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

THESIS

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AFIT/GST/ENC/86J-1

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**Title:** Comparing the Effectiveness of Two KC-10 Concepts of Operation

An examination of Tanker/Airlift Support in a Fighter Deployment to Europe.

**Thesis Advisor:** Daniel E. Reynolds
Assistant Professor
Department of Mathematics and Computer Science

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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 and 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.
COMPARING THE EFFECTIVENESS OF TWO KC-10 CONCEPTS OF OPERATION

--AN EXAMINATION OF TANKER/AIRLIFT SUPPORT IN A FIGHTER DEPLOYMENT TO EUROPE

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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No change per Ms. Amy Moore, AFIT/EN
Preface

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

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

I am indebted to Mr M.E. Estes (AFCSA/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 successfully deter aggression, limit conflict, or wage war depends on our ability to rapidly deploy and sustain fighting units. Airlift provides the capability to deliver forces where they are needed in time to make a difference (Joint SECAF and CSAF Memorandum, 29 September 1983) (22:97).

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

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

Because the KC-10 can play multiple-roles, its introduction into the Air Force inventory has been accompanied by controversy. Part of the sensitivity surrounding the KC-10 is the "who shall control" question, which results from the fact that it can refuel any type of receiver, including
Strategic Air Command (SAC) bombers, Military Airlift Command (MAC) airlifters, Tactical Air Command (TAC) fighters, and even Navy and Allied drogue-refueled aircraft. MAC is interested in KC-10 ownership because the KC-10 does have a significant airlift capability—much more than MAC's main work horse, the C-141B. In historical context, SAC was given charge of all tankers because the highest-priority refueling mission was to refuel SAC's bombers in the SIOP (the nuclear Single Integrated Operations Plan). Presently, only KC-135s are tasked to refuel SIOP bombers, and although SAC owns and operates the KC-10, the KC-10 currently has no part in the SIOP.

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

The analysis involved the study and evaluation of KC-10s serving in one or the other of two major roles during the deployment of fighter squadrons:
1. **Dual role:** all KC-10s operate as tanker/airlifters. This means that the KC-10s deploy with the fighters, refueling them enroute and carry their support equipment and personnel to the destination.

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

The Statement of the Problem

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

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

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

2. Evaluate the sensitivity of the deployment effectiveness to changes in the following factors:
   a. reliability of the KC-10
   b. ratio of fighters to KC-10s for air refuelings
   c. location of the Tanker Task Force (in the distinct roles concept)
3. Select the combination of the above three factor settings that produces the best performance for each role.

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

Methodology Overview

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

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

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

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

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

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

At this point in the research effort, it was discovered that the problem of scheduling rendezvous times (ie: when the TTF KC-10s were to meet the fighters) could
not be handled by the simulation models. That is, the air refuelings could not be scheduled unless the following questions were answered:

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

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

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

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

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

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

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

The Delimitations

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

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

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

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

This simplified scenario of a single route between two "centroid" bases provided adequate representation of a major
deployment. Insight concerning KC-10 usage could be gained, without getting bogged-down in the details of a more complex scenario.

Scenario Assumptions

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

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

2. The locations of the fighter air refuelings (ARs) were assumed to be an unchangeable requirement. This meant that the KC-10s were forced to fly to wherever the fighters needed the refuelings. No attempt was made to optimize the given fighters' routing or refueling requirements. The routing and the AR Track locations were provided by Hq TAC/DOXD, in the form of printouts from the TACAP computer.
program (reference 23). (See Appendix D for copies of the TACAP computer printouts. Maps showing the AR Track locations are presented in Chapter II.)

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

4. KC-10s at the TTF bases were unconstrained by time limits which are established by directives. This assumption freed the research from "planning" factors, so that potential capability could be demonstrated. The number of hours that would be flown by a KC-10 was limited only by how quickly maintenance and normal servicing could be accomplished.
5. The USAF KC-10 was assumed to be solely responsible for the tanker/airlift support of the deploying fighter squadrons. Specifically, this meant that:
   a. The allotted KC-10s were given no other duties.
   b. No other tankers (ie: KC-135s) were available for support of the deployment.
   c. No other airlifters (ie: C-141s, C-5s) were available for support of the deployment.

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

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

7. The research scenario assumed that the fighters available for the deployment were 700 F-16s, 300 F-15s, 100 F-111s, and 100 RF-4Cs. This was derived from information in Jane's. For example, Jane's predicts an acquisition of 2800 F-16s (1:260). Many of these will be stationed at forward bases around the globe. One fourth of the total 2800 are assumed to be in the CONUS, and ordered to deploy. Therefore it was estimated that 700 F-16s would deploy. The
number of types of fighters was similarly determined. It should be pointed out that no F-4s (other than reconnaissance RF-4Cs) were included since Jane's says they are being replaced by F-16 and F-15 aircraft. Similarly, A-7s were not included since they are not as capable as the F-16s. The deployment of A-10s was not modeled because they fly so slow as to require an overnight stay at the Azores for crew rest enroute to their destination. Thus, they couldn't fly the selected northern route.

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

This research provided the useful more information in fair weather.

Overview of Thesis

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

Chapter 11, 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.

1-15
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  Max TO Gross Wt = 35,400 lbs
Length  = 49 ft  Ferry Range (with drop tanks)
Height   = 17 ft  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  Max TO Gross Wt = 58,470 lbs
Length = 64 ft  Ferry Range (unrefueled)
Height = 18 ft  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 *Janes All the World's Aircraft*

Figure 2.8. RF-4C Air Refueling Tracks
Wingspan = 165 ft  Max TO Gross Wt = 588,200 lbs
Length = 181 ft  Range w/Max Cargo = 3,797 nm.
Height = 58 ft  w/No Cargo = 9,993 nm

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

Figure 2.10. Map of KC-10 Home Bases and TTF Bases
Refuelings from a Tanker Task Force. When Air Refuelings are provided by TTF KC-10s, the fighters launch as necessary to meet a pre-planned rendezvous with the tanker (reference 24). Launching in flights of 4, 6, 8, the fighters fly alone until they rendezvous with the TTF KC-10. (The number of fighters in the flight is also called "fighter-tanker ratio"). Meanwhile the KC-10 launches from the TTF base for a rendezvous with the fighters at the ARCP (Air Refueling Control Point) at the pre-scheduled ARCT (Air Refueling Control Time). After the rendezvous, the KC-10 proceeds down the AR track, offloading the required fuel to each fighter in turn. Upon reaching the end of the AR track, the fighters continue alone to subsequent AR tracks. Meanwhile, the KC-10, while it has sufficient fuel, returns again to the ARCP to refuel subsequent flights of fighters. The KC-10 then returns to the TTF base for more fuel.

Dual Role KC-10 Air Refuelings. When air refuelings are provided by Dual Role KC-10s, the fighters launch simultaneously with the KC-10 which has been loaded with cargo at the fighter base. The fighters fly in close formation with the tanker all the way to the destination being refueled at the AR tracks along the way. At the destination, the fighters are readied for battle by the maintenance personnel who were carried on board the KC-10. When the KC-10 has been unloaded of all the fighters' support equipment, the KC-10 returns to the CONUS to pick up remaining fighters.
Figures 2.11 and 2.12 show the difference in KC-10 routing for refueling of fighters by TTF KC-10s and Dual Role KC-10s. Notice that the fighter path is unchanged (although the locations of the air refuelings are slightly changed). (See Appendix D for exact fighter route data.)
Figure 2.11. Fighters being refueled by TTF KC-10s.

Figure 2.12. Fighters being refueled by Dual Role KC-10s.
Three things can happen at each ARCP:

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

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

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

3. **Abort due to Failed Refueling after a Successful Rendezvous.** There are two sources of possible failed refueling, assuming that the KC-10 and fighter crews have sufficient skill and that weather is not a factor:
a. **Fighter is broken.** The fighter's refueling system is a complex electrical and mechanical system. If a fighter's system is unable to function, then that one fighter, plus his wingman (always flying in pairs for mutual support) must fly to an abort base. (See Aborted Fighters) The other fighters that are functioning properly may receive their refuelings and continue their mission as planned, or they may all abort together as a flight. About 1% of the fighters will abort due to some mechanical failure. If the fighters abort together in flights of six, then 6% of the 1200 fighter will abort for this reason (reference: 25). Total: 72 aborted aircraft.

b. **KC-10 breaks in-flight.** If the KC-10 is so badly broken that it can no longer provide AR, then any unfueled fighters (and their wingmen) must abort. Because of the high reliability of the KC-10 air refueling system (it has many backup sub-systems), it is assumed that the refueling is successful, with a degraded AR system, must be fixed on the ground after the sortie (reference 27). Thus, a failed AR system would only affect subsequent KC-10 ground turn-around time, and not the current fighters. (There is a need for better statistics on the maintainability and reliability of the KC-10, to verify this assumption.)
**Aborted Fighters:** Once the aborting fighters have arrived safely on the ground at the abort base of choice, the fighter crews have their aircraft immediately refueled. At best, if there are no other aircraft ahead of them in a queue for service, the fighters could be ready for launch within one hour. A two or three hour turn-around time is reasonable, assuming no queuing (13:5).

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

The aircrews must enter crew rest (for 12 hours) if insufficient time for another sortie remains within their maximum (15 hour) crew duty day (13:5). When exiting crew
rest, or if sufficient crew duty day remains, the aircrews can take one of three actions. (This thesis assumes the first action is taken.)

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

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

3. **"Island Hopping."** The fighters could continue toward their destination without any ARs at all, by flying several short "hops." For example, F-16s can fly unrefueled from St. Johns (the abort base) to Goose Bay, Canada. There they would land, refuel on the ground, launch again, and fly to Keflavik, Iceland. Subsequent "hops" would be flown via Leuchars and then to Hahn (the Destination). Accounting for 3-hour turnarounds at each enroute base, and one crew rest
crew rest. The KC-10, when ready, is refueled by the ground crews, and launches on its mission of providing refuelings to several flights of fighters. This thesis assumed that these actions take a total of 36 hours (Therefore the first fighters arrived in Europe after 45 hours.)

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

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

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

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

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

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

1. Fuel on board at launch. This is calculated by

\[
\text{Max fuel Wt} = \text{Max TO Gross Wt} - \text{Cargo Wt} - \text{Aircraft Empty Wt}
\]

\[
= 588,200 - 0 - 243,209 - 344,991 = 344,991 \text{ pounds,}
\]
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):

\[
TOGW = 187,083 - 8.125 \times (PA) + 47.5 \times (RL) - 0.0013542 \times (RL) \times (RL) - 0.0004688 \times (PA) \times (RL)
\]

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

2. **Fuel consumed by the KC-10 to do all the following:**
   a. fly from the TTF Base to the ARCP
   b. orbit at the ARCP
   c. fly down track and back (each track lap)
   d. fly back to TTF Base

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

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

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

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

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

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

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

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

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

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

Figures 2.13, 2.14 on the following pages illustrate the flowplans of the Distinct Role TTF and Airlifter missions. They can be considered to be network representations of the "conceptual models" of the deployment.
DISTINCT ROLES:
Figure 2.13 Flowplan of Tanker Task Force Operation and Fighter Mission Simulation
(Upper Half of Figure) (Lower Half of Figure)
IN USA, AT FIGHTER DEPARTURE BASE:

- Cargo Assembled
- Arriving Airlifter
- Wait for Airlifter
- Loader
- Wait for Loader
- Arriving Aircrew
- Wait for Aircrew
- Preflight Delay?

IN EUROPE, AT DESTINATION BASE:

- Fly nonstop to Europe
- Fly via enroute base or AR
- Loader
- Wait for Loader
- Unload Cargo
- Cargo Arrives
- delays

IN EUROPE, AT RECOVERY BASE:

- Fly to recovery base
- Crew debrief
- Aircraft Postflight
- Refuel, etc.
- Preflight Delay?
- Launch
- Fly return mission to USA for more cargo
- Match Ready Airlifter
- Rested Aircrew

DISTINCT ROLES:

Figure 2.1 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>
<thead>
<tr>
<th>Passengers</th>
<th>Cargo Pallets</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>27</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>75</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 2.1  
KC-10 Passenger and Cargo Combinations
CAPACITY FOR 463L PALLETS OF KC-10A AND VARIOUS USAF CARGO AIRCRAFT

Figure 2.15. Comparison of Airlifter Pallet Capabilities (14:13).
Because of the large number of passengers that must be carried, the KC-10s will be limited to carrying only 17 to 23 pallets of equipment. (Note: A KC-10 could be forced to carry even fewer pallets when carrying large quantities of fuel, since it is limited by maximum takeoff gross weight. The Airlifter-Only KC-10s can carry a "bulky" load of cargo weighing 100,000 pounds for a distance of over 5000 nm. A Dual-Role KC-10, on the other hand, may not even be able to carry 20,000 pounds of cargo because of the large quantity of transferable fuel that it must carry.)

