3-2001

Effects of Alternative Performance Criteria upon Composition of Air Transportable Spare Parts Kits

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EFFECTS OF ALTERNATIVE PERFORMANCE CRITERIA UPON COMPOSITION OF AIR TRANSPORTABLE SPARE PARTS KITS

THESIS

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THESIS

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

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March 2001

AFIT/GLM/ENS/01M-05

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Acknowledgments

I would like to express my sincere appreciation to my thesis advisor, Lt Col Alan Johnson, for his guidance and encouragement throughout the course of this thesis effort. I would also like to thank the other members of my committee, Lt Col Gregory McIntyre and Major Marvin Arostegui. All their insights were critical to maintaining the focus of this effort.

I also owe thanks to Mr. Mike Niklas from the Wright Patterson AFB/AFMC who supplied me with the necessary data and on-hands experience for the ASM software package. And I thank my colleague, Captain Steven Martinez for directing me to contact the correct people for obtaining data.

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Abstract

Airlift capacity is a definitive factor in the success of large-scale military operations. History proves that the demand for airlift soon exceeds its capacity during simultaneous deployment of forces. Therefore, good solutions to the airlift capacity problem are important. This thesis contributes to the resolution of this problem by seeking ways to reduce readiness spare parts packages (RSPs) deployed for Air Force squadrons through addition of airlift criteria into the RSP selection process.

We find that item cost, weight, and volume are three important criteria for RSP computations. We then offer a method for implementing these three criteria in the RSP selection process. We evaluate our method using an experimental design based on the USAF Aircraft Sustainability Model.

The experiment results show that RSP sizes can be reduced, but typically at a high increase in cost. However, in some cases the three criteria used together can achieve smaller, cheaper RSPs than the current USAF approach (using only cost-based analysis) can produce. These results suggest that this method should be adopted for the RSP selection process, to enable cost vs. airlift requirement tradeoffs, and to achieve cost reductions on selected RSPs.

EFFECTS OF ALTERNATIVE PERFORMANCE CRITERIA UPON COMPOSITION OF AIR TRANSPORTABLE SPARE PARTS KITS

I. Introduction

A. Background

With the end of the cold war, the world became more prone to conflicts, most of which affect the western allied countries. The Gulf War and the Bosnia Crisis are two recent examples. In both cases the USA and the allied countries deployed a considerable amount of military forces to the conflict region. With its breath taking technology, capabilities, and speed, air power proved its importance in the battlefield during these recent wars. The leading force of the deployed military forces was the Air Force, which is the safest way of fighting, although quite expensive. But fighting expensively from air is a good trade off for high casualty rates, especially in today's political environment against military operations in developed democratic countries.

The World changes fast and conflicts are almost unpredictable. This nature of the conflicts requires fast decision-making and implementation. We witnessed the fast pace of the conflicts in the Gulf War. Shortly after Saddam Hussein's speech as a warning to Kuwait on July 17, 1990, Iraq invaded Kuwait on August 2. As a reaction to this fast development, the first USAF aircraft landed in the crisis area on August 8, only 6 days after the invasion. The 35th day of the deployment saw 398 USAF aircraft flying in the region, which was equal to Iraq's fighter capability. On the D-Day on January 17, when the Coalition air forces initiated Operation Desert Storm, USAF had 652 aircraft (Coyne, 1992:29; 181).

The urgency of the operations increases the importance of airlift because of its speed. Although airlift is fast, it has limited capacity. For example during the Gulf War when "…the Central Command published the first deployment schedule, it exceeded Military Airlift Command's capability by 200-300 percent. As a result deploying fighter squadrons did not receive necessary airlift support, and from there problems cascaded" (Keaney, 1993:208). In August, the first month of the Gulf War deployment, Military Airlift Command (MAC) "flew more than 2,000 missions hauling more than 106 millions pounds of cargo and carrying more than 72,000 people over distances exceeding 7,000 miles" (Coyne, 1992:130). In order to meet the demand, USAF activated the first two stages of the Civil Reserve Air Fleet (CRAF), for the first time in its thirty eight-year history. The CRAF contributed 3,813 additional aircraft to a total 18,466-aircraft airlift force (Coyne, 1992:30). But the number of the aircraft is not the only constraining factor, as seen in the Gulf War. The limited number of airfields did not let all aircraft be served at the same time. The Maximum on the Ground (MOG) rate was a big issue. Once an airfield's MOG is reached, the airlift flow stops. In order to mitigate the MOG problem, the USAF applied fast unloading and refueling methods to open space for incoming traffic. This helped increase the throughput and the airlift capacity to some degree (Coyne, 1992:130).

The urgent airlift need constitutes a difficult high demand, low capacity problem. There are two ways of solving high demand, low capacity problems. The first approach is to increase the capacity to match the demand. During the Gulf War the civilian airlines employment is an example of this approach. The second approach is to decrease the demand to match the capacity. The subject of this thesis is a subset of the second approach.

Logistics support for deployed air combat units is one of the sources of airlift demand during a deployment. Because the air operation is the first phase of the overall operation and has to start from the first day, the air combat unit deployment has priority. This is why airlift is preferred as a transportation method for air combat unit deployments. As a subset of the logistics support, spare parts are important to attain effective combat aircraft availability during a deployment. If the Air Force reduces the amount of spare parts needed to support the deployed units, this would reduce the overall demand for airlift.

