AN ANALYSIS OF THE KC-135 THREE-PERSON COCKPIT

THESIS

Robert A. Deivert, Major, USAF

AFIT/GSO/ENS/94D-6

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Wright-Patterson Air Force Base, Ohio

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Robert A. Deivert

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Abstract

In an effort to quantitatively determine the utility of mission effectiveness of the KC-135, this research used value-focused thinking to measure the impact of replacing the KC-135 navigator with upgraded avionics. A Value Model was developed as a hierarchy with fundamental objectives at the highest level and attributes at the lowest level. Weights were assigned to show the contribution each level had to the one above it. The attributes were given a score and an additive model was used to determine utility with and without a navigator. Break-even analysis and net present value calculations were done to show the costs associated with each alternative. This study reveals that the cockpit with the navigator has a higher utility than the cockpit with the upgraded avionics. Value-focused thinking identified additional equipment that would increase the utility of the upgraded avionics. This approach can be used to identify equipment alternatives in the future that add the most utility. This methodology can be used by the Air National Guard to determine whether they should keep navigators as part of the KC-135 crew.

AN ANALYSIS OF THE KC-135 THREE-PERSON COCKPIT

I. Introduction

1.1 Problem Statement

The NAVSTAR Global Positioning System (GPS) proved invaluable to the warfighter during Desert Storm. (10:242) All military aircraft will eventually acquire GPS receivers in their cockpit and have precise position information available at all times. (25) In these times of tight federal budgets and shrinking manpower authorizations, can the cost of GPS and other high technology avionics be offset by replacing any manpower positions. Specifically, can the KC-135 operate as effectively and with lower life-cycle costs if the navigator position is replaced with upgraded avionics?

1.2 Background

The KC-135 is currently planned to remain in the Air Force inventory through at least the year 2020. (17) A large percentage of the cockpit avionics of the KC-135 rely on 1950s and 1960s technology. This outdated technology has degraded the reliability, maintainability, and safety of the airplane. The Strategic Air Command (SAC) recognized this fact and issued a Statement of Need in 1987 to upgrade the KC-135 cockpit avionics. (7:3) Air Mobility Command (AMC) issued a Mission Need Statement in 1994 to continue the cockpit modernization. (15) A plan was developed to integrate upgraded avionics into the airplane through a series of modification blocks. This was a unique plan in that it shifted from a philosophy of reacting to urgent deficiencies to a long-range systematic modernization. Each step in the plan will integrate follow-on upgrades and maintain commonality with other Air force weapon systems. (3:1) "Current technology allows the KC-135 to be updated with avionics that have significantly higher levels of reliability and maintainability, thereby reducing life-cycle costs and increasing mission reliability."(19:1) The cockpit displays will be more automated, allow for better aircrew interface, provide enhanced navigation through the integration of GPS, and should reduce crew workload. (7:3) With the decrease in crew workload, SAC and later AMC, tasked the Crew Station Evaluation Facility (CSEF) at Wright-Patterson AFB to determine if a three-person crew without a navigator would be feasible. The CSEF does human engineering evaluations to support the System Programs Offices (SPOs). (26:1)

KC-135 crew reduction has been addressed several times over the past 20 years. A dual inertial navigation system (INS) was installed and tested in 1976. These tests determined the crew workload was prohibitively high with a three-man crew and recommended retaining the four-man crew. (26:1) A study done in 1981 completely revamped the cockpit equipment and displays with state of the art hardware and electronic multipurpose displays. The crew duties were also reallocated to evenly distribute the workloads. This simulation study concluded that the KC-135 mission could be done with a three-man crew only if the present cockpit avionics were updated and relocated. (26:1) Lessons learned during the Persian Gulf War renewed debate over the three-man cockpit question. Do the demands of combat missions with multiple mission changes, complex timing, area saturation and degraded navigation aids justify keeping the navigator as part of the KC-135 crew? (7:1)

The CSEF upgraded a simulator cockpit with advanced avionics and flew test missions with three- and four-man cockpits to study this question. The CSEF study centered on workloads in the cockpit. It found workloads increased for the three-man cockpit during inflight replanning, random refueling, navigation, and radar. (7:25) Further results revealed that workloads were always less for four-man crews (7:18) and that there was a statistically significant difference in workloads between the three-man and four-man configurations. (7:23) The CSEF concluded that it is feasible, provided that the necessary cockpit avionics modifications are made, to fly the KC-135 without a navigator as part of the crew. These modifications are contingent upon the use of leading edge technologies and the automation of tasks. (7:25) Another conclusion was that introducing new technology in the form of upgraded avionics will increase the mission efficiency of the KC-135. (7:1) However, there was no objective, quantitative measure of mission efficiency.

1.3 Research Scope and Objectives

The primary focus of this research effort is to analyze the benefits of replacing the navigator with upgraded avionics from a life-cycle cost and effectiveness viewpoint. The life-cycle costs of the upgraded avionics will be compared to the manpower cost of the KC-135 navigators. Every function that the navigator provides during each phase of the mission will be identified and assigned a utility. This functional list will be compared to the capabilities provided by the upgraded avionics to ensure that the system retains at least its current effectiveness.

This research will analyze life-cycle costs of the equipment identified in the CSEF three-man cockpit feasibility study. This equipment falls into three categories: equipment the KC-135 must have, equipment that it should have, and equipment that would be nice to have. (7:26) This paper will try to limit its analysis to the life-cycle costs of the must have equipment, but any equipment that substantially adds to the effectiveness of the KC-135 will be included. Some specific types of equipment have been identified and costed. (18) When available, costs for this equipment will be used. Where an explicit piece has yet to be identified, a cost estimate from the SPO or the Oklahoma City Air Logistics Center will be used.

Decision analysis techniques will be applied to provide weighted effectiveness measures for each navigator function. Functions will be grouped by the phase of the mission to which they apply. The contribution of each mission phase to safety of flight and mission accomplishment will be determined. The analysis will assses the net gain or loss in effectiveness of the cockpit with the upgraded equipment and no navigator compared to the cockpit with a navigator and no upgraded equipment.

1.4 Overview of Thesis

Chapter II develops a Value Model to quantitatively evaluate the mission effectiveness of the KC-135. This model will be used to compare the utility of mission effectiveness of the KC-135 with the navigator as part of the crew to one with upgraded avionics and no navigator. This will determine the change in mission effectiveness as manpower is reduced.

Chapter III compares the life-cycle equipment costs with the navigator manpower costs. Break-even analysis will show the payback period for the new equipment.

Chapter IV analyzes the results of the cost study and effectiveness analysis. Sensitivity analysis will show how the break-even point changes as additional equipment is added and what factors can change the utility.

Finally, Chapter V summarizes the analysis, reports significant findings and draws conclusions. Recommendations to increase safety of flight and mission accomplishment are made.

II. Utility Function

This chapter explains the methodology used to develop a Value Model to evaluate the mission effectiveness of the KC-135, currently equipped with the navigator as part of the crew. This model will then be used to determine the mission effectiveness of the KC-135 with upgraded avionics and no navigator.

2.1 Methodology

The technique chosen to quantitatively evaluate the mission effectiveness is Value-Focused Thinking. This method focuses on values being the driving force for decisionmaking instead of choices among available alternatives. (13:3) The method was similar to that used by Air University to evaluate space systems for the *Spacecast 2020* report. (21:S-4) The Value Model is a hierarchy with broad fundamental objectives that define our value at the top level, means objectives that are means to achieve fundamental objectives at the next level, and attributes that define a given objective's qualities more precisely at the lowest level. (13:203) Figure 2.1 shows this hierarchy.

<table>
<tr><td colspan="8">VALUE</td></tr>
<tr><td colspan="4">FUNDAMENTAL OBJECTIVE
(WEIGHT)</td><td colspan="4">FUNDAMENTAL OBJECTIVE
(WEIGHT)</td></tr>
<tr><td colspan="3">MEANS
OBJECTIVE
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Figure 2.1 Value Hierarchy with 2 of the 4 Branches Expanded

The value model was developed to objectively and quantitatively go from the lowest level of the hierarchy to an overall utility for mission effectiveness. The attributes were assigned scores which were multiplied by the relative weights for each attribute. These weights define the contribution the attributes make to their means objectives or mission phases. These products were then summed over each mission phase. This total was multiplied by the weight given to each mission phase and summed over all the mission phases. This total was multiplied by the weight given to each fundamental objective and summed over the fundamental objectives. This is summarized by the following equation:

$$U(x) = \sum_{f=1}^{F} W_f \sum_{m=1}^{M} W_m \sum_{a=1}^{A} W_a S_a(x)$$

f = fundament objectives

m = means objectives

a = attributes.

A more detailed explanation of the Value Model continues below.

2.1.1 Value

The value that we will examine is increasing mission effectiveness. The value of overall mission effectiveness is difficult to define. The meaning of a value can be articulated qualitatively by stating objectives. (13:7)

2.1.2 Objectives

According to Keeney, the first step in setting objectives is to define what an objective is and decide who should set them. Objectives are something one desires to achieve. They are characterized by three features: a decision context, an object, and a direction of preference. (13:34) Objectives should come from individuals interested in and knowledgeable about that situation. (13:56)

I used my own experience as a KC-135 Combat Crew Training Squadron (CCTS) instructor pilot to determine two objectives to help explicitly define the value of mission effectiveness. I validated these choices with other KC-135 CCTS instructors, Air Force Safety Agency (AFSA) personnel and the 380th Air Refueling Wing (ARW) commander. The fundamental objectives were to maximize safety of flight and to maximize mission accomplishment. The objectives possess the characteristics listed above. The contexts of these objectives are safety of flight and mission accomplishment. The objects are to maximize safety of flight and mission accomplishment. In both objectives the direction of preference is more is better. These fundamental objectives must be compatible with the decision context. In this case, they are nearly the same as the decision context. (13:36) These objectives however, are still too vague to be able to objectively quantify.

The objectives hierarchy must be expanded and more fully articulated. Means objectives or detail objectives (5:434) must be identified that add more specification to the fundamental objectives. The logical breakdown of an overall mission is into mission phases. The CSEF developed a list of twenty mission events. (26:5) This list of events was combined and simplified into the seven phases of flight shown in Table 2.1.

Table 2.1 Phases of Flight

1. MISSION PLANNING
2. SQUADRON/BASE OPERATIONS
3. PREFLIGHT
4. TAKEOFF & DEPARTURE
5. AIR REFUELING
6. CRUISE
7. DESCENT & APPROACH

Next, attributes need to be identified that indicate the extent to which the objectives are achieved. (12:64)

2.1.3 Attributes

Attributes are operational measures that correspond to an objective and quantify the extent that an objective is accomplished. (5:431) Attributes should be complete, so they cover all the important aspects of the problem; operational, so they can be used meaningfully; nonredundant, so that double counting of impacts can be avoided; minimal, so the problem dimension can be kept as small as possible; (12:50) and measurable, so that appropriate value judgments can be made. (13:112)

The functions a KC-135 navigator performs during each phase of flight are the basis for attributes to measure mission effectiveness. The CSEF analyzed the KC-135 mission and listed the navigator's tasks. (26:38-55) This list served as the basis from which attributes were created that had the desired properties listed above.

For many of the attributes there was no commonly understood index to objectively measure levels. In these cases where there was no natural attribute, a constructed or subjective index had to be defined. (13:101) A zero level of utility was defined along with an optimum level which was given the value of one. All attributes were assumed to be linear on this scale with a score between zero and one. Appendix A.1 contains all attributes along with their definitions of zero and optimum utility. From this bottom level of the hierarchy we need weights that relate each level's contribution to the level above it.

2.1.4 Survey

A survey was used to determine the relative contribution that each level of the hierarchy had on the level above it. The survey is included in Appendix A. Twenty-five questionnaires were sent out to KC-135 instructor pilots and navigators. Seventeen were returned. Sixteen respondents were members of the 93 Air Refueling Squadron, the KC-135 CCTS, at Castle AFB CA. All members of the squadron are highly experienced instructors in the KC-135. The final response came from a KC-135 wing commander.

The results from each survey question were averaged and scaled between zero and one. These values were used as the weights for each level of the value hierarchy. The results are expressed in the Value Model matrix in Appendix A.3.

2.1.5 Value Model

Before the Value Model could provide useful data, the model had to be simplified and scores had to be assigned to each attribute. The first step in this process was to combine some attributes that were redundant. The attributes fell into two categories. The first group were functions that could be automated with equipment. The second group were functions that could not be automated and had to be accomplished manually. Scores were assigned to all attributes according to the attribute description in Appendix A.1.

The first alternative to be scored was the case with a navigator as part of the crew. Scores were assigned for both the automated and manual attributes. The next alternative scored was the one with the upgraded avionics and no navigator. Scores were given to the automated attributes based on a systems descriptions contained in the CSEF's KC-135 Cockpit Design Study. (3) The manual functions still had to be accomplished by a crew of three instead of a crew of four. Each of these functions was then assigned three-quarters of the score given to the four-man crew. With all the weights and scores assigned, we move on to the choice of a utility function.

The utility function can be expressed as a composition of the two individual utility functions if mutual utility independence exists. (5:480) This multilinear function has the general form:

$$U(s,m) = k_s U_s(s) + k_m U_m(m) + (1 - k_s - k_m) U_s(s) U_m(m)$$

k_s = the weight given safety of flight

k_m = the weight given mission accomplishment.

Mutual utility independence holds if the certainty equivalent amount for the safety of flight objective remains the same no matter what the level of the mission accomplishment objective and the certainty equivalent amount for the mission accomplishment objective remains the same no matter what the level of the safety of flight objective. (5:478) This condition holds based an a certainty equivalent lottery with a KC-135 wing commander. Hence, mutual utility independence exists. Since $k_s + k_m = 1$, then the utility function is additive and has the form:

$$U(s,m) = k_s U_s(s) + k_m U_m(m). \qquad (5{:}481)$$

All of the scores and weights were run in this model for the case where the navigator is part of the crew. The model was then run again for the case where equipment has replaced the navigator. Figure 2.2 depicts the results.

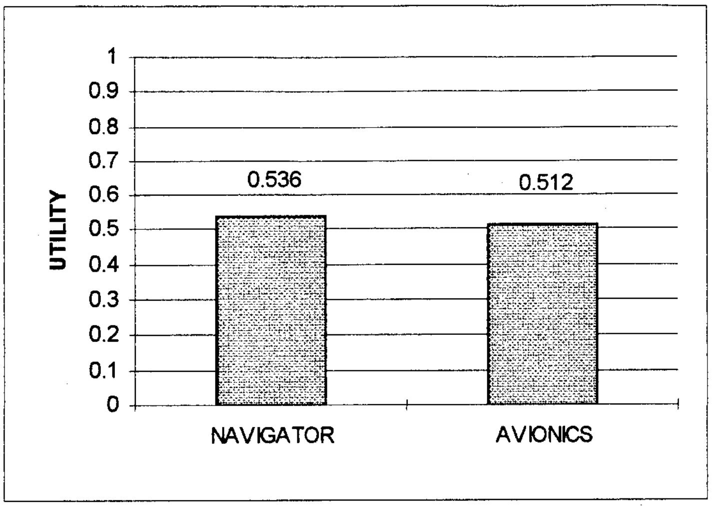


Figure 2.2 Value Model Results

With the upgraded equipment, the KC-135 has a 4% higher mission effectiveness with the navigator as part of the crew. The results of the sensitivity ananlysis will determine which objective changed to lower the mission effectiveness with upgraded avionics.