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

Table 2.2

<table>
<thead>
<tr>
<th>KC-10 Aircrew Duty Day Limits (reference 4)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Mission</td>
<td>16 Hours</td>
</tr>
<tr>
<td>Higher Headquarters Directed Mission</td>
<td>20 Hours</td>
</tr>
<tr>
<td>JCS Directed (actual contingency)</td>
<td>26 Hours</td>
</tr>
<tr>
<td>with Augmented Crew (ie: extra Pilot, Flight Engineer, Boom Operator)</td>
<td></td>
</tr>
</tbody>
</table>

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 unscheduled "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

<table>
<thead>
<tr>
<th>Weight ofFuel Offload and Cargo Transport per Fighter (in pounds)</th>
<th>Fuel</th>
<th>Cargo</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-16: 14,333</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>F-15: 41,277</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>F-111: 40,130</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>RF-4C: 49,588</td>
<td>10,000</td>
<td></td>
</tr>
</tbody>
</table>

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>
<thead>
<tr>
<th>Required KC-10 Onload (based on TANKER data)</th>
<th>Dual Role Payload and KC-10 Fuel Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Fuel offload</td>
<td>Total Cargo Weight</td>
</tr>
<tr>
<td>4 F-16s</td>
<td>57,332</td>
</tr>
<tr>
<td>5 &quot;</td>
<td>71,665</td>
</tr>
<tr>
<td>6 &quot;</td>
<td>85,998</td>
</tr>
<tr>
<td>7 &quot;</td>
<td>100,331</td>
</tr>
<tr>
<td>8 &quot;</td>
<td>114,664</td>
</tr>
<tr>
<td>2 F-15s</td>
<td>82,554</td>
</tr>
<tr>
<td>3 &quot;</td>
<td>123,831</td>
</tr>
<tr>
<td>4 &quot;</td>
<td>165,108</td>
</tr>
<tr>
<td>5 &quot;</td>
<td>206,385</td>
</tr>
<tr>
<td>6 &quot;</td>
<td>247,662</td>
</tr>
<tr>
<td>2 F-111s</td>
<td>80,260</td>
</tr>
<tr>
<td>3 &quot;</td>
<td>120,390</td>
</tr>
<tr>
<td>4 &quot;</td>
<td>160,520</td>
</tr>
<tr>
<td>5 &quot;</td>
<td>200,650</td>
</tr>
<tr>
<td>6 &quot;</td>
<td>240,780</td>
</tr>
<tr>
<td>2 RF-4Cs</td>
<td>99,176</td>
</tr>
<tr>
<td>3 &quot;</td>
<td>148,764</td>
</tr>
<tr>
<td>4 &quot;</td>
<td>198,352</td>
</tr>
<tr>
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<td>247,940</td>
</tr>
<tr>
<td>6 &quot;</td>
<td>297,528</td>
</tr>
</tbody>
</table>
The first row of the table shows that a Dual Role KC-10 can refuel 4 F-16s and carry all 40,000 pounds of their support equipment and personnel. The KC-10 would arrive at the destination with an extra 4,296 pounds of fuel reserve. The second row of the table shows that, by adding a fifth F-16, the extra 10,000 pounds of cargo plus 14,333 of fuel would place the KC-10 20,037 pounds above the Maximum Takeoff Gross Weight. Therefore, in order to carry the cargo, the KC-10 would have to reduce its fuel load, and receive an AR of 20,032 pounds. Notice that the 10,000 pounds of cargo directly displaces 10,000 pounds of fuel.

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

The flight route of the Dual Role KC-10 is basically the same as that of the Airlifter-Only KC-10. One significant difference between Dual Role and Airlifter-Only KC-10 mission profiles is that the Dual Role sorties must be at the same altitude and airspeed as the fighter aircraft which accompany them. This is a disadvantage to the KC-10.
since it must fly at a lower altitude, and at a much higher indicated airspeed than its optimum. The Dual Role KC-10 thus consumes much more fuel.

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

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

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

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

Introduction

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

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

A Journal Publication

Refueling Strategies. In an article titled "Vehicle fleet refueling Strategies to Maximize Operational Range," Mchrez 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 usage.

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 unfueled 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 unfueled 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 (i.e., 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 halfway between the receiver's launch base and its destination, then that 1 tanker could do what an infinite number of tankers (all launched from the same base as the receiver) could not do: double the range of the receiver! Therefore, forward positioning of the tanker base, such as in a Tanker Task Force, will yield great increases in effectiveness.

AFIT Theses

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

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

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

Minimizing fuel consumption when refueling airlifters. In his 1982 AFIT Master's thesis, Capt Tenny Lindholm used Dynamic Programming to "determine optimal rendezvous points,
fuel offloads, and tanker departure bases, using the total fuel consumed by both airlifter and tanker as the measure of effectiveness" (16:ii). It was hoped that this thesis methodology would be applicable to the deployment scenario where flights of fighters are refueled.

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

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

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

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

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

Major Marcotte and Capt Bordelon they analyzed the effects of varying takeoff fuel loads and rendezvous points. One conclusion was that optimal takeoff fuel loads are a function of relative fuel efficiencies of the tanker and the receiver (9:57). The most efficient aircraft should be tasked to carry the greater percentage of fuel. The minimum fuel consumption is achieved "by minimizing the combined percentage of fuel capacity used by the two aircraft"
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 (i.e.: if it takes off with very little fuel, it can carry more cargo, but needs to be refueled as early as feasible) (9:58). A conclusion applicable to the TTF KC-10s was that it also helps somewhat for the airlifter to fly closer to the tanker's base if the tanker base is enroute to the airlifter's destination (9:59).

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

Simulation of Strategic Airlift to Europe. In their 1981 AFIT thesis, Captains Holck and Ticknor developed a SLAM simulation model to study factors within the MAC airlift system which produce significant changes in the system's daily cargo delivery rate. This thesis provided a basic conceptual model for airlifter deployments. Four factors were studied: aircrew, maintenance, supply, and aerial port (16:viii). Although MAC uses a totally
different concept of aircrew management than SAC uses, this simulation model provided the logic and structure for developing my SLAM model of the Distinct Roles Airlifter KC-10 Mission.

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

Capt Stanberry examined maintenance manning at the Air Force Specialty Code level. He modeled the maintenance discrepancies and distributions for repair times (based on LtC Shaw's dissertation (20:35)) for the major aircraft subsystems and tested his maintenance model by inserting it into the airlift model developed by Captains Holek 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) \(^2\). 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 flexibility of allowing changes in policies, such as which cargo has higher priority or the length of the maximum aircrew duty day. Most importantly, the M-14 presents the opportunity to examine the cumulative and interactive effects of all the variables that it models (15:iii).

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

The model assumes that an unlimited number of KC-135 tankers will be available at every air refueling point, each capable of offloading 70,000 pounds of fuel (15:57).
the model does not specifically track tanker aircraft, it merely assigns an 80% probability that a tanker will be available if the air refueling area is not congested. It then assigns a 99% chance of successful rendezvous, and a 95% probability of successful air refueling. Thus, the M-14 does not consider the interactions which would affect the availability of tankers to provide the air refuelings. It did, however, provide excellent historical data which was used in this thesis effort to develop my simulation model. The available data includes payload-range equations, fuel consumption rates, and probability distributions for the times required to perform various maintenance and flight activities. These distributions are summarized on the following page:
Table 3.1

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

Mission Duration
to overhead destination = planned + 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)

<table>
<thead>
<tr>
<th>Cargo Offload or Onload</th>
<th>Min</th>
<th>Avg</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palletized Cargo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>using Cochran Loader</td>
<td>1.5</td>
<td>2.0</td>
<td>4.0 hrs</td>
</tr>
</tbody>
</table>

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

3-15
available at the closest tanker base. The tanker mission calculations were based on the tankers flying in the tanker-only role (as in a TTF). For each flight of six F-15s in the above non-stop flight to Germany, this study determined that 4 KC-10s would be necessary.

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

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

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

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

Conclusion

Very little information was found in the available literature which directly pertains to the KC-10s use in fighter deployments. Several AFIT simulations dealt with aspects of MAC airlifters supporting deployment. These studies were somewhat helpful, especially in building my simulation model for the Airlifter missions. No studies were found to be adequate for modeling the KC-10 maintenance, which leaves a critical need unmet for studying the TTF operations. Of several computer programs reviewed, none modeled the tanker's role in the deployment. This thesis' sponsor, Mr M.E. Estes of Center for Studies and Analysis, has carried out significant deterministic analysis of tankers supporting fighter deployments. His research, however, did not involve the examination of the total picture of fighter and cargo deployment.
At the conclusion of the Literature Review, simulation was considered to be the most relevant methodology for modeling complex operational concepts such as the KC-10 missions. As will be seen in the next Chapter, initial simulation results were promising, but the research had to turn to deterministic equations to address the complexities of the TTF operation.
IV. Methodology

Two Methodologies

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

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

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

The thesis research then placed its emphasis on the simulation models for the purpose of gaining an understanding of queuing effects, stochastic variances, and factor interactions. The simulation work, however, bogged down with the complex problem of "pre-determining" the Air
Refueling schedules for the TTF deployment. For the Dual Role simulation, there was no scheduling problem at all since, in real life, the fighters can wait on the ground until the KC-10, located at the same base, is ready to launch. This could be easily modeled by a simple queue. But when the fighters were to be refueled by Distinct Role TTF KC-10s, it would have been unrealistic to make a simulation model where the fighters queue until a KC-10 becomes available. Fighters do not queue in the air—they abort to a landing base if the KC-10 is not available when needed. It thus became apparent that, as in the real world, the scheduling of launches and ARCTs in the simulation model must be known prior to the first launch.

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

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

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

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

In real life, a schedule can be made using the discrete times when each fighter launches, air refuels, and arrives at the destination. This deterministic model, however, assumes an average, continuous flow of fighters. Continuous flows are the result of "smoothing out" the discrete, integer mission schedules. For instance, if 1 KC-10 can refuel 12 fighters on each mission, and can fly 2 such missions per day, then the continuous flow rate of fighter air refuelings is 24 per day, or 1 per hour.
It is also assumed that all four types of fighters are deployed simultaneously with no type of fighter having priority. Thus, with "parallel" deployments of F-16s, F-15s, F-111s, and RF-4Cs, the optimal overall deployment Closure Time is achieved if the last F-16 arrives at the same time as the last F-15, the last F-111, and the last RF-4C. In relation to the above figure, there are 4 reservoirs (F-16, F-15, F-111, RF-4C). Proportional flow rates were established so that all 4 reservoirs would be emptied at exactly the same instant.

Distinct Role Equations

Calculating "Closure Time" for TTF. The following paragraphs develop an equation to calculate Closure Time for fighters refueled by Distinct Role TTF KC-10s. This section also develops the apportioning of KC-10s among the 11 AR tracks, and by inference, the apportioning of KC-10s among the TTF bases. (The subsequent section, beginning on page 4-18, develops the equations for the Distinct Role Airlifters.)
By setting the Closure Times equal for each type of fighter, it is possible to apportion the TTF KC-10s among the AR tracks and TTF bases so that all the fighters receive refuelings according to their proportional flow rates. The total time to deploy fighters is described as the sum of the times required for five events (ie: five addends).

Closure Time =

Time to Set-up TTF  
[1st addend]

+ Time for KC-10 to fly to the ARCP (for 1st "track lap"). (Assume fighters launch as necessary to arrive on time.)  
[2nd addend]

+ Time it takes the TTF KC-10s to transport sufficient fuel to the ARCP to refuel all the fighters.  
[3rd addend]

+ Time for last fighter to fly from ARCT to destination.  
[4th addend]

+ Time necessary for aborted fighters to arrive at destination.  
[5th addend]

The above addends are illustrated on the following page in Figure 4.2.
Figure 4.2. Graphical Illustration of Fighter Arrivals, related to Deterministic TTF Closure Time Equations.
It should be noted from Figure 4.2 that the extra time needed to refuel aborted fighters [5th Addend], can also be represented in terms of planned times [3rd Addend], and AR reliability. (This thesis assumes that all aborted fighters must be re-scheduled into the AR track from which they aborted, as opposed to flying directly to the destination, or "island hopping," as described in Chapter II.)

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

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

Next, let's look more closely at the 3rd Addend, which is the only addend dependent on the KC-10 allocation. Since this addend is dependent on the number of KC-10s which are carrying fuel to the ARCP, then the ARCPs could be pictured as flow restrictions in the pipeline of deploying fighters. Thus, the 3rd Addend can be expanded in much further detail in terms of the number of fighters and the refueling sorties that they require of the KC-10s:
[3rd Addend] = Total Time to transport all required fuel to the ARCP (same for each KC-10 assigned to the track)

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

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

= (Time interval/sortie) \times (\text{Sorties/KC-10})

Each of the above two factors can be further explained.

The first factor is essentially an overall "interval."

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

in terms of hours/sortie

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

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

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

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

Since all of each type of fighter must go through all their AR tracks then "# of F-16s/AR Track" is equal to the Total
Number of that type of fighters deploying. For example, all 700 F-16s must go through each of the 2 F-16 AR tracks.

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

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

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

\[
\text{[3rd Addend]} = \text{Time to transport all fuel (for one type of fighter) to ARCP, per KC-10} = \frac{\text{Airborne Mission Time}}{\text{KC-10 sortie}} + \frac{\text{Ground turn-around time}}{\text{KC-10 sortie}}
\]

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

4-9
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}

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

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

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 \text{a or A} with F-16s, \text{b or B} with F-15s, \text{c or C} with F-111s, and \text{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

<table>
<thead>
<tr>
<th></th>
<th>F-16s</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$a_1 =$ refueling interval for AR 1</td>
<td>$A_1 =$ # KC-10s assigned to AR 1</td>
<td></td>
</tr>
<tr>
<td>$a_2 =$</td>
<td>&quot; AR 2</td>
<td>$A_2 =$ &quot; AR 2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>F-15s</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$b_1 =$ refueling interval for AR 1</td>
<td>$B_1 =$ # KC-10s assigned to AR 1</td>
<td></td>
</tr>
<tr>
<td>$b_2 =$</td>
<td>&quot; AR 2</td>
<td>$B_2 =$ &quot; AR 2</td>
<td></td>
</tr>
<tr>
<td>$b_3 =$</td>
<td>&quot; AR 3</td>
<td>$B_3 =$ &quot; AR 3</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>F-111s</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$c_1 =$ refueling interval for AR 1</td>
<td>$C_1 =$ # KC-10s assigned to AR 1</td>
<td></td>
</tr>
<tr>
<td>$c_2 =$</td>
<td>&quot; AR 2</td>
<td>$C_2 =$ &quot; AR 2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>RF-4Cs</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$d_1 =$ refueling interval for AR 1</td>
<td>$D_1 =$ # KC-10s assigned to AR 1</td>
<td></td>
</tr>
<tr>
<td>$d_2 =$</td>
<td>&quot; AR 2</td>
<td>$D_2 =$ &quot; AR 2</td>
<td></td>
</tr>
<tr>
<td>$d_3 =$</td>
<td>&quot; AR 3</td>
<td>$D_3 =$ &quot; AR 3</td>
<td></td>
</tr>
<tr>
<td>$d_4 =$</td>
<td>&quot; AR 4</td>
<td>$D_4 =$ &quot; AR 4</td>
<td></td>
</tr>
<tr>
<td>$d_5 =$</td>
<td>&quot; AR 5</td>
<td>$D_5 =$ &quot; AR 5</td>
<td></td>
</tr>
</tbody>
</table>

