004W	088	+25	132	2811	15	05+28	1750	4021	19509	21467	15769		517
43			5000N 030004W	088	+24	193	3004	22	05+50	2277	2499	17232	18968	6724		519

12-02-86 2235Z ROUTE

ROUTE WIND FACTOR +014

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 5	FUEL FLOW	WIND OR OVLOAD	GS
44	CK PT	5000N 02500W	088	+22	193	3197	23	06+13	2227	2281	15035	15637	5353		514
45	RP PT	5000N 02000W	088	+20	193	3390	22	06+35	2159	2202	12846	14485	5898		515
46	CK PT	5000N 01500W	088	+17	193	3583	23	06+58	2338	2165	10538	12319	6207		512
47	DESCEND	5001N 01121W	088	+14	141	3724	17	07+15	1072	1725	9536	10594	7171		513
48	LEVELOFF FL330	5001N 01137W	090	+13	28	3752	04	07+19	138	133	8323	10456	1882		488
49	RP PT	5000N 01200W	090	+12	24	3776	03	07+22	327	311	8071	10145	6766		488
50	AIR REFUELING CTL PT	5000N 00802W	089	+12	76	3852	09	07+31	1023	997	7048	9148	6600		488
51	RP PT	5000N 00800W	070	+11	1	3853	00	07+31	10	11	7038	9137	6600		488
52	START AAR 03	5002N 00723W	084	+11	24	3877	03	07+34	286	317	6752	8820	5559		487
53	LANDS END	5008N 00538W	084	+11	67	3944	08	07+42	809	925	5943	7894	6776		487
54	NO.1 ABORT,OFF, 2 ON	5010N 00531W	064	+10	5	3949	01	07+43	60	68	10350	7826	6800	4477	488
55	NO.2 ABORT,OFF, 3 ON	5041N 00347W	064	+10	73	4022	09	07+52	953	953	9407	6873	6425	4336	488
56	YEOVILTON	5100N 00238W	055	+ 9	48	4070	06	07+58	640	583	8767	6290	5538		488
57	NO.3 ABORT,OFF, 4 ON	5102N 00158W	084	+ 9	25	4095	03	08+01	338	295	8429	5994	6760	3874	489
58	NO.4 ABORT,OFF, 5 ON	5107N 00003W	085	+ 8	73	4168	09	08+10	1004	905	7425	5088	6769	3355	489
59	DOVER	5110N 00121E	086	+ 7	52	4220	06	08+16	645	649	6780	4439	6181		489
60	NO.5 ABORT,OFF, 6 ON	5108N 00154E	094	+ 7	21	4241	03	08+19	246	253	6534	4131	5192	2929	489
61	EBBU	5108N 00200E	094	+ 5	4	4245	00	08+19	39	42	6495	4139	6300		489
62	KOKSEY	5106N 00239E	094	+ 5	25	4270	03	08+22	295	310	6200	3829	6200		487
63	NO. 6 ABORT,OFF.	5042N 00337E	123	+ 5	44	4314	05	08+27	536	556	5654	5654	6178	2391	487
*******************									AVERAGE OVLOAD FOR AAR 3					3560	
64	LEVELOFF FL380	5030N 00405E	123	+ 5	21	4335	03	08+30	312	312	5352	5352	7488		487
65	FLORENNES	5015N 00439E	123	+ 5	27	4362	03	08+33	264	264	5088	5088	5110		512
66	DESCEND	5003N 00530E	130	+ 5	33	4395	04	08+37	323	323	4755	4755	5100		513
67	NATTENHEIM	5001N 00532E	130	+ 5	41	4436	08	08+45	302	302	4453	4453	2353		322

12-02-86 23352 ROUTE ROUTE WIND FACTOR +014

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
68	HAHN FLOOD	4957N 00716E	077	+ 4	29	4465	05	09+50	213	213	4250	4250	2367		488

ABORT BASES RECEIVER 1

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
*** AAR 1 ***															
	ABORT POINT	4225N 07049W				1266		02+25				7122			
16A	PEASE	4305N 07049W	000	+15	47	1306	05	02+30		484		6638	5927		485
16A	BINGO FUEL 2594														
16B	BANGOR	4448N 06850W	030	+19	157	1433	20	02+45		2020		5112	6000		496
16B	BINGO FUEL 4120														
16C	SHEARWATER	4438N 06330W	064	+23	344	1610	41	03+06		4173		2949	6092		502
16C	BINGO FUEL 6273														
*** AAR 2 ***															
	ABORT POINT	4351N 04522W				2356		04+34				12131			
33A	ST JOHNS	4737N 05245W	255	+23	251	2517	37	05+11		3972		8209	6511		427
33A	BINGO FUEL 6072														
*** AAR 3 ***															
	ABORT POINT	5010N 00531W				3949		07+43				5883			
54A	ST MAWGANS	5025N 00500W	051	+11	25	3974	03	07+46		304		5579	6080		486
54A	BINGO FUEL 2474														
54B	BOSCOMBE-DOWN	5110N 00144W	065	+ 3	155	4104	19	03+02		1962		3921	6163		486
54B	BINGO FUEL 4062														

12-02-86 22372 ROUTE

ROUTE WIND FACTOR +011

F-111D 4 PYLONS
5

TOTAL FUEL ONLOAD BY RECEIVER

FLT LEVEL	1	2	3	4	5
ALT UPPER	190	260	255		
LOWER	190	240	255		
TAS	393	443	451		
CAS					

FROM MCCONNELL

TO HAHN

TTF

BOOM TYPE REFUELING

RECVR 1	RECVR 2	RECVR 3	RECVR 4
41780	41492	41313	41134
RECVR 5	RECVR 6		
40925	40719		

MSN-TEMP-DEV +05C MAY CLIMATOLOGICAL WINDS 90 WORST PROB FACTOR

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
1	MCCONNELL	3737N 09716W									30500	30500			
2	START,TAXI,TAKEOFF	3737N 09716W							3830	3830	26670	26670			
3	LEVELOFF POINT FL250	3755N 09602W	074	- 8	51	61	09	00+09	1745	1745	24925	24925	11633		469
4	BUTLER VORTAC	3815N 09429W	073	- 7	76	137	10	00+19	1098	1098	23827	23827	5792		469
5	ST LOUIS VORTAC	3852N 09029W	077	- 5	191	328	24	00+43	2712	2712	21115	21115	5559		469
6	INDIANAPOLIS	3949N 08622W	072	- 3	199	527	25	01+08	2740	2740	18375	18375	6498		471
7	DAYTON	4001N 08424W	081	+ 0	91	618	12	01+20	1223	1223	17152	17152	6381		471
8	DRYER	4122N 08210W	050	+ 0	130	748	17	01+37	1752	1752	15400	15400	6333		468
9	JAMESTOWN	4211N 07907W	069	+ 4	145	893	18	01+55	1932	1932	13468	13468	6300		472
10	DESCEND	4213N 07848W	079	+ 8	14	907	02	01+57	189	189	13279	13279	6300		467
11	LEVELOFF FL240	4214N 07842W	080	+ 8	5	912	01	01+58	15	15	13264	13264	900		459
12	AIR REFUELING CTL PT	4230N 07628W	030	+ 8	100	1012	13	02+11	1294	1294	11970	11970	5972		459
13	START AAR 01	4233N 07554W	081	+10	25	1037	03	02+14	340	340	11630	11630	6375		459
14	ALBANY	4245N 07348W	082	+11	93	1130	12	02+26	1260	1260	10370	10370	6248		459
15	NO.1 ABORT,OFF, 2 ON	4243N 07329W	100	+13	14	1144	02	02+28	159	159	32785	10211	5300	22574	464
16	NO.2 ABORT,OFF, 3 ON	4222N 07105W	110	+14	108	1252	14	02+42	1599	1239	31135	5973	5932	23813	464
17	BOSTON	4221N 07100W	101	+15	4	1256	01	02+43	53	43	31123	5924	6960		464
18	NO.3 ABORT,OFF, 4 ON	4302N 06950W	056	+15	104	1360	14	02+57	1542	1297	29536	7627	6803	25158	456
19	NO.4 ABORT,OFF, 5 ON	4341N 06634W	057	+13	106	1466	14	03+11	1558	1311	28028	6316	6725	26469	456
20	YARMOUTH	4349N 06605W	059	+20	23	1489	03	03+14	345	281	27633	6035	5970		456

12-02-86 22373 ROUTE

ROUTE WIND FACTOR +011

LINE NBR	DATA POINT		COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL USED 1	FUEL USED 5	FUEL REMAIN 1	FUEL REMAIN 5	FUEL FLOW	WIND OR ONLOAD	GS
21	NO.5 ABORT,OFF, 6 ON		4431N 06425W	059	+20	83	1572	11	03+25	1190	1012	26493	5023	6611	27762	457
22	HALIFAX		4455N 06324W	060	+22	50	1622	07	03+32	713	606	25787	4417	6582		457
23	NO. 6 ABORT,OFF.		4522N 06214W	061	+23	56	1678	07	03+39	794	680	24986	32785	6526	29048	459
*****************										AVERAGE ONLOAD FOR AAR 1					25804	
24	LEVELOFF	FL255	4523N 06210W	061	+24	3	1681	01	03+40	95	95	24891	32690	5700		459
25	SYDNEY		4609N 06003W	061	+24	100	1781	13	03+53	1444	1537	23447	31153	7205		467
26	CHECK PT		4652N 05630W	072	+25	153	1934	20	04+13	2188	2328	21259	28825	7090		465
27	ST JOHNS		4729N 05251W	074	+27	153	2087	20	04+33	2136	2274	19123	26551	5951		467
28	CK PT		4800N 05000W	073	+27	119	2206	15	04+48	1647	1759	17475	24792	6853		463
29	DESCEND		4900N 04547W	068	+28	178	2384	23	05+11	2447	2604	15029	22188	5734		460
30	LEVELOFF	FL240	4902N 04540W	071	+28	5	2389	01	05+12	15	15	15014	22173	900		452
31	CK PT		4910N 04500W	071	+28	27	2416	04	05+16	351	363	14653	21805	5309		452
32	AIR REFUELING CTL PT		4930N 04312W	073	+27	73	2489	10	05+26	963	1004	13700	20801	6275		455
33	START AAR 02		4936N 04235W	075	+27	25	2514	03	05+29	319	332	13331	20469	6225		455
34	NO.1 ABORT,OFF, 2 ON		4954N 04041W	075	+27	76	2590	10	05+39	989	1037	31598	19432	6222	19206	455
35	RP PT		5000N 04000W	076	+25	27	2617	04	05+43	402	361	31195	19071	5891		455
36	NO.2 ABORT,OFF, 3 ON		5001N 03844W	088	+25	49	2666	07	05+50	738	671	30453	18400	6812	17679	450
37	NO.3 ABORT,OFF, 4 ON		5001N 03647W	089	+25	75	2741	10	06+00	1132	1025	29326	17374	6792	16155	450
38	CK PT		5000N 03500W	090	+25	69	2810	09	06+09	1027	941	23299	16433	6698		450
39	NO.4 ABORT,OFF, 5 ON		5000N 03451W	088	+24	6	2816	01	06+10	78	72	28221	16361	5586	14665	452
40	NO.5 ABORT,OFF, 6 ON		5002N 03254W	088	+24	75	2891	10	06+20	1098	1003	27123	15358	6655	13164	452
41	NO. 6 ABORT,OFF.		5001N 03057W	089	+23	75	2966	10	06+30	1090	996	26033	26033	6606	11671	452
*****************										AVERAGE ONLOAD FOR AAR 2					15423	
42	LEVELOFF	FL255	5001N 03053W	091	+22	3	2969	01	06+31	95	95	25938	25938	5700		452
43			5000N 03000W	091	+22	34	3003	04	06+35	501	501	25437	25437	6832		460