Which part and at what quantity to bring to the deployment site is one of the questions that logistics management must answer. Today the USAF uses a dynamic, reparable item inventory model called the Aircraft Sustainability Model (ASM) to solve the spare parts problem. The performance criteria for the spare parts optimization have been cost up to this time. A marginal analysis is used to select the correct parts that contribute the most to the total aircraft availability for each additional dollar. The ASM offers the spares parts mix that gives a desired level of aircraft availability with the least total cost according to the flight activity level required in the operations plans. From these spare parts "...recommendations, the deploying USAF unit builds Readiness Spares

Packages (RSP) for a 30 day deployment period" (Peterson, 2000:4). The RSPs are the cushion spare parts to serve the aircraft, until the local maintenance systems are set up and the logistics network are built with the home base. Because the RSP are needed from the first day of combat flight activities, they are transported with airlift right after the deployed units (Peterson, 2000: 4). Although the marginal cost optimization approach works well, there are other important considerations, such as the limited capacity of airlift, for deployments to crisis areas. We can reach the availability target with the cheapest parts composition, but this does not mean that this composition is the lightest to carry.

By using other performance criteria such as weight and volume, the deployed air units can achieve the same availability level with less airlift load, which frees some airlift for other uses. But employing other criteria rather than cost will cause a trade off between cost and those criteria. The relative effect of the different criteria is important when deciding which criteria to use in the spare parts optimization for deployments.

B. Statement Of Problem

Because of the fast pace of modern warfare, military airlift capacity has a strategic influence on the results of war. For this reason, the solution of airlift capacity problem is important for success. As mentioned previously, the solution to a high demand, low capacity problem has two approaches. We should either increase the capacity to match demand, or manage the demand to match the capacity. We address the problem by using the second approach.

This thesis looks at the ways of reducing the Readiness Spares Packages in measure of the airlift capacity constraints, such as total weight and volume. For achieving this purpose we use cost and other criteria in RSP calculations for different aircraft types.

C. Research Questions

This research addresses the following questions:

1. What airlift criteria affect the RSP selection in terms of airlift capacity?
2. How can we apply these airlift criteria to the RSP selection process?
3. How does application of these airlift criteria affect the RSPs?
4. How can we build RSPs that better suit the airlift capacity by using these airlift criteria?

D. Research Approach

This thesis first introduces the RSP calculation methodology currently in use. The methodology is first illustrated on a simple mathematical model. It is then discussed in the context of the Aircraft Sustainability Model (ASM), which is more complex.

After introducing the mathematical methods, the thesis evaluates possible airlift criteria that can be used for RSP calculations. Following the evaluation and the selection, the thesis shows how to use the selected criteria for RSP selection.

In this chapter, we introduced the airlift capacity problem and stressed the importance of a solution. We selected a demand reduction approach to solve the low capacity-high demand problem. Then we introduced the research questions that we aim to answer in this study.

In Chapter II, this thesis introduces the current mathematical approach for RSP calculations. Then we define the airlift criteria that we can use for RSP calculations. Following the criteria selection we will show how to use the new criteria with the cost criterion. This way we will answer the 1^{st} and 2^{nd} research questions.

The thesis answers the 3^{rd} and 4^{th} research questions through a series of experimental RSP calculations, which is introduced in Chapter III and IV. The ASM is used as model to execute the experiment. The experimental design examines the effects of each criterion on RSPs. Simultaneously, the thesis shows different ways to use the cost and other criteria in the RSP selection process, and examines the effects in terms of airlift assets and measures. In Chapter V, we brief conclusions and recommendations of this research.

II. Literature Review

A. Cost Based Marginal Analysis

1. Cost As A Criteria For Spare Parts Calculations

Supply chain requirements calculation has always been a problem area for the Air Force, given the limited budgets. Stock levels have a strong effect on aircraft availability levels. Starting in the early 1950s and increasing parallel to the improvements in computer technology, simple materials requirements calculation methods gained a momentum toward more advanced methods (Notes, 2000).

Because of the difficulties in data collection and computation with manual methods during early 1950s, the methods used for setting the stock levels were simple. The experience of the personnel in charge was the definitive factor on the stock levels. The stock levels were set item by item and for each base and upper levels independently, which is called the "*item approach*". Although not optimal this method was sufficient until aircraft technology became more complex and expensive to maintain. The Cold War increased the Air Force cost of operation, which resulted in a focused attention on the cost factors, including the materials requirements process. A study group established in 1952 by the Air Force "…found that half of the spares budget went to purchasing three percent of the items, while 95 percent of the 725,000 items in the inventory cost less than $10 each." (Notes, 2000). These results, for the first time, pointed out the cost differences of the items purchased. As a result a new policy was applied that takes a selective attitude against cost-drivers, which was called the "Hi-Value" program.

Another result of this study was the separation of consumable and repairable inventory management (Notes, 2000).

From the 1950s to 1960s, focused studies on the requirements calculation problem brought a new dimension by adding the probability-based pipeline concept. Using these concepts, RAND built the Base Stockage Model in 1965. The Base Stockage Model used a marginal optimization method for the Air Force repairable item requirement generation process. This marginal optimization method minimized the expected back orders with the minimum possible purchase of items. Although the Air Force did not officially use the Base Stockage Model, the marginal optimization method the model brought was adapted to succeeding models (NOTES, 2000).

The Logistics Management Institute (LMI) criticized cost for not being sufficiently predictive of mission capable rates. Setting the same fill rate for the different types of aircraft resulted in lover MC rates for the more complex aircraft. In the1970s, a study at LMI pointed out that expected back orders could be translated in terms of aircraft availability levels, which better describes aircraft readiness. This new idea changed the marginal optimization method slightly. The new purpose of the optimization was to obtain the highest possible level of aircraft availability with the lowest possible total purchase cost (Notes, 2000). This approach is named the "*weapon-system approach*".