**Greek letters:**

**Proportionality between tracks**

\[
\begin{align*}
\alpha &= 1 + \frac{a_2}{a_1} \\
\beta &= 1 + \frac{b_2}{b_1} + \frac{b_3}{b_1} \\
\gamma &= 1 + \frac{c_2}{c_1} \\
\delta &= 1 + \frac{d_2}{d_1} + \frac{d_3}{d_1} + \frac{d_4}{d_1} + \frac{d_5}{d_1}
\end{align*}
\]

**Proportionality between Fighter Types**

\[
\begin{align*}
\theta &= B_1/A_1 \\
\phi &= C_1/A_1 \\
\psi &= D_1/A_1
\end{align*}
\]
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 
\[ a_1 = \frac{9.4}{18} = 0.52 \text{ hours/fighter}. \]
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 
\[ a_2 = \frac{13.4}{42} = 0.32 \text{ hours/fighter}. \]
(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:

\[
[3rd \ Addend] = \text{Time to transport all fuel (for one type of fighter) to ARCP, per KC-10} \\
= \ \text{Airborne Mission Time} + \text{Ground turn around time sortie} \\
x \ \frac{(# \text{ Fighters/AR Track})}{(KC-10s/AR Track)} (\frac{(# \text{ Fighters})}{(track \ laps)} \frac{1}{(track \ lap)} \frac{1}{(sortie)})
\]

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Note that this is equivalent to:

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

where \( \text{Time/AR Track} = a_1 \) for F-16 Track 1
and \( \text{KC-10s/AR Track} = A_1 \) 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:

\[
(Goose\ Bay) (F-16\ Addend 3)_{\text{TRACK 1}} = (Mildenhall) (F-16\ Addend 3)_{\text{TRACK 2}}
\]

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:

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

\[ (Goose\ Bay) \]

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

\[ (Mildenhall) \]
Using the above equation to solve for the relative proportions of tankers on each track:

\[ A_2 = \frac{a_2}{a_1} A_1 \]
\[ = 0.697 A_1 \]

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

\[ B_2 = \frac{b_2}{b_1} B_1 \]
\[ B_3 = \frac{b_3}{b_1} B_1 \]
\[ C_2 = \frac{c_2}{c_1} C_1 \]
\[ D_2 = \frac{d_2}{d_1} D_1 \]
\[ D_3 = \frac{d_3}{d_1} D_1 \]
\[ D_4 = \frac{d_4}{d_1} D_1 \]
\[ D_5 = \frac{d_5}{d_1} D_1 \]

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 constraint was that the total number of KC-10s allocated to all the AR tracks had to equal to the number of available tankers. That is:
\[(A_1 + A_2) + (B_1 + B_2 + B_3) + (C_1 + C_2) + (D_1 + D_2 + D_3 + D_4 + D_5) = 100\% \text{ of TTF Tankers}\]

or,

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

or,

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

or,

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

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

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

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

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

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

Solving for the relationship between \(A_1\) and \(B_1\),

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

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

\[
= \theta A_1
\]

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:

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

\[
= \frac{365.55}{A_1}
\]

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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]**  
  $$\alpha = 1 + (a_2/a_1) = 1 + [(10.4 + 3)/7] = 1.611$$
  $$[(6.4 + 3)/3]$$

- **[F-15]**  
  $$\beta = 1 + (b_2/b_1) + (b_3/b_1)$$
  $$= 1 + [(6.2 + 3)/2] + [(8.6 + 3)/5] = 1.935$$
  $$[(4.4 + 3)/1] [(4.4 + 3)/1]$$

- **[F-111]**  
  $$\gamma = 1 + (c_2/c_1)$$
  $$= 1 + [(7.9 + 3)/2] = 1.673$$
  $$[(5.1 + 3)/1]$$

- **[RF-4C]**  
  $$\delta = 1 + (d_2/d_1) + (d_3/d_1) + (d_4/d_1) + (d_5/d_1)$$
  $$= 1 + [(5.3 + 3)/2] + [(7.5 + 3)/3] +$$
  $$[(7.8 + 3)/2] [(7.8 + 3)/2]$$
  $$+ [(8.4 + 3)/3] + [(11.7 + 3)/6] = 3.574$$
  $$[(7.8 + 3)/2] [(7.8 + 3)/2]$$
The ratios between fighter AR₁ tracks were as follows:

\[ \frac{[F-15s/F-16s]}{[F-16s/F-15s]} = \frac{(300 \text{ F-15s})(4.4 + 3 \text{ hours/sortie})_{F15}}{(700 \text{ F-16s})(6.4 + 3 \text{ hours/sortie})_{F16}} \times \frac{(6 \text{ F-16s/tracklap})(3 \text{ tracklaps/sortie})_{F16}}{(6 \text{ F-15s/tracklap})(1 \text{ tracklap/sortie})_{F15}} = 1.012 \]

\[ \frac{[F-111s/F-16s]}{[F-16s/F-111s]} = \frac{(100 \text{ F-111s})(8.1)(6)(3)}{(700 \text{ F-16s})(9.4)(6)(1)} = 0.369 \]

\[ \frac{[RF-4Cs/F-16s]}{[F-16s/RF-4Cs]} = \frac{(100 \text{ RF-4Cs})(10.8)(6)(3)}{(700 \text{ F-16s})(9.4)(6)(2)} = 0.246 \]

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

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

\[ = 100\% / 5.066 \]

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

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

\[ A_2 = \left( \frac{a_2}{a_1} \right) A_1 = (0.611)(19.74) = 12.06\% \text{ of the KC-10s} \]
Likewise, for the F-15 AR Tracks:

\[ B_1 = \theta A_1 = (1.012)(19.74) = 19.977\% \text{ of the KC-10s} \]
\[ B_2 = (b_2/b_1) B_1 = (0.622)(19.977\%) = 12.42\% \]
\[ B_3 = (b_3/b_1) B_1 = (0.314)(19.977\%) = 6.263\% \]

For the F-111 AR Tracks:

\[ C_1 = \phi A_1 = (0.369)(19.74) = 7.248\% \text{ of the KC-10s} \]
\[ C_2 = (c_2/c_1) C_1 = (0.673)(7.248) = 4.901\% \]

For the RF-4C AR Tracks:

\[ D_1 = \psi A_1 = (0.246)(19.74) = 4.856\% \text{ of the KC-10s} \]
\[ D_2 = (d_2/d_1) D_1 = (0.768)(4.856\%) = 3.731\% \]
\[ D_3 = (d_3/d_1) D_1 = (0.648)(4.856\%) = 3.147\% \]
\[ D_4 = (d_4/d_1) D_1 = (0.704)(4.856\%) = 3.417\% \]
\[ D_5 = (d_5/d_1) D_1 = (0.454)(4.856\%) = 2.205\% \]

The following table summarizes KC-10 track apportionments:

<table>
<thead>
<tr>
<th>FIGHTER</th>
<th>AR 1</th>
<th>AR 2</th>
<th>AR 3</th>
<th>AR 4</th>
<th>AR 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-16</td>
<td>19.7%</td>
<td>12.1%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-15</td>
<td>20.0%</td>
<td>12.4%</td>
<td>6.26%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-111</td>
<td>7.3%</td>
<td>4.9%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF-4C</td>
<td>4.9%</td>
<td>3.7%</td>
<td>3.1%</td>
<td>3.4%</td>
<td>2.2%</td>
</tr>
</tbody>
</table>

Table 4.3

APPORTIONMENT OF TTF KC-10 S AMONG AR TRACKS

4-20
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:

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

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 = \( \frac{365.55}{19.74} \) = 18.52 hours (if 100 TTF tankers)

time = \( \frac{18.52}{.60} \) = 30.86 hours
(if 60 TTF tankers)

time = \( \frac{18.52}{.20} \) = 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-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:

\[36 + 2 + 7 + 97.5 = 142.5 \text{ hours}\]
(or 6 days, 4 hours)
Computerized Model. The above equations for finding the TTF Closure Time and KC-10 apportionment among AR Tracks are fairly complex, and certainly tedious to calculate manually. Thus, in order to accomplish further analysis for this thesis, and hopefully, for other future researchers, a computerized model of the TTF Deterministic Equations was built. The computerized model verified the hand-calculated results shown on the previous pages. Also, the computer output is found in Appendix B. The self-documenting source code is found in Appendix B. This computer model accomplishes the following:

<table>
<thead>
<tr>
<th>Input</th>
<th>Major Functions</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>All AR Track Information</td>
<td>Calculate Great Circle Distances between TTFs, AR Tracks</td>
<td>Track and TTF Apportionment of KC-10s</td>
</tr>
<tr>
<td>Locations of TTFs</td>
<td>Search for closest TTF to each AR Track</td>
<td>Closure Time</td>
</tr>
<tr>
<td></td>
<td>Call modified &quot;TANKER&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-determines sortie duration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-maximum feasible number of &quot;tracklaps&quot;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use Deterministic Equations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-KC-10 apportionment</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Fighter Closure Time</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.3 Overview of Deterministic Computer Program

The "input" information required by the FORTRAN program "TTFDETERM" is listed in Figure 4.4 on the following page.
For every AR Track:

Coordinates (Latitude, Longitude) of the ARCP, EAR

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

Air refueling attitude
  " " calibrated airspeed
  " " time down track
  " " distance down track
  " " fuel offload

For every TTF:

Coordinates of the airfield (latitude, longitude)

Name of the airfield (ie: "Mildenhall")

KC-10 Maximum Takeoff Gross Weight at that airfield

For the deployment:

Numbers of deploying fighters, by type

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

Number of KC-10s supporting the deployment

KC-10 Reliability

KC-10 Ground Turn-around Time

TTF Setup time

Figure 4.4. Input to Deterministic Program
Using the above information, the program follows the following pseudo-code logic:

Call "CalcDistance" to find:
- Distances between TTFs and ARCPs
  by calling "GreatCircle"
  (based on spherical trigonometry (2:199))
- Distances between TTFs and EARs
  by calling "GreatCircle"

Call "NonDominated" to find:
- Closest TTF to each AR Track

For every fighter
- With the TTF closest to each AR Track
  Call "Tanker" to determine:
  - The maximum feasible # Tracklaps/KC-10 sortie
  - KC-10 sortie duration

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

Figure 4.5. Deterministic Program Logic
Distinct Role Airlifter-only KC-10s and Dual Role KC-10s

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

\[ C.T. = \sum \text{(time per lap) number of laps} \]

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 \((\text{Time/Trip}) \times (\text{No. of Trips})\). 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:

\[
\text{Closure Time} = \frac{(\text{Total Cargo})}{(\text{Cargo per KC-10, per lap})} \times \frac{1}{(\text{No. of KC-10s})} - 1 \text{ Trip} \] \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:

\[
\text{Total Cargo} = \frac{\text{(pounds of Cargo)x(Number of Fighters)}}{(\text{Fighter})}
\]

\[
\frac{\text{Cargo}}{\text{KC-10 - lap}} = \frac{(\text{No. of Pallets})\times(\text{Pounds of Cargo})}{(\text{KC-10 - lap})} \frac{1}{\text{Pallet}}
\]

Therefore, Closure Time becomes:
Cargo Closure Time = \( \frac{(\text{pounds of Cargo}) \times (\text{Number of Fighters})}{(\text{Fighter})} \)

\[
\% \left[ \left( \frac{\text{(No. of Pallets)} \times \text{(Pounds of Cargo)}}{\text{(KC-10 - lap) Pallet}} \right) \right]
\%
\% \left[ \text{(No. of KC-10s)} \times (\text{-1 Trip}) \right]
\times (\text{Time/lap})
\quad + \quad (\text{Preparation Time + First One-way Trip})
\]

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

\[
(1200 \text{ Fighters}) \times (10,000 \text{ lbs cargo/fighter})
= 12,000,000 \text{ lbs cargo}
\]

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 =

\[
\frac{12,000,000 \text{ lbs}}{(80,000 \text{ pounds}/(\text{KC-10 lap})} \times \frac{1}{(\text{No. of KC-10s})} - 1 \text{ trip}
\times 45 \text{ hrs/lap}
+ 45 \text{ hrs for Preparation and 1st One-way Trip}
= 168 \text{ hours (ie: 1 week)}
\]
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 unfueled Dual Role KC-10s could only deploy the following numbers of fighters plus their supporting cargo:

\[
\begin{align*}
4 \text{ F}-16s & \pm 40,000 \text{ pounds cargo} \\
2 \text{ F}-15s & \pm 20,000 \\
2 \text{ F}-11s & \pm 20,000 \\
2 \text{ RF-4Cs} & \pm 20,000 \\
\end{align*}
\]

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

\[
\text{KC-10 trips (F-16s)} = \frac{10,000 \text{ lbs}}{\text{Fighter}} \times 700 \text{ F}-16s \\
\times \frac{1 \text{ KC-10 trip}}{40,000 \text{ lbs}} \\
= 175 \text{ trips}
\]

4-30
KC-10 trips (F-15s) = \( \frac{10,000 \text{ lbs}}{\text{Fighter}} \times 300 \text{ F-15s} \times 1 \text{ KC-10 trip} \times \frac{20,000 \text{ lbs}}{20,000 \text{ lbs}} = 150 \text{ trips} \)

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

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

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,

\[ \text{C.T.} = \left( \frac{425 \text{ KC-10 trips}}{60 \text{ No. of KC-10s}} - 1 \text{ trip} \right) \times 45 \text{ hrs/lap} \times 45 \text{ hrs/lap} + 36 \text{ hrs} + 9 \text{ hrs} \]

\[ \text{C.T.} = [(7.08) - 1] \times 45 + 36 + 9 = 319 \text{ hrs} = 1 \text{ week, 6 days, 7 hours} \]
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 that the Closure Time for the (unrefueled) Dual Role KC-10s was more than twice that of the Distinct Role KC-10s.

<table>
<thead>
<tr>
<th>Role Description</th>
<th>Closure Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual Role (based on 60 Dual Role KC-10s, unrefueled)</td>
<td>Closure Time = 319 hrs = 1 wk, 6 days, 7 hrs</td>
</tr>
<tr>
<td>Distinct Roles</td>
<td></td>
</tr>
<tr>
<td>Fighters (based on 20 TTF KC-10s)</td>
<td>Closure Time = 142 hrs = 5 days, 22 hrs</td>
</tr>
<tr>
<td>Cargo (based on 40 Airlifter-Only KC-10s)</td>
<td>Closure Time = 141 hrs = 5 days, 21 hrs</td>
</tr>
</tbody>
</table>

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

Figure 5.1. Summary of Closure Time Results

5-1
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

+ Time for KC-10 to fly to the ARCP (for 1st "track lap"). (Assume fighters launch as necessary to arrive on time.)