12-02-86 2237Z ROUTE

ROUTE WIND FACTOR +011

LINE NBR	DATA POINT		COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL USED 1	FUEL USED 5	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
44	CK PT		5000N 02500W	098	+22	193	3196	25	07+00	2860	2860	22577	22577	6756		455
45	RP PT		5000N 02000W	098	+20	193	3389	25	07+25	2778	2778	19799	19799	6588		456
46	CK PT		5000N 01500W	098	+17	193	3582	26	07+51	2727	2727	17072	17072	6416		453
47	RP PT		5000N 01000W	098	+14	193	3775	26	08+17	2688	2688	14384	14384	6325		453
48	RP PT		5000N 00800W	089	+12	77	3852	10	08+27	1056	1056	13328	13328	6273		453
49	LANDS END		5008N 00538W	084	+11	91	3943	12	08+39	1245	1245	12083	12083	6225		452
50	YEOVILTON		5100N 00238W	064	+10	126	4069	17	08+56	1711	1711	10372	10372	6147		452
51	DOVER		5110N 00121E	084	+ 9	150	4219	20	09+16	2009	2009	8363	8363	6057		452
52	EBBU		5108N 00200E	094	+ 7	25	4244	03	09+19	330	330	8033	8033	6000		452
53	KOKSEY		5106N 00239E	094	+ 5	25	4269	03	09+22	328	328	7705	7705	5964		452
54	FLORENNES		5015N 00439E	123	+ 5	92	4361	12	09+34	1213	1213	6492	6492	5966		452
55	DESCEND		5004N 00613E	100	+ 5	61	4422	08	09+42	790	790	5702	5702	5925		452
56	NATTENHEIM		5001N 00632E	100	+ 4	13	4435	02	09+44	46	46	5656	5656	1533		434
57	HAHN	FLOOD	4957N 00716E	097	+ 4	29	4464	04	09+48	106	106	5550	5550	1551		444

ABORT BASES RECEIVER 1

*** AAR 1 ***

LINE NBR	DATA POINT		COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL USED 1	FUEL USED 5	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
	ABORT POINT		4243N 07329W				1144		02+28				10211			
15A	GRIFFIS		4314N 07524W	291	+12	89	1233	13	02+41		1191		9020	5333		398
15A	BINGO FUEL	3941														
15B	PEASE		4305N 07049W	078	+15	119	1263	15	02+44		1391		8820	5395		460
15B	BINGO FUEL	4141														
15C	BANGOR		4448N 06850W	056	+19	237	1381	31	02+59		2866		7345	5547		458
15C	BINGO FUEL	5616														

13-02-86 01402 ROUTE

ROUTE WIND FACTOR +012

RF-4C 2X370GAL 500CL PYLONS FOAM

FROM MCCONNELL

TO HAHN

TTF

BOOM TYPE REFUELING

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

TOTAL FUEL ONLOAD BY RECEIVER

RECVR 1	RECVR 2	RECVR 3	RECVR 4	RECVR 5	RECVR 6
50023	49974	49927	49867	49753	49549

MSN-TEMP-DEV +05C MAY CLIMATOLOGICAL WINDS 90 WORST PROB FACTOR

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL USED 1	FUEL USED 6	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
1	MCCONNELL	3737N 09716W									20200	20200			
2	START,TAXI,TAKEOFF	3737N 09716W							2215	2215	17985	17985			
3	LEVELOFF POINT FL290	3756N 09559W	074	- 3	54	64	09	00+09	2020	2020	15955	15955	13333		501
4	BUTLER VORTAC	3816N 09429W	073	- 7	73	137	09	00+18	1027	1027	14953	14958	7032		495
5	ST LOUIS VORTAC	3852N 09029W	077	- 5	191	328	23	00+41	2601	2601	12337	12337	6756		495
6	INDIANAPOLIS	3949N 08622W	072	- 3	199	527	24	01+05	2599	2599	9738	9738	6498		496
7	DESCEND	3952N 08556W	081	+ 0	20	547	02	01+07	254	254	9434	9434	5359		497
8	LEVELOFF FL280	3952N 08552W	08	0	3	550	01	01+08	10	10	9474	9474	1200		492
9	DAYTON	4001N 08424W	082	+ 0	58	518	08	01+16	838	838	8636	8636	6132		492
10	AIR REFUELING CTL PT	4021N 08351W	050	+ 0	32	550	04	01+20	397	397	8239	8239	6108		489
11	START AAR 01	4037N 08326W	051	+ 1	25	675	03	01+23	303	303	7935	7936	6050		489
12	NO.1 ABORT,OFF, 2 ON	4117N 08218W	051	+ 2	55	740	08	01+31	798	793	20200	7138	6061	13062	489
13	DRYER	4122N 08210W	052	+ 3	9	748	01	01+32	113	91	20087	7047	7533		489
14	NO.2 ABORT,OFF, 3 ON	4142N 08059W	069	+ 4	57	805	07	01+39	869	693	19218	6354	7557	13846	494
15	NO.3 ABORT,OFF, 4 ON	4204N 07936W	070	+ 5	65	870	08	01+47	978	781	18240	5573	7523	14627	494
16	JAMESTOWN	4211N 07907W	070	+ 7	23	893	03	01+50	322	271	17918	5302	7156		494
17	NO.4 ABORT,OFF, 5 ON	4218N 07811W	079	+ 8	42	935	05	01+55	608	504	17310	4798	7153	15402	487
18	NO.5 ABORT,OFF, 6 ON	4228N 07644W	080	+ 9	65	1000	08	02+03	950	790	16350	4008	7125	16192	487
19	NO. 6 ABORT,OFF. EAR	4237N 07517W	081	+10	65	1065	08	02+11	929	777	15431	20200	6958	16959	487

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AVERAGE ONLOAD FOR AAR 1 15016

13-02-86 0140Z ROUTE

ROUTE WIND FACTOR +012

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL USED 1	FUEL USED 6	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
20	LEVELOFF FL285	4237N 07513W	082	+12	3	1069	01	02+12	150	150	15231	20050	18000		487
21	ALBANY	4245N 07348W	082	+12	63	1131	08	02+20	876	954	14405	19096	7532		492
22	BOSTON	4221N 07100W	100	+13	126	1257	15	02+35	1700	1853	12705	17243	7363		498
23	YARMOUTH	4349N 06605W	056	+15	233	1490	29	03+04	3089	3325	9615	13918	7000		490
24	HALIFAX	4455N 06324W	059	+20	133	1623	16	03+20	1700	1808	7915	12110	6696		490
25	DESCEND	4535N 06138W	061	+23	85	1708	10	03+30	1074	1134	6842	10976	6542		492
26	LEVELOFF FL280	4537N 06134W	062	+24	3	1711	01	03+31	10	10	6832	10955	1200		487
27	SYDNEY	4609N 06003W	062	+24	71	1782	09	03+40	871	917	5951	10049	6324		487
28	AIR REFUELING CTL PT	4618N 05923W	072	+25	29	1811	04	03+44	351	363	5610	9686	6223		485
29	START AAR 02	4625N 05848W	072	+25	25	1836	03	03+47	301	305	5309	9380	6120		485
30	NO.1 ABORT,OFF, 2 ON	4643N 05718W	073	+25	65	1901	08	03+55	721	813	20210	8552	6135	15682	485
31	CHECK PT	4652N 05630W	074	+25	34	1935	04	03+59	522	427	19671	8135	7557		485
32	NO.2 ABORT,OFF, 3 ON	4700N 05546W	074	+27	31	1966	04	04+03	478	384	19103	7751	7547	15685	488
33	NO.3 ABORT,OFF, 4 ON	4716N 05413W	075	+27	65	2031	08	04+11	989	799	18204	6952	7511	15684	488
34	ST JOHNS	4729N 05251W	076	+27	57	2088	07	04+18	834	702	17370	6250	7149		488
35	NO.4 ABORT,OFF, 5 ON	4731N 05240W	073	+27	8	2096	01	04+19	107	90	17253	6150	7133	15658	484
36	NO.5 ABORT,OFF, 6 ON	4748N 05108W	074	+27	64	2160	08	04+27	936	791	16327	5359	7109	15646	484
37	CK PT	4800N 05000W	075	+28	47	2207	06	04+33	673	574	15654	4785	6962		484
38	NO. 6 ABORT,OFF. EAR	4836N 04936W	068	+28	17	2224	02	04+35	244	207	15410	20200	6971	15612	481

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AVERAGE ONLOAD FOR AAR 2 15666