III. Cost Analysis

Break-even analysis will determine if and when replacing manpower with upgraded avionics will save money over the life-cycle of the KC-135. (8:199) The yearly training costs and salaries for active duty navigators will be compared with the costs of new equipment and reduced manpower. Presently, the Air National Guard has no plans to reduce manpower. (22) Current plans are for the KC-135 to remain in the inventory until at least the year 2020. (17) Yearly cash flows will be computed and a break-even curve will be constructed. Net present value calculations will be done to compare the overall life-cycle costs. All cash flows will be brought back to 1995, the first year of the upgraded avionics contracts. Operating costs for the new equipment will be assumed equal to the current equipment and so will not be considered in this analysis. This study also assumes that there are no manpower shortages at the beginning of the study period.

3.1 Navigator Costs

The costs for navigators depend on the number of aircraft and the crew ratio per aircraft. The total number of KC-135 aircraft assigned to the active duty forces is 187. There are 1.36 navigators assigned per aircraft for a total of 254 navigators. (23) This number will be kept constant for all calculations through 2020. Historically, sixty-four navigators will have to be trained each year for the tanker in order to maintain the crew ratio. (23) Training costs for new navigators and salaries for the existing navigators make-up the total manpower costs.

3.1.1 Training Costs

The training costs for KC-135 navigators include the following: commissioning costs, Officer Training School (OTS) (11), Air Force Reserve Officer Training Course (AFROTC) (11), or the United States Air Force Academy (USAFA) (20); Specialized Undergraduate Navigator Training (SUNT) (16); and Initial Qualification Training (IQT) (16). Table 3.1 summarizes the 1994 training costs for KC-135 navigators.

Table 3.1 Navigator Training Costs

Commissioning Source	Cost per Navigator	Number
OTS	17,510	655
AFROTC	42,996	1,731
USAFA	172,852	1,008
weighted average	76,644	
SUNT	118,118	64
Qualification Training	124,437	64
TOTAL	319,199	64

Appendix B.1 shows the cash flows associated with training 64 navigators for each year from 1995 through 2020. Each year is inflated at the rate projected by the Congressional Budget Office. (24:36)

3.1.2 Manpower Costs

Manpower costs were computed based on paying 254 navigators at an average rank of captain. Salaries are composite and include salary plus contributions toward retirement. The composite rate for 1995 was listed as $71,554. (1:Table A19-1) This rate was inflated at the same rate as training costs. Yearly cash flows for manpower were figured and are listed in Appendix B.1.

The yearly cash flows for training and manpower were added to show the total expenditure for navigators.

3.2 Equipment Costs

Current plans call for the upgraded avionics to be provided under three contracts: Radar, Global Positioning System (GPS), and Compass. The total cost to upgrade approximately 600 aircraft in constant 1995 dollars is $432 million. (18) Table 3.2 shows the cash flows in $millions in constant 1995 dollars for the upgraded equipment.

Table 3.2 Equipment Cash Flow

	CONTRACT		
YEAR	Compass	Radar	GPS
1995	13.1	5.4	22.8
1996	17.5	21.6	24.5
1997	23.3	32.3	35.5
1998	21.6	30.1	34.6
1999	19.2	26.6	30.3
2000	15.9	21.5	25.3
2001	2.8	3.9	4.5
Totals	113.4	141.4	177.5

Actual installation of the equipment will begin in 1997. At that time the number of navigators will start to be reduced. One-fifth of the force will be reduced each year until the number drops to forty-two. This small number of navigators will be retained to plan and fly complex missions. (23) Ten navigators will be trained every year. Composite salaries will also have to be paid to forty-two navigators.

The total costs for the upgraded equipment will include the equipment itself plus training and manpower costs for a reduced number of navigators. Appendix B.2 details the cash flows every year for this option. Again, all costs have been inflated over time.

3.3 Break-even Analysis

A break-even analysis will show when the savings from reduced manpower will equal the cost of the new equipment. The yearly cash flows in constant 1995 dollars were inflated and then added to get cumulative cash flows for navigators versus upgraded equipment.

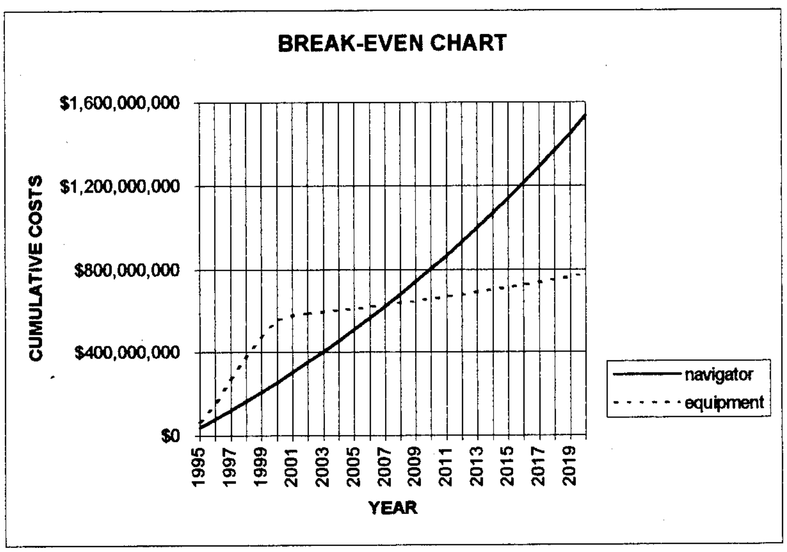


Figure 3.1 Break-even Curve

Figure 3.1 shows that approximately six years after the upgraded equipment is completely installed, the money saved from active duty manpower reductions will pay for the upgraded equipment. Money will be saved over the next thirteen years of the fleet's planned lifetime.

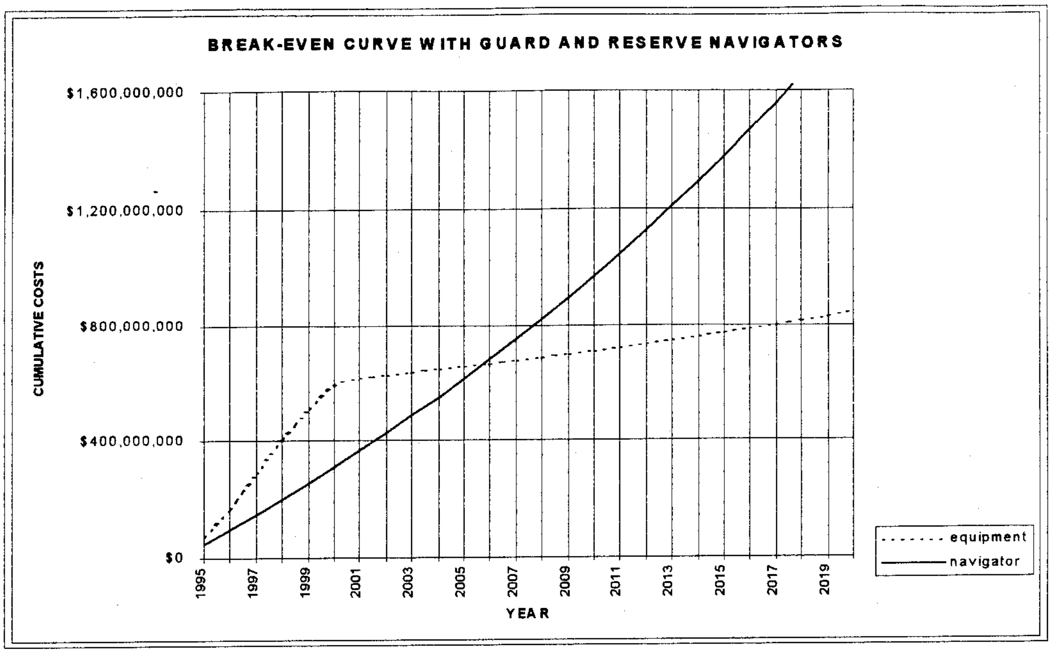


Figure 3.2 Break-even Curve with Guard and Reserve Manpower Reductions

Figure 3.2 shows the break-even point is a year and a half earlier if the Air National Guard and Air Force Reserve were to eliminate their KC-135 navigators. This curve is based on the Air National Guard having 259 navigators and the Air Force Reserve having 72 navigators. These numbers are based on a 1.27 crew ratio. The manpower reductions would begin in the year 2000 when the Guard and Reserve start to receive upgraded avionics. Twenty percent of the navigators would be removed every year until the Guard drops to 43 navigators and the Reserve drops to 12 navigators.

3.4 Present Value

Another way to look at the money saved is from a net present value calculation. This technique allows us to collapse the stream of cash flows for the two alternatives into a single number for each alternative. Present value takes into account the time value of money and gives us a single value in present dollars. (8:23) Appendix B.3 shows the net present value calculations with an interest rate of 5.8 percent (1:Financial Management Analysis Bulletin Board) used to discount the yearly cash flows back to 1995, the first year of the equipment contracts. This calculation shows that the net present value of the upgraded equipment is over $179 million or approximately 24% less than the net present value of keeping 1.36 navigators per aircraft.

IV. Sensitivity Analysis

The two previous chapters have determined a base value for the utility of mission effectiveness, identified the break-even point and calculated net present value. This chapter will analyze those results. Sensitivity analysis will be done to determine if any of the weights assigned to the objectives of the Value Model change the result that the cockpit with the navigator has the higher utility. The break-even point will be analyzed to determine the affect of uncertain equipment costs and varying inflation rates. The net present values of manpower costs and equipment costs will be examined with changing discount rates.

In addition to analyzing the Value Model, suggestions will be made for additional equipment that will increase the utility of the KC-135 mission effectiveness. Once the utility is shown to increase with additional equipment, the break-even point and net present value will be calculated for the added equipment.

4.1 Value Model Sensitivity

The main concern of respondents to the value survey was that the weight they assigned to safety of flight and mission accomplishment would vary based on mission importance. In peacetime, more weight would be given to safety. During war, more weight would be given to mission accomplishment. Sensitivity analysis to the weights assigned by the survey would determine if their concerns were valid.

DPL (6:334) was used to identify the critical weights that would change the recommended policy of the Value Model. The influence diagram depicted in Figure 4.1 was used for sensitivity analysis.

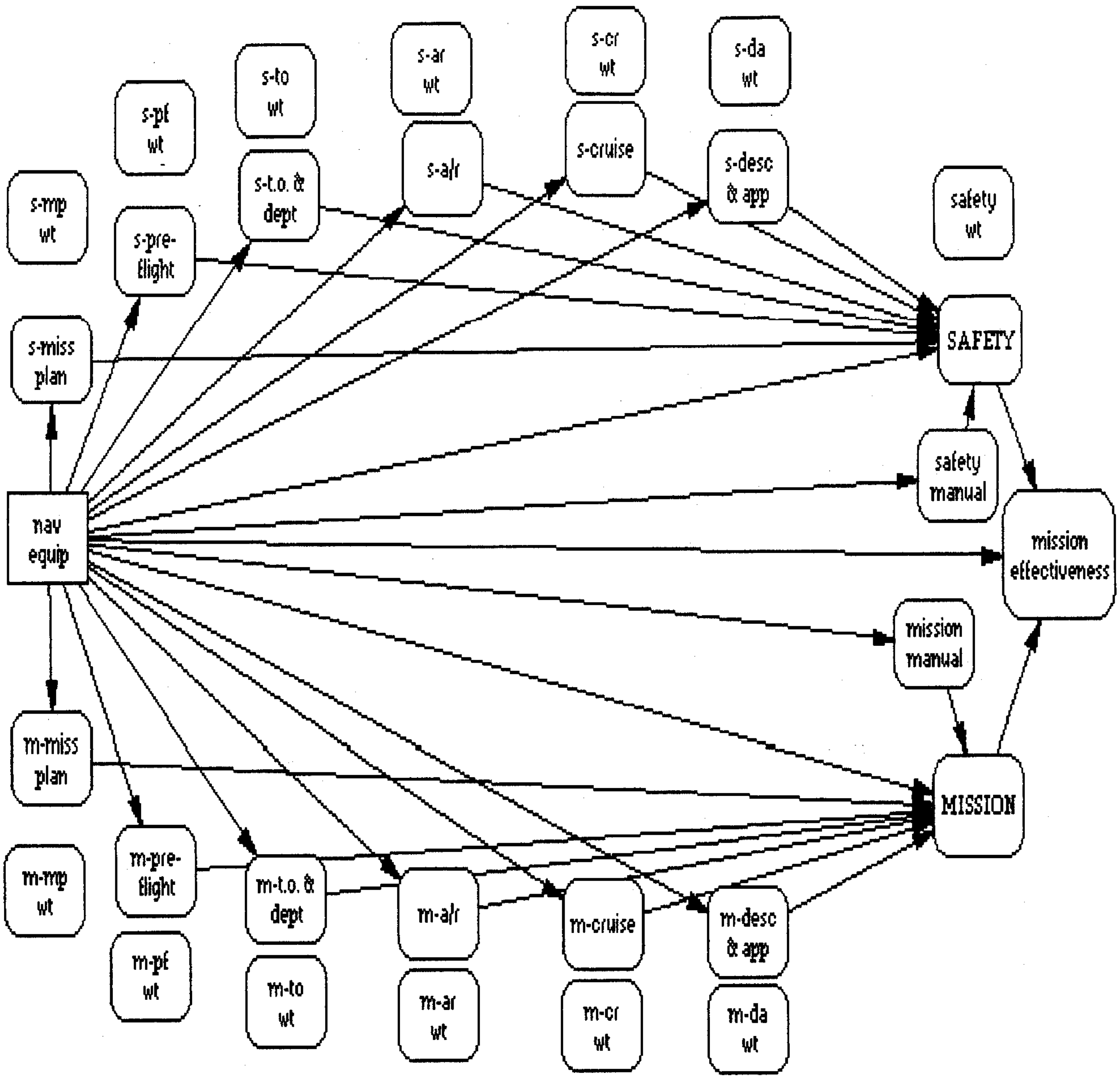


Figure 4.1 DPL Influence Diagram Used for Sensitivity Analysis

The tornado diagram in Figure 4.2 shows the results of this analysis. The only weights that did alter the recommended alternative were the weights assigned to the fundamental objectives of safety of flight (safety_wt) and mission planning under the fundamental objective safety of flight (s_mp_wt). A safety of flight weight less than

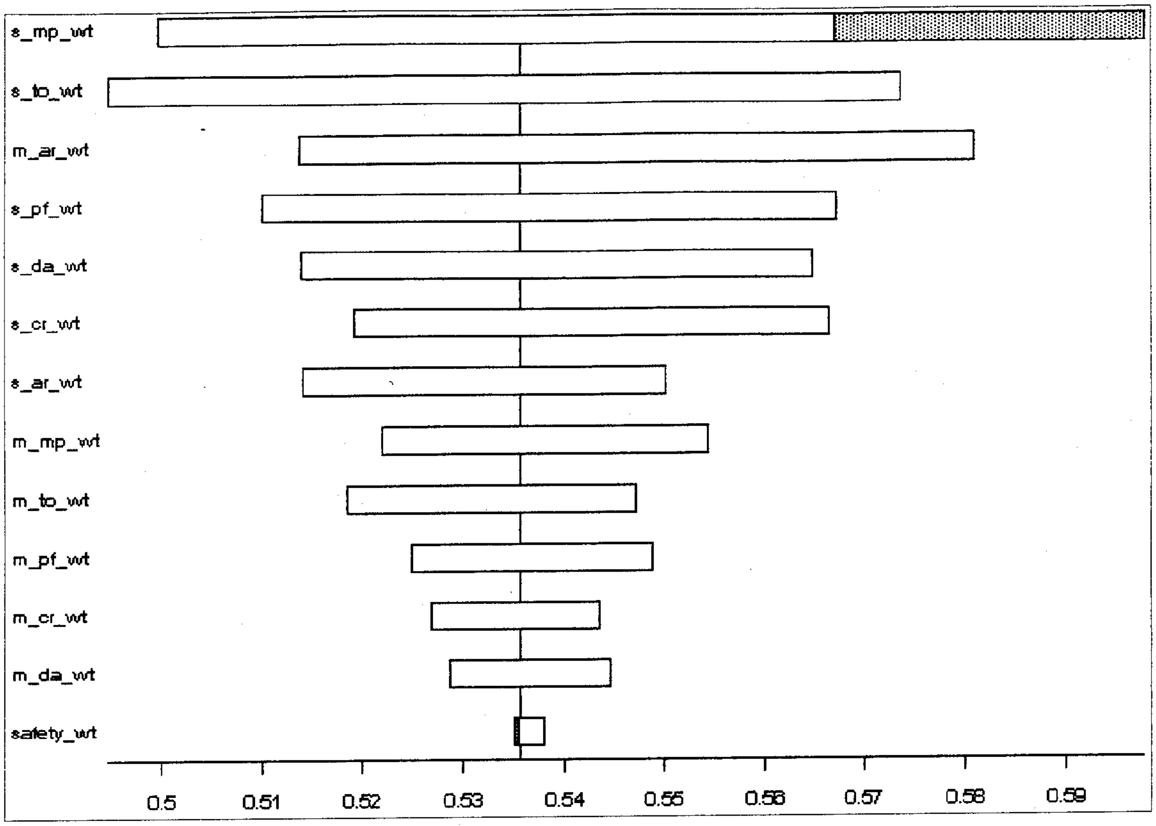


Figure 4.2 Tornado Diagram Shows Sensitivity to Weights

23.3% caused the utility of the upgraded equipment to exceed the utility of the navigator. None of the survey responses were less than this value. Any mission planning weight greater than 41.5% caused the utility of the upgraded equipment to exceed the utility of the navigator. Only 2 survey responses out of 17 or approximately 12% exceeded this value.