+ Time it takes the TTF KC-10s to transport sufficient fuel to the ARCP to refuel all the fighters.

+ Time for last fighter to fly from ARCT to destination.

+ Time necessary for aborted fighters to arrive at destination.

The [3rd addend] of the Closure Time was: 5-2
[3rd Addend] = Time to transport all fuel (for one type of fighter) to ARCP, per KC-10

= Sortie interval x Number of consecutive Sorties required

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

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

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

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

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

\[ [3rd \text{ Addend}] = \text{Sortie interval} \times \text{Number of consecutive Sorties required} \]

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. **Number of consecutive sorties required.** This
term is also very significant. Because it is a
"multiplicand" (i.e., 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 =

\[
\frac{\text{(# Fighters/AR Track)}}{\text{(KC-10s/AR Track)}} \times \frac{\text{(# Fighters)}}{\text{(track laps)}} \times \frac{\text{(track lap)}}{\text{(sortie)}}
\]
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 Reliability to examine sensitivity. Figure 5.5, on the following page, shows several curves of Closure Time versus AR Reliability, based on different values of Ground Turn-around Time.

5-10
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 5.8 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.)
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:

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

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

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

![Graph showing Closure Time vs. Total Number of 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 arrivals of fighters and cargo at the destination, as delivered by the two deployment concepts, Dual and Distinct Roles.

![Diagram showing cumulative arrival of fighters and cargo for Dual and Distinct Role Deployment](image)

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

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

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

In terms of this visual concept, the major sensitivity question that has to be asked then, is "is there sufficient uncertainty in the slope or in the horizontal displacement of the two Roles to doubt that Distinct Roles is better?"
In the above graphs, the horizontal displacement is the Set-up Time plus time to fly the first trip across the ocean. For the horizontal displacement to make up the difference between the Roles would require an error of incredible magnitude: 4 days!

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

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

Next, the graph of the Airlifter-only deployment must be considered. Since Airlifter KC-10s and Dual Role KC-10s fly the same route, the set-up times (horizontal displacement) are identical. The slope of the Airlifter-only deployment (ie: cargo deployment rate) would also have to be examined. Indeed, there is significant question,
based on the "bulkiness" of the cargo, as to how much cargo each airlifter KC-10 can carry per trip. The difference, though great, would not be enough to make 40 Distinct Role Airlifter KC-10s perform worse than 60 Dual Role KC-10s.

Selection of the Best Factor Settings

Recall from chapter 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, however, to choose a ground turn-around time without having information about the Maintenance Repair Time distribution. This therefore remains for future research.

The best ratio of fighters to KCs-10s was found to be six to one, for the overall deployment.
Of the three TTFs considered, only one was on the east side of the Atlantic Ocean, Mildenhall TTF was therefore mandatory to make the deployment feasible. On the west side of the Atlantic, a choice of two possible TTFs existed. Goose Bay, being closer to most of the AR tracks, was more effective than Loring AFB. It should be noted, however, that the use of two smaller TTFs, with some at Loring (refueling the AR tracks over New England) and some at Goose Bay (refueling the Atlantic AR tracks) would provide even better Closure Time.

Concept of Refueling the Dual Role KC-10s

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

1. **TTF effectiveness.** The 20 Distinct Role TTF KC-10s were able to deliver 30,114,100 pounds of fuel to the fighters in the same amount of time that it took 40 Distinct Role Airlifter KC-10s to deploy 12,000,000 pounds of cargo. This indicates that the KC-10 was twice as
effective in the TTF mission as it was in the Airlifter mission. In contrast to the TTF tankers which were able to provide ARs every few hours, the Dual Role KC-10s had to fly across the Atlantic and back (like the Distinct Role Airlifter) between ARs.

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

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

Although the Dual role KC-10s would only be able to make 1 lap every 45 hours, they would be able to deploy with many more fighters each lap. The "Tanker" program was used to calculate that the following numbers of fighters could be refueled if the Dual Role KC-10s were provided an AR:

8 F-16s, 6 F-15s, 6 F-111s, 6 RF-4Cs. Using the Dual Role deterministic equation, the total deployment would require 172 KC-10 trips.
The air refueling support for these Dual Role KC-10s could be provided by 1 TTF KC-10 for each Dual Role KC-10s deploying with F-15s, F-111s, and RF-4Cs. F-16 deployments, being more fuel efficient, only require 1 TTF KC-10 for every 2 Dual Role KC-10s. The total TTF support would thus be 128 KC-10 sorties, each 6.5 hours long. The deterministic TTF equation, previously used to find Fighter Closure Time, was used to derive the graph of Closure Time (of fighters and cargo being deployed by Refueled Dual Role KC-10s) versus Number of TTF KC-10s. Then, using the same iterative procedure that was used for apportioning KC-10s between the Distinct Role TTF and Airlifter missions, the following apportionment was calculated between TTF and Refueled Dual Role KC-10s:

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

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

The expected value of the Refueled Dual Role Closure Time was calculated to be 3.74 laps = 168 hours. This was 26 hours (18%) longer than the Distinct Role deployment Closure Time, which was 142 hours.
Is Distinct Role Significantly Better than Refueled Dual Role? The difference of 26 hours between the Closure Times of the Distinct Role and Refueled Dual Role concepts lies within the range of uncertainty. Recall that the upper bound of Closure Time uncertainty for the Distinct Role Airlifters was 20% greater (170 hours), based on only 80,000 pounds of cargo being carried per trip. Notice that, at this point, the Refueled Dual Role KC-10s would be carrying nearly as much cargo as the "bulked out" Airlifter-only KC-10s. This deletes one of the main advantages of the Distinct Role concept over the Dual Role concept: that the Distinct Role airlifters carried more cargo per lap. If the Distinct Role airlifters carried as little as 80,000 pounds per lap, the Distinct Role would have an insignificant advantage over refueled KC-10s. Further data needs to be obtained to reduce the large range of uncertainty surrounding Distinct Role Airlifter Closure Time.

(It should also be pointed out that this argument is based on "expected" Closure time for the transAtlantic laps. In reality, 3.74 laps means that 35 of the Dual role KC-10s would stop after 3 laps, and 11 of them would return for a fourth lap. Compare that to the Distinct Role concept: although 20 of the Airlifter KC-10s had to return for the fourth lap, all the fighters had actually arrived by 142 hours. What this means is that, even if the refueled Dual Role had an "expected" Closure Time equal to the Distinct Role Closure Time, the Dual Role would have 66 fighters...
arriving a half-lap (22 hours) later. Therefore, there is still a slight advantage to the Distinct Role concept.)

Summary

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

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

One attempt to reduce this inefficiency has been the idea of air refueling the Dual Role KC-10s to allow them to
deploy with more fighters and their cargo. In this way, the extra cargo can be carried by the Dual Role KC-10s, and the extra fuel can be carried by another tanker. It was shown that providing the extra ARs for the Dual Role KC-10s did not improve the effectiveness beyond that of the Distinct role.

The following chapter will summarize conclusions and make recommendations.
VI. Conclusions and Recommendations

Conclusions

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

Recommendations

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

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

2. **Reduce uncertainty.** Future research into the area of Distinct Role operations should also look more closely at the TTF operations to reduce the uncertainty surrounding the Closure Time resulting from TTF support of the fighter deployment. Three areas of TTF operation should be studied in depth:
   a. **KC-10 Maintainability/Reliability.** In order
to determine the optimal refueling rate, the KC-10 ground turn-around time must be scheduled so as to reduce late take offs (which cause missed ARs), and at the same time, increase the sortie rate (more AR sorties means faster Closure Time). In order to make that decision, the calculation of the Distribution of 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. **Consider the survivability of the KC-10.** Attrition of the KC-10s was not studied in this thesis. Consideration should be given in future studies to the increased vulnerability of the KC-10 while on the ground unloading cargo at the destination. In contrast to the estimated KC-10 unloading duration of 3 hours, the MAC airlifters, with rear-opening cargo doors, can unload cargo in one sixth the time, which could greatly improve survivability at a fighter destination base. On the other hand, there is also a disadvantage to putting all the KC-10s into large TTFs, because they become very lucrative targets.

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

**AFB.** Air Force Base.

**AFIT.** The Air Force Institute of Technology.

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

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

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

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

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

**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, responsible for the KC-10 both in peacetime and in crisis fighter deployments.

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

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

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

**USAF.** The United States Air Force.
Definitions of Terms

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

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

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

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

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

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

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

Conceptual Model. A logical/descriptive representation of the deployment operation.
Computerized Model. The conceptual model implemented on a computer.

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

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

Operational Concept. See Concept of Operation.

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

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

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

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

Receiver Aircraft. An aircraft receiving fuel from a tanker. In this thesis, fighter aircraft such as the F-15 are the receivers.
Refueling Boom. The apparatus on the tanker aircraft by which fuel is transferred to the receiver aircraft during flight.

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

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

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

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

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

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

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

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

DETERMINISTIC TTF PROGRAM

PROGRAM OUTPUT
Sensitivity of Fighter Closure Time

to Changes in TTF Ground Turn-Around Time

PRINTOUT FROM PROGRAM DETERMTTF.FOR

TURNTIME IS 1.0
FIGHTER CLOSURE TIME IS 121.9 HOURS

TURNTIME IS 1.5
FIGHTER CLOSURE TIME IS 127.0 HOURS

TURNTIME IS 2.0
FIGHTER CLOSURE TIME IS 132.2 HOURS

TURNTIME IS 2.5
FIGHTER CLOSURE TIME IS 137.3 HOURS

TURNTIME IS 3.0
FIGHTER CLOSURE TIME IS 142.5 HOURS

TURNTIME IS 3.5
FIGHTER CLOSURE TIME IS 147.7 HOURS

TURNTIME IS 4.0
FIGHTER CLOSURE TIME IS 152.8 HOURS

TURNTIME IS 4.5
FIGHTER CLOSURE TIME IS 158.0 HOURS

TURNTIME IS 5.0
FIGHTER CLOSURE TIME IS 163.1 HOURS

TURNTIME IS 5.5
FIGHTER CLOSURE TIME IS 168.3 HOURS

TURNTIME IS 6.0
FIGHTER CLOSURE TIME IS 173.5 HOURS

TURNTIME IS 6.5
FIGHTER CLOSURE TIME IS 178.6 HOURS

TURNTIME IS 7.0
FIGHTER CLOSURE TIME IS 183.8 HOURS

TURNTIME IS 7.5
FIGHTER CLOSURE TIME IS 188.9 HOURS

TURNTIME IS 8.0
FIGHTER CLOSURE TIME IS 194.1 HOURS
APPORTIONMENTS TO AR TRACKS AND TO TTFS

-- DATA FROM DETERMTTF PROGRAM

TURN TIME IS 3.0

GREEK ETA = 365.56

100 TANKER, 1.00 RELIABILITY ADDEND = 18.52
BASED ON 20 TANKERS, ADDEND = 92.62
BASED ON 0.95 RELIABILITY, ADDEND = 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
  RECOMPIRATION 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/
& ARCLATT, ARCLONG,
& EARLATT, EARLONG,
& TFLATT, TFLONG,
& ALTRAR, CASRAR, TIMERAR, DISTRAR, OFFRAR,
& TTFMAX70

real
& ARCPLATT(4,5), ARCPLONG(4,5),
& ERLATT(4,5), EARLONG(4,5),
& TTFLLATT(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 /EDNS/ CLOSURE, SETUPTM, FLYTOAR1, FLYTODST,
  & FTRCELL, TOTNOFTR, TURNTIME, KCFITIME,
  & KCLAPS, GOOUT, GORTB,
  & TOTALTK, TTFAPPRT, RELIBLT, KCTRACK,
  & IITTFL, JFTRL, KTRAKL, NEARTTF,
  & DOMINATD

REAL CLOSURE, SETUPTM, FLYTOAR1, FLYTODST,
& FTRCELL(4), TOTNOFTR(4), TURNTIME(3), KCFITIME(4,5),
& KCLAPS(4,5), GOOUT(3,4,5), GORTB(3,4,5),
& TOTALTK, TTFAPPRT(3), RELIBLT, KCTRACK(4,5)

REAL SORINTVL(4,5), AVGGLAPINT(4,5)

INTEGER IITTFL, 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 /THESS/FULSUB, TOWN, OPWT, FULLND, CRUDDG, RBTALT, RTBTIM, FLTWT
  & CBT, DIST1S, FARCAS, DIST3, WTIT, 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, LCA8, IPNT

REAL
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')
& STATUS='OLD')
IF (ITANKR.EQ.4) OPEN(10,FILE='GST86J:JHUNSUJ.FUELSJK135.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 FLYTOARI/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,G0U0T,00R0B)
*
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 (G0U0T(I,J,K).EQ.0.) GO TO 0100
         (IE: TRACK IS NON-EXISTANT, SO GO TO NEXT TRACK)
* IF THIS IS NOT THE CLOSEST TTF TO THIS TRACK,  
* THEN SKIP THE CALCULATIONS,  
* ELSE ** CALL TANKER ** TO CALCULATE FUEL, FEASIBILITY: 

* IF (NEARTTF(J,K),NE.1) GO TO 0100  
CONTINUE

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

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

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

CALL TANKER  
REWRITE(10)

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

* TRANSLATE THE 'TANKER' VALUES INTO VARIABLE NAMES USED BY  
* THIS PROGRAM:  
* KCLAPS(J,K)=NUMFA1  
* KCFTIME(J,K)=TIME  
* KCFUELUS(I,J,K)=TOTAL  
* KCFUELOF(I,J,K)=OFLOAD(1)*NUMFA1*ANUMRC(1)
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(IX,'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(IX,',' 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(IX, ' 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,
\& TTFLNXTD

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),
\& TTFLNXTD(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.

* UHLOADs 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.
  TTFMXTOD(1) = 588200.

* Coords for TTF Base -- Mildenhall, England:
  TTFNAME(2) = 'MILDENHALL'
  TTFLATT(2) = 5222.
  TTFLONG(2) = -00029.
  TTFMXTOD(2) = 588200.

* Coords for TTF Base -- Loring AFB, Maine, USA:
  TTFNAME(3) = 'LORING AFB'
  TTFLATT(3) = 4657.
  TTFLONG(3) = 06753.
  TTFMXTOD(3) = 588200.