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL USED 1	FUEL USED 6	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
39	LEVELOFF FL285	4837N 04932W	059	+23	3	2227	01	04+36	150	150	15250	20050	18000		481
40	DESCEND	4845N 04656W	069	+23	110	2337	14	04+50	1555	1707	13705	18343	7531		486
41	LEVELOFF FL280	4844N 04652W	071	+23	3	2340	01	04+51	10	10	13695	18333	1200		481
42	CK PT	4910N 04500W	071	+23	77	2417	10	05+01	1066	1145	12629	17138	7156		481
43	AIR REFUELING CTL PT	4715N 04426W	073	+22	23	2440	03	05+04	306	334	12323	16854	7157		484

x

13-02-85 0140Z ROUTE

ROUTE WIND FACTOR +012

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 5	FUEL FLOW	WIND OR ONLOAD	GS
44	START AAR 03	4923N 04349W	074	+27	25	2465	03	05+07	323	357	11995	16497	7140		484
45	NO.1 ABORT,OFF, 2 ON	4936N 04238W	074	+27	48	2513	06	05+13	639	685	20200	15811	6976	8844	484
46	NO.2 ABORT,OFF, 3 ON	4947N 04126W	075	+27	48	2561	06	05+19	743	685	19457	15125	7556	8626	484
47	NO.3 ABORT,OFF, 4 ON	4958N 04013W	076	+27	48	2609	06	05+25	743	675	18714	14450	7556	8403	484
48	RP PT	5000N 04000W	077	+25	9	2618	01	05+26	140	124	18574	14326	7636		484
49	NO.4 ABORT,OFF, 5 ON	5001N 03859W	088	+25	39	2657	05	05+31	587	541	17987	13785	7338	8194	479
50	NO.5 ABORT,OFF, 6 ON	5002N 03745W	088	+25	48	2705	05	05+37	715	675	17272	13109	7150	7968	479
51	NO. 6 ABORT,OFF. EAR	5001N 03630W	089	+25	48	2753	05	05+43	716	654	16556	20200	7160	7745	479
*****************									AVERAGE ONLOAD FOR AAR 3					8297	
52	LEVELOFF FL285	5001N 03625W	090	+25	3	2756	01	05+44	150	150	16406	20050	18000		479
53	CK PT	5000N 03500W	090	+25	55	2811	07	05+51	794	854	15612	19195	7535		484
54	DESCEND	5002N 03229W	098	+24	97	2908	12	06+03	1385	1483	14227	17713	7415		486
55	LEVELOFF FL280	5002N 03224W	090	+23	3	2911	01	06+04	10	10	14217	17703	1200		481
56		5000N 03000W	090	+23	93	3004	12	06+16	1301	1377	12916	16326	7122		481
57	AIR REFUELING CTL PT	5000N 02949W	088	+22	7	3011	01	06+17	93	93	12823	16233	6975		475
58	START AAR 04	5001N 02910W	088	+22	25	3036	03	06+20	339	360	12480	15873	6768		475
59	NO.1 ABORT,OFF, 2 ON	5002N 02757W	088	+22	47	3083	06	06+26	642	685	20200	15188	6966	8352	475
60	NO.2 ABORT,OFF, 3 ON	5001N 02644W	089	+21	47	3130	06	06+32	743	677	19457	14511	7556	8350	475
61	NO.3 ABORT,OFF, 4 ON	5001N 02531W	090	+20	47	3177	06	06+38	743	665	18714	13846	7556	8358	475
62	CK PT	5000N 02500W	091	+20	20	3197	03	06+41	316	282	18398	13564	7584		475
63	NO.4 ABORT,OFF, 5 ON	5001N 02418W	088	+20	27	3224	03	06+44	410	383	17988	13131	7235	8349	476
64	NO.5 ABORT,OFF, 6 ON	5002N 02305W	088	+19	47	3271	06	06+50	704	645	17234	12536	7159	8331	476
65	NO. 6 ABORT,OFF. EAR	5002N 02152W	089	+19	47	3318	06	06+56	704	643	16530	20200	7159	8307	476
*****************									AVERAGE ONLOAD FOR AAR 4					8341	
66	LEVELOFF FL285	5001N 02147W	090	+13	3	3321	01	06+57	150	150	16430	20050	18000		476

X UNCLASSIFIED X

13-02-86 01402 ROUTE

ROUTE WIND FACTOR +012

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL USED 1	FUEL USED 5	FUEL REMAIN 1	FUEL REMAIN 5	FUEL FLOW	WIND OR OVLOAD	GS
67	RP PT	5000N 02000W	090	+18	57	3390	09	07+06	1004	1080	15426	18970	7535		481
68	CK PT	5000N 01500W	088	+17	193	3583	24	07+30	2750	2932	12675	16038	7269		477
69	RP PT	5030N 01000W	098	+16	193	3776	24	07+54	2630	2779	10045	13259	6890		478
70	RP PT	5000N 00800W	039	+10	77	3853	10	08+04	1016	1063	9030	12195	6644		478
71	LANDS END	5008N 00538W	084	+11	91	3944	11	08+15	1193	1244	7837	10952	6547		476
72	DESCEND	5014N 00520W	064	+10	13	3957	02	08+17	166	173	7671	10779	6488		476
73	LEVELOFF FL280	5015N 00515W	064	+10	3	3960	01	08+18	10	10	7651	10769	1200		471
74	AIR REFUELING CTL PT	5056N 00252W	054	+10	100	4060	13	08+31	1279	1324	6332	9445	5255		471
75	YEOVILTON	5100N 00233W	057	+ 9	2	4062	01	08+32	110	113	6272	9332	5164		471
76	START AAR 05	5103N 00213W	084	+ 9	16	4035	02	08+34	201	205	6071	9127	6150		472
77	NO.1 ABORT,OFF, 2 ON	5106N 00033W	034	+ 8	53	4148	08	08+42	900	817	9354	8310	6128	4083	472
78	NO.2 ABORT,OFF, 3 ON	5110N 00108E	036	+ 8	63	4211	08	08+50	817	803	8537	7502	5128	3467	472
79	DOVER	5110N 00121E	087	+ 7	8	4219	01	08+51	102	101	8435	7401	6120		472
80	ERBU	5105N 00200E	074	+ 7	25	4244	03	08+54	314	313	8121	7088	6077		472
81	KOKSEY	5106N 00239E	094	+ 5	25	4269	03	08+57	313	313	7808	6775	6058		471
82	NO.3 ABORT,OFF, 4 ON	5103N 00246E	123	+ 5	5	4274	01	08+58	61	60	7747	6715	6100	2855	471
83	NO.4 ABORT,OFF, 5 ON	5028N 00409E	123	+ 5	63	4337	08	09+06	807	801	6940	5914	6053	2234	471
84	FLORENNES	5015N 00439E	124	+ 5	24	4361	03	09+09	301	301	6639	5613	6020		471
85	NO.5 ABORT,OFF, 6 ON	5008N 00539E	100	+ 5	39	4400	05	09+14	490	488	6149	5125	6000	1616	472
86	VATTENHEIM	5001N 00532E	100	+ 5	35	4435	04	09+18	440	435	5709	4690	5930		472
87	NO. 5 ABORT,OFF. EAR	4957N 00715E	077	+ 4	28	4463	04	09+22	349	345	5350	5360	5983	1016	472
******************															
	AVERAGE OVLOAD FOR AAR 5													2545	
88	HAHN	4957N 00716E	077	+ 4	1	4464	00	09+22	10	10	5350	5350	6000		472

ABORT PASES RECEIVED 1

x

12-02-86 2241Z ROUTE

ROUTE WIND FACTOR +013

F-16A / 5 2X370GAL; 300CLT

TOTAL FUEL ONLOAD BY RECEIVER

FLT LEVEL	1	2	3	4	5
ALT UPPER		320			
LOWER		300			
TAS		495			
CAS					

FROM MCCONVELL

TO HAHN

BUDDY

BOOM TYPE REFUELING

RECVR 1	RECVR 2	RECVR 3	RECVR 4
14364	14349	14343	14325
RECVR 5	RECVR 6		
14314	14303		

MSN-TEMP-DEV +05C   MAY CLIMATOLOGICAL WINDS   90 WORST PROB FACTOR

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 5	FUEL FLOW	WIND OR ONLOAD	GS
1	MCCONVELL	3737N 09716W									13732	13732			
2	START,TAXI,TAKEOFF	3737N 09716W							592	592	13140	13140			
3	LEVELOFF POINT FL300	3748N 09630W	074	- 3	38	33	05	00+05	631	631	12509	12509	7024		518
4	BUTLER VORTAC	3816N 09429W	073	- 3	99	137	12	00+17	592	592	11917	11917	3036		505
5	ST LOUIS VORTAC	3852N 09029W	077	- 5	191	329	23	00+40	1119	1119	10798	10798	2971		505
6	INDIANAPOLIS	3949N 08622W	072	- 5	199	527	24	01+04	1129	1129	9659	9659	2883		507
7	DAYTON	4001N 08424W	081	+ 0	91	618	11	01+15	505	505	9154	9154	2832		508
8	DRYER	4122N 08210W	050	+ 1	130	748	15	01+30	715	715	8449	8449	2786		505
9	JAMESTOWN	4211N 07907W	059	+ 4	145	893	17	01+47	775	775	7674	7674	2735		510
10	ALBANY	4245N 07348W	079	+ 8	238	1131	28	02+15	1262	1262	6412	6412	2676		503
11	BOSTON	4221N 07100W	100	+13	126	1257	15	02+30	648	648	5764	5764	2627		509
12	YARMOUTH	4349N 06605W	056	+15	233	1490	28	02+58	1199	1199	4565	4565	2578		500
13	HALIFAX	4455N 06324W	059	+20	133	1523	15	03+14	671	671	3894	3894	2532		501
14	SYDNEY	4609N 06003W	061	+23	159	1782	19	03+33	785	785	3109	3109	2492		503
15	START AAR 1	4616N 05931W	072	+25	23	1805	03	03+36	116	115	2993	2993	2486		501
16	NO.1 ABORT,OFF, 2 ON	4631N 05822W	072	+26	50	1855	06	03+42	243	243	13732	2750	2471	10982	501
17	NO.2 ABORT,OFF, 3 ON	4644N 05712W	073	+26	50	1905	05	03+48	307	240	13425	2510	3122	11222	501
18	CHECK PT	4652N 05630W	074	+27	30	1935	04	03+52	182	142	13243	2368	3120		501
19	NO.3 ABORT,OFF, 4 ON	4658N 05601W	074	+27	20	1955	02	03+54	120	94	13123	2274	3130	11458	503
20	NO.4 ABORT,OFF, 5 ON	4710N 05450W	075	+27	50	2005	06	04+00	305	239	12818	2035	3102	11697	503