4.2 Analysis of Break-even Point

The break-even point was calculated with the assumption that all the costs and rates of inflation are known with certainty. We can examine the impact of cost overruns and varying inflation rates.

Figure 4.3 shows the sensitivity of the break-even point to a 10% and a 25% cost overrun on equipment. This graph shows that the break-even point is one year later with a 10% cost increase and is a little more than two years later with a 25% cost increase.

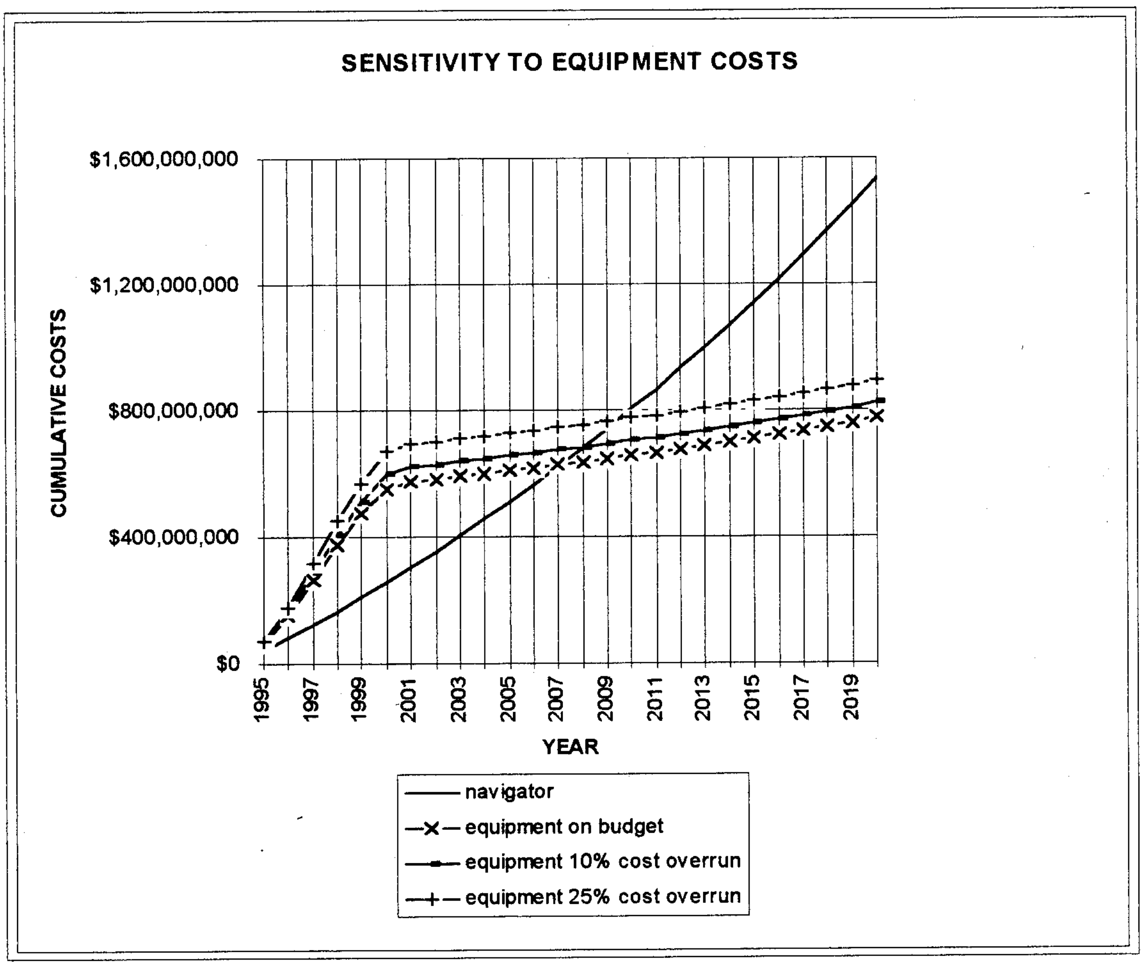
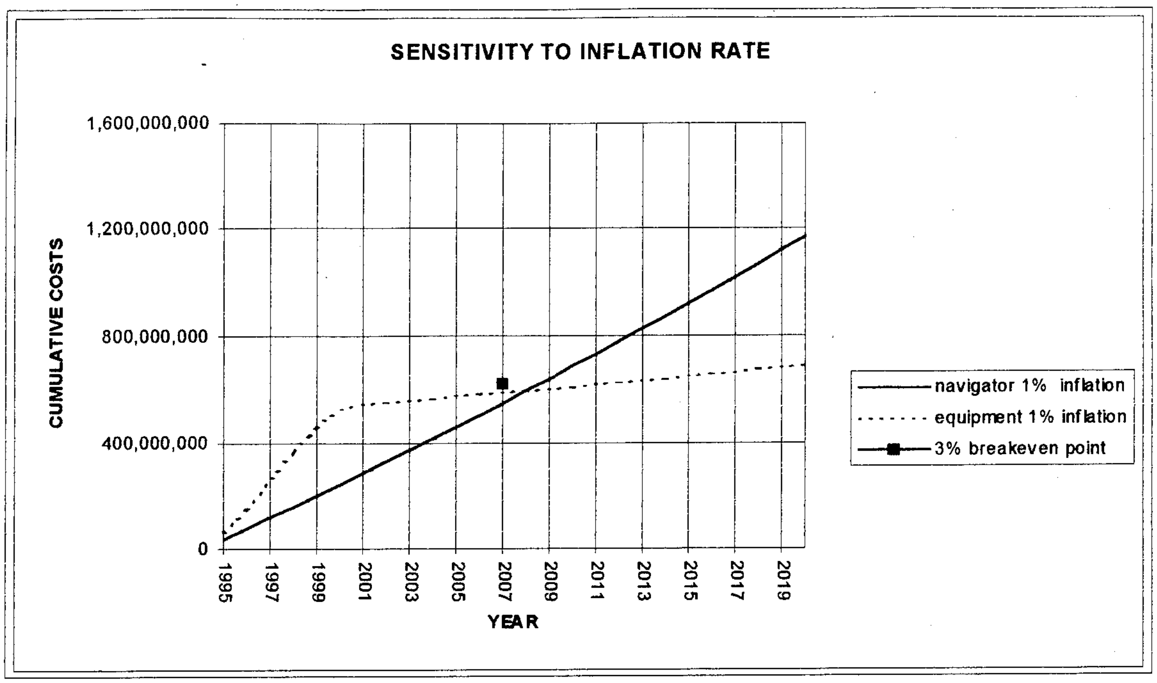


Figure 4.3 Sensitivity to Equipment Costs

Figure 4.4 displays the impact of a changing inflation rate on the break-even point.



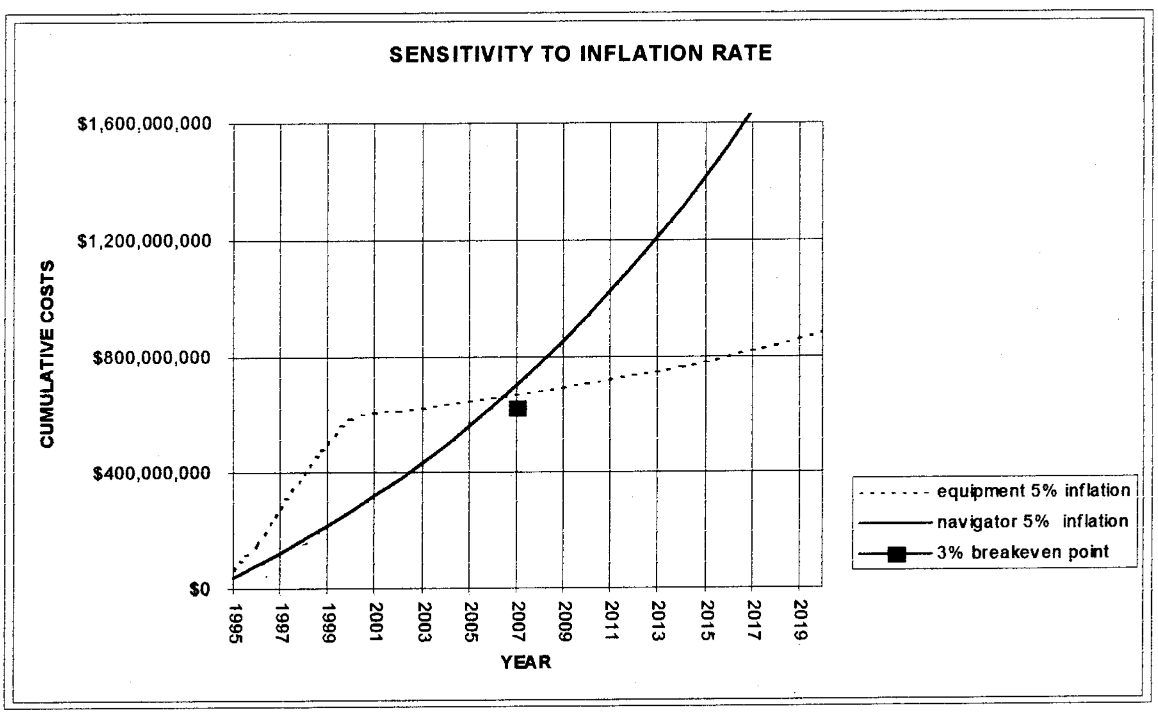


Figure 4.4 Sensitivity to Inflation Rate

The manpower costs include training costs and salaries. Equipment costs include those same training costs and salaries for a reduced number of navigators as well as the equipment itself. The inflation rate was varied plus and minus two percent from the base rate of three percent. The graphs show that reducing the inflation rate moves the break-even point one year later. Increasing the inflation rate, moves the break-even point one year earlier. This happens because the inflation rate has a greater affect on the manpower costs which occur during the entire life-cycle.

4.3 Analysis of the Net Present Value

The discount rate or the minimum attractive rate of return (8:78) used to compute the net present value was varied from the base inflation rate of three percent to the historical rate of ten percent. (1) This analysis in Figure 4.5 shows that the change in NPV for equipment is much less than the change in NPV for manpower. Manpower costs continue to increase every year over the life-cycle, while the equipment costs occur only during the first seven years of the life-cycle. These manpower costs in the later years of the life-cycle are heavily discounted.

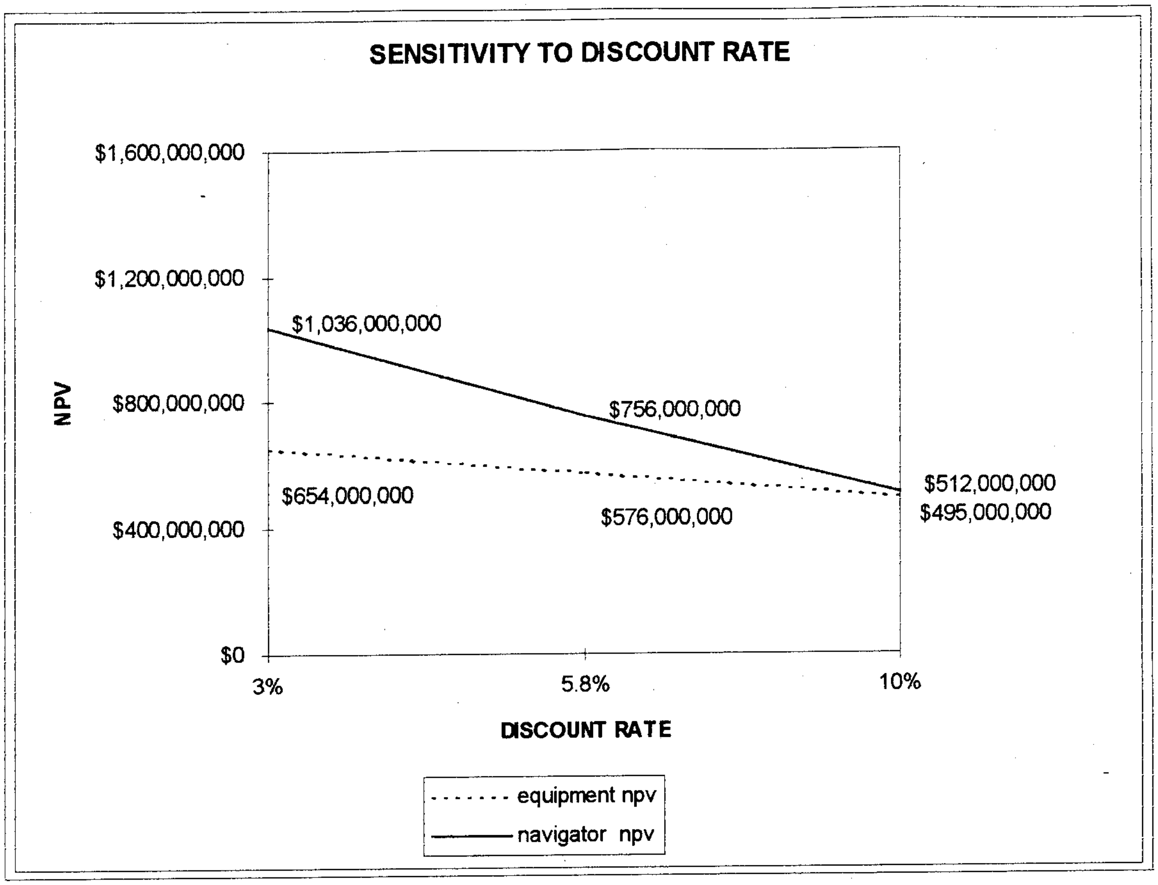


Figure 4.5 Sensitivity to Discount Rate

4.4 Increasing Utility of Value Model

In order to increase the utility with upgraded equipment, we must return to theValue Model. Once the weights for the objectives and attributes are assigned, the only way to increase utility is to add equipment that increases the scores of the attributes. The largest increase in utility will occur with the addition of equipment that has the largest affect on many attributes across multiple mission phases. Two pieces of additional equipment were found that met this criterion. The first is a Ground Collision Avoidance System (GCAS). The second is a Terminal Collision Avoidance System (TCAS).