RETURN
END

******************************************************************************
SUBROUTINE CALCDISTANCE(ITTF, ISI, IPTTF, JFTRL, KXRAIL, ARCPLATT,
PROGRAM TO CALCULATE THE DISTANCES BETWEEN THE TTF AND AR TRACK.

INTEGER ITTF, ISKIPTTF, JFTRL, KTRAKL
REAL ARCPLATT(4,5), ARCPLONG(4,5), EARLATT(4,5), EARLONG(4,5),
& TTFATT(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 = ITTF, ITTFL
  (I is the TTF)
  IF (I.EQ.ISKIPTTF) GO TO 2222
  DO 2222, J = JFTRL, JFTRL
  (J is the fighter type)
  DO 2222, K = KTRAKL, 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(TTFATT(I), TTFLONG(I),
    & ARCPLATT(J,K), ARCPLONG(J,K))
    GORTB(I,J,K) = GREATCIR(EARLATT(J,K), EARLONG(J,K),
    & TTFATT(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 Lattitude, West Longitude, and negative values for South Lattitude, East Longitude.

* It can therefore be seen that
  * c = distance from North Pole to Origin = 90 degrees - Origin Latitude
  * b = distance from North Pole to Dest. = 90 degrees - Destination Latt. 
  * A = angle at top of triangle = Origin Longitude - Destination Longitude.

* The law of cosines for sides of a spherical triangle states that:
  * \( \cos a = \cos b \cos c + \sin b \sin c \cos A \)
  * Thus, the Great Circle Distance between the Origin and Destination is
  * \( a \), the arccos of the above value.

* The distance is converted to nautical miles by multiplying \( a \times 60 \), statute miles \( a \times 60 \times 1.151 \), kilometers \( a \times 60 \times 1.852 \).
NOTE: This program assumes all latitudes are North and all longitudes are West.

To enter South Latitudes 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 =}
  GreatCir=smalla*60
  (in nautical miles)}

  * #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)

B-16
real deg, x radians
* (This function converts radians back to degrees.)

parameter pi = 3.141592653589793.

* (begin)
  .deg = x radians * (360.0/(2.0*pi))
  return
* (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, FLYTOARI, FLYTODST,
& FTRCELL, TOTNOFTR, TURNTIME, KCEFTIME,
& KCLAPS, GOOUT, GORTB,
& TOTALTNK, TTFAPPRT, RELIBLT, KCTRACK,
& ITTFL, JFTRL, KTRAKL, NEARTTF,
& TTFNAME, FIGHTER,
& DOMINATD

REAL CLOSURE, SETUPTM, FLYTOARI, FLYTODST,
& FTRCELL(4), TOTNOFTR(4), TURNTIME(3), KCEFTIME(4,5),
& KCLAPS(4,5), GOOUT(3,4,5), GORTB(3,4,5),
& TOTALTNK, TTFAPPRT(3), RELIBLT, 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

B-17
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=IITTFL
    DO 0101 J=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
    ELSE
        WRITE(12,0008)
        FORMAT('***BEST SOLUTION -- CLOSEST TO AR TRACK')
    END IF

0101 CONTINUE

RETURN
END

* OF SUBROUTINE NOTDOMINATED
*

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

SUBROUTINE CLOSURETIME
*
* (THIS SUBROUTINE APPORTIONS TANKERS AMONG SEVERAL TTFS, AND CALCULATES THE
*  RESULTING OPTIMAL CLOSURE TIME FOR THE DEPLOYING RECEIVERS (FIGHTERS).)
*
* COMMON/EOONS/CLOSURE, SETUPTM, FLYTOAR1, FLYTODST,
*    FTRCELL, TOTNOFTR, TURNTIME, KCFLTME,
*    KCLAPS, GOOUT, GORTB,
*
B-18
**REAL** CLOSURE, SETUPTM, FLYTOAR1, FLYTODIST,
& 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):*101, 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(IX,'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 (GODOUT(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))
   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)))
0400 CONTINUE

*!! 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)

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

*!! 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)
   END DO
   NEXT, SUM THE APPORTIONMENTS OF EACH TTF:
   TTFAPPRT(NEARTTF(J,K)) = TTFAPPRT(NEARTTF(J,K))
& + KCTRACK(J,K)
0600 CONTINUE

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

ADDEND3 = GREEKETA/KCTRACK(1,1)

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

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

ADDEND3 = ADDEND3 / (TOTALTNK/100.)

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

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

ADDEND3 = ADDEND3 / RELIBLTY

B-21
* 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.

CLOSE = SETUPTM + FLYTOAR1 + ADDEND3 + FLYTODST

RETURN
END

*(OF SUBROUTINE CLOSURE TIME)*

=================================================================
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
*** DETERM TF 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 ,YTABI ,YTAB2
& ,CCALT ,CCNAM
& DOUBLE PRECISION CCALT (17)
& ,CCNAM (17)
& ,YTABI (17,7)
& ,YTAB2 (17,7)
REAL ONLOAD ,RFDRAG

B-22
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:
COMM /HUNSUCK/ITANKR, IFULOP, NUMFAR, NUMFAI
COMMON /THESIS/FULSUB,TONT,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,WTIT,WTTTIY1,Y2,Y3,Y4
INTEGER I,IX
& ,ICELL,IDECRM,LEND,IERR,IFLAG,IFULOP,ITANKR
& ,ITEMP,J,JJ,K,LL,ML,NUMAAR,NUMLSV,NUMLEG,NUMFAI
& ,NUMFA1
C ptr DATA ALTX /15000.,20000.,25000.,30000.,35000.,40000.,45000./
C ptr DATA ALTI /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)NUMFAI,ANUMRC(NUMFAI)
* 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)

B-23
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
* NUMFAI = 1
* WRITE(*,0101) TOWT
* 0101 FORMAT(1X,'ENTER T.O. WEIGHT (DEFAULT =',F12.0,')')
* READ(*,*) TOWT
TOWT=TOWT
* WRITE(*,0402) CWT
* 0402 FORMAT(1X,'ENTER CARGO WT (DEFAULT =',F12.0,')')
* READ(*,3:) CWT
OPWT=OPWT+CWT
TOTFUL=TOWT-OPWT
* WRITE(*,0102) TOTFUL
* 0102 FORMAT(1X,'T.O. FUEL =',F8.I)
TOWT=TOWT-FULSUB
TIME=0.
* WRITE(*,0800) CRUDRGRFDRAG
* 0800 FORMAT(1X,'ENTER CRUISE AND REFUEL DRAG FACTOR (DEFAULT = ',
* & '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) DISTIS
* 0900 FORMAT (1X,'DISTANCE TO FIRST TAR OR RAR OR AAR (DEFAULT = ',
* & 'F12.0,')')
* READ(*,*) DISTIS
DISTI = DISTIS
* IF(DISTI.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

B-24
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) WTT, 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 ',BE12.2)
* 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.FUELS1KRW.DAT',
* & STATUS='OLD')
* IF(ITANKR.EQ.2) OPEN(10,FILE='GST86J:JHUNSUCK.FUELS1KRTT.DAT',
* & STATUS='OLD')
* IF(ITANKR.EQ.3) OPEN(10,FILE='GST86J:JHUNSUCK.FUELS1KRXA.DAT',
* & STATUS='OLD')
* IF(ITANKR.EQ.4) OPEN(10,FILE='GST86J:JHUNSUCK.FUELS1KC135.DAT',
* & STATUS='OLD')
READ (10,*) FULSUB
READ (10,*) TOWT, OPWT, FULLND, FULRES, CRUDRG, RFDRAG, RTBALT,
& RTBTL,J,FRTWT
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), I=1,17), J=1,7)
* 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

B-25
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.
ITEMP=IDINT(CCNAM(I))-(ITEMP*1000)
CCCAS(I)=FLOAT(ITEMP1)
TEMP=CCCAS(I)+(CCALT(I)*10.)
CCNAM(I)=CCNAM(I)-ITEMP

5030 CONTINUE
DO 5040 I=1,17
DO 5040 J=1,5
LCAS(I,J)=DAT1(I,J)/L
DAT1(I,J)=DAT1(I,J)-1.*LCAS(I,J)
ICTAS(I,J)=DAT2(I,J)/L
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 ENWIF
DO 6030 I=1,17
DO 6030 J=1,7
YTAB1(I,J) = DAT(I,J,LL)
IF(IFLAG.NE.1)
& YTAB2(I,J) = DAT(I,J,LL)
C ENDDO
6030 CONTINUE
C ENDDO
*IF(IFLAG.NE.1)
& DIFF = ((ALT - ALT1(J))/1000.)/5.
C ENDIF
   GO TO 1Z, (7110,8210,9130)
C******************************************************************************
6300 CONTINUE

   ***     WRITE(*,*) '*** LABEL 6300, PROLAT'
      IF(DIST.LE.250.) GO TO 6320
      Y1 = TNT1(CURRWT,17,WT,CCALT,2,IERR)
      WRITE(*) 'Y1=',Y1,ALT
      IF(Y1.LE.ALT) GO TO 6310
      CALL PROLAT TO GET CLIMB NUMBERS
      WRITE(*) 'WT BEFORE PROLAT=',CURRWT
      CALL PROLAT(Y1,Y2,Y3,ALT,CURRWT)
      TIME = TIME + (Y3/60.)
      DIST = DIST - Y2
      WRITE(*) 'TIME AFTER PROLAT=',TIME
      WRITE(*) 'WT AFTER PROLAT',CURRWT
      Y1 = TNT1(CURRWT,17,WT,CCALT,2,IERR)
      WRITE(*) 'ALT AFTER PROLAT=',Y1
6310 CONTINUE
C ENDIF
   CALL CRUCLM(TIME,DIST,CURRWT,CRUDR)
   GO TO 6340
C ELSE
6320 CALL CRUISE(ALT,DIST,CURRWT,TIME,CRUDR)
6340 CONTINUE
C ENDIF
   GO TO 1Z, (7190,8220,9165)
C******************************************************************************
6500 CONTINUE

   ***     WRITE(*,*) '*** LABEL 6500, NORMAL CLIMB AND TAR'
      TOWT1 = TOWT
      DO 6510 I=1,7
      Y1 = TNT1(TOWT1,17,WT,CCALT,2,IERR)
      Y1 CONTAINS A HACK AT CRUISE CLIMB ALT
      CALL CLIMB(TOWT1,TIME,Y1,Y2,Y3,Y4)
6510 TOWT1 = TOWT - (Y2*CRUDR)
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,CRUDR)
   WRITE(*) 'TIME,CURRWT,CLDIST=',TIME,CURRWT,CLDIST
   CLDIST=0.

B-27
* 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
O 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*******************************************************************************/
C THE FOLLOWING LINES ADDED BY HUNSUCK TO MAKE DECREMENT OCCUR BY CELL:
6600 NUMFAR = NUMFAR -1
IF (NUMFAR.EQ.0) IEND = 1
NUMFA1=NUMFAR
C*******************************************************************************/
**$ THE FOLLOWING LINES ADDED BY HUNSUCK TO MAKE DECREMENT OCCUR BY CELL:
*** WRITE(*,*) '***$ LABEL 6600 DCRM'
* 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(I).EQ..5) GO TO 6620
* ANUMRC(I) = .5
* GO TO 6650
*C ELSE
* 6620 ANUMRC(NUMFAR) = 0. /*
* NUMFAR = NUMFAR - 1 /*
* IF(NUMFAR.GT.0)
* & ANUMRC(I) = 1.
*C ENDIF
* IF(NUMFAR.EQ.0)
* & IEND = 1 /*
*C ENDIF
* 6650 CONTINUE
*C ENDIF
GO TO 7070
C*******************************************************************************/
C IF(NOPRNT.EQ.0)WRITE(*,*) 'ENTER LOITER ALT,TIME OVER RTB BASE'
C IF(NOPRNT.EQ.0)READ(*,*) RTBAL,RTBTim
6700 FARALT(CML) = RTBALT
C*******************************************************************************/
*** WRITE(*,*) '***$ LABEL 6700 LOITER AND LAND'
TML(TML) = RTBTim
TOTA=OPWT+TOTFUL-CURRW
CALL LOITER(TIME,CURRW,TML,CURDGR)
TIME = TIME -.583

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* IF(NOPRNT.EQ.0)
  * & WRITE(*,6710) TIME
  C ENDIF
  * 6710 FORMAT(1X,'TOTAL TIME ',F8.1)
  C WRITE(*,*) 'ENTER LANDING FUEL'
  C READ(*,*) FULLND
  CURRWT = CURRWT - FULLND
  TOTA = TOTA + FULLND
  WTTT = CURRWT - OPWT
  GO TO IX, (7050,9075)
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,(' ', 'FB.8)'))
  * 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(*,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

B-29
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(I6,'WHAT IS DISTANCE TO TAR (DEFAULT = ',F12.0,')')
READ(*,*) DISTTA
WRITE(*,7023) TARTIME
7023 FORMAT(I6,'ENTER TIME (MIN) FOR TAR (DEFAULT = ',F12.0,')')
READ(*,*) TARTIME
WRITE(*,7024) TARALT,TARCAS
7024 FORMAT(I6,'WHAT IS TAR ALTITUDE AND CAS? (DEFAULT = ',F12.0,' & ',F12.0,')')
READ(*,*) TARALT, TARCAS
WRITE(*,7025) DIST2
7025 FORMAT(I6,'WHAT IS DISTANCE TO NEXT TAR OR RTB BASE? (DEFAULT = ',F12.0,')')
READ(*,*) DIST2
7026 CONTINUE
C ENDIF
STIME = TIME
SGWT = CURRWT
TOTFUL=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=TOTFUL
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 = ICHECK(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,DIF
ASSIGN 7110 TO 12
GO TO 6000
7110 CONTINUE
C END INCLUDE
C IF ((ML.GT.NUMFA).OR.(IDECRM.EQ.1)) THEN
7120 CRUTIM = TIMELT(8)
& IF ((RCVR.EQ.5).AND.(ML.GT.1))
    & TIMELT(ML) = TANKLT - CRUTIM - FARTIMC1)
& IF(TIMELT(ML).LT.0) WRITE(*,7130)
7130 FORMAT(1H,'TIME TO SMALL')
*** the following added by hunhick:
* IDECRM=ICHECK(IFULOP,CURRWT,OPWT,FULRES)
  IF (TotFull.le.35000) IDECRM=1
  IF (IDECRM.EQ.1) GO TO 7030
***
CALL LoTER(TIME,CURRWT,ML,CURDWRG)
IDECRM = ICHECK(IFULOP,CURRWT,OPWT,FULRES)
*** the following added by hunhick:
  IF (TotFull.le.35000) IDECRM=1
  IF (IDECRM.EQ.1) GO TO 7030
***
* IF(IDECRM.EQ.1) GO TO 7190
* 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, CURRENT, OPWT, FULRES)