12-02-86 22412 ROUTE

ROUTE WIND FACTOR +013

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 5	FUEL FLOW	WIND OR ONLOAD	GS
21	NO.5 ABORT,OFF, 6 ON	4722N 05339W	076	+27	50	2055	05	04+06	302	235	12516	1777	3071	11935	503
22	ST JOHNS	4729N 05251W	076	+27	38	2088	04	04+10	199	157	12317	1640	3062		503
23	NO. 6 ABORT,OFF.	4734N 05227W	073	+27	17	2105	02	04+12	102	81	12215	13732	3060	12173	500
*****************									AVERAGE ONLOAD FOR AAR 1					11578	
24	CK PT	4800N 05000W	074	+23	102	2207	12	04+24	612	634	11603	13098	3118		500
25	CK PT	4910N 04500W	068	+28	210	2417	25	04+49	1239	1287	10356	11811	3052		497
26	RP PT	5000N 04000W	073	+27	201	2618	24	05+13	1147	1189	9217	10622	2960		500
27	CK PT	5000N 03500W	088	+25	193	2811	23	05+36	1082	1112	8135	9503	2859		494
28		5000N 03000W	088	+24	193	3004	23	05+59	1052	1085	7083	8417	2797		496
29	CK PT	5000N 02500W	088	+22	193	3197	24	06+23	1038	1067	6045	7350	2724		491
30	RP PT	5000N 02000W	088	+20	193	3390	24	06+47	1017	1043	5028	6307	2663		491
31	CK PT	5000N 01500W	088	+17	193	3583	24	07+11	1006	1032	4022	5275	2613		489
32	RP PT	5000N 01000W	093	+14	193	3776	24	07+35	985	1009	3037	4256	2554		488
33	RP PT	5000N 00800W	089	+12	77	3853	09	07+44	386	395	2651	3872	2528		488
34	START AAR 2	5007N 00554W	084	+11	81	3934	10	07+54	406	417	2245	3453	2502		486
35	LANDS END	5008N 00538W	085	+10	10	3944	01	07+55	49	51	2196	3403	2500		486
36	NO.1 ABORT,OFF, 2 ON	5024N 00444W	064	+10	38	3982	05	08+00	186	170	5372	3213	2478	3382	486
37	NO.2 ABORT,OFF, 3 ON	5044N 00335W	065	+ 9	48	4030	06	08+06	254	243	5138	2970	2583	3127	486
38	YEOVILTON	5100N 00238W	065	+ 9	40	4070	05	08+11	209	202	4929	2768	2559		486
39	NO.3 ABORT,OFF, 4 ON	5101N 00225W	084	+ 9	8	4078	01	08+12	35	37	4891	2731	2533	2885	487
40	NO.4 ABORT,OFF, 5 ON	5105N 00109W	084	+ 8	48	4126	06	08+18	252	241	4659	2491	2563	2628	487
41	NO.5 ABORT,OFF, 6 ON	5108N 00007E	085	+ 5	48	4174	05	08+24	249	241	4390	2251	2532	2379	487
42	DOVER	5110N 00121E	086	+ 7	45	4220	06	08+30	236	227	4154	2024	2529		487
43	NO. 6 ABORT,OFF.	5110N 00124E	094	+ 7	2	4222	00	08+30	8	3	4145	4145	2400	2130	487
*****************									AVERAGE ONLOAD FOR AAR 2					2755	

12-02-86 2241Z ROUTE — ROUTE WIND FACTOR +013

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL 1	REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
44	EBBU	5108N 00200E	094	+ 7	23	4245	03	08+33	118	118	4028	4028	2529		487
45	KOKSEY	5106N 00239E	094	+ 5	25	4270	03	08+36	126	126	3902	3902	2520		487
46	FLORENNES	5015N 00439E	123	+ 5	92	4362	11	08+47	471	471	3431	3431	2501		485
47	DESCEND	5003N 00616E	100	+ 5	63	4425	08	08+55	318	318	3113	3113	2478		487
48	HATTENHEIM	5001N 00632E	100	+ 4	11	4436	03	08+58	36	36	3077	3077	864		266
49	HAHN FL000	4957N 00716E	077	+ 4	29	4465	07	09+05	97	97	2930	2930	859		487

ABORT BASES RECEIVER 1

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL 1	REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
*** AAR 1 ***															
	ABORT POINT	4631N 05922W				1855		03+42				2750			
15A	STEPHENVILLE	4833N 05833W	356	+23	122	1977	15	03+57		614		2136	2440		483
15A	BINGO FUEL 2070														
15B	GANDER	4856N 05434W	045	+29	211	2066	26	04+08		1033		1717	2431		495
15B	BINGO FUEL 2498														
15C	ST JOHNS	4737N 05245W	071	+23	238	2093	29	04+11		1157		1523	2427		498
15C	BINGO FUEL 2622														
*** AAR 2 ***															
	ABORT POINT	5024N 00444W				3982		08+00				2010			
36A	ST MAWGANS	5026N 00500W	280	+10	10	3992	01	08+01		53		1957	2446		443
36A	BINGO FUEL 1518														
36B	BOSCOMBE-DOWN	5113N 00144W	056	+ 3	122	4104	15	08+15		603		1407	2412		486
36B	BINGO FUEL 2069														

12-02-86 2240Z ROUTE

ROUTE WIND FACTOR +013

F-15C/D 3X510TNKS

TOTAL FUEL ONLOAD BY RECEIVER

FLT LEVEL	1	2	3	4	5
ALT UPPER		320			
LOWER		300			
TAS		485			
CAS					

FROM MCCONNELL
TO HAHN
BOOM TYPE REFUELING

BUDDY

RECVR 1	RECVR 2	RECVR 3	RECVR 4	RECVR 5	RECVR 6
41361	41408	41332	41225	41149	41180

MSN-TEMP-DEV +05C MAY CLIMATOLOGICAL-WINDS 90 WORST PROB FACTOR

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 6	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
1	MCCONNELL	3737N 09716W									25800	25800			
2	START,TAXI,TAKEOFF	3737N 09716W							2500	2500	23300	23300			
3	LEVELOFF POINT FL300	3749N 09526W	074	- 3	41	41	07	00+07	1800	1800	21500	21500	16615		518
4	BUTLER VORTAC	3816N 09429W	073	- 3	96	137	11	00+18	1315	1315	20185	20185	6921		505
5	ST LOUIS VORTAC	3852N 09029W	077	- 5	191	328	23	00+41	2570	2570	17615	17615	6823		506
6	INDIANAPOLIS	3949N 08522W	072	- 3	199	527	24	01+05	2619	2619	14996	14996	6587		507
7	DAYTON	4001N 08424W	081	+ 0	91	518	11	01+16	1182	1182	13814	13814	6528		508
8	DRYER	4122N 08210W	050	+ 0	130	748	15	01+31	1681	1681	12133	12133	6549		505
9	JAMESTOWN	4211N 07907W	069	+ 4	145	893	17	01+48	1834	1834	10299	10299	6473		510
10	START AAR 1	4225N 07708W	079	+ 8	89	982	11	01+59	1136	1136	9163	9163	6430		503
11	NO.1 ABORT,OFF, 2 ON	4236N 07528W	081	+10	75	1057	09	02+08	992	992	25800	8171	6688	17629	503
12	ALBANY	4245N 07343W	082	+12	74	1131	09	02+17	1049	987	24751	7184	7152		503
13	NO.2 ABORT,OFF, 3 ON	4245N 07347W	100	+13	1	1132	00	02+17	13	10	24738	7174	7800	18626	509
14	NO.3 ABORT,OFF, 4 ON	4231N 07205W	100	+13	76	1208	09	02+26	1055	873	23683	6296	7112	19504	509
15	BOSTON	4221N 07100W	101	+15	49	1257	06	02+32	668	564	23015	5732	7032		509
16	NO.4 ABORT,OFF, 5 ON	4232N 07026W	066	+15	27	1284	03	02+35	376	331	22640	5402	7031	20398	500
17	NO.5 ABORT,OFF, 6 ON	4301N 06852W	066	+15	75	1359	09	02+44	1045	927	21595	4475	6967	21325	500
18	NO. 6 ABORT,OFF.	4329N 06717W	067	+13	75	1434	09	02+53	1041	927	20554	25800	6949	22252	500
******************											AVERAGE ONLOAD FOR AAR 1			19956	
19	YARMOUTH	4349N 06605W	068	+19	56	1490	07	03+00	768	799	19786	25001	7155		500

12-02-86 2240Z ROUTE

ROUTE WIND FACTOR +013

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 5	FUEL FLOW	WIND OR ONLOAD	GS
44	NO.2 ABORT,OFF, 3 ON	5030N 00424W	054	+10	52	3996	05	08+03	687	684	10119	6953	5441	6774	486
45	NO.3 ABORT,OFF, 4 ON	5059N 00240W	055	+ 2	72	4069	09	08+12	943	868	9176	6095	6430	5819	486
46	YEOVILTON	5100N 00238W	056	+ 2	2	4070	00	08+12	21	21	9155	6074	6300		486
47	NO.4 ABORT,OFF, 5 ON	5106N 00047W	084	+ 9	70	4140	09	08+21	958	872	8197	5202	6654	4838	487
48	NO.5 ABORT,OFF, 6 ON	5110N 00108E	086	+ 3	72	4212	09	08+30	989	905	7203	4295	5743	3831	487
49	DOVER	5110N 00121E	087	+ 7	8	4220	01	08+31	98	88	7120	4208	5867		487
50	EBBU	5108N 00200E	094	+ 7	25	4245	03	08+34	296	309	6824	3899	6180		487
51	KOKSEY	5106N 00239E	094	+ 5	25	4270	03	08+37	296	309	6528	3590	6180		487
52	NO. 6 ABORT,OFF.	5058N 00258E	123	+ 5	14	4284	02	08+39	167	175	6351	6351	5176	2946	486
*****************										AVERAGE ONLOAD FOR AAR 3				5323	
53	FLORENNES	5015N 00439E	123	+ 5	78	4362	10	08+49	961	961	5400	5400	6006		486
54	DESCEND	5004N 00513E	100	+ 5	61	4423	08	08+57	772	772	4628	4628	6176		487
55	WATTENHEIM	5001N 00632E	100	+ 4	13	4436	03	09+00	114	114	4514	4514	2533		291
56	HAHN FL000	4957N 00716E	097	+ 4	29	4465	05	09+06	264	264	4250	4250	2555		487