The weapon-system approach gave dramatic advantages over the traditional *item approach*, which typically uses individual item measures to determine how many spares of the item were required. A comparison of these two approaches is given by Slay, at all:

LMI compared the two approaches using F-16C aircraft data from the USAF. The results show (see Table 1) that, for the same costs incurred under the item approach, the weapon-system approach increased aircraft availability by 30 percent. Alternatively, for same availability, using the weapon-system approach provided a 40 percent budget saving over the item approach (LMI, 1996:1-5).

Table 1. Item vs. Weapons-System Approach (LMI, 1996:1-5)

Performance Measure	Item Approach	Weapon-system Approach	
		Minimizing Cost	Maximizing Availability
Availability (percent)	54	54	84
Cost ($ millions)	14.5	8.6	14.5

(*USAF F-16C Aircraft Reparable Database*)

Weapon system approach optimizes spares parts packages by using aircraft availability and total purchase cost. Figure 1 graphs the aircraft availability versus cost curve. Above the curve is the infeasible region. The curve itself represents the maximum availability level for each cost point. Figure 1 illustrates the example summarized in Table 1 as points A, B, and C. As seen from the graph, points B and C are on the availability-cost curve, which means that these solutions are optimized for cost. Yet, point A is below the curve, which means we pay more for the availability we are getting. We conclude that the *item approach* gives spares packages that fall below the availability-cost curve, while the *weapon system approach* gives solutions on the curve.

The recent defense budget cuts forces the armed forces to be more cost efficient without reducing effectiveness. On the other hand, sustaining modern weapon systems requires a great amount of spares parts inventory. For example, "...the Air Force today manages almost $24 billion worth of inventory of aircraft repairable spare parts. In September 1998, the Material Support Division Operating Obligation Request was $1.285 billion for procurement and $1.92 billion for repair of these components." (Notes, 2000). The logistics expenses are a big percentage of total defense expenses. The logisticians have to plan the use of budget carefully to be cost efficient, yet still satisfy the performance requirements.

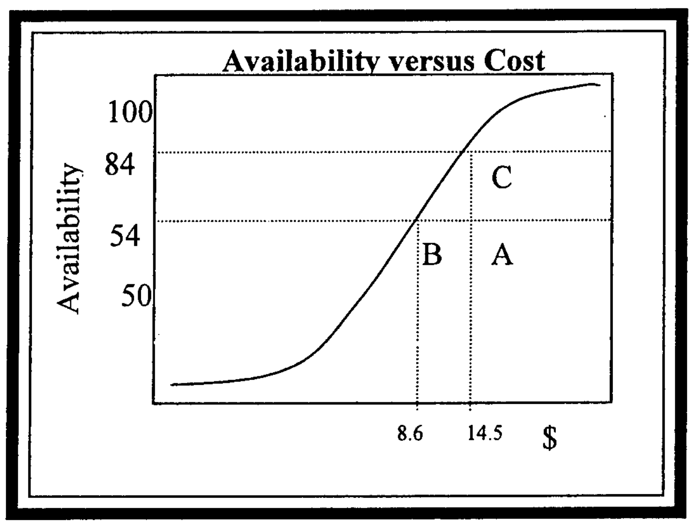


Figure 1. Aircraft availability versus cost

Being an important logistics cost driver, the repairable inventories deserve emphasis for cost reductions. The use of aircraft availability and cost in spares packages helps the logisticians to reduce the cost given the same performance targets. In conclusion, the cost is a necessary optimization criterion for spares packages computations.

In this part of the chapter, we briefly summarized the evolution of the use of availability and cost as criteria for the spares packages calculations. We emphasized the importance of the cost reductions, without causing a loss in performance levels. We now introduce the cost-based marginal analysis in *the weapon system approach.*

2. A Single Site Aircraft Availability Model

We explain the marginal analysis method by using a single base and single type item scenario. We assume that the base has a repair shop and the item can be repaired at base. There is no condemnation of the unserviceable items. Let us consider a single item in the base pipeline. When the item failures on the aircraft the flight line personnel sends the part to the repair shop, while requesting the same type item for replacement. If the item is in base supply, the flight line personnel immediately replaces the item. If the item is not in the base supply, the aircraft waits until an item becomes available. The graphical view of the single site model is illustrated in Figure 2.

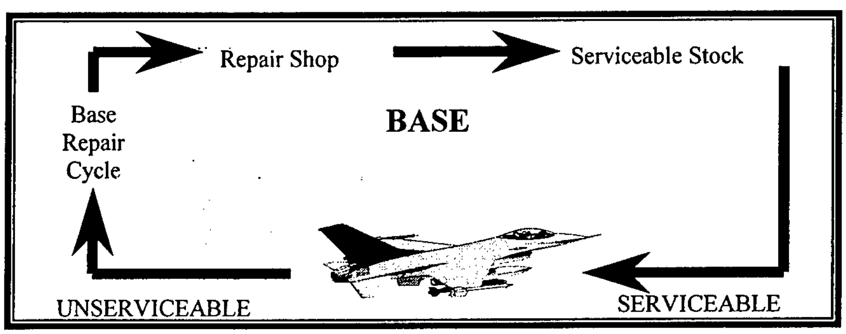


Figure 2. The Single Site Model Graphical View (Notes1, 2000).