*  IF(IDECRM.EQ.1) GO TO 7180

*** the following added by hunsuck:
  if (totful.le.35000) idecrm=1
  if (idecrm.eq.1) go to 7030
  if (currwt.lt.(opwt+ofload(riil)+ANUMRC(riil)+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***********************************************************MAR REFUELING NUMBER 1**************
8000 WRITE(*,8005) DISTA, ONLOAD
***  WRITE(*,*) '*** LABEL 8000, TAR REF 1'

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FORMAT(1X,'ENTER DISTANCE AND ONLOAD FOR TAR (DEFAULT = ', & F12.0,' , ',F12.0,')')
READ(*,*) DISTTA,ONLOAD
WRITE(*,8008) TARTIME

FORMAT(1X,'ENTER TIME (MIN) FOR TAR NUMBER 1 (DEFAULT = ', & F12.0,')')
READ(*,*) TARTIME
WRITE(*,8008) TARTIME

FORMAT(1X,'WHAT IS TAR ALTITUDE AND CAS? (DEFAULT = ', & F12.0,' , ',F12.0,')')
READ(*,*) TARALT, TARCAS
WRITE(*,8030) DIST2

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(*,'(14)') 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*****************************************************************************

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.O.)
    ONLOAD = ONLOAD - WTTT
C ENDIF

8160 CONTINUE
C ENDIF

8170 CONTINUE
C END IF
C INCLUDE TAR REFUELING
ASSIGN 8170 TO IY
GO TO 8200

8200 ALT = TARALT
*** WRITE(*,*) '*** LABEL 8200, TAR REFUELING'
C INCLUDE SET YTAB1,YTAB2,DIF
ASSIGN 8210 TO IZ
GO TO 6000

8210 CONTINUE
C END INCLUDE
TOTFUL=TOTFUL+ONLOAD
CALL LOAD(1,CURRWT,TARCAS,IFLAG,DIF,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***********************************************************************
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 ENDDD
TIMELT(1) = 15.
WRITE(*,9012) ANMRC
9012 FORMAT(IX,'ENTER NUMBER OF RECEIVERS (DEFAULT = ',
& F12.0,')'),READ(*,*) ANMRC
ANMRC(1)=ANMRC
IF(FARALT(1).NE.0.) GO TO 9014
WRITE(*,9013) FARALT(1),FARCAS
9013 FORMAT(IX,'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 ENDD
WRITE(*,9015) NULSV,NUMAAR
9015 FORMAT(IX,'ENTER NUMBER OF LEGS AND NUMBER OF AARs (DEFAULT = ',
& I4,?,',',I4,?)'),READ(*,*) NULSV,NUMAAR
NUMLEG=NULSV
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),DLEGM(I),I = 1,NUMLEG)
9016 FORMAT(10X,F9.0,5X,F9.0,/) READ(4,*) (DLEGSV(I),DLEGM(I),I = 1,NUMLEG)
DO 9027 I = 1,NUMLEG
9027 DLEG(I)=DLEGSV(I)
IF(DLEG(I).LE.CLDIST)
& DLEG(I) = 0.
C ENDF
C ENDIF 9017 CONTINUE
ICHG=0
WRITE(*,*1) 'TYPE 1 TO ENTER NEW TIME,DISTANCE & OFLOAD FOR AAR'
READ(*,'(I4)') ICHG
IF(ICHG.NE.1) GO TO 9019
WRITE(*,*1) 'ENTER TIME,DISTANCE & OFLOAD FOR AAR S IN ORDER'
WRITE(*,*1) 'DEFAULTS ARE:'
WRITE(*,9018) (FARTIM(I),FARDST(I),OFLOAD(I),I=I=NUMAAR)
9018 FORMAT(10XF8.0,3XF8.0,3XFS.0,I)
READ(*,*) (FARTIM(I),FARDST(I),OFLOAD(I),I=I=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(*,*1) '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,')')
READ(*,*) TARALT,TARCAS
WRITE(*,9024) DIST2
9024 FORMAT(1X,'DISTANCE TO NEXT TAR OR RTB (DEFAULT = ',
& F12.0,')')
READ(*,*) DIST2
9030 CONTINUE
C ENDIF
C ENDIF
STIME = TIME
SGWT = CURRWT
STOTFUL=STOTFUL
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(IDECRM.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
C ENDIF
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)

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 END Include
AARLEG
   ASSIGN 9150 TO IY
      GO TO 9600
9150 CONTINUE
C END Include
   ML = ML + 1
9160 CONTINUE
C END IF(IDECRM.NE.1.AND. (ML.LE.NUMLEG.OR.ML.LE.NUMAAR)) GO TO 9135
C ENDDD
   IF(DIST3.EQ.0) GO TO 9180
   DIST = DIST3
C INCLUDE PROLAT SECTION
   ASSIGN 9165 TO IZ
   GO TO 6300
9165 CONTINUE
C END
9180 CONTINUE
C ENDIF
9190 CONTINUE
C ENDIF
GO TO IX,(9050)
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 = TMT2(CURRWT,FARCAS,17,7,WT,AS,YTAB1,IERR1,IERR2,17,0)
      IF(IFLAG.EQ.1) GO TO 9530
      Y2 = TMT2(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)
   CURRT = CURRWT - A
   IDECRM = ICHEK(IFULOP,CURRWT,OPWT,FULRES)
   IF(NOPRNT.EQ.0.AND.IPNT.EQ.1)
      WRITE(*,9540)ML,1,DIST,A,CURRT
540 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**********************************************************************
9600 CONTINUE
***     WRITE(*,9600) '**** 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
     ENDIF
C     IF(OFLOAD(ML) .LT.0)
       & TOTFUL=TOTFUL-OFLOAD(ML)
C     ENDIF
     CALL LOAD(ML,CURRWT,FARCAS,IFLAG,DIFF,CRUDRG,2)
     IDECM = ICHEK(IFULOP,CURRWT,OPWT,FULRES)
9650 CONTINUE
C      ENDIF
     GO TO IY, (9150)
C**********************************************************************
9700 CONTINUE
***     WRITE(*,9700) '**** 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 CLIME(TOWT1,TIME,Y1,Y2,Y3,Y4)
     CURRWT = TOWT - Y2
     CDIST = 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),DAT(:,17,5),LCAS(17,5),
& INPNT
COMMON/B/ALTX(8),CCCAS(17),CFUEL(17,7),CTIME(17,7),CDIST(17,7),
& TARTIME
COMMON/C/RFDRTA,ONLOAD,YTAB1(17,7),YTAB2(17,7),CCALT(17),
& CCNAM(17)
COMMON/D/FARDST(15),TIMELT(15),OFLOAD(15),NUMREC,FARALT(15),
& ALT(:,5),FARTIM(15)
DOUBLE PRECISION CTIME,CCNAM,CCCAS
DOUBLE PRECISION CFUEL,CDIST,CCALT
DOUBLE PRECISION YTAB1,YTAB2
WTT=CURRWT
B-38
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)
WRITE(*) 'Y1=',Y1
C
Y2=TNT2(WTT,AALT,17,7,WT,ALTX,CDIST,IERR1,IERR2,17,0)
C
Y3=TNT2(WTT,AALT,17,7,WT,ALTX,CTIME,IERR1,IERR2,17,0)
C
GO TO 1
3 CONTINUE
Y4=TNT2(WTT,AALT,17,7,WT,ALTX,CFUEL,IERR1,IERR2,17,0)
C
Y5=TNT2(WTT,AALT,17,7,WT,ALTX,CDIST,IERR1,IERR2,17,0)
C
Y6=TNT2(WTT,AALT,17,7,WT,ALTX,CTIME,IERR1,IERR2,17,0)
C
GO TO 1
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
SUBROUTINE CRUICECLIME(TIME, DISTER, WTT, DRAG)
COMMON/A/DISTTA(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/RFDRA,G,ONLOAD,YTAB1(17,7),YTAB2(17,7),CCALT(17),& CCNAM(17)
COMMON/D/FARDST(15),TIMELT(15),DFLOAD(15),NUMREC,FARALT(15),& ALTI(5),FARTIM(15)
COMMON/F/NOPRNT
DOUBLE PRECISION CCNAM,CCCAS,CCALT
DOUBLE PRECISION CDIST,CFUEL,CTIME
DOUBLE PRECISION YTAB1,YTAB2
WRITE(*) '*** SUBROUTINE CRUICECLIMA***
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)
CONTINUE
RETURN
END

SUBROUTINE LOAD (1, CURRWWT, TARCAS, IFLAG, DIFF, CRUDR3, MM)
COMMON /A/ DISTAAWTT(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),
& TARCAS
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 = DISTTAWT/S.
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(CURRWWT, 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(CURRWWT, TARCAS, 17, 7, WT, AS, YTAB1, IERR1, IERR2, 17, 0)
IF (IFLAGG.NE.1) Y2 = TNT2(CURRWWT, TARCAS, 17, 7, WT, AS, YTAB2, IERR1, IERR2, & 17, 0)
IF (IFLAGG.NE.1) Y1 = Y1 + (DIFF$$(Y2-Y1))
2 A = FUEL(Y1, DIST, CRUDR3)
IF (MM.EQ.1) CURRWWT = CURRWWT - A + ONLOAD/S.
A = FUEL(Y1, DIST, RFDRAG)
IF (MM.EQ.2) CURRWWT = CURRWWT - A - LOADD/S.
IF (CURRWWT.LE.100000) CURRWWT = 100000
WRITE(*,100) J, DIST, CURRWWT
100 FORMAT(1X, 'ON TAR OR RAR SUBLEG ', I2, ', DIST = ', F5.0, & ', CURRWWT = ', F8.0)
CONTINUE
C WRITE(*,105) CURRWT
* IF(NOPRNT.EQ.0) WRITE(*,105) CURRWT
* 105 FORMAT(1X,'CURRENT WT=',F7.0,' AFTER TAR OR RAR NUM ',I1)
RETURN
END

SUBROUTINE CLIMB(TOWT1,TIFIE,Y1,Y2- ,Y3,Y4)
COMION/A/ISTAWT(1
/7,AS(7),DA117,7,4),DA117,5),LCAS(17,5),
& IPNT
COMMON/B/ALTX(8),CCAS(17),CFUEL(17,7),CTIME(17,7),CDIST(17,7),
& TARTIME
COMMON/C/RFDRA,ONLOAD,YTAB1(17,7),YTAB2(17,7),CCALT(17),
& CCNAM(17)
COMMON/D/FARDST(C15),TIME,T15),OFLOAD(C15),NUMREC,FAALT(15),
& ALTI(5),FARTIM(15)
DOUBLE PRECISION CTIME,CCNAM,CCAS
DOUBLE PRECISION CFUEL,CD1ST,CCALT
DOUBLE PRECISION YTAB1,YTAB2
C WRITE(*,100) Y1,Y2,Y3,Y4
100 FORMAT(2X,'FINAL ALT,WT,DIST,TIME=',
& 2X,F7.1,2X,F7.11,2XF5.1,2XF4.1)
RETURN
END

FUNCTION TNT1(XARG,NTBARG,XTBARG,YTBARG,NPTARG,NERR)
DIMENSION XTBARG(NTBARG),YTBARG(NTBARG)
DOUBLE PRECISION YTBARG
*

FUNCTION TNT1 '*** FUNCTION TNT1'
1 NTAB=NTBARG
X=XARG
NPT=MINO(NTAB,NPTARG)
C *****************************************************************************
 TABLE SEARCH*****************************************************************************
 CALL TLU1(X,NTAB,XTBARG,J,NERR)
 IF(NERR.NE.0) GOTO 901
 JMIN=MAX(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=XTBARG(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

B-41
CONTINUE
GO TO 1001

C ~~~~~~~~~~~~~~~ X OUT OF RANGE OF TABLE ~~~~~~~~~~~~~~~
Y = 0.0
RETURN
END

FUNCTION TNT2(X1ARG, X2ARG, N1ARG, N2ARG, XIARG, X2TARG, YTBARG, &
J1ARG, J2ARG, IDIM, II)
DIMENSION XIARG(N1ARG), X2TARG(N2ARG), YTBARG(IDIM, N2ARG)
DIMENSION N(2), X(2), Y(2), XI(TAB(2), X2TAB(2), YTAB(2, 2), TEMP(2)
DOUBLE PRECISION YTBARG
N(1) = N1ARG
N(2) = N2ARG
X(1) = XIARG

C ~~~~~~~~~~~~~~~ SEARCH FIRST INDEPENDENT TABLE ~~~~~~~~~~~~~~~
K = 1
CALL TLUI(X(1), N(1), XIARG, N1, J1ARG)
X(2) = X2ARG

C ~~~~~~~~~~~~~~~ SEARCH SECOND INDEPENDENT TABLE ~~~~~~~~~~~~~~~
CALL TLUI(X(2), N(2), X2TARG, N2, J2ARG)
IF(J1ARG .NE. 0 .OR. J2ARG .NE. 0) GO TO 901
N1 = MAX01, MIN0(N1, N(1) - 1))
N2 = MAX01, MIN0(N2, N(2) - 1))

C ~~~~~~~~~~~~~~~ STORE TABLE VALUES IN TEMPORARY LOCATION ~~~~~~~~~~~~~~~
DO 121 J1 = 1, 2
M1 = J1 + N1 - 1
M2 = J1 + N2 - 1
XI(TAB(J1)) = XIARG(M1)
X2TAB(J1) = X2TARG(M2)
DO 121 J2 = 1, 2
M2 = J2 + N2 - 1
YTAB(J1, J2) = YTBARG(M1, M2)

C ~~~~~~~~~~~~~~~ PERFORM INTERPOLATION ~~~~~~~~~~~~~~~
IF(N(1) .GT. 1) GO TO 241
IF(N(2) .GT. 1) GO TO 231
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(:) = X(1) - XI(TAB(1))
TEMP(] = 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
GO TO 1001
RETURN
END