ABORT BASES RECEIVED 1

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	USED 5	FUEL REMAIN 5	FUEL FLOW	GS
*** AAR 1 ***												
	ABORT POINT	4236N 07528W				1357		02+03		5171		
11A	GRIFFIS	4314N 07524W	003	+12	38	1395	05	02+13	520	7651	5783	486
11A	BINGO FUEL 2620											
11B	PEASE	4305N 07049W	080	+15	235	1253	24	02+32	2530	5641	6221	505
11B	BINGO FUEL 4630											
11C	BANGOR	4448N 06850W	053	+12	315	1373	38	02+46	3890	4231	6207	504
11C	BINGO FUEL 5990											

12-02-86 22437 ROUTE

ROUTE WIND FACTOR +013

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL 1	REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
20	HALIFAX	4455N 06324W	059	+20	133	1623	16	03+16	1808	1880	17975	23121	7094		501
21	SYDNEY	4619N 06003W	051	+23	157	1782	19	03+35	2116	2195	15852	20925	5971		503
22	CHECK PT	4652N 05530W	072	+25	153	1935	18	03+53	2023	2093	13839	18827	6879		501
23	ST JOHNS	4729N 05251W	074	+27	153	2088	18	04+11	1984	2042	11855	16778	6755		503
24	START AAR 2	4752N 05049W	073	+27	85	2173	10	04+21	1102	1136	10753	15642	6652		500
25	CK PT	4800N 05100W	075	+27	34	2207	04	04+25	431	444	10322	15178	5650		500
26	NO.1 ABORT,OFF, 2 ON	4815N 04903W	068	+28	41	2248	05	04+30	526	541	25800	14657	6624	16004	497
27	NO.2 ABORT,OFF, 3 ON	4840N 04713W	069	+28	74	2322	09	04+39	1061	981	24739	13676	7153	16008	497
28	NO.3 ABORT,OFF, 4 ON	4903N 04531W	070	+28	74	2396	09	04+48	1056	972	23683	12704	7119	16009	497
29	CK PT	4913N 04500W	072	+27	21	2417	03	04+51	294	274	23389	12430	7056		497
30	NO.4 ABORT,OFF, 5 ON	4926N 04342W	073	+27	53	2470	06	04+57	738	684	22651	11746	7029	15989	500
31	NO.5 ABORT,OFF, 6 ON	4943N 04150W	074	+27	75	2545	09	05+06	1045	972	21606	10774	6967	15993	500
32	RP PT	5000N 04000W	076	+27	73	2618	09	05+15	1006	934	20600	9840	6938		500
33	NO. 6 ABORT,OFF.	5000N 03957W	083	+25	2	2620	00	05+15	24	22	20575	25800	7200	15982	494

******************* AVERAGE ONLOAD FOR AAR 2 15998

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL 1	REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
34	CK PT	5000N 03500W	088	+25	191	2811	23	05+38	2633	2735	17943	23054	7106		494
35		5000N 03000W	088	+24	193	3004	23	06+01	2604	2701	15339	20353	5955		496
36	CK PT	5000N 02500W	088	+22	193	3197	24	06+25	2582	2674	12757	17639	5827		491
37	RP PT	5000N 02000W	088	+20	193	3390	24	06+49	2542	2621	10215	15058	6692		491
38	CK PT	5000N 01500W	088	+17	193	3583	24	07+13	2606	2601	7609	12457	6597		488
39	RP PT	5000N 01000W	088	+14	193	3776	24	07+37	2408	2559	5201	9908	6478		488
40	START AAR 3	5000N 00803W	089	+12	75	3851	09	07+46	948	983	4253	8925	5411		488
41	RP PT	5000N 00800W	090	+11	2	3853	00	07+46	21	23	4232	8902	6900		488
42	NO.1 ABORT,OFF, 2 ON	5006N 00610W	084	+11	71	3924	09	07+55	896	983	11054	7919	6779	7728	486
43	LANDS END	5003N 00538W	085	+10	20	3944	02	07+57	258	272	10836	7647	6800		486

12-02-86 2241Z ROUTE

ROUTE WIND FACTOR +010

FLT LEVEL	1	2	3	4	5
ALT UPPER		260			
LOWER		240			
TAS		443			

CAS 305

F-111D 4 PYLONS
5

FROM MCCONNELL

TO HAHN Buddy

BOOM TYPE REFUELING

TOTAL FUEL ONLOAD BY RECEIVER

RECVR 1	RECVR 2	RECVR 3	RECVR 4
40677	40389	40208	40018
RECVR 5	RECVR 6		
39835	39552		

MSN-TEMP-DEV +05C MAY CLIMATOLOGICAL WINDS 90 WORST PROB FACTOR

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
1	MCCONNELL	3737N 09716W									30500	30500			
2	START,TAXI,TAKEOFF	3737N 09716W							3830	3830	26670	26670			
3	LEVELOFF POINT FL240	3754N 09606W	074	-3	58	58	08	00+08	1650	1650	25020	25020	12375		467
4	BUTLER VORTAC	3816N 09429W	073	-2	79	137	10	00+18	1112	1112	23908	23908	5478		460
5	ST LOUIS VORTAC	3852N 09029W	077	-5	191	328	25	00+43	2637	2637	21271	21271	5354		460
6	INDIANAPOLIS	3949N 08622W	072	-3	199	527	26	01+09	2672	2672	18599	18599	5214		462
7	DAYTON	4001N 08424W	081	+0	91	618	12	01+21	1212	1212	17387	17387	6163		462
8	DRYER	4122N 08210W	050	+0	130	748	17	01+38	1720	1720	15667	15667	5137		459
9	JAMESTOWN	4211N 07907W	069	+4	145	893	17	01+57	1881	1881	13786	13786	6335		463
10	START AAR 1	4235N 07538W	079	+8	156	1049	20	02+17	2043	2043	11743	11743	6009		458
11	ALBANY	4245N 07343W	082	+11	82	1131	11	02+28	1134	1134	10609	10609	6359		458
12	NO.1 ABORT,OFF, 2 ON	4241N 07315W	130	+13	25	1156	03	02+31	304	304	32735	10305	5700	22480	464
13	BOSTON	4221N 07100W	110	+14	101	1257	13	02+44	1425	1142	31200	9163	6900		464
14	NO.2 ABORT,OFF, 3 ON	4224N 07051W	056	+16	7	1264	01	02+45	105	85	31135	9077	7000	23708	456
15	NO.3 ABORT,OFF, 4 ON	4305N 06938W	066	+15	105	1370	14	02+59	1573	1327	29607	7750	6812	25035	456
16	NO.4 ABORT,OFF, 5 ON	4344N 06623W	067	+18	105	1476	14	03+13	1558	1313	28049	5437	5725	26348	456
17	YARMOUTH	4349N 06605W	069	+20	14	1490	02	03+15	202	170	27847	6267	6733		456
18	NO.5 ABORT,OFF, 6 ON	4435N 06414W	059	+20	92	1582	12	03+27	1336	1134	26511	5133	6625	27652	456
19	HALIFAX	4455N 06324W	060	+22	41	1623	05	03+32	583	494	25928	4639	6600		456
20	NO. 6 ABORT,OFF.	4526N 06203W	061	+23	65	1688	09	03+41	924	791	25004	32735	5522	28937	458

12-02-86 22412 ROUTE

ROUTE WIND FACTOR +010

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL REMAIN 1	FUEL REMAIN 5	FUEL FLOW	WIND OR ONLOAD	GS
*****************									AVERAGE ONLOAD FOR AAR 1					25693	
21	SYDNEY	4539N 05903W	052	+24	94	1782	12	03+53	1326	1414	23678	31371	6898		458
22	CHECK PT	4552N 05630W	072	+25	153	1935	20	04+13	2129	2279	21549	29092	6803		456
23	ST JOHNS	4720N 05251W	074	+27	153	2088	20	04+33	2050	2224	19459	26858	6672		458
24	CK PT	4830N 05000W	073	+27	119	2207	15	04+49	1618	1719	17851	25149	6569		454
25	CK PT	4910N 04500W	068	+23	210	2417	28	05+17	2525	2975	15023	22174	6421		452
26	START AAR 2	4942N 04156W	073	+27	124	2541	16	05+33	1642	1715	13381	20459	6274		455
27	NO.1 ABORT,OFF, 2 ON	5000N 04301W	076	+27	75	2517	10	05+43	989	1037	30539	19422	5222	18197	455
28	RP PT	5003N 04300W	076	+25	1	2518	00	05+43	11	11	30578	19411	6600		455
29	NO.2 ABORT,OFF, 3 ON	5012N 03803W	088	+25	75	2593	10	05+53	1133	1032	29445	18379	6798	16681	449
30	NO.3 ABORT,OFF, 4 ON	5011N 03507W	089	+25	75	2768	10	06+03	1119	1025	28325	17353	6714	15173	449
31	CK PT	5000N 03500W	091	+25	43	2811	05	06+09	637	554	27639	16759	5705		449
32	NO.4 ABORT,OFF, 5 ON	5001N 03410W	039	+24	32	2843	04	06+13	463	423	27225	16341	6614	13670	452
33	NO.5 ABORT,OFF, 6 ON	5002N 03214W	089	+24	75	2918	10	06+23	1091	1003	26135	15338	6612	12183	452
34	NO. 6 ABORT,OFF.	5000N 03017W	090	+23	75	2993	10	06+33	1078	996	25057	25057	6533	10715	452
*****************									AVERAGE ONLOAD FOR AAR 2					14437	
35		5000N 03000W	091	+22	11	3004	01	06+34	152	152	24905	24905	5514		452
36	CK PT	5000N 02500W	088	+22	193	3197	26	07+00	2767	2767	22138	22138	6410		447
37	RP PT	5000N 02000W	035	+20	193	3390	26	07+26	2688	2688	19450	19450	6251		448
38	CK PT	5000N 01500W	085	+17	193	3583	26	07+52	2671	2671	16779	16779	5154		445
39	RP PT	5000N 01000W	088	+14	193	3776	26	08+18	2626	2625	14153	14153	6060		445
40	RP PT	5000N 00830W	089	+12	77	3853	10	08+23	1027	1027	13126	13126	5983		445
41	LANDS END	5005N 00535W	084	+11	91	3944	12	08+40	1213	1213	11908	11908	5990		444
42	YEOVILTON	5100N 00238W	054	+10	126	4070	17	08+57	1737	1737	10171	10171	5131		444
43	DOVER	5110N 00121E	084	+ 9	150	4220	20	09+17	1841	1841	8330	8330	5468		444