Discussions with the air logistics center item manager provided insight into the capabilities of GCAS. (9) Along with providing audio and visual warnings for ground collision, the system could also warn of improper gear or flap configuration and windshear. Attribute numbers 21, 24, 45, 48, and 53 from Appendix C.1 had significantly higher scores with the addition of GCAS. The utility increased from 0.512 to 0.555, an increase of approximately 8%.

Interviews with Headquarters AMC personnel helped to determine the potential benefits of TCAS. (4) The primary purpose of TCAS is to provide warning against collisions with other aircraft. An additional capability being considered is the ability to monitor position within a formation. Attribute numbers 18, 23, 30, 34, and 49 from Appendix C.1 had higher scores with TCAS installed. The utility increased from 0.512 to 0.558, an increase of approximately 8%.

Appendix C.1 shows the spreadsheet with upgraded avionics plus GCAS and TCAS. The overall utility improved to 0.601, an improvement of approximately 15%. The impact on the break-even point must be considered.

4.5 Break-even Analysis with Additional Equipment

Cash flows for GCAS and TCAS had to be determined before break-even analysis could be done. Budgeted numbers were obtained directly from the Oklahoma Air Logistics Center (ALC) for GCAS. (9) Estimates for TCAS were obtained from the KC-135 SPO (17) and the ALC (2). These estimates ranged from $71 million to $100 million.

The mean value of a uniform distribution between 71 million and 100 million was used for the TCAS cost estimate. An assumption was made that it would take three years to get money for TCAS into the budget. (4) Money would be in the budget for TCAS starting in 1998 and would be spent over eight years as shown in Table 4.1.

Table 4.1 Cash Flows for GCAS and TCAS in Constant 1995 Millions of Dollars

YEAR	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	TOTALS
GCAS	12.2	6.7	9.9	9.6	9.0	4.4	3.0	2.5	2.0	0.0	0.0	59.3
TCAS	0.0	0.0	0.0	8.6	12.8	17.1	17.1	12.8	8.5	4.3	4.3	85.5

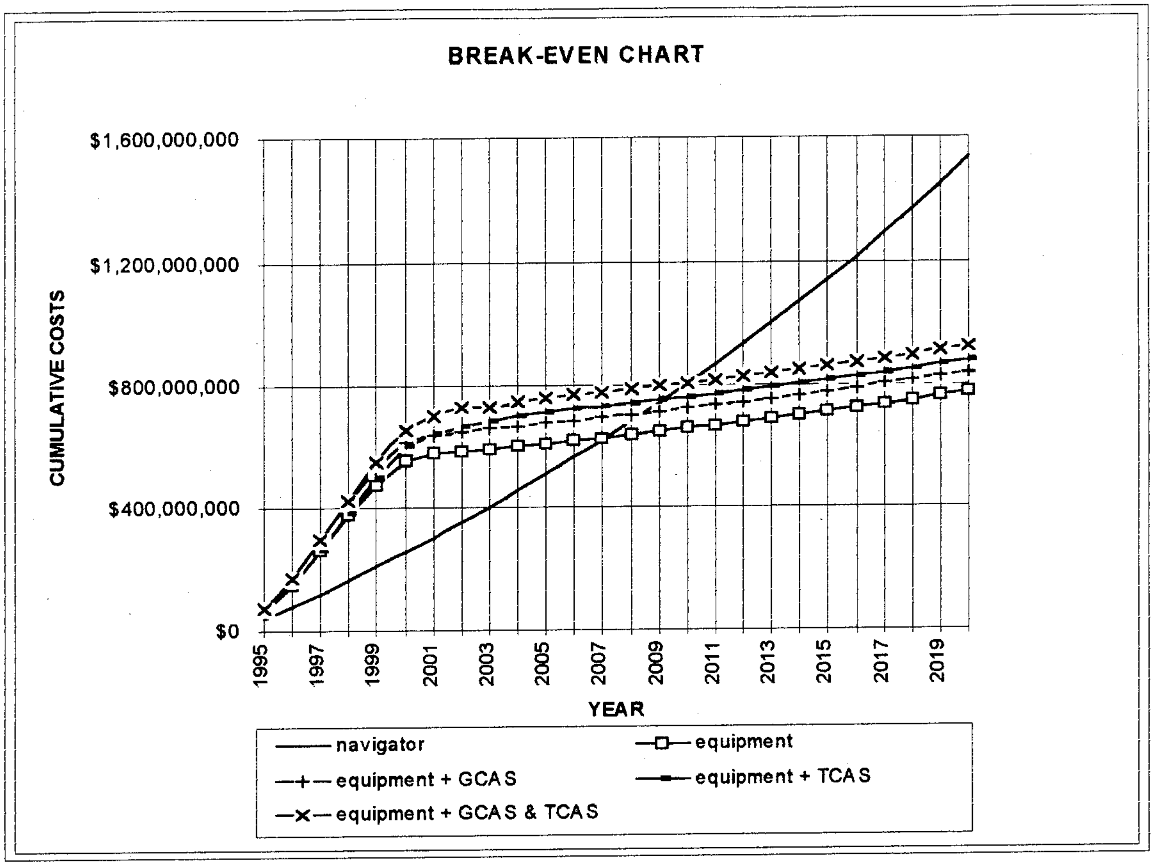


Figure 4.6 Break-even Curve With Added Equipment

The graph in Figure 4.6 shows the result on the break-even point as additional equipment is added individually and together. GCAS adds a little more than a year to the break-even point. TCAS adds approximately two years. If both pieces are added the break-even point moves three years to 2010. Money will be saved over at least the next ten years of the planned life-cycle of the KC-135.

4.5 NPV Calculations With Additional Equipment

NPV calculations can be done by discounting the cash flows from the break-even analysis. Table 4.2 summarizes these results in $millions as well as the marginal NPV and annual equivalent amount. The marginal NPV is the difference between the NPV of the additional equipment and the basic upgraded avionics package. The annual equivalent amount expresses the NPV as a series of equal payments that would have to be made yearly with an interest rate of 5.8% over the life-cycle of the KC-135. (8:44)

Table 4.2 Summary of NPV With the Addition of GCAS and TCAS

	NPV	MARGINAL NPV	ANNUAL EQUIVALENT
EQUIPMENT	$577		$44
GCAS	$632	$55	$48
TCAS	$650	$73	$50
TCAS & GCAS	$693	$116	$53

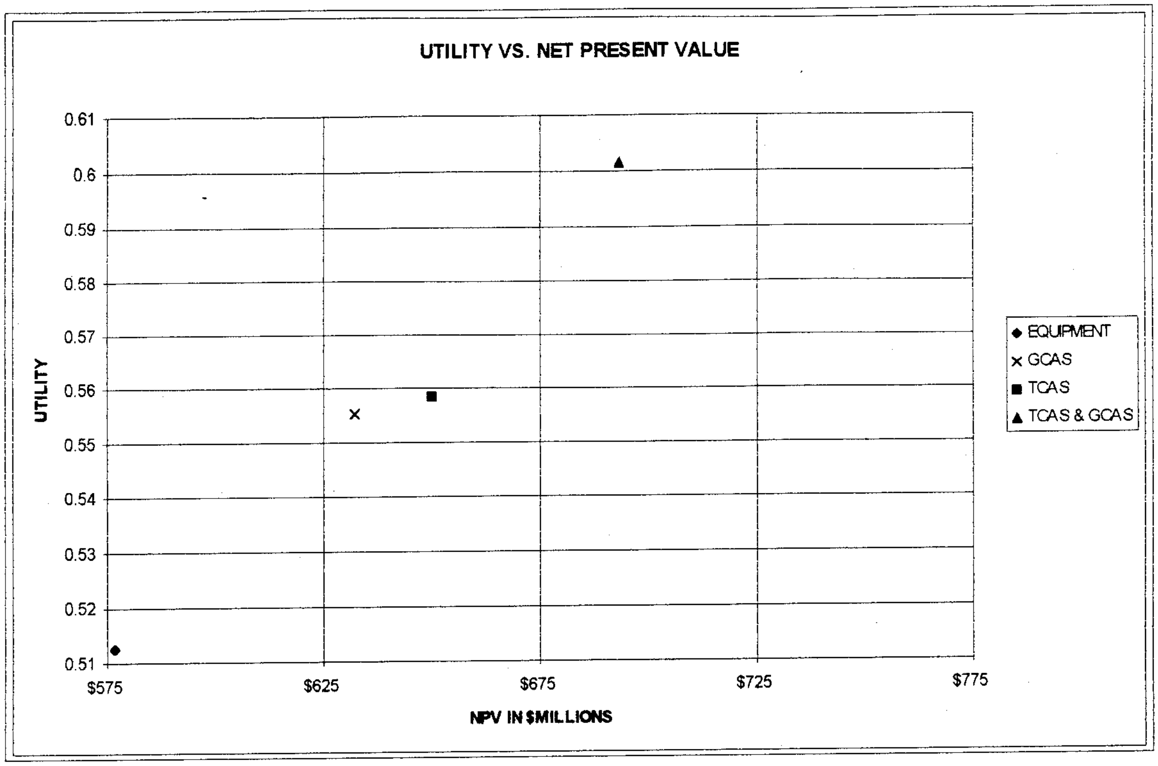


Figure 4.7 Utility Versus NPV

Figure 4.7 shows a plot of utility versus NPV for the different equipment options. This graph reveals that no single option dominates the others. As equipment is added to increase utility, the cost measured in NPV also increases.

Figure 4.8 shows how the different equipment options affect the fundamental objectives. The upgraded avionics which replace the navigator add mission accomplishment (2%) at the expense of some safety of flight (-7%). The addition of either GCAS or TCAS add both mission accomplishment and safety of flight. Both GCAS and TCAS have more safety of flight and mission accomplishment than the cockpit with the navigator. TCAS adds more to mission accomplishment; GCAS adds more to safety of flight. The addition of GCAS and TCAS together add significantly to both mission accomplishment (12%) and safety of flight (10%).

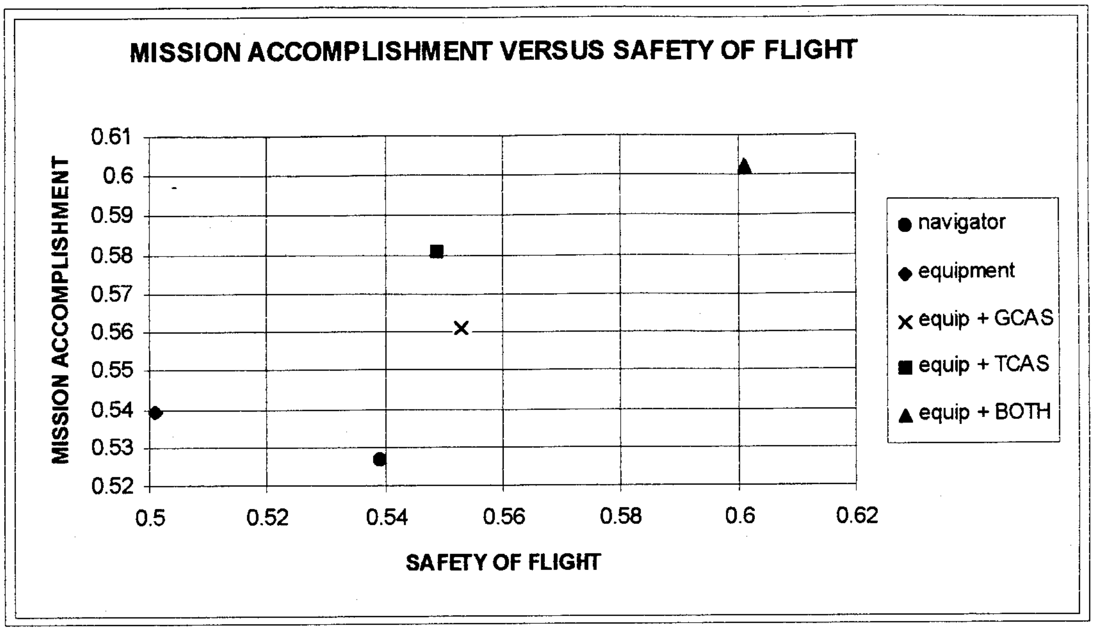


Figure 4.8 Mission Accomplishment Versus Safety of Flight

V. Conclusions and Recommendations

This chapter examines conclusions reached from the Value Model and cost analysis. It recommends using value-focused thinking by the Air National Guard to determine their manpower needs and proposes additional equipment to improve the mission effectiveness of the KC-135.

5.1 Conclusions

The primary focus of this research was to determine the impact on mission effectiveness and life-cycle costs of replacing the KC-135 navigator with upgraded avionics. The study emphasizes the use of value-focused thinking to objectively measure mission effectiveness and identify additional equipment that will increase mission effectiveness. The break-even point was used to measure the impact on life-cycle costs.

The cockpit with the navigator had a higher mission effectiveness than the cockpit with upgraded avionics when the upgraded equipment included GPS, new radar and compass. The break-even point in this case was 2007, 12 years after the initial year of the equipment contracts and 6 years after installation was complete. Sensitivity analysis showed that the results of the Value Model were changed only by the weight given to the safety of flight objective and mission planning under the objective of safety of flight. The break-even point was not significantly changed by varying the inflation rate or equipment costs.

By using value-focused thinking, GCAS and TCAS were identified as equipment that added the most value. This was due to their contributions to utility across many phases of flight. When either was added to the Value Model, the mission effectiveness utility increased by approximately 8%. The addition of both GCAS and TCAS increased utility by nearly 15%. The break-even point was a little more than a year later with the addition of GCAS. The purchase of TCAS added about two years to the break-even point. GCAS and TCAS together moved the break-even point three years later. Money will be saved over the last ten years of the planned life-cycle if both pieces of equipment are bought.

5.2 Recommendations

The Air National Guard has some reservations about replacing manpower with upgraded avionics. (22) The Air Nation Guard's main concern is wartime missions with much complexity and many airplanes in a small airspace. They believe their crews may become task saturated. Although all the navigator functions have been reallocated, at times multiple functions must be performed simultaneously. Value-focused thinking could be used to develop a Value Model, similar to the one used in this research, that would enable them to quantitatively evaluate the utility their navigators provide. They could determine their own objectives and attributes and assess their value from their perspective. This would allow them to identify missions or phases of missions where task saturation occurs. A determination could then be made whether additional training, additional equipment or retaining navigators is the solution to task saturation.

The active duty Air Force is keeping a small number of navigators to fly complex missions to relieve task saturation. Mission activities must be identified where the use of additional manpower is beneficial or necessary. With modern avionics this additional manpower does not have to be a navigator. He could be another pilot, a boom operator, or even a flight engineer. The use of a boom operator or flight engineer would save in training costs and composite salaries.

The choice of GCAS and TCAS was from available technology. If this constraint were removed, additional equipment could be designed to further increase mission effectiveness. Equipment that is used during many mission phases would provide the most effectiveness. A mission database could be available for both planning and inflight use. This would incorporate a terrain map, all instrument approaches and departures from current Flight Information Publications, and all enroute charts. A color chart would be automatically drawn and a flight plan produced once mission parameters were entered. It could plan and display alternate missions if the primary mission changed. It could display terrain on the electronic horizontal situation indicator and tie into the GCAS to provide additional ground collision warning. It could also tie in with differential GPS to provide approach monitoring and display. This system could make paper in the cockpit unnecessary.

Another future system would be an intelligent monitor and warning system. This system could monitor all aircraft systems. If a malfunction occurred, the system would inform you of the problem and computerized checklists for that malfunction would come up automatically. Another feature would monitor flight parameters. You could set an altitude, heading, and airspeed and deviations would be automatically announced. It would know where you are in flight and determine when the gear, flaps, and fuel panel are set incorrectly.