We assume that the base is operating in a steady state, typical of peacetime operations. Although the daily total flight hours might differ during peacetime, there are no major fluctuations in the flight hours; so we assume that flight hours are constant each day. Thus a stationary random (stochastic) process can describe the arrival of demands, and a Poisson process or negative binomial distribution can be used to describe this demand activity. We use the Poisson process for the model. At any demand rate, for a stationary Poisson process, if λ represents the expected number of demands per day, then the expected number of demands in a time period, ***T***, is λT. For a Poisson process, the probability that exactly ***n*** demands occurs in ***T*** days is:

$$p(n) = \frac{e^{-\lambda T}(\lambda T)^n}{n!} \quad (1)$$

In our scenario, each part that failed on the aircraft is sent to the repair shop. We assume that the repair capacity is infinite and there is no queuing at the repair shop. The parts passing through the repair shop constitute a stream of unserviceable parts. We call this stream of parts the base repair pipeline (BRpipe). Each part entering the BRpipe spends a repair time, which we call base repair time (BRT). We assume that the BRT is constant. Given the constant daily demand rate λ for the parts, ***x***, the total number of the parts in the BRpipe is simply equal to λBRT . If we replace λBRT with the λT in Equation (1), we can calculate the probability of having ***x*** number items in BRpipe (LMI, 1996:2-3,2-6).

The pipeline quantity probability is important, because assuming the base operates under (s-1,s) inventory policy, we can calculate a performance measure called Expected Back Orders (EBO). The EBO is an important performance measure that let us calculate aircraft availability, which is a practical input for base flight plans. A back order occurs whenever the demand level x exceeds the base inventory level s. Then the number of backorders is equal to $x - s$, for x greater than s (LMI,:2-5),

$$EBO = \sum_{x,s} (x - s)p(x). \qquad (2)$$

We can derive the aircraft availability by using the EBOs. For simplicity we assume that there is no cannibalization and all items are installed directly on the aircraft. We name this type of items as Line Replaceable Units (LRUs).

When the base supply cannot replace a failed part, this causes a backorder. "This backorder causes a hole on the aircraft, and the plane is Non Mission Capable for Supply (NMCS)" (LMI, 1996:2-12). With the assumption of no cannibalization, we take the number of back orders as the number of the NMCS aircraft. We assume that Non Mission Capable rate is only a function of supply and we neglect the effect of other factors, such as maintenance delays. Therefore, we define aircraft availability, as the percentage of planes not NMCS. "Computing aircraft availability involves calculating the number of backorders (or holes on the aircraft) and how many planes those backorders make NMCS (how many different planes have holes)" (LMI, 1996:2-12).

To find the expected availability, we can use the EBO instead of number of the backorders:

$$availability = 1 - \frac{EBO}{NAC} = 1 - \frac{E(NMCS)}{NAC}.$$

where ***NAC*** is number of aircraft, and ***E(NMCS)*** is expected number of NMSC.

"We can interpret availability as the probability that a randomly selected aircraft is not NMCS. The extension to multiple components is straightforward when we assume independence of the backorder process across components. Let $\boldsymbol{EBO_l}$ be the expected backorder total for $\boldsymbol{LRU_l}$, with a given spares level. With the assumption that backorders of different types of components are independent, the probability that a randomly selected aircraft is not NMCS for any $\boldsymbol{LRU_l}$, is the product, over all the LRUs, of the probabilities that the aircraft is not NMCS for each one. Thus" (LMI,:2-13)

$$availability = \prod_l \left(1 - \frac{EBO_l}{NAC} \right). \qquad (3)$$

The availability function that the ASM uses is more complicated than Equation (3). Because we are only discussing how the marginal analysis works, the formulation up to this point is enough for our purpose. Next we discuss how marginal analysis applies to the availability model that we give in Equation (3).

3. <u>The Marginal Analysis</u>

Logisticians face two spares parts objectives. The first objective is to achieve the maximum aircraft availability with a limited budget. This objective is formulated as:

$$max \left\{ \prod_l \left(1 - \frac{EBO_l}{NAC} \right) \right\} \qquad (4)$$

$$subject\ to \left\{ \sum_l c_l s_l \le Budget \right\}$$

where $\boldsymbol{c_l}$ and $\boldsymbol{s_l}$ stands for cost and stock level of $\boldsymbol{LRU_l}$. $\boldsymbol{NAC}$ is the number of aircraft.

The second objective is to minimize the cost of achieving pre-defined aircraft availability. This objective is given below:

$$min\left\{\sum_{l} c_l s_l\right\} \tag{5}$$

$$subject\ to\left\{\prod_{l}\left(1-\frac{EBO_l}{NAC}\right) \geq Predefined\ Availability\right\}$$

Marginal analysis helps logisticians to decide which spare parts, and how many, to buy. The addition of every part increases total availability. But some parts add more availability than others do, while some are cheaper. Marginal analysis looks at the selection problem from a value point of view. The general value equation is:

$$Value = \frac{Benefit}{Cost}$$

If we define benefit as aircraft availability, we obtain value equation for spare parts selection, which is:

$$Value = \frac{Aircraft\ Availability}{Cost}$$

Both spare parts selection objectives, Equation (4) and (5), are maximizing value either by minimizing cost given the availability constant, or by maximizing the availability given the cost constant. The marginal analysis compares the value of the addition of each candidate item to the system. The marginal value can be defined as:

$$Marginal\ Value = \frac{Marginal\ Availability}{Item\ Cost} \quad (6)$$

Given two separate parts, LRUs, the rule of selection is:

If ***Marginal Value*** of $\boldsymbol{LRU_1}$ > ***Marginal Value*** of $\boldsymbol{LRU_2}$ then select $\boldsymbol{LRU_1}$,

If ***Marginal Value*** of $\boldsymbol{LRU_2}$ > ***Marginal Value*** of $\boldsymbol{LRU_1}$ then select $\boldsymbol{LRU_2}$,

If ***Marginal Value*** of $\boldsymbol{LRU_1}$ = ***Marginal Value*** of $\boldsymbol{LRU_2}$ then select Randomly.