12-02-86 2241Z ROUTE

ROUTE WIND FACTOR +010

LINE NBR	DATA POINT		COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 6	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
44	EBBU		5138N 00200E	074	+ 7	25	4245	03	09+20	314	314	8016	8016	5709		444
45	KOKSEY		5106N 00239E	074	+ 5	25	4270	03	09+23	314	314	7702	7702	5709		444
46	FLORENNES		5015N 00439E	123	+ 5	92	4362	12	09+35	1170	1170	6532	6532	5651		444
47	DESCEND		5002N 00622E	100	+ 5	67	4429	09	09+44	844	844	5638	5688	5627		444
48	NATTENHEIM		5001N 00632E	100	+ 4	7	4436	01	09+45	26	26	5652	5652	1733		468
49	HAHN	FLOOD	4957N 00716E	097	+ 4	29	4465	04	09+49	112	112	5550	5550	1680		444

ABORT BASES RECEIVER 1

LINE NBR	DATA POINT		COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 6	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
	*** AAR 1 ***															
	ABORT POINT		4241N 07315W				1156		02+31				10335			
12A	PEASE		4305N 07049W	076	+15	109	1265	14	02+45		1259		9046	5320		460
12A	BINGO FUEL	4009														
12B	BANGOR		4448N 06850W	054	+19	229	1385	30	03+01		2753		7540	5530		458
12B	BINGO FUEL	5515														
12C	SHEARWATER		4438N 06330W	071	+23	438	1594	58	03+29		5350		4955	5583		457
12C	BINGO FUEL	8100														
	*** AAR 2 ***															
	ABORT POINT		5000N 04001W				2617		05+43				12392			
27A	ST JOHNS		4737N 05245W	259	+28	522	3139	1 19	07+02		7553		4839	5736		396
27A	BINGO FUEL	10303														
27B	LAJES		3846N 02706W	135	+17	859	3486	1 57	07+40		10979		1413	5650		447
27B	BINGO FUEL	13729														

12-02-86 2239Z ROUTE

ROUTE WIND FACTOR +012

FLT LEVEL	1	2	3	4	5
ALT UPPER		300			
LOWER		280			
TAS		470			

CAS 305

RF-4C 2X370WT600CL PYLONS FOAM

FROM MCCONNELL

TO HAHN BUDDY

BOOM TYPE REFUELING

TOTAL FUEL ONLOAD BY RECEIVER

RECVR 1	RECVR 2	RECVR 3	RECVR 4	RECVR 5	RECVR 6
47661	49532	49610	49573	49546	49500

MSN-TEMP-DEV +05C MAY CLIMATOLOGICAL WINDS 90 WORST PROB FACTOR

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 6	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
1	MCCONNELL	3737N 09716W									20200	20200			
2	START,TAXI,TAKEOFF	3737N 09716W							2215	2215	17985	17985			
3	LEVELOFF POINT FL280	3755N 09502W	074	- 3	51	61	09	00+09	1870	1870	16115	16115	13062		500
4	BUTLER VORTAC	3914N 09429W	073	- 7	75	137	09	00+18	1080	1080	15035	15035	5958		489
5	ST LOUIS VORTAC	3852N 09029W	077	- 5	191	328	23	00+41	2608	2608	12427	12427	5716		490
6	INDIANAPOLIS	3949N 08622W	072	- 3	199	527	24	01+05	2589	2589	9838	9838	5393		491
7	DAYTON	4001N 08424W	081	+ 0	91	618	11	01+16	1124	1124	8714	8714	6131		492
8	START AAR 1	4039N 08323W	050	+ 0	60	678	07	01+23	752	752	7962	7962	5097		489
9	NO.1 ABORT,OFF, 2 ON	4119N 08215W	051	+ ?	65	743	08	01+31	799	799	20200	7163	6068	13037	489
10	DRYER	4122N 08210W	052	+ 4	5	748	01	01+32	76	61	20124	7102	7600		489
11	NO.2 ABORT,OFF, 3 ON	4143N 08055W	069	+ 4	60	808	07	01+39	920	733	19204	6369	7562	13831	493
12	NO.3 ABORT,OFF, 4 ON	4205N 07933W	070	+ 5	65	873	08	01+47	989	791	18215	5578	7511	14622	493
13	JAMESTOWN	4211N 07907W	070	+ 7	20	893	02	01+49	286	244	17929	5334	7150		493
14	NO.4 ABORT,OFF, 5 ON	4219N 07807W	079	+ 8	45	938	06	01+55	656	543	17273	4791	7156	15409	487
15	NO.5 ABORT,OFF, 6 ON	4229N 07640W	080	+ 9	65	1003	08	02+03	949	790	16324	4001	7118	16199	487
16	NO. 6 ABORT,OFF.	4237N 07513W	081	+10	65	1068	08	02+11	929	773	15395	20200	6968	16977	487
*****************									AVERAGE ONLOAD FOR AAR 1					15013	
17	ALBANY	4245N 07348W	082	+12	63	1131	08	02+19	886	970	14509	19230	7558		487
18	BOSTON	4221N 07100W	100	+13	126	1257	15	02+34	1713	1873	12796	17357	7345		493
19	YARMOUTH	4349N 06605W	056	+16	233	1490	29	03+03	3071	3341	9725	14016	5960		485

12-02-86 2239Z ROUTE

ROUTE WIND FACTOR +012

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL USED 1	FUEL USED 5	FUEL REMAIN 1	FUEL REMAIN 5	FUEL FLOW	WIND OR ONLOAD	GS
20	HALIFAX	4455N 06324W	059	+20	133	1623	16	03+19	1672	1817	8053	12199	6648		485
21	SYDNEY	4609N 06003W	061	+23	159	1782	20	03+39	1962	2078	6091	10121	6394		487
22	START AAR 2	4626N 05846W	072	+25	56	1838	07	03+46	691	712	5400	9409	6191		485
23	NO.1 ABORT,OFF, 2 ON	4644N 05715W	073	+25	55	1893	08	03+54	791	813	20200	8591	6135	15591	485
24	CHECK PT	4652N 05630W	074	+25	42	1935	04	03+58	491	397	19739	8194	7554		485
25	NO.2 ABORT,OFF, 3 ON	4701N 05543W	074	+27	33	1968	04	04+02	504	405	19235	7789	7560	15594	487
26	NO.3 ABORT,OFF, 4 ON	4717N 05410W	075	+27	65	2033	08	04+10	1002	809	18233	6980	7515	15603	487
27	ST JOHNS	4729N 05251W	076	+27	55	2088	07	04+17	799	672	17434	6308	7155		487
28	NO.4 ABORT,OFF, 5 ON	4732N 05237W	073	+27	10	2098	01	04+18	144	120	17290	6188	7200	15602	483
29	NO.5 ABORT,OFF, 6 ON	4749N 05105W	074	+27	64	2162	08	04+26	937	791	16323	5397	7116	15593	483
30	CK PT	4800N 05000W	075	+23	45	2207	06	04+32	639	544	15684	4853	6971		483
31	NO. 6 ABORT,OFF.	4807N 04933W	058	+23	19	2226	02	04+34	267	223	15417	20200	6955	15575	481
*****************									AVERAGE ONLOAD FOR AAR 2					15593	
32	CK PT	4910N 04500W	059	+23	191	2417	24	04+58	2687	2937	12730	17263	7404		481
33	START AAR 3	4924N 04343W	073	+27	52	2469	06	05+04	697	762	12033	16501	7144		484
34	NO.1 ABORT,OFF, 2 ON	4937N 04232W	074	+27	48	2517	06	05+10	640	685	20200	15816	6966	8807	484
35	NO.2 ABORT,OFF, 3 ON	4948N 04120W	075	+27	48	2565	06	05+16	743	635	19457	15130	7556	8590	484
36	NO.3 ABORT,OFF, 4 ON	4959N 04007W	076	+27	48	2613	06	05+22	743	675	18714	14454	7556	8363	484
37	RP PT	5000N 04000W	077	+25	5	2618	01	05+23	77	68	18637	14386	7700		484
38	NO.4 ABORT,OFF, 5 ON	5001N 03853W	088	+25	43	2661	05	05+28	650	597	17937	13739	7358	8146	478
39	NO.5 ABORT,OFF, 6 ON	5002N 03738W	088	+25	48	2709	06	05+34	715	675	17272	13113	7150	7941	478
40	NO. 6 ABORT,OFF.	5001N 03624W	089	+25	48	2757	06	05+40	716	655	16556	20200	7160	7742	478
*****************									AVERAGE ONLOAD FOR AAR 3					8265	
41	CK PT	5000N 03500W	090	+25	54	2811	07	05+47	779	844	15777	19356	7558		478
42		5000N 03000W	088	+24	193	3004	24	06+11	2742	2925	13035	16430	7285		480

12-02-86 22392 ROUTE | ROUTE WIND FACTOR +012

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL USED 1	FUEL USED 6	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
43	START AAR 4	5001N 02859W	038	+22	39	3243	05	06+16	534	569	12501	15851	6967		475
44	NO.1 ABORT,OFF, 2 ON	5002N 02746W	038	+22	47	3290	06	06+22	643	685	20200	15175	6976	8342	475
45	NO.2 ABORT,OFF, 3 ON	5001N 02633W	089	+21	47	3137	05	06+29	743	677	19457	14498	7556	8339	475
46	NO.3 ABORT,OFF, 4 ON	5000N 02520W	090	+20	47	3184	05	06+34	743	665	19714	13833	7556	8342	475
47	CK PT	5000N 02500W	091	+20	13	3197	02	06+36	203	190	18511	13653	7613		475
48	NO.4 ABORT,OFF, 5 ON	5001N 02407W	088	+20	34	3231	04	06+40	512	473	17999	13190	7314	8330	476
49	NO.5 ABORT,OFF, 6 ON	5002N 02254W	088	+19	47	3278	05	06+45	703	645	17295	12534	7149	8321	476
50	NO. 6 ABORT,OFF.	5001N 02141W	089	+18	47	3325	06	06+52	703	643	16593	20200	7149	8309	476