Equipment such as these systems may not be cost effective for the current KC-135, but by using a value-focused approach, future systems can be envisioned that will provide increased mission effectiveness for the future.

This research assumed that operating costs for upgraded equipment would equal operating costs for the old equipment. The failure rates for the new equipment should actually be much lower than the old equipment. (4) Further research could determine the operating costs of the new equipment evaluate the affect on the break-even point.

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Appendix A. Value Model

A.1 Descriptions of the Attributes

The attribute scales were assumed to be linear. A zero level and a one level were specified. The attribute was then scored between those points.

1. DEVELOP ROUTE OF FLIGHT
    - 0 >4 hours required and all work done manually
    - 1 < 30 minutes required and all work computerized
2. DEVELOP FLIGHT PLAN
    - 0 >4 hours required and all work done manually
    - 1 < 30 minutes required and all work computerized
3. COORDINATING COMMUNICATIONS AND INTELLIGENCE REQUIREMENTS
    - 0 No crewmember except pilots available to accomplish
    - 1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
4. DRAWING CHART TO COVER ROUTE OF FLIGHT
    - 0 Chart drawn completely manually by pilots
    - 1 Chart drawn automatically by computer
5. DETERMINE IF SCHEDULE CHANGES HAVE AFFECTED MISSION
    - 0 No crewmember except pilots available to accomplish
    - 1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
6. DETERMINE IMPACT OF WEATHER ON MISSION
    - 0 Weather impact not considered
    - 1 Computer automatically overlays weather on intended route of flight
7. DETERMINE IF NOTAMS AFFECT MISSION
    - 0 No crewmember except pilots available to accomplish
    - 1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
8. OBTAIN TIME HACK (SYNCHRONIZE WATCHES WITH OFFICIAL TIME)
    - 0 No crewmember except pilots available to accomplish
    - 1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
9. DETERMINE IF RECEIVER STATUS WILL CHANGE PLANNED MISSION
    - 0 No crewmember except pilots available to accomplish
    - 1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
10. PICK UP FLIGHT INFORMATION PUBLICATION (FLIP) DOCUMENTS
    - 0 No crewmember except pilots available to accomplish
    - 1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
11. PREFLIGHT EQUIPMENT
    - 0 > 1 hour required to preflight navigation equipment
    - 1 < 15 minutes required to preflight navigation equipment
12. LOAD MISSION DATA
    - 0 >15 minutes required
    - 1 < 5 minutes required
13. DISTRIBUTE FLIP DOCUMENTS TO CREWMEMBERS
    - 0 No one distributes
    - 1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
14. DETERMINE IF RECEIVER STATUS WILL CHANGE TAKEOFF TIME OR MISSION
    - 0 Receiver status never updated
    - 1 Designated crewmember available who doesn't have to interrupt other duties to accomplish

15. PLAN ALTERNATE MISSION IF REQUIRED (MAINTENANCE, RECEIVER REQUEST)
    0 No one accomlishes
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
16. RECEIVE ARTCC CLEARANCE
    0 Pilots only crewmembers available to receive clearance
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
17. ASSIS BOOM OPERATOR WITH LOADING CARGO
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
18. DIRECT AIRCRAFT INTO AND MAINTAIN FORMATION POSITION
    0 No specialized equipment or crewmember available to accomplish
    1 Designated crewmember with specialized equipment available to accomplish
19. MONITOR/DIRECT DEPARTURE AFTER TAKEOFF
    0 Pilots only crewmembers available to accomplish and no visual display
    1 Equipment displays departure and shows deviations
20. CHECK HEADING, ALTITUDE, AND AIRSPEED
    0 Pilots only crewmembers available to accomplish and no equipment monitors deviations
    1 Equipment or crewmember monitors continuously
21. MAINTAIN TERRAIN CLEARANCE
    0 Pilots only crewmembers available to accomplish and no equipment monitors deviations
    1 Equipment monitors continuously and warns crew verbally
22. MAINTAIN CLEARANCE FROM HAZARDOUS WEATHER
    0 No equipment available to accomplish
    1 Equipment monitors continuously
23. SCAN FOR OTHER TRAFFIC DURING TAKEOFF AND DEPARTURE
    0 Pilots only crewmembers available to accomplish and no equipment monitors other aircraft
    1 Equipment monitors continuously and warns of conflicts
24. ENSURE CORRECT FLAP CONFIGURATION SET FOR TAKEOFF
    0 Pilots only crewmembers available to accomplish and no equipment monitors deviations
    1 Equipment monitors continuously
25. ENSURE RADIO COMMUNICATIONS MONITORED
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
26. REQUIRED ALTITIUDE CALLS MADE
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
27. PERFORM AIR REFUELING RENDEZVOUS
    0 Pilots only crewmembers available to accomplish and no specialized equipment
    1 Equipment automatically accomplishes
28. MAINTAIN AIRCRAFT WITHIN AIR REFUELING AREA
    0 Pilots only crewmembers available to accomplish and no visual display
    1 Equipment displays area and shows deviations
29. MAINTAIN REQUIRED MISSION TIMING
    0 Pilots only crewmembers available to accomplish and no specialized equipment
    1 Equipment continuously monitors and displays deviations

30. MAINTAIN FORMATION POSITION
    0 No equipment available to monitor
    1 Equipment continuously monitors and displays position
31. SET RENDEZVOUS EQUIPMENT
    0 Pilots only crewmembers available to accomplish and all equipment manual
    1 Equipment automatically set
32. COMMUNICATE RENDEZVOUS INFORMATION WITH RECEIVER
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
33. IDENTIFY RECEIVER RADAR BEACON
    0 No ability to receive beacon
    1 Equipment automatically displays and identifies beacon
34. DETERMINE OVERRUN
    0 No ability to determine electronically
    1 Equipment automatically determines overrun
35. DETERMINE EQUIPMENT STATUS
    0 No ability to monitor equipment status
    1 Status automatically determined and malfunctions prominently displayed
36. UPDATE INERTIAL NAVIGATION SYSTEM
    0 No ability to update INS
    1 Automatically updated by GPS
37. TRACK POSITION WITH RESPECT TO DESIRED COURSE
    0 No ability to track position electronically
    1 Equipment continuously monitors and displays position with respect to desired course
38. DIVERT TO UNPLANNED DESTINATION
    0 Pilots only crewmembers available to accomplish and no automatic equipment
    1 Equipment automatically computes and displays distance, time and heading
39. MEET MISSION TIMING
    0 Pilots only crewmembers available to accomplish and no specialized equipment
    1 Equipment continuously monitors and displays deviations
40. TROUBLE-SHOOT MALFUNCTIONS
    0 Pilots only crewmembers available to manually search technical orders
    1 Computerized malfunction information available online
41. MONITOR RADIOS
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
42. POSITION SWITHCES AND CIRCUIT BREAKERS FOR PILOTS
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
43. ASSIST BOOM OPERATOR WITH PASSENGER CONTROL
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
44. ENSURE AIRCRAFT ARRIVES AT DESTINATION/FIX
    0 Pilots only crewmembers available to accomplish and no automatic equipment
    1 Equipment automatically computes and displays

45. MAINTAIN TERRAIN CLEARANCE
    0 Pilots only crewmembers available to accomplish and no equipment monitors deviations
    1 Equipment monitors continuously and warns crew verbally
46. PERFORM AIRBORN RADAR DIRECTED APPROACH
    0 No ability to perform
    1 Equipment automatically displays approach and shows deviations
47. MONITOR POSITION WITH RESPECT TO ENROUTE CHARTS
    0 Pilots only crewmembers available to perform and all manual
    1 Equipment automatically displays position and can accept identifiers for naviads/intersections
48. MONITOR DRIFT AND GROUNDSPEED DURING APPROACH
    0 No ability to monitor
    1 Equipment automatically and continuously displays/warns for windshear
49. SCAN FOR TRAFFIC DURING DESCENT AND APPROACH
    0 Pilots only crewmembers available to accomplish and no equipment monitors other aircraft
    1 Equipment monitors continuously and warns of conflicts
50. MONITOR WEATHER REPORTS THAT COULD AFFECT APPROACH OR LANDING
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
51. WARN PILOT APPROACHING ASSIGNED ALTITUDES OR APPROACH DECISION POINTS
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
52. ENSURE ATC CLEARANCE IS RECEIVED FOR DESIRED APPROACH
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
53. ENSURE GEAR, FLAPS AND FUEL PANEL CONFIGURED CORRECTLY
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
54. MONITOR HEADING, ALTITUDE, AIRSPEED, AND BANK ANGLE
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
55. MONITOR RUNWAY REMAINING VERSUS SPEED
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish
56. MONITOR APPROACH
    0 Pilots only crewmembers available to accomplish
    1 Designated crewmember available who doesn't have to interrupt other duties to accomplish

A.2 Survey

This survey will be used for an AFIT thesis to determine the utility of the KC-135 with the navigator as part of the crew. I broke the tanker mission into mission phases with the functions that navs typically accomplish during these phases of flight. This rating will be compared to the KC-135 with upgraded avionics and no navigator. Maj Robert Deivert is the author of this thesis. I was a CCTS flightline instructor at the 93AREFS until May of 1993. If you feel I have overlooked anything navs do, please add your comments at the end of the questionnaire. I know how busy you are and I appreciate the time you spend filling out this survey. For each question divide 100 points among the selections so that the total is 100 points.

1. How much emphasis should be placed on safety of flight versus mission accomplishment? (Give a score to each on so they add to 100. i.e. 60 for safety of flight, 40 for mission accomplishment)

SAFETY OF FLIGHT______
MISSION ACCOMPLISHMENT______

2. Rate how much each phase of flight contributes to safety of flight. (once again all the numbers should add to 100)

MISSION PLANNING_____
SQUADRON/BASE OPS_____
PREFLIGHT_____
TAKEOFF AND DEPARTURE_____
AIR REFUELING_____
CRUISE_____
DESCENT AND APPROACH_____

3. Rate how much each phase of flight contributes to overall mission accomplishment.

MISSION PLANNING_____
SQUADRON/BASE OPS_____
PREFLIGHT_____
TAKEOFF AND DEPARTURE_____
AIR REFUELING_____
CRUISE_____
DESCENT AND APPROACH_____

4. How much does each phase of mission planning contribute to safety of flight?

ROUTE OF FLIGHT_____
CHART PREPARATION_____
FLIGHT PLAN PREPARATION_____
COORDINATE COMM AND INTEL_____

5. How much does each phase of mission planning contribute to mission accomplishment?
   ROUTE OF FLIGHT______
   CHART PREPARATION______
   FLIGHT PLAN PREPARATION______
   COORDINATE COMM AND INTEL______

6. How much do squadron/base ops activities contribute to safety of flight?
   CHECK FOR SCHEDULE CHANGES______
   CHECK FOR WEATHER IMPACT ON MISSION______
   CHECK NOTAMS______
   TIME HACK______
   CHECK RECEIVER STATUS______
   GET FLIP DOCUMENTS______

7. How much do squadron/base ops activities contribute to mission accomplishment?
   CHECK FOR SCHEDULE CHANGES______
   CHECK FOR WEATHER IMPACT ON MISSION______
   CHECK NOTAMS______
   TIME HACK______
   CHECK RECEIVER STATUS______
   GET FLIP DOCUMENTS______

8. How much do preflight actions contribute to safety of flight?
   PREFLIGHT EQUIPMENT______
   LOAD MISSION DATA______
   DISTRIBUTE FLIP______
   SECURE VOICE______
   RECEIVER STATUS______
   COMPUTE ALTERNATE MSSION TIMING______
   ARTCC CLEARANCE______
   ASSIST WITH CARGO______

9. How much do preflight actions contribute to mission accomplishment?
   PREFLIGHT EQUIPMENT______
   LOAD MISSION DATA______
   DISTRIBUTE FLIP______
   SECURE VOICE______
   RECEIVER STATUS______
   COMPUTE ALTERNATE MSSION TIMING______
   ARTCC CLEARANCE______
   ASSIST WITH CARGO______

10. How much do takeoff and departure actions contribute to safety of flight?
CROSS-CHECK SPEED BRAKES AND FLAPS______
MONITOR ARTCC COMMUNICATIONS______
MONITOR/DIRECT DEPARTURE______
CHECK HEADING, ALTITUDE, AND AIRSPEED______
DIRECT FORMATION JOIN UP______
MONITOR FORMATION POSITION______
MONITOR TERRAIN CLEARANCE______
AVOID HAZARDOUS WEATHER______
MONITOR HF COMMUNICATIONS______
MAKE ALTITUDE CALLS______
SCAN FOR TRAFFIC______

11. How much do takeoff and departure actions contribute to mission accomplishment?
CROSS-CHECK SPEED BRAKES AND FLAPS______
MONITOR ARTCC COMMUNICATIONS______
MONITOR/DIRECT DEPARTURE______
CHECK HEADING, ALTITUDE, AND AIRSPEED______
DIRECT FORMATION JOIN UP______
MONITOR FORMATION POSITION______
MONITOR TERRAIN CLEARANCE______
AVOID HAZARDOUS WEATHER______
MONITOR HF COMMUNICATIONS______
MAKE ALTITUDE CALLS______
SCAN FOR TRAFFIC______

12. How much do air refueling actions contribute to safety of flight?
COMPUTE ORBIT INFORMATION______
SET RENDEZVOUS EQUIPMENT______
COMMUNICATE WITH RECEIVER______
MAINTAIN ORBIT______
RENDEZVOUS CALCULATIONS______
PERFORM RENDEZVOUS______
IDENTIFY RECEIVER BEACON______
MAINTAIN FORMATION POSITION______
DETERMINE OVERRUN______
MAINTAIN ANCHOR AREA______
MAINTAIN MISSION TIMING______
RECORD AIR REFUELING DATA______

13. How much do air refueling actions contribute to mission accomplishment?

COMPUTE ORBIT INFORMATION______
SET RENDEZVOUS EQUIPMENT______
COMMUNICATE WITH RECEIVER______
MAINTAIN ORBIT______
RENDEZVOUS CALCULATIONS______
PERFORM RENDEZVOUS______
IDENTIFY RECEIVER BEACON______
MAINTAIN FORMATION POSITION______
DETERMINE OVERRUN______
MAINTAIN ANCHOR AREA______
MAINTAIN MISSION TIMING______
RECORD AIR REFUELING DATA______

14. How much do actions performed during cruise contribute to safety of flight?

MONITOR NAVIGATION EQUIPMENT STATUS______
UPDATE INS AS REQUIRED______
TRACK AIRCRAFT POSITION______
MONITOR ARTCC, UHF, VHF AND HF RADIOS_______
MAINTAIN COURSE CENTERLINE______
ADJUST COURSE/SPEED TO MEET MISSION TIMING______
TROUBLE SHOOT DURING MALFUNCTIONS/EMERGENCIES______
COMMUNICATE WITH ARTCC DURING EMERGENCIES______
POSITION SWITCHES/CIRCUIT BREAKERS FOR PILOTS______
ASSIST BOOM OPERATOR WITH PASSENGERS______
DIRECT PLANE TO NEW DESTINATION DURING DIVERT______

15. How much do actions performed during cruise contribute to mission accomplishment?

MONITOR NAVIGATION EQUIPMENT STATUS______
UPDATE INS AS REQUIRED______
TRACK AIRCRAFT POSITION______
MONITOR ARTCC, UHF, VHF AND HF RADIOS_______
MAINTAIN COURSE CENTERLINE______
ADJUST COURSE/SPEED TO MEET MISSION TIMING______
TROUBLE SHOOT DURING MALFUNCTIONS/EMERGENCIES______
COMMUNICATE WITH ARTCC DURING EMERGENCIES______
POSITION SWITCHES/CIRCUIT BREAKERS FOR PILOTS______
ASSIST BOOM OPERATOR WITH PASSENGERS______
DIRECT PLANE TO NEW DESTINATION DURING DIVERT______