Let us apply the marginal analysis to an example. We use a single 10-aircraft site, making the same assumptions that we made in the previous section to find availability equation. The necessary information for the marginal analysis for the two-LRU example system is given in Table 2:

Table 2. Example Model Parameters

	Demand Rate (λ)	**BRT**	**Cost ($ x10,000)**
Part 1	*15*	*0.1*	*3*
Part 2	*10*	*0.2*	*1*

Assuming the demands for parts are a Poisson process, the means of the Poisson distribution for each part can be calculated as below:

$$\mu_1 = \lambda_1 \cdot BRT_1 = 15 \times 0.1 = 1.5$$

$$\mu_2 = \lambda_2 \cdot BRT_2 = 10 \times 0.2 = 2$$

The probabilities of having x demands for these two mean values in a specific day are shown in Table 3:

Table 3. The probabilities of having demand x for mean values 1.5 and 2.

x	*Poisson(x|1.5)*	*Poisson(x|2)*
0	0.22313016	0.135335283
1	0.33469524	0.270670566
2	0.25102143	0.270670566
3	0.125510715	0.180447044
4	0.047066518	0.090223522
5	0.014119955	0.036089409
6	0.003529989	0.012029803
7	0.000756426	0.003437087
8	0.00014183	0.000859272
9	0	0.000190949
10	0	0

Given these probability values and using Equation (2), we can calculate the EBO_l for each part. Table 4 gives the EBOs for both items for different stock levels. For example if we set the stock level of LRU_1 to 2 we may expect 0.28 backordered LRU_1 at any time. Given an EBO we can calculate aircraft availability rates and apply marginal analysis to select an optimal set of spare parts stock. Let us apply the marginal analysis to our example for obtaining 95% aircraft availability with the least possible cost.

Table 4. EBOs for stock level ***s*** for each part.

	Expected Back Orders	
s	EBO_1	EBO_2
0	1.5	2
1	0.72313016	1.135335283
2	0.280955561	0.541341133
3	0.089802391	0.218017549
4	0.024159937	0.07514101
5	0.005584	0.022487992
6	0.00112802	0.005924384
7	0.000202028	0.001390578
8		0.000293859

Assuming the stock levels for both items is 0. Using Equation (3) aircraft availability for zero stock levels is calculated as:

$$Availability[0] = \left(1 - \frac{EBO_1(0)}{NAC}\right) \cdot \left(1 - \frac{EBO_2(0)}{NAC}\right)$$

$$Availability[0] = \left(1 - \frac{1.5}{10}\right) \cdot \left(1 - \frac{2}{10}\right) = 0.85 \times 0.8 = 0.68$$

where $\boldsymbol{EBO_l(s_l)}$ stands for the EBO for the LRU_l for the stock level s_l, and ***availability[j]*** is the final aircraft availability after the addition of the ***jth*** purchase to the system.

The availability for zero stock levels shows that if we do not purchase any items for the system, the aircraft availability is expected to be 0.68. After this point purchases to the system will increase the aircraft availability. We will either buy $\boldsymbol{LRU_1}$ or $\boldsymbol{LRU_2}$. To decide which item to buy we need to compare their marginal value to the system. Let us calculate the aircraft availability when we buy one $\boldsymbol{LRU_1}$ setting s_1 to 1 and s_2 to 0.

$$Availability_1[1] = \left(1 - \frac{EBO_1(1)}{NAC}\right) \cdot \left(1 - \frac{EBO_2(0)}{NAC}\right)$$

$$Availability_1[1] = \left(1 - \frac{0.72313016}{10}\right) \cdot \left(1 - \frac{2}{10}\right) = 0.927687 \times 0.8 = 0.742$$

When we add one part 1 to the system the aircraft availability increases from 0.68 to 0.742. Using Equation (6), we can calculate the marginal value of the first $\boldsymbol{LRU_1}$ to the system:

$$Marginal\ Value_1\ [1] = \frac{Availability_1[1] - Availability[0]}{Cost\ of\ LRU_1}$$

$$Marginal\ Value_1\ [1] = \frac{0.742 - 0.68}{\$3} = 0.02$$

where ***Marginal Value$_l$ [j]*** is the marginal value of purchasing $\boldsymbol{LRU_l}$ for the system as ***jth*** purchase.

Repeating the calculation for the $\boldsymbol{LRU_2}$ by setting $\boldsymbol{s_1}$ to 0 and $\boldsymbol{s_2}$ to 1 yields:

$$Availability_2[1] = \left(1 - \frac{EBO_1(0)}{NAC}\right) \cdot \left(1 - \frac{EBO_2(1)}{NAC}\right)$$

$$Availability_2[1] = \left(1 - \frac{1.5}{10}\right) \cdot \left(1 - \frac{1.135335283}{10}\right) = 0.85 \times 0.886466 = 0.753$$

The addition of LRU_2 instead of LRU_1 increases the aircraft availability from 0.68 to 0.753. The marginal value of LRU_2 to the system is:

$$Marginal\ Value_2[1] = \frac{Availability_2[1] - Availability[0]}{Cost\ of\ LRU_2}$$

$$Marginal\ Value_2[1] = \frac{0.753 - 0.68}{\$1} = 0.07$$

Using the marginal values for each selection, we can determine which item to buy. The marginal value of the first LRU_2 to the system ,0.07, is greater than the marginal value of the first LRU_1, 0.02. Based on the marginal analysis selection rules we select LRU_2, and set s_2, the stock level of LRU_2 , to 1 and increase the expected system aircraft availability to 0.753.