****

AVERAGE ONLOAD FOR AAR 4 8331

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL USED 1	FUEL USED 6	FUEL REMAIN 1	FUEL REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
51	RP PT	5000N 02000W	090	+18	65	3390	08	07+00	943	1020	15650	19180	7556		476
52	CK PT	5000N 01500W	088	+17	193	3583	25	07+25	2777	2953	12873	16222	7244		472
53	RP PT	5000N 01000W	088	+14	193	3776	24	07+49	2615	2791	10258	13431	6863		473
54	RP PT	5000N 00500W	089	+12	77	3853	10	07+59	1092	1067	9256	12364	6600		473
55	LANDS END	5008N 00538W	034	+11	91	3944	12	08+11	1172	1241	8084	11123	6475		471
56	YEOVILTON	5100N 00238W	054	+10	126	4070	16	08+27	1613	1672	6471	9451	5270		471
57	START AAR 5	5101N 00213W	084	+ 9	16	4086	02	08+29	200	204	6271	9247	6120		472
58	NO.1 ABORT,OFF, 2 ON	5106N 00033W	084	+ 8	63	4149	08	08+37	801	817	9354	8430	6128	3884	472
59	NO.2 ABORT,OFF, 3 ON	5110N 00108E	086	+ 8	63	4212	08	08+45	817	809	8537	7621	6128	3278	472
60	DOVER	5110N 00121E	087	+ 7	8	4220	01	08+46	102	101	8435	7520	6120		472
61	ERBU	5108N 00270E	094	+ 7	25	4245	03	08+49	314	313	8121	7207	6077		472
62	KOKSEY	5106N 00239E	094	+ 6	25	4270	03	08+52	313	313	7808	6894	6058		471
63	NO.3 ABORT,OFF, 4 ON	5103N 00246E	123	+ 6	5	4275	01	08+53	61	59	7747	6835	6100	2680	471
64	NO.4 ABORT,OFF, 5 ON	5028N 00409E	123	+ 6	63	4338	08	09+01	807	800	6940	6035	6053	2086	471
65	FLORENNES	5015N 00439E	124	+ 5	24	4362	03	09+04	301	301	6639	5734	6020		471
66	NO.5 ABORT,OFF, 6 ON	5008N 00539E	100	+ 5	39	4401	05	09+09	490	490	6149	5244	6000	1492	472

12-02-86 22392 ROUTE

ROUTE WIND FACTOR +012

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL 1	REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
67	NATTENHEIM	5001N 00532E	100	+ 5	35	4436	04	09+13	440	435	5739	4839	6000		472
63	NO. 5 ABORT/OFF.	4957N 00715E	097	+ 5	28	4464	04	09+17	349	345	5350	5350	5983	897	472
******************									AVERAGE ONLOAD FOR AAR 5					2386	
69	HAHN	4957N 00716E	097	+ 5	1	4465	00	09+17	10	10	5350	5350	6000		472

ABORT BASES RECEIVER 1

LINE NBR	DATA POINT	COORDINATES	TRUE CRS	MAG VAR	DISTANCE LEG	DISTANCE TOTAL	TIME LEG	TIME TOTAL	FUEL 1	USED 5	FUEL 1	REMAIN 6	FUEL FLOW	WIND OR ONLOAD	GS
	*** AAR 1 ***														
	ABORT POINT	4119N 08215W				743		01+31				2153			
9A	RICKENBACKER	3949N 08256W	199	+ 2	95	338	13	01+44		1275		5838	5024		445
9A	BINGO FUEL 4025														
9B	GRIFFIS	4314N 07524W	057	+12	325	1068	40	02+11		3983		3180	5945		485
9B	BINGO FUEL 6733														
	*** AAR 2 ***														
	ABORT POINT	4544N 05715W				1203		03+54				4609			
23A	STEPHENVILLE	4833N 05833W	334	+28	121	2024	15	04+19		1583		3026	5863		447
23A	BINGO FUEL 4333														
23B	ST JOHNS	4737N 05245W	072	+23	190	2093	24	04+15		2297		2312	5840		482
23B	BINGO FUEL 5047														
	*** AAR 3 ***														
	ABORT POINT	4937N 04232W				2517		05+10				11393			
34A	ST JOHNS	4737N 05245W	257	+23	422	2939	1 01	06+11		6222		5171	6120		415
34A	BINGO FUEL 8972														

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 accessable 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 unaccessable because of update or if a particular MDS is being updated and not accessable 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.

OO
LZ
Modas

G063

KC010A - Maintainability Report #4
For Nov 85
* All Systems *
Ranked by
Latest 3 Month MH/FH (Unscheduled Manhours) [illegible]

05 MAR 1986

Rank	Wuc	Noun	# Failures	3 Month Manhours	MH/Failure	3 Month MH/FH	Ranking Factor
1	46***	System 46	[illegible]	4198.1	22.616	0.64927	100.00
2	23***	System 23	[illegible]	2392.9	18.126	0.37008	57.00
3	71***	System 71	141	1556.7	11.040	0.24076	37.08
4	14***	System 14	57	1308.0	[illegible]	0.20229	31.16
5	13***	System 13	[illegible]	1034.8	[illegible]	0.16004	24.65
6	52***	System 52	[illegible]	896.0	[illegible]	0.13857	21.34
7	24***	System 24	[illegible]	876.6	[illegible]	0.13557	20.88
8	44***	System 44	111	832.3	7.498	0.12872	19.83
9	45***	System 45	49	761.8	15.547	0.11782	18.15
10	41***	System 41	37	549.2	14.843	0.08494	13.08
11	64***	System 64	77	459.2	5.964	0.07102	10.94
12	51***	System 51	55	459.0	6.275	0.07099	10.93
13	68***	System 68	17	372.8	21.929	0.05766	8.88
14	11***	System 11	24	364.2	15.175	0.05633	8.68
15	63***	System 63	15	346.1	23.073	0.05353	8.24
16	72***	System 72	30	341.9	11.397	0.05288	8.14

*

For Nov 85

17	12***	System 12	19	334.2	[illegible]	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	24	174.7	7.279	0.02702	4.16
21	65***	System 65	9	97.0	10.778	0.01500	2.31
22	61***	System 61	10	72.0	7.200	0.01114	1.72
[illegible]	69***	System 69	9	[illegible]	5.000		

*

05 MAR 1986

Modas — KC010A LZ - Reliability Report #4 — 05 MAR 1986

For Nov 85

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	161	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
LI500 PREPARED: 05 MAR 1986LI300

END ART DESIG: KC010A BASE: **** - FLEET SUMMARY
WORK UNIT CODE: 46*** - FUEL SYSTEM
TYPE FAILURE: 1
LI500

	FLIGHT HOURS		TOTAL FAILURE	MEAN TIME BETWEEN MAINTENANCE		
DATE	ACTUAL	CUM.	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
8410	2036.6	16273.6	61	33.39	36.54	30.47
8411	1869.0	18142.6	71	26.32	31.61	29.99
8412	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 GC63 *** 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
83 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
8510	2442.0	40544.1	61	40.03	38.04	28.53
8511	2124.3	42668.4	70	30.35	35.14	28.62
8512	0.0	42668.4	55	0.00	24.55	27.60
TOTAL	42668.4		1546			

3 month Totals = 184 failures

Latest 3 month Flying hours = 6465.9

LI500LZDSD G063 LI2000PERATIONAL STATUS REPORT *** M O D A S *** VERSION 1.01 PAGE 1 OF 2 PAGES

LI500 PREPARED: 05 MAR 1986LI

MDS: KC010A BASE: **** - FLEET SUMMARY

COMMAND: ***

LI500

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

DATE	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.

[illegible] DISTANCE FROM LORING AFB TO RF-4C ARCP 1 IS: 796.
LORING AFB RF-4C EAR 1 : 408.

[illegible] FROM LORING AFB TO RF-4C ARCP 2 IS: 352.
LORING AFB RF-4C EAR 2 : 742.