16. How much do descent and approach actions contribute to safety of flight?

DIRECT PLANE TO DESTINATION/FIX______
REVIEW AND MONITOR APPROACHES______
MAINTAIN TERRAIN CLEARANCE______
MONITOR WEATHER REPORTS______
MAKE ALTITUDE CALLS______
ENSURE PILOTS FLY CLEARED APPROACH______
ANNOUNCE APPROACH DECISION POINT______
PERFORM RADAR DIRECTED APPROACH______
MONITOR POSITION WITH RESPECT TO ENROUTE CHARTS______
MONITOR WINDSHEAR(GROUNDSPEED DURING APPROACH)______
RELAY DRIFT AND GROUNDSPEED INFORMATION______
ENSURE GEAR, FLAPS, AND FUEL PANEL SET CORRECTLY______
SCAN FOR TRAFFIC______
ENSURE MISSED APPROACH PROCEDURES FOLLOWED______
MONITOR ALTITUDE, HEADING, AND AIRSPEED______
MONITOR BANK ANGLE______
MONITOR LANDING ROLLOUT AND RUNWAY REMAINING______

17. How much do descent and approach actions contribute to mission accomplishment?

DIRECT PLANE TO DESTINATION/FIX______
REVIEW AND MONITOR APPROACHES______
MAINTAIN TERRAIN CLEARANCE______
MONITOR WEATHER REPORTS______
MAKE ALTITUDE CALLS______
ENSURE PILOTS FLY CLEARED APPROACH______
ANNOUNCE APPROACH DECISION POINT______
PERFORM RADAR DIRECTED APPROACH______
MONITOR POSITION WITH RESPECT TO ENROUTE CHARTS______
MONITOR WINDSHEAR(GROUNDSPEED DURING APPROACH)______
RELAY DRIFT AND GROUNDSPEED INFORMATION______
ENSURE GEAR, FLAPS, AND FUEL PANEL SET CORRECTLY______
SCAN FOR TRAFFIC______
ENSURE MISSED APPROACH PROCEDURES FOLLOWED______
MONITOR ALTITUDE, HEADING, AND AIRSPEED______
MONITOR BANK ANGLE______
MONITOR LANDING ROLLOUT AND RUNWAY REMAINING______

COMMENTS OR SUGGESTIONS:

A.3 Scored Value Model

			UTILITY WITH NAVIGATOR					
FUNDAMENTAL OBJECTIVE	MISSION PHASE	ATTRIBUTE NUMBER	ATTRIBUTES	WEIGHT	SCORE	ATTRIBUTE (WT) * (SCORE)	MEANS OBJ. (WT) * (SUM)	MANUAL
	MISSION	1	ROUTE OF FLIGHT	0.34	0.4	0.136		
	PLANNING	2	FLIGHT PLAN	0.27	0.5	0.135		
	0.24		**MANUALLY ACCOMPLISHED**					
		3	COORDINATE MISSION COMM AND INTEL REQUIREMENTS	0.16	0.5	0.08		
		4	CHART	0.24	0.3	0.072		
						0.423	0.10152	0.03648
			MANUALLY ACCOMPLISHED					
		5	CHECK FOR SCHEDULE CHANGES	0.16	0.5	0.08		
	SQUADRON/	6	CHECK WEATHER IMPACT ON MISSION	0.34	0.3	0.102		
	BASE OPS	7	CHECK NOTAMS	0.21	0.5	0.105		
	0.07	8	TIME HACK	0.06	0.5	0.03		
		9	RECEIVER STATUS	0.09	0.5	0.045		
		10	FLIP DOCUMENTS	0.15	0.5	0.075		
SAFETY OF						0.437	0.03059	0.03059
FLIGHT	PREFLIGHT	11	PREFLIGHT EQUIPMENT	0.36	0.8	0.288		
0.7	0.09	12	LOAD MISSION DATA	0.15	0.8	0.12		
			MANUALLY ACCOMPLISHED					
		13	DISTRIBUTE FLIP	0.09	0.5	0.045		
		14	RECEIVER STATUS	0.06	0.5	0.03		
		15	COMPUTE ALTERNATE MISSION TIMING	0.13	0.5	0.065		
		16	ARTCC CLEARANCE	0.15	0.5	0.075		
		17	ASSIST WITH CARGO	0.07	0.5	0.035		
						0.658	0.05922	0.0225
	TAKEOFF	18	FORMATION	0.21	0.8	0.168		
	AND	19	MONITOR/DIRECT DEPARTURE	0.07	0.5	0.035		
	DEPARTURE	20	CHECK HEADING, ALTITUDE, AIRSPEED	0.11	0.5	0.055		
	0.18	21	MAINTAIN TERRAIN CLEARANCE	0.09	0.7	0.063		
		22	AVOID HAZARDOUS WEATHER	0.14	0.8	0.112		
		23	SCAN FOR TRAFFIC	0.06	0.3	0.018		
			MANUALLY ACCOMPLISHED					
		24	FLAP CONFIGURATION	0.1	0.8	0.08		
		25	MONITOR RADIO COMMUNICATIONS	0.14	0.5	0.07		
		26	MAKE ALTITUDE CALLS	0.08	0.5	0.04		
						0.641	0.11538	0.0342
	AIR	27	PERFORM RENDEZVOUS	0.27	0.5	0.135		
	REFUELING	28	MAINTAIN REFUELING AREA	0.18	0.5	0.09		
	0.14	29	MAINTAIN MISSION TIMING	0.06	0.5	0.03		
		30	FORMATION POSITION	0.11	0.8	0.088		
			MANUALLY ACCOMPLISHED					
		31	SET RENDEZVOUS EQUIPMENT	0.07	0.5	0.035		
		32	COMMUNICATE WITH RECEIVER	0.17	0.5	0.085		
		33	IDENTIFY RECEIVER BEACON	0.05	0.8	0.04		-
		34	DETERMINE OVERRUN	0.09	0.5	0.045		
						0.548	0.07672	0.0287
		35	DETERMINE EQUIPMENT STATUS	0.1	0.5	0.05		
		36	UPDATE INS	0.1	0.4	0.04		
	CRUISE	37	TRACK AIRCRAFT POSITION	0.19	0.7	0.133		
	0.07	38	DIVERT TO UNPLANNED DESTINATION	0.12	0.7	0.084		
		39	MEET MISSION TIMING	0.06	0.5	0.03		
			MANUALLY ACCOMPLISHED					
		40	TROUBLE SHOOT MALFUNCTIONS	0.12	0.6	0.072		
		41	MONITOR RADIOS	0.2	0.5	0.1		
		42	POSITION SWITCHES/CIRCUIT BREAKERS FOR PILOTS	0.06	0.5	0.03		
		43	ASSIST BOOM OPERATOR WITH PASSENGERS	0.05	0.5	0.025		
						0.564	0.03948	0.01589
	DESCENT	44	DIRECT PLANE TO DESTINATION FIX	0.06	0.7	0.042		
	AND	45	MAINTAIN TERRAIN CLEARANCE	0.1	0.5	0.05		
	APPROACH	46	PERFORM ARDA	0.03	0.5	0.015		
	0.2	47	MONITOR POSITION WITH RESPECT TO ENROUTE CHARTS	0.03	0.5	0.015		
		48	MONITOR DRIFT AND GROUNDSPEED	0.14	0.5	0.07		
		49	SCAN FOR TRAFFIC	0.05	0.3	0.015		
			MANUALLY ACCOMPLISHED					
		50	MONITOR WEATHER REPORTS	0.06	0.5	0.03		
		51	MAKE ALTITUDE CALLS	0.11	0.8	0.088		
		52	ENSURE ATC CLEARS DESIRED APPROACH	0.06	0.5	0.03		
		53	ENSURE CORRECT GEAR, FLAPS, FUEL PANEL CONFIG.	0.09	0.5	0.045		
		54	MONITOR HEADING, ALTITUDE, AIRSPEED, AND BANK ANGLE	0.12	0.5	0.06		
		55	MONITOR LANDING ROLLOUT	0.03	0.8	0.024		
		56	MONITOR APPROACH	0.14	0.7	0.098		
						0.582	0.1164	0.075
						MEANS OBJ.SUM	0.53931	0.24336
						SAFETY OF FLIGHT UTILITY	0.377517	
						MISSION ACCOMP. UTILITY	0.158214	
						TOTAL VALUE	0.535731	

			UTILITY WITH NAVIGATOR					
FUNDAMENTAL OBJECTIVE	MISSION PHASE	ATTRIBUTE NUMBER	ATTRIBUTES	WEIGHT	SCORE	ATTRIBUTE (WT) * (SCORE)	MEANS OBJ. (WT) * (SUM)	MANUAL
	MISSION	1	ROUTE OF FLIGHT	0.31	0.4	0.124		
	PLANNING	2	FLIGHT PLAN	0.29	0.5	0.145		
	0.27		**MANUALLY ACCOMPLISHED**					
		3	COORDINATE MISSION COMM AND INTEL REQUIREMENTS	0.16	0.5	0.08		
		4	CHART	0.23	0.3	0.069		
						0.418	0.11286	0.04023
	SQUADRON/		**MANUALLY ACCOMPLISHED**					
	BASE OPS	5	CHECK FOR SCHEDULE CHANGES	0.25	0.5	0.125		
	0.07	6	CHECK WEATHER IMPACT ON MISSION	0.31	0.3	0.093		
		7	CHECK NOTAMS	0.1	0.5	0.05		
		8	TIME HACK	0.07	0.5	0.035		
		9	RECEIVER STATUS	0.15	0.5	0.075		
		10	FLIP DOCUMENTS	0.13	0.5	0.065		
MISSION						0.443	0.03101	0.03101
ACCOMPLISHMENT	PREFLIGHT	11	PREFLIGHT EQUIPMENT	0.31	0.8	0.248		
0.3	0.09	12	LOAD MISSION DATA	0.19	0.8	0.152		
			MANUALLY ACCOMPLISHED					
		13	DISTRIBUTE FLIP	0.15	0.5	0.075		
		14	RECEIVER STATUS	0.13	0.5	0.065		
		15	COMPUTE ALTERNATE MISSION TIMING	0.14	0.5	0.07		
		16	ARTCC CLEARANCE	0.11	0.5	0.055		
		17	ASSIST WITH CARGO	0.06	0.5	0.03		
						0.695	0.06255	0.02655
	TAKEOFF	18	FORMATION	0.24	0.8	0.192		
	AND	19	MONITOR/DIRECT DEPARTURE	0.09	0.5	0.045		
	DEPARTURE	20	CHECK HEADING, ALTITUDE, AIRSPEED	0.1	0.5	0.05		
	0.12	21	MAINTAIN TERRAIN CLEARANCE	0.09	0.7	0.063		
		22	AVOID HAZARDOUS WEATHER	0.14	0.8	0.112		
		23	SCAN FOR TRAFFIC	0.06	0.3	0.018		
			MANUALLY ACCOMPLISHED					
		24	FLAP CONFIGURATION	0.06	0.8	0.048		
		25	MONITOR RADIO COMMUNICATIONS	0.17	0.5	0.085		
		26	MAKE ALTITUDE CALLS	0.06	0.5	0.03		
						0.643	0.07716	0.01956
	AIR	27	PERFORM RENDEZVOUS	0.33	0.5	0.165		
	REFUELING	28	MAINTAIN REFUELING AREA	0.17	0.5	0.085		
	0.25	29	MAINTAIN MISSION TIMING	0.09	0.5	0.045		
		30	FORMATION POSITION	0.09	0.8	0.072		
			MANUALLY ACCOMPLISHED					
		31	SET RENDEZVOUS EQUIPMENT	0.08	0.5	0.04		
		32	COMMUNICATE WITH RECEIVER	0.12	0.5	0.06		
		33	IDENTIFY RECEIVER BEACON	0.05	0.8	0.04		
		34	DETERMINE OVERRUN	0.06	0.5	0.03		
						0.537	0.13425	0.0425
	CRUISE	35	DETERMINE EQUIPMENT STATUS	0.11	0.5	0.055		
	0.08	36	UPDATE INS	0.1	0.4	0.04		
		37	TRACK AIRCRAFT POSITION	0.2	0.7	0.14		
		38	DIVERT TO UNPLANNED DESTINATION	0.1	0.7	0.07		
		39	MEET MISSION TIMING	0.13	0.5	0.065		
			MANUALLY ACCOMPLISHED					
		40	TROUBLE SHOOT MALFUNCTIONS	0.09	0.6	0.054		
		41	MONITOR RADIOS	0.16	0.5	0.08		
		42	POSITION SWITCHES/CIRCUIT BREAKERS FOR PILOTS	0.05	0.5	0.025		
		43	ASSIST BOOM OPERATOR WITH PASSENGERS	0.05	0.5	0.025		
						0.554	0.04432	0.01472
		44	DIRECT PLANE TO DESTINATION FIX	0.08	0.7	0.056		
	DESCENT	45	MAINTAIN TERRAIN CLEARANCE	0.04	0.5	0.02		
	AND	46	PERFORM ARDA	0.05	0.5	0.025		
	APPROACH	47	MONITOR POSITION WITH RESPECT TO ENROUTE CHARTS	0.1	0.5	0.05		
	0.11	48	MONITOR DRIFT AND GROUNDSPEED	0.1	0.5	0.05		
		49	SCAN FOR TRAFFIC	0.04	0.3	0.012		
			MANUALLY ACCOMPLISHED					
		50	MONITOR WEATHER REPORTS	0.06	0.5	0.03		
		51	MAKE ALTITUDE CALLS	0.13	0.8	0.104		
		52	ENSURE ATC CLEARS DESIRED APPROACH	0.08	0.5	0.04		
		53	ENSURE CORRECT GEAR, FLAPS, FUEL PANEL CONFIG.	0.06	0.5	0.03		
		54	MONITOR HEADING, ALTITUDE, AIRSPEED, AND BANK ANGLE	0.08	0.5	0.04		
		55	MONITOR LANDING ROLLOUT	0.03	0.8	0.024		
		56	MONITOR APPROACH	0.16	0.7	0.112		
						0.593	0.06523	0.0418
						MEANS OBJ.SUM	0.52738	0.21637
						MISSION ACCOMP.		
						UTILITY	0.158214	