The next step is the selection of the second item that we will add to the system. We can buy the first LRU_1, increase s_1 to 1 or buy the second LRU_2, increase s_2 to 2The availability of the first LRU_1 is:

$$Availability_1[2] = \left(1 - \frac{EBO_1(1)}{NAC}\right) \cdot \left(1 - \frac{EBO_2(1)}{NAC}\right)$$

$$Availability_1[2] = \left(1 - \frac{0.72313016}{10}\right) \cdot \left(1 - \frac{1.135335283}{10}\right)$$

$$Availability_1[2] = 0.927687 \times 0.886466 = 0.822$$

and the marginal value is:

$$Marginal\ Value_1[2] = \frac{Availability_1[2] - Availability[1]}{Cost\ of\ LRU_1}$$

$$Marginal\ Value_1[2] = \frac{0.822 - 0.753}{\$3} = 0.02$$

The addition of the second LRU_2 to the system's availability is:

$$Availability_2[2] = \left(1 - \frac{EBO_1(0)}{NAC}\right) \cdot \left(1 - \frac{EBO_2(2)}{NAC}\right)$$

$$Availability_2[2] = \left(1 - \frac{1.5}{10}\right) \cdot \left(1 - \frac{0.541341133}{10}\right) = 0.85 \times 0.945866 = 0.804$$

and the marginal value of the second LRU_2 is:

$$Marginal\ Value_2[2] = \frac{Availability_2[2] - Availability[1]}{Cost\ of\ LRU_2}$$

$$MarginalValue_2[2] = \frac{0.804 - 0.753}{\$1} = 0.05$$

Once more the marginal value of adding LRU_2 is greater than adding LRU_1. With the addition of the LRU_2, s_2 will be set to 2, while s_1 stays 0. The new system aircraft availability is 0.804. Continuing this process to obtain a goal of 95% aircraft availability yields the buy list and system availability shown in Table 5.

Table 5. Buy list and system aircraft availability level.

Iteration	**Shopping List**	**Availability (%)**	**Cumulative Cost (Thousand $)**
0	none	68.0	-
1	LRU_2	75.3	1
2	LRU_2	80.4	2
3	LRU_2	83.1	3
4	LRU_1	90.7	6
5	LRU_1	95.0	9

The shopping list with 3 $\boldsymbol{LRU_2}$ and 2 $\boldsymbol{LRU_1}$ gives us 95 percent aircraft availability with the least possible cost. Figure 3 plots the availability versus total purchase cost. The area above the line is infeasible, while the area below represents non-optimal solutions.

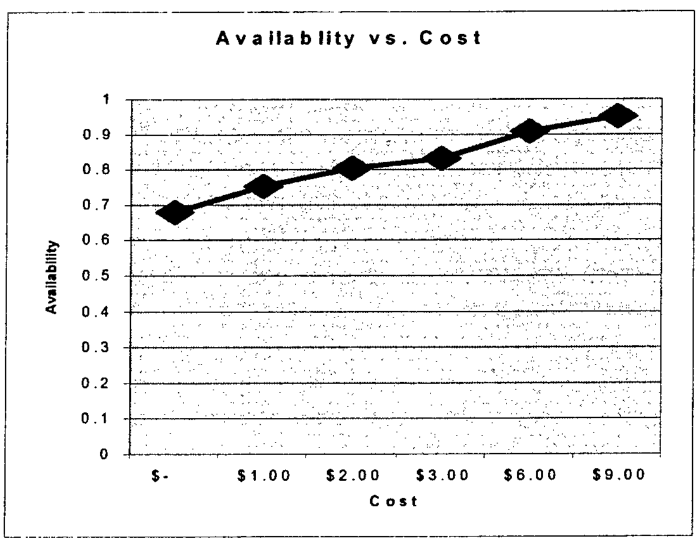


Figure 3. Aircraft availability versus total cost for the shopping list.

4. Aircraft Sustainability Model

a) Introduction To The Model

We introduced cost based marginal analysis on a simple mathematical model. Although this mathematical model can be useful in small-scale repairable inventory management problems, it only captures a limited amount of real life detail. The variety of Air Force operational activities requires complicated models for repairable inventory management. One high-level repairable inventory management model is the Aircraft Sustainability Model (ASM). "The ASM, developed by the Logistics Management Institute for the United States Air Force, is a mathematical statistical model that computes optimal spares mixes to support a wide range of possible operating scenarios" (LMI, 1996:iii).

The ASM is used by USAF to determine RSPs for deploying squadrons, initial provisioning for F-22 Advanced Tactical Fighter, and the E-8 Joint Surveillance and Target Attack Radar System (JSTARS) (LMI, 1996:iv). The ASM has been applied to other high technology and heavy-duty systems such as petroleum pumping machinery and space stations (Kline, 1999:1-1).

Another model that has widespread use in the USAF, although older than the ASM, is Dyna-METRIC. Dyna-METRIC has analytic and simulation versions. Similar to ASM, the analytic versions of Dyna-METRIC can calculate RSPs for dynamic demands and uses a marginal analysis method for optimization.

We use the ASM in this research. The reason we use the ASM is the fact that the ASM has been built over the experience of Dyna-METRIC and is replacing it in the USAF. We now brief the ASM's functional characteristics and capabilities. For a thorough description of the model, we recommend the reader consider Kline (1999) and LMI (1996).

The ASM can calculate spares part packages for a wide range of scenarios. These scenarios range from peacetime steady-state operating conditions to wartime fluctuating conditions. The model also lets user define a peacetime scenario that is followed by a wartime scenario. The model is built upon three different spare part calculations, which are initial provisioning, replenishment, and readiness spares packages (RSP).

When the Air Force buys a new weapon system, it has to build the logistics replenishment system for the new system simultaneously. The time required for the design and implementation of new replenishment system, or the coverage period, changes according to the system's complexity and technology. Until the implementation of a new replenishment system, the weapon system entering to inventory has to be supported with spare parts to keep the mission capable rates at the desired level. For spares part support during the coverage period, Air Force buys spare parts along with the weapon system, --a process called initial provisioning. The ASM can calculate initial provisioning requirements given the budget, desired availability level at the end of coverage period and the duration of coverage period (Kline, 1999:1-1).