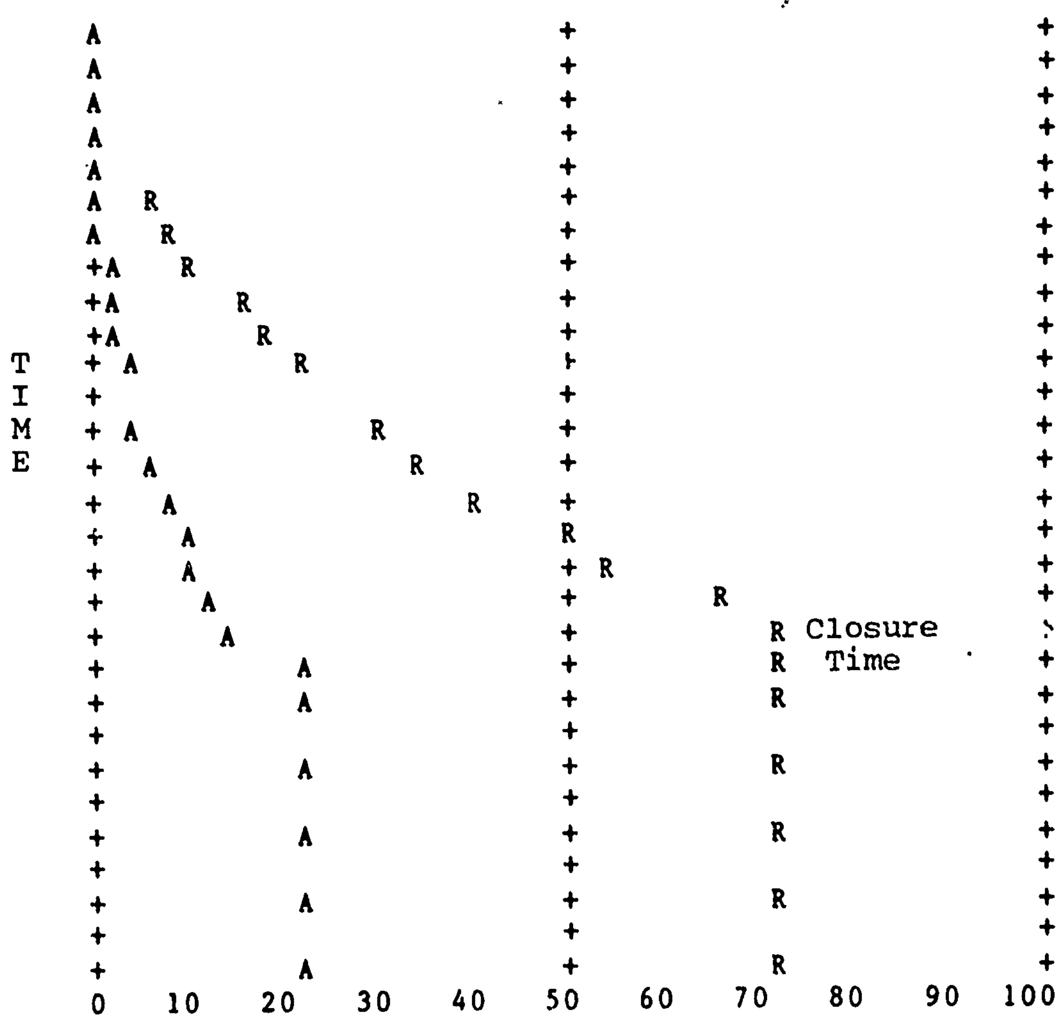
[illegible] FROM LORING AFB TO RF-4C ARCP 3 IS: 946.
LORING AFB RF-4C EAR 3 : 1252.

[illegible] AFB TO RF-4C ARCP 4 IS: 1509.
[illegible] AFB RF-4C EAR 4 : 1810.

[illegible] TO RF-4C ARCP 5 IS: 2511.
[illegible] RF-4C EAR 5 : 2866.

SLAM TTF Output

Plot of Cumulative Fighters Refueled (R)
and Aborted Fighters due to Missed ARs (A)
VS. Time.

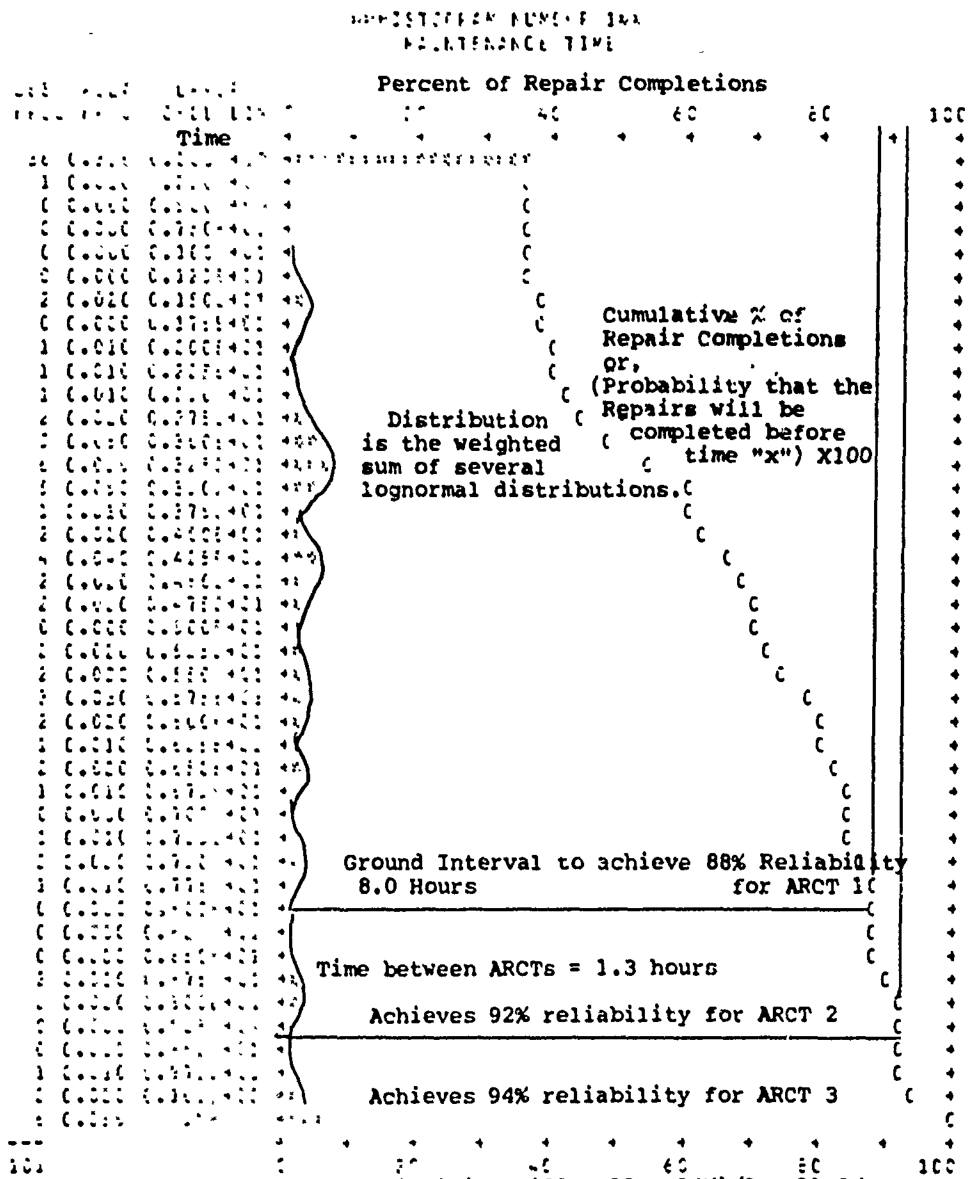


Cumulative Refuelings and Aborts

Maintenance Repair Time Distribution

(Output from the SLAM TTF Maintenance Routine)

Note that this Distribution is very pessimistic because it requires that the KC-10 be 100% functional, without consideration of back-up systems.



Overall AR Reliability =(88 + 92 + 94%)/3 = 91.3%

```
      PROGRAM MAIN
      DIMENSION NSET(50000)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET(50000)
      EQUIVALENCE(NSET(1),QSET(1))
      NNSET=50000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      NPLOT=2
      CALL SLAM
      STOP
      END
      SUBROUTINE INTLC
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      RETURN
      END
      SUBROUTINE OTPUT
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      RETURN
      END


      SUBROUTINE EVENT(I)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      DIMENSION NSET(50000)
      COMMON QSET(50000)
      EQUIVALENCE(NSET(1),QSET(1))
      EQUIVALENCE (ATRIB(1),FLYHRS),(ATRIB(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 /ATRIB(1),FLYHRS/ ATRIB(2),STCREWDD/ ATRIB(3),STARTMX;
EQUIVALENCE /ATRIB(4),MXTIME/ ATRIB(5),MYLAPS  / ATRIB(6),CREWDUTY;
EQUIVALENCE /ATRIB(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,CREWGOOS(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

KCGOO 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,CREWGOOS/+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,CREWGOOS/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;           ** NECESSARY? ***
          TERM;

           ENDNETWORK;
INIT,0,168;
;MONTR,TRACE,0,50;
;MONTR,SUMRY,168;
FIN;
```

```
      PROGRAM MAIN
      DIMENSION NSET(10000)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      COMMON QSET(10000)
      EQUIVALENCE(NSET(1),QSET(1))
      NNSET=10000
      NCRDR=5
      NPRNT=6
      NTAPE=7
      NPLOT=2
      CALL SLAM
      STOP
      END

**********************************************************************
      SUBROUTINE EVENT(I)
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,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(ATRIB(1).EQ.1)THEN
              GO TO 11
          ELSE
              CALL ERROR(11)
          ENDIF

***Acft is a KC-10
***RULE:  Assign optimum # fighters to acft, then asssign fuel for
*** KC-10, offload, then assign cargo load (as attributes to entity).
 11    IF (XX(14).LE.(XX(12)-XX(13)))THEN
              ATRIB(7)=1
              ATRIB(8)=XX(14)
              XX(13)=XX(13)+XX(14)
***                        An entire flight of fighters is
***                        assigned to the KC-10.
***                        NOTE: ATRIB(7) indicates 1=AR,0=No Air Refl
***                              ATRIB(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
                 ATRIB(7)=0
                 ATRIB(8)=XX(12)-XX(13)
                 ENDIF
              IF (ATRIB(8).GE.1) THEN
                 ATRIB(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*ATRIB(8)
***                        Next assign any remaining payload to cargo
***                                              if any cargo remains!
      IF((XX(1)-XX(2)).GT.(ATRIB(4)-ATRIB(5))) THEN
          ATRIB(6)=ATRIB(4)-ATRIB(5)
          XX(2)=XX(2)+ATRIB(6)
        ELSE
          ATRIB(6)=XX(1)-XX(2)
          XX(2)=XX(1)
        ENDIF

*                               NOTE:ATRIB(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-ATRIB(2))
2       IF (ATRIB(1).EQ.1) THEN
*       Aircraft is a KC-10
         XX(3)=XX(3)+3.0
         ATRIB(5)=ATRIB(5)-3.0
         ENDIF

      IF (ATRIB(1).GT.1) CALL ERROR(2)
      RETURN

*******************************
*****           EVENT 3 CALCULATES INFLIGHT FUEL CONSUMPTION
3     DURATION=TNOW-ATRIB(2)
      IF (ATRIB(1).EQ.1) THEN
*       Aircraft is a KC-10
         XX(3)=XX(3)+15*DURATION
         ATRIB(5)=ATRIB(5)-15*DURATION
         ENDIF

      IF (ATRIB(1).GT.1) CALL ERROR(3)
      RETURN
      END

************************************************************************
      SUBROUTINE INTLC
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      RETURN
      END
      SUBROUTINE OTPUT
      COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,NCLNR
```

```
     1,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),SSL(100),TNEXT,TNOW,XX(100)
      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
```

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