SUBROUTINE TLUI(ARG, NTAB, TAB, J, IERR)
DIMENSION TAB(NTAB)
IERR=0
DO 21 J1=1,NTAB
IF(TAB(1).GT.TAB(2))VAR=TAB(J1)-AR
IF(TAB(1).LT.TAB(2))VAR=AR-TAB(J1)
IF(VAR)41,61,21
21 CONTINUE
IERR=1
J=NTAB
GO TO 5001
41 IF(J1.GT.1) GO TO 101
IERR=-1
J=1
GO TO 5001
61 J1=J1+1
101 J=J1-1
5001 RETURN
END
SUBROUTINE LOITER (TIME,CURRT,ML,CURDRT)
COMMON/A/DIST1,WT(17),AS(7),DAT(17,7,4),DAT1(17,5),LCAS(17,5),
& IPNT
COMMON/B/ALTX(8),CCAS(17),CFUEL(17,7),CTIME(17,7),CDIST(17,7),
& TAR
COMMON/C/RFDRAG,ONLOAD,YTAB1(17,7),YTAB2(17,7),CCALT(17),
& CCNAM(17)
COMMON/D/FARDST(15),TIMELT(IS),DFLOAD(IS),NUMREC,FARALT(15),
& ALT1(5),FARTIM(15)
COMMON/F/NOPRNT
DOUBLE PRECISION CTIME,CCNAM,CCAS
DOUBLE PRECISION CFUEL,CDIST,CCALT
DOUBLE PRECISION YTAB1,YTAB2
DIMENSION YTAB3(17),YTAB4(17),YTAB5(17),YTAB6(17)
DOUBLE PRECISION YTAB3,YTAB4,YTAB5,YTAB6
*** WRITE(*,*) '********* SUBROUTINE LOITER! *** ***'
IFLAG=0
IF(IPNT.EQ.1.AND.NOPRNT.EQ.0)WRITE(*,100)ML,TIME,CURRT
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.)
TIMEI=TIMELT(ML)/5.
DO 2 I=1,17
YTAB3(I)=DAT1(I,JJ)
IF(IFLAG.NE.1)YTAB4(I)=DAT1(I,LL)
YTAB5(I)=LCAS1(I,JJ)
2 IF(IFLAG.NE.1)YTAB6(I)=LCAS1(I,LL)
IF(IFLAG.NE.1)DIFF=(FARALT(ML)-ALTX(JJ))/1000./5.
DO 3 I=1,5
Y1=TNT1(CURRT,17,ML,YTAB3,2,IER)
B-43
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.*AI
** WRITE(*,2,IY,DISTER,CRUDRG TIME1,A1)
** 200 FORMAT(1X,'Y1,F7.0,' DISTER:',F7.0, ' CRUISE:' ,F7.0, 
** &' TIME1:',F7.0, ' A1:',F7.0)
A=FUEL(Y1,DISTER,CRUDRG)
CURRWT=CURRWT-A
TAS=AI
IF(IPNT.EQ.1.AND.NOPRNT.EQ.0)WRITE(*,101)ML,TAS,DISTER
WRITE(*,102) TIME1,A,CURRWT
100 FORMAT(1H,'ON LOITER LEG ',II,' THE TIME= ',F8.1, ' CURRWT= ', 
& F8.0)
101 FORMAT(1H,'LOITER LEG',II,' SUBLEG',II,' TAB= ',F8.2, 
& ' DIST= ',F6.1)
102 FORMAT(1H,'TIME= ',F3.0, ' FUEL USED= ',F8.0, ' GWT= ',F8.0)
RETURN
END
SUBROUTINE CRUISE(Y,Z,CURRWT,CUMTIME,CRUDRG)
COMMON/A/DISTA,WT(17),AS(7),DAT(17,7,4),DAT(17,5,LCAS(17,5)), 
& IPNT
COMMON/FARDST(15),TIMELT(15),OFLOAD(15),NUMREC,FARALT(15), 
& ALTI(5),FARTIM(15)
COMMON/F/NOPRNT
COMMON /G/ DAT2(17,5),ICTAS(17,5)
C *** Y = ALTITUDE, Z = DISTANCE, CURRWT = CURRENT WEIGHT, 
C *** CUMTIME = CUMMULATIVE FLIGHT TIME, CRUDRG = CRUISE DRAG FACTOR 
C *** COMMON/D/FARDST(15),TIMELT(15),OFLOAD(15),NUMREC,FARALT(15), 
& ALTI(5),FARTIM(15)
C *** WRITE(*,103) 'CRUISE TABLES DAT2 & ICTAS = ',YTAB3(I),YTAB5(I)
*** WRITE(*,104) 'CRUISE ALTI & DIST = ',Y,Z
RETURN
END
IF (IFLAG .NE. 1) YTAB6(1) = CTAS(I, LL)
IF (IFLAG .NE. 1) DIFF = (MT1(J,J)/1000.) / 5.
DO 3 I = 1, 5
   Y1 = TNT1(CURRWT, 17, WT, YTAB2, 2, IERR)
   IF (IFLAG .NE. 1) Y2 = TNT1(CURRWT, 17, WT, YTAB4, 2, IERR)
   C WRITE(*, 1) 'NAM/LB = ', Y1
   IF (IFLAG .NE. 1) Y1 = Y1 + (DIFF * (Y2 - Y1))
   A = FUEL(Y1, DIST, CRUDE)
   Y1 = TNT1(CURRWT, 17, WT, YTAB4, 2, IERR)
   IF (IFLAG .NE. 1) Y2 = TNT1(CURRWT, 17, WT, YTAB6, 2, IERR)
   CURRWT = CURRWT - A
   C WRITE(*, 1) 'TAS = ', Y1
   A1 = Y1
   IF (IFLAG .NE. 1) A1 = Y1 + (DIFF * (Y2 - Y1))
   TIME = DIST/A1
   CUMTIME = CUMTIME + TIME
3   IF (IPNT .EQ. 1 .AND. NOPRNT .EQ. 0) WRITE(*, 102) DIST, A, CURRWT
   IF (IPNT .EQ. 1 .AND. NOPRNT .EQ. 0) WRITE(*, 103) DIST, A1, TIME, TIMER, Y
   TIMELT = TIMER + TIME
   IF (IPNT .EQ. 1 .AND. NOPRNT .EQ. 0) WRITE(*, 104) DIST = ',', F6.1,
   & ' FUEL USED = ',', F8.0,' GT=' ,F8.0
   IF (IPNT .EQ. 1 .AND. NOPRNT .EQ. 0) WRITE(*, 105) DIST = ',', F6.1,
   & ' TAS = ',', F8.1,' TIME FOR LEG = ',', F6.2,
   & ' FUEL USED = ',', F8.0,' GT=' ,F8.0
   IF (IPNT .EQ. 1 .AND. NOPRNT .EQ. 0) WRITE(*, 106) DIST = ',', F6.1,
   & ' FUEL USED = ',', F8.0,' GT=' ,F8.0
RETURN
END
FUNCTION FUEL(FARG1, FARG2, FARG3)
***
WRITE(*, 1) 'FUNCTION FUEL'
***
CALL %FXOPT(69, 1, 1, 0) ' FOR ERROR MESSAGE ' ' '
CALL %FXOPT(71, 1, 1, 0) ' FOR DIVIDE ERROR ' ' '
FUEL = 1./FARG1*FARG2*FARG3
CALL %FXOPT(69, 1, 0, 0)
CALL %FXOPT(71, 1, 0, 0)
RETURN
END
FUNCTION ICHEK(IFULOP, CURRWT, OPWT, FULRES)
***
WRITE(*, 1) 'FUNCTION ICHEK'
***
C       ENDIF
*     IF(IFULOP.NE.1.AND.CURRWT.LE.OPWT)
*** THE FOLLOWING ADDED BY HUNSUCK: ***
     IF (CURRWT.LE.(OPWT+8000))
       & M = 1
C       ENDIF
     ICHEK = M
     RETURN
     END
C******************************************************************************
C*** BLOCK DATA PORTION
C**
C
**** COMMON /INPUT/
     & ARCP.LATT, ARCP.LONG,
     & EARLATT, EARLONGLONG,
     & TTFLATT, TTFLONGLONG,
     & ALTRAR, CASRAR, TIMERAR, DISTRAR, OFFRAR,
     & TTFMAXTO

     real
     & ARCP.LATT(4,5), ARCP.LONGLONG(4,5),
     & EARLATT(4,5), EARLONGLONG(4,5),
     & TTFLATT(3), TTFLONGLONG(3),
     & ALTRAR(4), CASRAR(4), TIMERAR(4,5), DISTRAR(4,5), OFFRAR(4,5),
     & TTFMAXTO(3)

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

******* COMMON/EONS/ CLOSURE, SETUPTM, FLYTOARI, FLYTODST,
     & FTRCELL, TOTNOSR, TURNTIME, KCFTIME,
     & KCLAPS, GDOUT, GORTU,
     & TOTALNKR, TTFAPPY, RELIBLY, KCTRACK,

     & ITTFL, JFTKL, KTRAIL, NEARTIF,

     & DOMINATD

REAL CLOSURE, SETUPTM, FLYTOARI, FLYTODST,
     & FTRCELL(4), TOTNOSR(4), TURNTIME(3), KCFTIME(4,5),
     & KCLAPS(4,5), GDOUT(3,4,5), GORTU(3,4,5),
     & TOTALNKR, TTFAPPY(3), RELIBLY, KCTRACK(4,5)

REAL SDRINTVL(4,5), AVGLAPINT(4,5)

B-46
INTEGER ITTL, JFTRL, KTRAKL, NEARITTF(4,5)
LOGICAL DOMINATD(3,4,5)

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

COMMON /HUNSGUC/ITANKER, IFULOP, NUMFAR, NUMFA1
COMMON /THESS/FULSUB, TOWT, OPWT, FULLND, CRUDRT, RTBALT, RTBTIM, FLTWT
& INTEGER ITANKER, IFULOP, NUMFAR, NUMFA1

INTEGER L, J, K, 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, CCAS, CFUEL, CTIME
& ,CUL1, FARTIME
DOUBLE PRECISION CCAS (17)
& ,CUL1 (17,7)
& ,FULL (17,7)
& ,CTIME (17,7)
REAL TARTIME, ALTX (8)
COMMON /C / RFDRAG, UNLOAD, YTABI, YTAB2
& ,CCALT, CCNAM
DOUBLE PRECISION CCALT (17)
& ,CCNAM (17)
& ,YTABI (17,7)
& ,YTAB2 (17,7)
REAL UNLOAD, RFDRAG
COMMON /D / FARDST, TINELT, UNLOAD, NUMREC
& ,FARALT, ALTIS, FARTIM
REAL
& ,FARALT (15)
& ,FARDST (15)
& ,FARTIM (15)
& ,UNLOAD (15)
& ,TINELT (15)
INTEGER NUMREC
COMMON /E / SPECIAL ,ANUMRC
DOUBLE PRECISION SPECIAL (1/)
REAL ANUMRC (15)
COMMON /F / NOPRNT
COMMON /G / DAT2 ,ICTAS
REAL DAT2 (17,5)
INTEGER NOPRNT ,ICTAS (17,5)

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

Explanation of Tanker Program
Sample Output of Tanker Program

COMMAND/EXPLANATION OF TANKER UTILITY PROGRAM

1. ENTER TANKER
   Select tanker eg. 1 = KC-135A, 2 = KC-135R, 3 = 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 BAR OR AAR
   TAR is Refuel Tanker, BAR is Orbit Refuel, AAR is Buddy Refuel.

6. ENTER A 1 FOR A TAR OR A 2 FOR A BAR 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 ONSLOAD FOR TAR
   Enter distance run during TAR in nm and fuel onload in pounds.

8. ENTER TIME (MIN) FOR TAR NUMBER
   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 BAR
    Enter distance to next event. If BAR, distance to ARCP. If AAR, distance to joinup.

11. ENTER A 2 FOR BAR 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 BAR 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 BAR
   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, 65, 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.
Sample Tanker Data

Dual Role KC-10 refueling Four F-16s

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 = 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 & OPLoad FOR AAR
1
ENTER TIME, DISTANCE & OPLoad 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., OPLoad USED = 0.
RECEIVERS BY CELL .40E+01
ENTER TANKER (DEFAULT = 3)

C-3
Airlifter Only KC-10
Carrying 120,000 pounds of cargo

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
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 AAR'S (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

ENTER T.O. WEIGHT (DEFAULT = 588200.)
588200
ENTER CARGO WT (DEFAULT = 0.)
0
T.O. FUEL = 34491.0
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 = 31000, 310)
ENTER TIME, DISTANCE AND OLOAD 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 = 2.4
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)**

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

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| 54   | DESCOFT | 52151 77692 | 170 | 5 47 4116 05 08×67 | 237 | 232 | 3119 | 3119 | 2400 | 505 |
| 55   | NATTENHEIM | 50101 77632 | 129 | 5 73 4646 04 08×66 | 64 | 64 | 3074 | 3074 | 593 | 783 |
| 56   | HANNA | FLOORS | 49575 77176 | 077 | 6 77 4645 06 09×67 | 96 | 96 | 2950 | 2950 | 881 | 487 |

*** APR 1 ***

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**UNCLASSIFIED**

ROUTE PAGE 03
## Chart of Movement

| 26-22-83 | 20:350 | ROUTE | 65 HAHN | FLOOD | 4657n 777162 | 097 | 17 | 6660 | 05 | 01+50 | 213 | 213 | 4258 | 4750 | 2367 | 488 |

### Abort Bases Receiver 1

| 16A BINGO FUEL | 2554 | 16A PEASE | 01+50 | 17 | 13.06 | 05 | 02+59 | 684 | 6618 | 5927 | 485 |
| 169 BINGO | 4639 | 153 BINGO FUEL | 4170 | +13 | 147 | 1531 | 20 | 02+45 | 2053 | 5172 | 6000 | 496 |
| 15C BINGO FUEL | 4170 | 15C BINGO FUEL | 6774 | +25 | 167 | 1641 | 41 | 03+45 | 6173 | 2049 | 6002 | 502 |