			UTILITY WITH UPGRADED EQUIPMENT					
FUNDAMENTAL OBJECTIVE	MISSION PHASE	ATTRIBUTE NUMBER	ATTRIBUTES	WEIGHT	SCORE	ATTRIBUTE (WT) * (SCORE)	MEANS OBJ. (WT) * (SUM)	MANUAL
	MISSION	1	ROUTE OF FLIGHT	0.34	0.8	0.272		
	PLANNING	2	FLIGHT PLAN	0.27	0.8	0.216		
	0.24		**MANUALLY ACCOMPLISHED**					
		3	COORDINATE MISSION COMM AND INTEL REQUIREMENTS	0.16	0.375	0.06		
		4	CHART	0.24	0.225	0.054		
						0.602	0.14448	0.02736
			MANUALLY ACCOMPLISHED					
		5	CHECK FOR SCHEDULE CHANGES	0.16	0.375	0.06		
	SQUADRON/	6	CHECK WEATHER IMPACT ON MISSION	0.34	0.225	0.0765		
	BASE OPS	7	CHECK NOTAMS	0.21	0.375	0.07875		
	0.07	8	TIME HACK	0.06	0.375	0.0225		
		9	RECEIVER STATUS	0.09	0.375	0.03375		
		10	FLIP DOCUMENTS	0.15	0.375	0.05625		
SAFETY OF						0.32775	0.0229425	0.022943
FLIGHT	PREFLIGHT	11	PREFLIGHT EQUIPMENT	0.36	0.4	0.144		
0.7	0.09	12	LOAD MISSION DATA	0.15	0.9	0.135		
			MANUALLY ACCOMPLISHED					
		13	DISTRIBUTE FLIP	0.09	0.375	0.03375		
		14	RECEIVER STATUS	0.06	0.375	0.0225		
		15	COMPUTE ALTERNATE MISSION TIMING	0.13	0.375	0.04875		
		16	ARTCC CLEARANCE	0.15	0.375	0.05625		
		17	ASSIST WITH CARGO	0.07	0.375	0.02625		
						0.4665	0.041985	0.016875
	TAKEOFF	18	FORMATION	0.21	0.3	0.063		
	AND	19	MONITOR/DIRECT DEPARTURE	0.07	0.7	0.049		
	DEPARTURE	20	CHECK HEADING, ALTITUDE, AIRSPEED	0.11	0.3	0.033		
	0.18	21	MAINTAIN TERRAIN CLEARANCE	0.09	0.1	0.009		
		22	AVOID HAZARDOUS WEATHER	0.14	0.8	0.112		
		23	SCAN FOR TRAFFIC	0.06	0.2	0.012		
			MANUALLY ACCOMPLISHED					
		24	FLAP CONFIGURATION	0.1	0.6	0.06		
		25	MONITOR RADIO COMMUNICATIONS	0.14	0.375	0.0525		
		26	MAKE ALTITUDE CALLS	0.08	0.375	0.03		
						0.4205	0.07569	0.02565
	AIR	27	PERFORM RENDEZVOUS	0.27	0.9	0.243		
	REFUELING	28	MAINTAIN REFUELING AREA	0.18	0.8	0.144		
	0.14	29	MAINTAIN MISSION TIMING	0.06	0.7	0.042		
		30	FORMATION POSITION	0.11	0.3	0.033		
			MANUALLY ACCOMPLISHED					
		31	SET RENDEZVOUS EQUIPMENT	0.07	0.375	0.02625		
		32	COMMUNICATE WITH RECEIVER	0.17	0.375	0.06375		
		33	IDENTIFY RECEIVER BEACON	0.05	0	0		
		34	DETERMINE OVERRUN	0.09	0.375	0.03375		
						0.58575	0.082005	0.017325
		35	DETERMINE EQUIPMENT STATUS	0.1	0.4	0.04		
		36	UPDATE INS	0.1	1	0.1		
	CRUISE	37	TRACK AIRCRAFT POSITION	0.19	0.9	0.171		
	0.07	38	DIVERT TO UNPLANNED DESTINATION	0.12	0.9	0.108		
		39	MEET MISSION TIMING	0.06	0.7	0.042		
			MANUALLY ACCOMPLISHED					
		40	TROUBLE SHOOT MALFUNCTIONS	0.12	0.45	0.054		
		41	MONITOR RADIOS	0.2	0.375	0.075		
		42	POSITION SWITCHES/CIRCUIT BREAKERS FOR PILOTS	0.06	0.375	0.0225		
		43	ASSIST BOOM OPERATOR WITH PASSENGERS	0.05	0.375	0.01875		
						0.63125	0.0441875	0.011918
	DESCENT	44	DIRECT PLANE TO DESTINATION FIX	0.06	0.9	0.054		
	AND	45	MAINTAIN TERRAIN CLEARANCE	0.1	0.3	0.03		
	APPROACH	46	PERFORM ARDA	0.03	0	0		
	0.2	47	MONITOR POSITION WITH RESPECT TO ENROUTE CHARTS	0.03	0.6	0.018		
		48	MONITOR DRIFT AND GROUNDSPEED	0.14	0.4	0.056		
		49	SCAN FOR TRAFFIC	0.05	0.2	0.01		
			MANUALLY ACCOMPLISHED					
		50	MONITOR WEATHER REPORTS	0.06	0.375	0.0225		
		51	MAKE ALTITUDE CALLS	0.11	0.6	0.066		
		52	ENSURE ATC CLEARS DESIRED APPROACH	0.06	0.375	0.0225		
		53	ENSURE CORRECT GEAR, FLAPS, FUEL PANEL CONFIG.	0.09	0.375	0.03375		
		54	MONITOR HEADING, ALTITUDE, AIRSPEED, AND BANK ANGLE	0.12	0.375	0.045		
		55	MONITOR LANDING ROLLOUT	0.03	0.6	0.018		
		56	MONITOR APPROACH	0.14	0.525	0.0735		
						0.44925	0.08985	0.05625
						MEANS OBJ.SUM	0.50114	0.17832
						SAFETY OF FLIGHT		
						UTILITY	0.350798	
						MISSION ACCOMP.		
						UTILITY	0.16168725	
						TOTAL		
						VALUE	0.51248525	

			UTILITY WITH UPGRADED EQUIPMENT					
FUNDAMENTAL OBJECTIVE	MISSION PHASE	ATTRIBUTE NUMBER	ATTRIBUTES	WEIGHT	SCORE	ATTRIBUTE (WT) * (SCORE)	MEANS OBJ. (WT) * (SUM)	MANUAL
	MISSION	1	ROUTE OF FLIGHT	0.31	0.8	0.248		
	PLANNING	2	FLIGHT PLAN	0.29	0.8	0.232		
	0.27		**MANUALLY ACCOMPLISHED**					
		3	COORDINATE MISSION COMM AND INTEL REQUIREMENTS	0.16	0.375	0.06		
		4	CHART	0.23	0.225	0.05175		
						0.59175	0.1597725	0.03017
	SQUADRON/		**MANUALLY ACCOMPLISHED**					
	BASE OPS	5	CHECK FOR SCHEDULE CHANGES	0.25	0.375	0.09375		
	0.07	6	CHECK WEATHER IMPACT ON MISSION	0.31	0.225	0.06975		
		7	CHECK NOTAMS	0.1	0.375	0.0375		
		8	TIME HACK	0.07	0.375	0.02625		
		9	RECEIVER STATUS	0.15	0.375	0.05625		
		10	FLIP DOCUMENTS	0.13	0.375	0.04875		
MISSION						0.33225	0.0232575	0.02326
ACCOMPLISHMENT	PREFLIGHT	11	PREFLIGHT EQUIPMENT	0.31	0.4	0.124		
0.3	0.09	12	LOAD MISSION DATA	0.19	0.9	0.171		
			MANUALLY ACCOMPLISHED					
		13	DISTRIBUTE FLIP	0.15	0.375	0.05625		
		14	RECEIVER STATUS	0.13	0.375	0.04875		
		15	COMPUTE ALTERNATE MISSION TIMING	0.14	0.375	0.0525		
		16	ARTCC CLEARANCE	0.11	0.375	0.04125		
		17	ASSIST WITH CARGO	0.06	0.375	0.0225		
						0.51625	0.0464625	0.01991
	TAKEOFF	18	FORMATION	0.24	0.3	0.072		
	AND	19	MONITOR/DIRECT DEPARTURE	0.09	0.7	0.063		
	DEPARTURE	20	CHECK HEADING, ALTITUDE, AIRSPEED	0.1	0.3	0.03		
	0.12	21	MAINTAIN TERRAIN CLEARANCE	0.09	0.1	0.009		
		22	AVOID HAZARDOUS WEATHER	0.14	0.8	0.112		
		23	SCAN FOR TRAFFIC	0.06	0.2	0.012		
			MANUALLY ACCOMPLISHED					
		24	FLAP CONFIGURATION	0.06	0.6	0.036		
		25	MONITOR RADIO COMMUNICATIONS	0.17	0.375	0.06375		
		26	MAKE ALTITUDE CALLS	0.06	0.375	0.0225		
						0.42025	0.05043	0.01467
	AIR	27	PERFORM RENDEZVOUS	0.33	0.9	0.297		
	REFUELING	28	MAINTAIN REFUELING AREA	0.17	0.8	0.136		
	0.25	29	MAINTAIN MISSION TIMING	0.09	0.7	0.063		
		30	FORMATION POSITION	0.09	0.3	0.027		
			MANUALLY ACCOMPLISHED					
		31	SET RENDEZVOUS EQUIPMENT	0.08	0.375	0.03		
		32	COMMUNICATE WITH RECEIVER	0.12	0.375	0.045		
		33	IDENTIFY RECEIVER BEACON	0.05	0	0		
		34	DETERMINE OVERRUN	0.06	0.375	0.0225		
						0.6205	0.155125	0.02438
	CRUISE	35	DETERMINE EQUIPMENT STATUS	0.11	0.4	0.044		
	0.08	36	UPDATE INS	0.1	1	0.1		
		37	TRACK AIRCRAFT POSITION	0.2	0.9	0.18		
		38	DIVERT TO UNPLANNED DESTINATION	0.1	0.9	0.09		
		39	MEET MISSION TIMING	0.13	0.7	0.091		
			MANUALLY ACCOMPLISHED					
		40	TROUBLE SHOOT MALFUNCTIONS	0.09	0.45	0.0405		
		41	MONITOR RADIOS	0.16	0.375	0.06		
		42	POSITION SWITCHES/CIRCUIT BREAKERS FOR PILOTS	0.05	0.375	0.01875		
		43	ASSIST BOOM OPERATOR WITH PASSENGERS	0.05	0.375	0.01875		
						0.643	0.05144	0.01104
		44	DIRECT PLANE TO DESTINATION FIX	0.08	0.9	0.072		
	DESCENT	45	MAINTAIN TERRAIN CLEARANCE	0.04	0.3	0.012		
	AND	46	PERFORM ARDA	0.05	0	0		
	APPROACH	47	MONITOR POSITION WITH RESPECT TO ENROUTE CHARTS	0.1	0.6	0.06		
	0.11	48	MONITOR DRIFT AND GROUNDSPEED	0.1	0.4	0.04		
		49	SCAN FOR TRAFFIC	0.04	0.2	0.008		
			MANUALLY ACCOMPLISHED					
		50	MONITOR WEATHER REPORTS	0.06	0.375	0.0225		
		51	MAKE ALTITUDE CALLS	0.13	0.6	0.078		
		52	ENSURE ATC CLEARS DESIRED APPROACH	0.08	0.375	0.03		
		53	ENSURE CORRECT GEAR, FLAPS, FUEL PANEL CONFIG.	0.06	0.375	0.0225		
		54	MONITOR HEADING, ALTITUDE, AIRSPEED, AND BANK ANGLE	0.08	0.375	0.03		
		55	MONITOR LANDING ROLLOUT	0.03	0.6	0.018		
		56	MONITOR APPROACH	0.16	0.525	0.084		
						0.477	0.05247	0.03135
						MEANS OBJ.SUM	0.5389575	0.15478
						MISSION ACCOMP.		
						UTILITY	0.16168725	

Appendix B. Costs

B.1 Navigator Costs

YEAR	COMMISSIONING COSTS	SUNT	KC-135 IQT	ACQUIRE 64 NAVS/YR 64*(A+B+C)	COMPOSITE SALARY	NAVIGATOR COMPOSITE SALARIES (254*E)	YEARLY CASH FLOW (F+ D)
	A	B	C	D	E	F	G
1995	$78,943	$124,946	$131,631	$21,473,307	$71,554	$18,174,716	$39,648,023
1996	$81,391	$128,820	$135,711	$22,138,980	$73,772	$18,738,132	$40,877,112
1997	$83,914	$132,813	$139,918	$22,825,288	$76,059	$19,319,014	$42,144,302
1998	$86,515	$136,930	$144,256	$23,532,872	$78,417	$19,917,904	$43,450,776
1999	$89,197	$141,175	$148,728	$24,262,391	$80,848	$20,535,359	$44,797,750
2000	$91,962	$145,552	$153,338	$25,014,525	$83,354	$21,171,955	$46,186,480
2001	$94,813	$150,064	$158,092	$25,789,975	$85,938	$21,828,285	$47,618,261
2002	$97,657	$154,566	$162,834	$26,563,675	$88,516	$22,483,134	$49,046,809
2003	$100,587	$159,203	$167,720	$27,360,585	$91,172	$23,157,628	$50,518,213
2004	$103,605	$163,979	$172,751	$28,181,402	$93,907	$23,852,357	$52,033,759
2005	$106,713	$168,898	$177,934	$29,026,845	$96,724	$24,567,928	$53,594,772
2006	$109,914	$173,965	$183,272	$29,897,650	$99,626	$25,304,965	$55,202,615
2007	$113,212	$179,184	$188,770	$30,794,579	$102,615	$26,064,114	$56,858,694
2008	$116,608	$184,559	$194,433	$31,718,417	$105,693	$26,846,038	$58,564,455
2009	$120,106	$190,096	$200,266	$32,669,969	$108,864	$27,651,419	$60,321,388
2010	$123,709	$195,799	$206,274	$33,650,068	$112,130	$28,480,962	$62,131,030
2011	$127,421	$201,673	$212,462	$34,659,570	$115,494	$29,335,390	$63,994,961
2012	$131,243	$207,723	$218,836	$35,699,358	$118,958	$30,215,452	$65,914,810
2013	$135,181	$213,955	$225,401	$36,770,338	$122,527	$31,121,916	$67,892,254
2014	$139,236	$220,374	$232,163	$37,873,448	$126,203	$32,055,573	$69,929,022
2015	$143,413	$226,985	$239,128	$39,009,652	$129,989	$33,017,240	$72,026,892
2016	$147,715	$233,794	$246,302	$40,179,941	$133,889	$34,007,758	$74,187,699
2017	$152,147	$240,808	$253,691	$41,385,340	$137,905	$35,027,990	$76,413,330
2018	$156,711	$248,032	$261,302	$42,626,900	$142,043	$36,078,830	$78,705,730
2019	$161,413	$255,473	$269,141	$43,905,707	$146,304	$37,161,195	$81,066,902
2020	$166,255	$263,138	$277,215	$45,222,878	$150,693	$38,276,031	$83,498,909

B.2 Equipment Costs

YEAR	NAVIGATOR COMPOSITE SALARY	NUMBER OF NAVS	TOTAL COMPOSITE SALARIES (A * B)	ACQUIRE 10 NAVS/YR	EQUIPMENT CASH FLOW	YEARLY CASH FLOW (C + D + E)
	A	B	C	D	E	F
1995	$71,554	254	$18,174,716	$3,355,204	$41,300,000	$62,829,920
1996	$73,772	254	$18,738,132	$3,459,216	$65,571,600	$87,768,948
1997	$76,059	203	$15,440,000	$3,566,451	$96,835,747	$115,842,198
1998	$78,417	152	$11,919,375	$3,677,011	$94,577,274	$110,173,661
1999	$80,848	102	$8,246,483	$3,790,999	$85,984,331	$98,021,813
2000	$83,354	51	$4,251,062	$3,908,520	$73,040,017	$81,199,599
2001	$85,938	42	$3,609,402	$4,029,684	$13,451,478	$21,090,563
2002	$88,516	42	$3,717,684	$4,150,574	$0	$7,868,258
2003	$91,172	42	$3,829,214	$4,275,091	$0	$8,104,305
2004	$93,907	42	$3,944,091	$4,403,344	$0	$8,347,435
2005	$96,724	42	$4,062,413	$4,535,444	$0	$8,597,858
2006	$99,626	42	$4,184,286	$4,671,508	$0	$8,855,793
2007	$102,615	42	$4,309,814	$4,811,653	$0	$9,121,467
2008	$105,693	42	$4,439,109	$4,956,003	$0	$9,395,111
2009	$108,864	42	$4,572,282	$5,104,683	$0	$9,676,965
2010	$112,130	42	$4,709,450	$5,257,823	$0	$9,967,274
2011	$115,494	42	$4,850,734	$5,415,558	$0	$10,266,292
2012	$118,958	42	$4,996,256	$5,578,025	$0	$10,574,280
2013	$122,527	42	$5,146,144	$5,745,365	$0	$10,891,509
2014	$126,203	42	$5,300,528	$5,917,726	$0	$11,218,254
2015	$129,989	42	$5,459,544	$6,095,258	$0	$11,554,802
2016	$133,889	42	$5,623,330	$6,278,116	$0	$11,901,446
2017	$137,905	42	$5,792,030	$6,466,459	$0	$12,258,489
2018	$142,043	42	$5,965,791	$6,660,453	$0	$12,626,244
2019	$146,304	42	$6,144,765	$6,860,267	$0	$13,005,031
2020	$150,693	42	$6,329,107	$7,066,075	$0	$13,395,182