The model, given the existing levels of spare parts, can also predict the supplementary replenishment spare parts to reach a new availability level or operation scenario. The third capability of the ASM is the calculation of the RSP needed for spare parts support of a deploying squadron until the establishment of a supply system.

The characteristics of the ASM are (LMI, 1996:1-2):

- The model is a single weapon system,
- An aircraft is assumed not mission-capable-supply upon failure of a component for which no spare is available,
- All failures occurs at bases
- All bases are uniform with respect to demands, re-supply times, and repair capabilities,
- Demand rates can be defined as steady-state or changing,
- Items that cannot be repaired at bases are shipped to second echelon (depot), and replenishment from depot is immediately requested,
- At the depot, the item can be repaired or condemned,
- Both echelons- base and depot- are presumed to operate using an (s-1,s) inventory policy, under which, with every demand, a re-supply action is initiated immediately.
- The model built upon multi indenture policy, which classifieds items as line replaceable units and shop replaceable units,
- The model allows cannibalization.

Specific input parameters of the model include (LMI, 1996:1-2):

- Failures per flight hour,
- Base and depot repair times,
- The probability of repair at each site,
- Condemnation rates,
- Transportation times,
- Unit cost,
- Quantity per application,
- Procurement lead-time.

The model requires operating tempo of the bases in the form of daily planned flight hours. Flight programs can be defined as steady state for peacetime or changing for wartime operations (LMI, 1996:1-2).

b) The Methodology

The basic methodology, as taken from LMI (1996:1-3) consists of three steps:

- The first step involves characterizing the probability distribution of the number of items in various stages of the re-supply process (or "pipeline")-unserviceable in repair at bases or depot and serviceable/unserviceable in transit. The relationship between these quantities and the number and location of spares in the system determines the probability of a backorder.

- The second step is to relate that item information to weapon-system performance; specifically, to determine the expected number of item backorders, the expected number of aircraft not mission capable-supply, and several other weapon system-oriented measures of supply performance.

- The third step is to produce the availability-versus-cost curve and the associated optimal spares mix for a specified availability or budget target.

- The model uses a marginal analysis technique that determines the best mixes of spares for a wide range of targets (LMI, 1996:1-3).

This three-step methodology and the possible types of calculations that the ASM offers are exhibited in Figure 4.

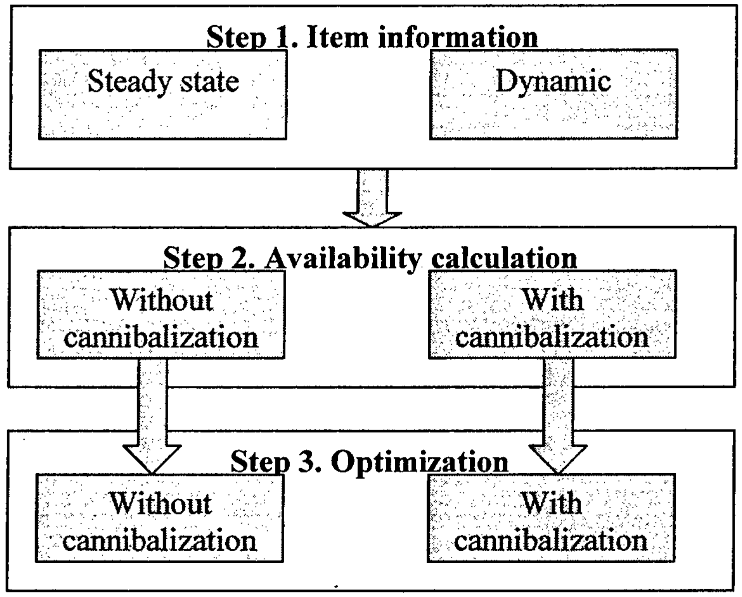


Figure 4. Basic Model Methodology (LMI, 1996:1-4).

B. Other Criteria Based Marginal Analysis

1. Selection Of Alternative Criteria

Because this study aims to reduce airlift demand, the alternative criteria that we want to include in RSP calculation process should be related to airlift constraints. In order to define the alternative criteria, we will examine RSP calculation process in the context of warfare planning with the aid of management science literature.

Decision-making and planning processes are two inseparable functions of management in an organization. Decisions made by managers give directions to the planning activities. Griffin defines decision making as the cornerstone of planning (1999:200). According to Griffin, a planning process is a generic activity, although each organization adds its own nuances and variations to the process. "All planning occurs within an environmental context. If managers do not understand this context, they are unable to develop effective plans. Thus understanding the environment is essentially the first step in planning." (Griffin, 1999:200). Griffin's environmental context is shown in Figure 5.

The Environmental Context

Figure 5. The environmental context (Griffin, 1999:201).

Griffin explains the environmental context as:

> The mission outlines the organization's purpose, premises, values, and directions. Following from the mission are parallel streams of goals and plans. Directly following the missions are strategic goals. These goals and the mission help determine strategic plans. Strategic goals and plans are primary inputs for developing tactical goals. Tactical goals and the original strategic plans help shape tactical plans. Tactical plans, in turn, combine with the tactical goals to shape operational goals. These goals and the appropriate tactical plans determine operational plans. Finally, goals and plans at each level can also be used as input for future activities at all levels (Griffin, 1999:201)

Organizational planning occurs in a hierarchical structure, in which all levels interact with each other. As a large organization, the Armed Forces establish a similar environmental structure. Starting from the highest strategic level, the National Security Policy, decisions direct the overall planning process down to the operational level. Military power is an instrument to achieve national security objectives. The National Security Directives, threat characteristics and concepts of operations affect the Armed Forces' strategies and missions. For example the START and conventional forces reduction caused a decrease in the threat against Western Block Countries. The decrease in the strategic weapons led to more frequent regional Third World conflicts. This threat change caused a strategy and mission change for the armed forces, especially for the USA (Nelson, 1992:33). New scenarios require "rapid deployment, massive airlift, and mobile, high power systems instead of a European scenario between industrially advanced nations with high technology and heavy armor" (Nelson, 1992:33).