### Abort Point 2

| 15A ST JOHNS | 47774 | 15C BINGO FUEL | 6774 | +24 | 751 | 5717 | 37 | 05+11 | 5972 | 8239 | 6511 | 427 |

### Abort Point 3

<p>| 54A ST MAY | 5375n | 54A BINGO FUEL | 7434 | +11 | 2274 | 03 | 07+46 | 1255 | 5579 | 5380 | 486 |
| 54B BINGO FUEL | 7434 | 54D MOSCOW-DOHM | 5110n | 4104 | 19 | 03+02 | 1962 | 3921 | 6163 | 486 |
| 549 BINGO FUEL | 4062 | | | | | | | | | | |</p>
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**NOTE**:
- **WGS 84 DATA POINT**
- **DISTANCE** in statute miles
- **TIME** in hours
- **FUEL** in US gallons
- **AIRCRAFT**
- **FUEL REMAIN** in US gallons
- **FUEL WIND OR FLOW ON LOAD** in US gallons
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ABORT BASES RECEIVED 1

*** AAR 1 ***

ABORT POINT

15A ST. STEPHENVILLE 46°14' 35°22'

15A BINGO FUEL 2697

15A GANDER 48°56' 45°34'

16A BINGO FUEL 2498

15C ST. JOHNS 47°17' 75°24'

15C BINGO FUEL 2622

*** AAR 2 ***

ABORT POINT

36A ST. MARGARET'S 50°29' 45°00'

36A BINGO FUEL 1519

359 DISCOMBE DOWN 51°10' 33°44'

369 BINGO FUEL 2699

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ROUTE

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**Average Payload for AAR 1:** 5323

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**AAR 1:**

**Abort Point:** 6254 235324

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**11A Bingo Fuel:** 2670

**11B Pease:** 63054 237464 080 15 295 1248 24 02+32 2532 5661 6221 504

**11B Bingo Fuel:** 4640

**11C Savage:** 44449 058504 063 17 315 1373 38 02+46 3892 4291 6237 504

**11C Bingo Fuel:** 5990

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**AVERAGE ONLOAD FOR AAR 1**

| AAR 1 | 475093 |

**ROUTE WIND FACTOR +210**

| AAR 2 | 14537 |

**UNCLASSIFIED**

**ROUTE**

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**Average Onload on AAR 2: 15593**

**Average Onload for AAR 3: 8265**
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**FALSE DATA POINT COORDINATES**

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**UNCLASSIFIED**

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<th>FUEL REMAIN</th>
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<td>449 435</td>
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**AVERAGE ONLOAD FOR AAR 5**

| 69   | HANH       | 40°57' N 117°16'E | 097     | +5      | 6665     | 06   | 09+17 | 10 10 | 5553 5550 6000 | 472   |

**AAR BASES RECEIVER 1**

*** AAR 1 ***

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<th>FUEL FLOW</th>
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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 "0"

Entering a "system" puts a user into a set of ALCs, as described in the operations manual. There are few copies of this manual available (in reprint) at this time. The ONLY copy in AFIT is maintained by Capt Smith, room 302, building 641 (School of Systems and Logistics).

MODAS is also accessible by the following commercial numbers:

SYSTEM "A": (513) 257-5672/73/74/75/76/77
SYSTEM "B": (513) 257 2179, 5667/68/69/70/71

AT THE PROMPT ("_"), ENTER: LOGON_AFTLSMA_DX_SYS(A or B)
(pay attention to the spaces ( )
PASSWORD:MAKE.POW
(the password DOES NOT echo, get it right)

PAY ATTENTION TO THE MESSAGES ON THE OPENING MENU!! They tell you if a particular ALC is unaccessible because of update or if a particular MDS is being updated and not accessible at that time.

SEARCHES CAN TAKE A LONG TIME. If you begin a dat intensive search and can not stay with the system, YOU MUST CALL MR. FRANK MAGUIRE, 513-257-6906 (AV 787-6906), FOR A DISCONNECT!! To just turn your system off and hang up leaves the line connected and denies other users access. A search once started, must be completed.

E-1
# Maintainability Report #4

**For Nov 85**

**Ranked by Latest 3 Month MH/FH (Unscheduled Manhours)**

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**For Nov 85**

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E-2
### Latest 3 Month MTBM (Type 1 Failures)

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## RELIABILITY STATUS REPORT

**END ART DESIGN:** KCO10A  
**BASE:** ****  
**WORK UNIT CODE:** 46**  
**FUEL SYSTEM**  
**TYPE FAILURE:** 1

### FLEET SUMMARY

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**TOTAL:** 42668.4

**DATE ACTUAL CUM.** | **COUNT** | **MONTHLY** | **3 MONTH** | **CUM.**
-------------------|-----------|-------------|-------------|-------------
**85** | **6** | **ACTUAL** | **31646.7** | **111** | **16.36** | **25.38** | **27.83** | **LI100**
| **7** | **2012.2** | **33659.9** | **103** | **19.54** | **23.48** | **27.14** |
| **8** | **2543.6** | **36202.5** | **67** | **37.96** | **22.67** | **27.70** |
| **9** | **1899.6** | **38102.1** | **53** | **35.84** | **28.93** | **28.02** |
| **10** | **2442.0** | **40544.1** | **61** | **40.03** | **38.04** | **28.03** |
| **11** | **1224.7** | **42668.4** | **70** | **30.35** | **30.17** | **28.62** |
| **12** | **U** | **55** | **0.00** | **24.55** | **27.60** |

**TOTAL:** 42668.4

**LI500Z DSO 0063**

**VERSIO**

**DATE ACTUAL CUM.** | **COUNT** | **MONTHLY** | **3 MONTH** | **CUM.**
-------------------|-----------|-------------|-------------|-------------
**85** | **6** | **ACTUAL** | **31646.7** | **111** | **16.36** | **25.38** | **27.83** | **LI100**
| **7** | **2012.2** | **33659.9** | **103** | **19.54** | **23.48** | **27.14** |
| **8** | **2543.6** | **36202.5** | **67** | **37.96** | **22.67** | **27.70** |
| **9** | **1899.6** | **38102.1** | **53** | **35.84** | **28.93** | **28.02** |
| **10** | **2442.0** | **40544.1** | **61** | **40.03** | **38.04** | **28.03** |
| **11** | **1224.7** | **42668.4** | **70** | **30.35** | **30.17** | **28.62** |
| **12** | **U** | **55** | **0.00** | **24.55** | **27.60** |

**TOTAL:** 42668.4

**F-4**
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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)*

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<th>ARCP 3</th>
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F - 1
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.

F-2
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SLAM TTF Output

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

Cumulative Refuelings and Aborts
Maintainence 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.

Percent of Repair Completions

- Cumulative % of Repair Completions
- Distribution will be the weighted sum of several lognormal distributions.
- Ground Interval to achieve 88% Reliability for ARCT 1
- Time between ARCTs = 1.3 hours
- Achieves 92% reliability for ARCT 2
- Achieves 94% reliability for ARCT 3

Overall AR Reliability = (88 + 92 + 94%)/3 = 91.3%
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 i.e.: 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
C Event 1 calculates MXTIME for the 46*** subsystem.
  1 MTBF = 35.14075
  MTTR = 22.816 / 2.7188
  GO TO 98
C
C Event 2 calculates MXTIME for the 71*** subsystem.
  2 MTBF = 45.85741
  MTTR = 11.040 / 2.7188
  GO TO 98
C
C Event 3 calculates MXTIME for the 23*** subsystem.
  3 MTBF = 48.96407
  MTTR = 18.128 / 2.7188
  GO TO 98
C
C Event 4 calculates MXTIME for the 44*** subsystem.
  4 MTBF = 58.25133
  MTTR = 7.498 / 2.7188
  GO TO 98
C
C Event 5 calculates MXTIME for the 52*** subsystem.
  5 MTBF = 71.84328
  MTTR = 9.956 / 2.7188
  GO TO 98
C
C Event 6 calculates MXTIME for the 13*** subsystem.
  6 MTBF = 77.90236
  MTTR = 12.467 / 2.7188
  GO TO 98
C
C Event 7 calculates MXTIME for the 64*** subsystem.
  7 MTBF = 83.97269
  MTTR = 5.964 / 2.7188
  GO TO 98
C
C Event 8 calculates MXTIME for the 14*** subsystem.
  8 MTBF = 113.43577
  MTTR = 22.947 / 2.7188
  GO TO 98
C
C Event 9 calculates MXTIME for the 47*** subsystem.
  9 MTBF = 117.56177
  MTTR = 5.133 / 2.7188
  GO TO 98
C
C Event 10 calculates MXTIME for the 51*** subsystem.
  10 MTBF = 117.56177
  MTTR = 8.345 / 2.7188
  GO TO 98
C
C Event 11 calculates MXTIME for the 45*** subsystem.

G-5
11 \( MTBF = 131.35703 \)
\( MTTR = 15.547 / 2.7188 \)
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,TF1 2HR 4RATIO,4/1/1986,1,NO,NO,YES,NO,YES,72;**

**LIMITS,35,8,2500;**

**T1MST,XX(1),CREWREST;**

**T1MST,XX(2),KCCREWDD;**

**T1MST,XX(3),F16ARCT1;**

**T1MST,XX(4),F16ARCT2;**

**T1MST,XX(5),TRACK161;**

**T1MST,XX(6),RTB16_1;**

**T1MST,XX(7),GNDINTVL;**

**T1MST,XX(8),KCAR16_1;**

**T1MST,XX(9),ABORTS;**

**T1MST,XX(10),F16PERLAP;**

**T1MST,XX(11),TOT_F16S;**

**T1MST,XX(12),ORBITTM;**

**T1MST,XX(13),MAXCRWDD;**

**T1MST,XX(14),LAPS161;**

**T1MST,XX(15),LAUNCHI;**

**T1MST,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),LAUNCHI;**

**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,LAUNCHI =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:**
Initially, there are no KC-10 crews at Goose. Only 4 KC-10s are allowed on track. Make 4 KC-10s instantly at Goose Bay, starting at time = 6 hrs. Entity goes to 2 nodes. Newly arrived crews must rest before flying. Landing tankers bring extra aircrews, who become available after completing crew rest. Duration of mission flying to TTF from Home. Plane is unloaded. (ALL crews already resting) Tired crew gets freed after 13 hours rest. Plane enters maintenance. KC-10 is divided into its 23 subsystems for repair as necessary.
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:

01 QUEUE(1),,MATC;
02 QUEUE(2),,MATC;
03 QUEUE(3),,MATC;
04 QUEUE(4),,MATC;
05 QUEUE(5),,MATC;
The aircraft subsystems are matched by the fact that they all have a common $A_{trib}(3) = \text{STARTMX}$ time. When all maintenance is completed, the 23 subsystems of the KC-10 proceed together to $A_1$, where they are accumulated into a single KC-10 entity again.

```
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 = $A_{trib}(4)$.

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 fit
   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 AWAITH(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
SCHED GOON, 1; assigns scheduled launch time, and flight plan route
```

G-11
ACT, TNOW.LE.LAUNCH1,FIRST;   ie: this is a "no earlier than" 
       time. NOTE: independent of crew or mx.  
ACT, 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 6001,1; Choose one of the following three actions: 
ACT/1, SCHEDTO-TNOW, SCHEDTO.GE.TNOW.AND.MYLAPS.EQ.LAPS161, LAUNCH;  
       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, LAUNCH;  
       Delayed TO!  
ACT/4,,,LAUNCH; 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;  

G-12
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,,FREI; this KC-10 entity will free the track for subseq. RZ
ACT,,FIGHT; this entity will become a fighter
FREI- FREE,F16_1RZ/1,1;
ACT,TRACK161+ORBITTM,MYLAPS.GT.0,RZ161;; Take another lap
vax RZ
;

RTB GOON,1;;
ACT,RTB16_1;; fly back to the TTF base from this track
ASSIGN,FLYHRS=TNOW-SCHEDTO,1;

LAND
ASSIGN,CREWDDT=TNOW-STCREWDD,1;
COLCT,FLYHRS,MISSION LENGTH,24,0,0,1;
COLCT,CREWDDT,CREW DUTY DAY,24,0,0,1;
ACT,0,CREWDDT.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
;

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

G-13
COLCT,TNOW,TIME OF TERMINATION;
TERM;
STATS CREATE, 12, 0;
COLCT, TOT_F16S, F16s REMAINING;
COLCT, ABORTS, F16s ABORTING;
TERM;
ENDNETWORK;
INIT, 0, 168;
;MONTR, TRACE, 0, 50;
;MONTR, SUMRY, 168;
FIN;
PROGRAM MAIN
DIMENSION NSET(10000)
COMMON/SCOMI/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))
NSET=10000
NCRDR=5
NPRNT=6
NTAPE=7
NPLOT=2
CALL SLAM
STOP
END

SUBROUTINE EVENT(I)
COMMON/SCOMI/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(I)
GO TO (1, 2, 3)
1
***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(I)
ENDIF

***RULE: Assign optimum # fighters to acft, then assign fuel for KC-10, offload, then assign cargo load (as attributes to entity).
11 IF (XX(14).LE.(XX(12)-XX(13))) THEN
   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

Next assign fuel to KC-10

\[ ATRIB(5) = 200 + 25 \times ATRIB(8) \]

Next assign any remaining payload to cargo

\[ \text{if any cargo remains!} \]

\[ \text{IF}(XX(1) - XX(2)) > (ATRIB(4) - ATRIB(5)) \text{ THEN} \]
\[ ATRIB(6) = ATRIB(4) - ATRIB(5) \]
\[ XX(2) = XX(2) + ATRIB(6) \]
\[ \text{ELSE} \]
\[ ATRIB(6) = XX(1) - XX(2) \]
\[ XX(2) = XX(1) \]
\[ \text{ENDIF} \]

\* 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

***********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 INFIGHT FUEL CONSUMPTION

3 DURATION = TNOW - ATRIB(2)

3 \* 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/SCOMI/ATRIBC100, DD(100), DDL(100), DTNOW, II, MFA, MSTOP, NCLNR 1, NCRDR, NPRINT, NNSET, NTAPE, SS(100), SSL(100), TNEXT, TNOW, XX(100)
RETURN
END

SUBROUTINE OUTPUT
COMMON/SCOMI/ATRIBC100, DD(100), DDL(100), DTNOW, II, MFA, MSTOP, NCLNR

6-15
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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