B.3 Break-even and Net Present Value Caluclations

YEAR	EQUIPMENT YEARLY TOTAL	EQUIPMENT CUMULATIVE TOTAL	EQUIPMENT NPV IN 1995 $576,824,401	NAVIGATOR YEARLY TOTAL	NAVIGATOR CUMULATIVE TOTAL	NAVIGATOR NPV IN 1995 $755,829,690
1995	$62,829,920	$62,829,920	$62,829,920	$39,648,023	$39,648,023	$39,648,023
1996	$87,768,948	$150,598,868	$82,957,418	$40,877,112	$80,525,135	$38,636,212
1997	$115,842,198	$266,441,066	$103,489,301	$42,144,302	$122,669,437	$37,650,221
1998	$110,173,661	$376,614,727	$93,029,519	$43,450,776	$166,120,213	$36,689,393
1999	$98,021,813	$474,636,539	$78,231,212	$44,797,750	$210,917,963	$35,753,086
2000	$81,199,599	$555,836,138	$61,252,743	$46,186,480	$257,104,443	$34,840,672
2001	$21,090,563	$576,926,701	$15,037,449	$47,618,261	$304,722,704	$33,951,544
2002	$7,868,258	$584,794,959	$5,302,478	$49,046,809	$353,769,513	$33,053,015
2003	$8,104,305	$592,899,264	$5,162,148	$50,518,213	$404,287,726	$32,178,266
2004	$8,347,435	$601,246,699	$5,025,532	$52,033,759	$456,321,485	$31,326,667
2005	$8,597,858	$609,844,557	$4,892,531	$53,594,772	$509,916,257	$30,497,606
2006	$8,855,793	$618,700,350	$4,763,050	$55,202,615	$565,118,872	$29,690,486
2007	$9,121,467	$627,821,817	$4,636,996	$56,858,694	$621,977,566	$28,904,727
2008	$9,395,111	$637,216,929	$4,514,277	$58,564,455	$680,542,021	$28,139,762
2009	$9,676,965	$646,893,893	$4,394,807	$60,321,388	$740,863,409	$27,395,043
2010	$9,967,274	$656,861,167	$4,278,498	$62,131,030	$802,994,439	$26,670,032
2011	$10,266,292	$667,127,458	$4,165,268	$63,994,961	$866,989,400	$25,964,209
2012	$10,574,280	$677,701,739	$4,055,034	$65,914,810	$932,904,209	$25,277,065
2013	$10,891,509	$688,593,248	$3,947,717	$67,892,254	$1,000,796,463	$24,608,107
2014	$11,218,254	$699,811,502	$3,843,241	$69,929,022	$1,070,725,485	$23,956,853
2015	$11,554,802	$711,366,304	$3,741,529	$72,026,892	$1,142,752,377	$23,322,834
2016	$11,901,446	$723,267,750	$3,642,510	$74,187,699	$1,216,940,076	$22,705,595
2017	$12,258,489	$735,526,239	$3,546,110	$76,413,330	$1,293,353,406	$22,104,690
2018	$12,626,244	$748,152,483	$3,452,263	$78,705,730	$1,372,059,136	$21,519,689
2019	$13,005,031	$761,157,514	$3,360,898	$81,066,902	$1,453,126,037	$20,950,170
2020	$13,395,182	$774,552,696	$3,271,952	$83,498,909	$1,536,624,946	$20,395,723

	NET PRESENT VALUE IN 1995
NAVIGATORS	$755,829,690
EQUIPMENT	$576,824,401
DIFFERENCE	$179,005,289

Appendix C. Value Model With Additional Equipment

C.1 Increased Utility With Upgraded Equipment, GCAS and TCAS

			UTILITY WITH UPGRADED EQUIPMENT, GCAS AND TCAS		
FUNDAMENTAL OBJECTIVE	MISSION PHASE	ATTRIBUTE NUMBER	ATTRIBUTES	WEIGHT	SCORE
	MISSION	1	ROUTE OF FLIGHT	0.34	0.8
	PLANNING	2	FLIGHT PLAN	0.27	0.8
	0.24		**MANUALLY ACCOMPLISHED**		
		3	COORDINATE MISSION COMM AND INTEL REQUIREMENTS	0.16	0.375
		4	CHART	0.24	0.225
			MANUALLY ACCOMPLISHED		
		5	CHECK FOR SCHEDULE CHANGES	0.16	0.375
	SQUADRON/	6	CHECK WEATHER IMPACT ON MISSION	0.34	0.225
	BASE OPS	7	CHECK NOTAMS	0.21	0.375
	0.07	8	TIME HACK	0.06	0.375
		9	RECEIVER STATUS	0.09	0.375
		10	FLIP DOCUMENTS	0.15	0.375
SAFETY OF					
FLIGHT	PREFLIGHT	11	PREFLIGHT EQUIPMENT	0.36	0.4
0.7	0.09	12	LOAD MISSION DATA	0.15	0.9
			MANUALLY ACCOMPLISHED		
		13	DISTRIBUTE FLIP	0.09	0.375
		14	RECEIVER STATUS	0.06	0.375
		15	COMPUTE ALTERNATE MISSION TIMING	0.13	0.375
		16	ARTCC CLEARANCE	0.15	0.375
		17	ASSIST WITH CARGO	0.07	0.375
	TAKEOFF	18	FORMATION	0.21	0.8
	AND	19	MONITOR/DIRECT DEPARTURE	0.07	0.7
	DEPARTURE	20	CHECK HEADING, ALTITUDE, AIRSPEED	0.11	0.3
	0.18	21	MAINTAIN TERRAIN CLEARANCE	0.09	0.9
		22	AVOID HAZARDOUS WEATHER	0.14	0.8
		23	SCAN FOR TRAFFIC	0.06	0.9
			MANUALLY ACCOMPLISHED		
		24	FLAP CONFIGURATION	0.1	0.9
		25	MONITOR RADIO COMMUNICATIONS	0.14	0.375
		26	MAKE ALTITUDE CALLS	0.08	0.375
	AIR	27	PERFORM RENDEZVOUS	0.27	0.9
	REFUELING	28	MAINTAIN REFUELING AREA	0.18	0.8
	0.14	29	MAINTAIN MISSION TIMING	0.06	0.7
		30	FORMATION POSITION	0.11	0.8
			MANUALLY ACCOMPLISHED		
		31	SET RENDEZVOUS EQUIPMENT	0.07	0.375
		32	COMMUNICATE WITH RECEIVER	0.17	0.375
		33	IDENTIFY RECEIVER BEACON	0.05	0
		34	DETERMINE OVERRUN	0.09	0.9
		35	DETERMINE EQUIPMENT STATUS	0.1	0.4
		36	UPDATE INS	0.1	1
	CRUISE	37	TRACK AIRCRAFT POSITION	0.19	0.9
	0.07	38	DIVERT TO UNPLANNED DESTINATION	0.12	0.9
		39	MEET MISSION TIMING	0.06	0.7
			MANUALLY ACCOMPLISHED		
		40	TROUBLE SHOOT MALFUNCTIONS	0.12	0.45
		41	MONITOR RADIOS	0.2	0.375
		42	POSITION SWITCHES/CIRCUIT BREAKERS FOR PILOTS	0.06	0.375
		43	ASSIST BOOM OPERATOR WITH PASSENGERS	0.05	0.375
	DESCENT	44	DIRECT PLANE TO DESTINATION FIX	0.06	0.9
	AND	45	MAINTAIN TERRAIN CLEARANCE	0.1	0.9
	APPROACH	46	PERFORM ARDA	0.03	0
	0.2	47	MONITOR POSITION WITH RESPECT TO ENROUTE CHARTS	0.03	0.6
		48	MONITOR DRIFT AND GROUNDSPEED	0.14	0.9
		49	SCAN FOR TRAFFIC	0.05	0.9
			MANUALLY ACCOMPLISHED		
		50	MONITOR WEATHER REPORTS	0.06	0.375
		51	MAKE ALTITUDE CALLS	0.11	0.6
		52	ENSURE ATC CLEARS DESIRED APPROACH	0.06	0.375
		53	ENSURE CORRECT GEAR, FLAPS, FUEL PANEL CONFIG.	0.09	0.8
		54	MONITOR HEADING, ALTITUDE, AIRSPEED, AND BANK ANGLE	0.12	0.375
		55	MONITOR LANDING ROLLOUT	0.03	0.6
		56	MONITOR APPROACH	0.14	0.525
				SAFETY OF FLIGHT	
				UTILITY	0.4206475
				MISSION ACCOMP.	
				UTILITY	0.18070425
				TOTAL	
				VALUE	0.60135175

FUNDAMENTAL OBJECTIVE	MISSION PHASE	ATTRIBUTE NUMBER	ATTRIBUTES	WEIGHT	SCORE
			UTILITY WITH UPGRADED EQUIPMENT, GCAS AND TCAS		
	MISSION	1	ROUTE OF FLIGHT	0.31	0.8
	PLANNING	2	FLIGHT PLAN	0.29	0.8
	0.27		**MANUALLY ACCOMPLISHED**		
		3	COORDINATE MISSION COMM AND INTEL REQUIREMENTS	0.16	0.375
		4	CHART	0.23	0.225
	SQUADRON/		**MANUALLY ACCOMPLISHED**		
	BASE OPS	5	CHECK FOR SCHEDULE CHANGES	0.25	0.375
	0.07	6	CHECK WEATHER IMPACT ON MISSION	0.31	0.225
		7	CHECK NOTAMS	0.1	0.375
		8	TIME HACK	0.07	0.375
		9	RECEIVER STATUS	0.15	0.375
		10	FLIP DOCUMENTS	0.13	0.375
MISSION					
ACCOMPLISHMENT	PREFLIGHT	11	PREFLIGHT EQUIPMENT	0.31	0.4
0.3	0.09	12	LOAD MISSION DATA	0.19	0.9
			MANUALLY ACCOMPLISHED		
		13	DISTRIBUTE FLIP	0.15	0.375
		14	RECEIVER STATUS	0.13	0.375
		15	COMPUTE ALTERNATE MISSION TIMING	0.14	0.375
		16	ARTCC CLEARANCE	0.11	0.375
		17	ASSIST WITH CARGO	0.06	0.375
	TAKEOFF	18	FORMATION	0.24	0.8
	AND	19	MONITOR/DIRECT DEPARTURE	0.09	0.7
	DEPARTURE	20	CHECK HEADING, ALTITUDE, AIRSPEED	0.1	0.3
	0.12	21	MAINTAIN TERRAIN CLEARANCE	0.09	0.9
		22	AVOID HAZARDOUS WEATHER	0.14	0.8
		23	SCAN FOR TRAFFIC	0.06	0.9
			MANUALLY ACCOMPLISHED		
		24	FLAP CONFIGURATION	0.06	0.9
		25	MONITOR RADIO COMMUNICATIONS	0.17	0.375
		26	MAKE ALTITUDE CALLS	0.06	0.375
	AIR	27	PERFORM RENDEZVOUS	0.33	0.9
	REFUELING	28	MAINTAIN REFUELING AREA	0.17	0.8
	0.25	29	MAINTAIN MISSION TIMING	0.09	0.7
		30	FORMATION POSITION	0.09	0.8
			MANUALLY ACCOMPLISHED		
		31	SET RENDEZVOUS EQUIPMENT	0.08	0.375
		32	COMMUNICATE WITH RECEIVER	0.12	0.375
		33	IDENTIFY RECEIVER BEACON	0.05	0
		34	DETERMINE OVERRUN	0.06	0.9
	CRUISE	35	DETERMINE EQUIPMENT STATUS	0.11	0.4
	0.08	36	UPDATE INS	0.1	1
		37	TRACK AIRCRAFT POSITION	0.2	0.9
		38	DIVERT TO UNPLANNED DESTINATION	0.1	0.9
		39	MEET MISSION TIMING	0.13	0.7
			MANUALLY ACCOMPLISHED		
		40	TROUBLE SHOOT MALFUNCTIONS	0.09	0.45
		41	MONITOR RADIOS	0.16	0.375
		42	POSITION SWITCHES/CIRCUIT BREAKERS FOR PILOTS	0.05	0.375
		43	ASSIST BOOM OPERATOR WITH PASSENGERS	0.05	0.375
		44	DIRECT PLANE TO DESTINATION FIX	0.08	0.9
	DESCENT	45	MAINTAIN TERRAIN CLEARANCE	0.04	0.9
	AND	46	PERFORM ARDA	0.05	0
	APPROACH	47	MONITOR POSITION WITH RESPECT TO ENROUTE CHARTS	0.1	0.6
	0.11	48	MONITOR DRIFT AND GROUNDSPEED	0.1	0.9
		49	SCAN FOR TRAFFIC	0.04	0.9
			MANUALLY ACCOMPLISHED		
		50	MONITOR WEATHER REPORTS	0.06	0.375
		51	MAKE ALTITUDE CALLS	0.13	0.6
		52	ENSURE ATC CLEARS DESIRED APPROACH	0.08	0.375
		53	ENSURE CORRECT GEAR, FLAPS, FUEL PANEL CONFIG.	0.06	0.8
		54	MONITOR HEADING, ALTITUDE, AIRSPEED, AND BANK ANGLE	0.08	0.375
		55	MONITOR LANDING ROLLOUT	0.03	0.6
		56	MONITOR APPROACH	0.16	0.525
				MISSION ACCOMP.	
				UTILITY	0.18070425

Vita

Major Robert A. Deivert was born in 1958 in Hawkinsville, Georgia. His family was transferred to McGuire AFB, New Jersey in 1963 where he remained until he was graduated from Northern Burlington High School in 1976. He graduated from the University of Florida in 1980 with a Bachelor of Science degree in Chemistry and was commissioned as a Distinguished Graduate of Air Force ROTC. He attended Undergraduate Navigator Training at Mather AFB, California where he also married his wife, Sally. He was assigned to Grand Forks AFB, North Dakota where he served as a B-52 navigator, instructor and flight examiner. He was accepted to Undergraduate Pilot Training at Reese AFB, Texas. Major Deivert transferred to Castle AFB, California in 1990 as a KC-135 aircraft commander. He upgraded to instructor pilot and served as a flight commander, assistant operations officer, and chief of training for the 924th Air Refueling Squadron. While still at Castle AFB, he performed as a Combat Crew Training Squadron instructor pilot until he entered the Graduate School of Engineering, Air Force Institute of Technology in 1993.

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Abstract

In an effort to quantitatively determine the utility of mission effectiveness of the KC-135, this research used value-focused thinking to measure the impact of replacing the KC-135 navigator with upgraded avionics. A Value Model was developed as a hierarchy with fundamental objectives at the highest level and attributes at the lowest level. Weights were assigned to show the contribution each level had to the one above it. The attributes were given a score and an additive model was used to determine utility with and without a navigator. Break-even analysis and net present value calculations were done to show the costs associated with each alternative. This study reveals that the cockpit with the navigator has a higher utility than the cockpit with the upgraded avionics. Value-focused thinking identified additional equipment that would increase the utility of the upgraded avionics. This approach can be used to identify equipment alternatives in the future that add the most utility. This methodology can be used by the Air National Guard to determine whether they should keep navigators as part of the KC-135 crew.

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