The strategic level of management assesses the threats and considers the possible military response options in the light of current force structure and their capability to change the lower level operations plans to meet the new threats. The current force structure capability is important, because if the force structure does not have enough capacity to meet new operational plans, then the strategic level should solve the problem either by changing strategic level objectives or by increasing capacity via acquisition. If the strategic level sets the goals and makes the plans without considering the lower level capabilities, then these goals and plans might be infeasible. On the other hand the strategic level has the aggregate level information which is more desegregated at lower levels in regard to capacity issues (Silver, 1985:508). At this level the detailed information either is not available or unnecessary to consider. Strategic level planners test the feasibility of the goals and plans by using this aggregate level information.

Use of CRAF during the Gulf War is a good example of the capacity situation. The strategic goals of the Gulf War required an incredible amount of military force in the region in a short time. Deployment plans prepared in the direction of strategic goals required the deployment of military assets and personnel in a specific time, which was infeasible with the MAC airlift assets. Therefore strategic level management opted to employ the CRAF to increase the airlift capacity and made the deployments plans feasible.

The strategic level's goals and plans constitute the input to the tactical level of planning. The tactical level has more detailed information than the strategic level and generally plans for utilization of the resources on hand (Silver, 1985:508). For example, an Air Force tactical level planner takes the strategic level directive of focusing on a conflict in the Persian Gulf and the strategic targets to make an operation plan. At this level the operational plan's purpose is to achieve the mission with the best utilization of the aircraft and other resources in hand. In a deployment scenario tactical planning questions that might be asked are:

- what type of aircraft to deploy,
- how
- many aircraft to deploy,
- how the flight plan will be,

- what aircraft availability level is necessary for the achievement of the mission,
- what level of maintenance resources the units should have.

Silver includes inventory level as one of the variables that tactical management has control over (Silver, 1985:508). From this point, we will include the selection of the composition of readiness spare parts in the tactical level of planning because it is an inventory level activity.

Operational level planning takes the tactical level goals and planning as input and has the most detailed information, compared to the strategic and tactical levels. For example the RSP required for a deploying unit is determined by tactical planning and is the input for the operations level. The operations level will schedule airlift, assign the given RSP to airlift resources, load it to airlift assets and carry it to the deployment area. For this specific example, which type of aircraft will carry the RSP, on what day and in which transport aircraft, and how the RSP will be loaded might be some of the questions that an operational level planner has to answer.

After examining the warfare planning with the RSP planning in consideration, we can conclude that the RSP support to a deploying unit starts with the selection of the RSP at the tactical level and ends with the deployment of the RSP to a deployment base. In order to select the criteria that should be used at the tactical level RSP selection process, we need to look the two levels of activities in more detail.

The main considerations for RSP selection are the required flight plan, aircraft availability requirement, maintenance resources and the cost of the selected RSP. RSP is the only variable that tactical level management has control over. By selecting different combinations of RSP, tactical planners try to achieve required aircraft availability level with the minimum cost. On the other hand, at the operational level the considerations are the RSP that has to be deployed in a given time and limited airlift resources. Operational level planners have control over use of airlift resources, but not over RSP. They aim to achieve the shipment of RSP along with other assets they are responsible for shipping in a given time. The main planning jobs they execute are scheduling flights and loading of the cargo to aircraft.

Upper level planning activities should consider the capacity constraints at the lower levels at an aggregate level of detail. The main constraint the operational level management faces is the airlift capacity as introduced throughout this thesis. The method currently used for RSP selection does not consider an airlift capacity constraint. In order to find possible constraints, we can look at the disaggregated RSP constraints that operational level planning faces, and seek ways to use them by aggregating.

Aircraft loading is the main activity at the operational level that directly deals with RSPs. The way cargo is loaded in an aircraft affects the aircraft utilization. First, aircraft being loaded are idle, and use resource needed to load other aircraft. Shorter loading-times increase the aircraft turn around and the cargo carried. Second, proper cargo packing utilizes space, which increases the amount of cargo carried per flight.

The USAF uses the 463L Pallet system to carry cargo on aircraft. A number of studies have been done on 463L Pallet loading optimization algorithms, to improve loading activity. There are many constraints that can affect the packing of the cargo. Manship and Tilley define major constraints to the packing problem as the length, width, and height of each cargo and pallet, weight of the cargo, pallet position in the aircraft, hazardous cargo, and the priority of the cargo (Manship, 1998).

We need to examine these constraints to determine if and how we can use them in an upper level planning activity. The first constraint to the pallet-packing problem is the length, width, and height of each cargo. This information is an attribute of the cargo and has two forms. One form is volume, which is the product of the three attributes. The space carrying capacity (cube) and the weight carrying capacity (payload) define the carrying capability of an aircraft (Bell, 1969). The cube is important information for aggregate level capacity planning. By reducing total volume of the RSPs, we can save some airlift space at the operational level.

The second form of the length, width, and height of the cargo is the cargo's shape. The packing problem solution method changes according to cargo's shape. Assuming all cargo is rectangular, which is a common packing problem assumption, then the problem is categorized as the manufacturer's problem or distributor's problem according to cargo shape. The manufacture's problem deals with identically sized cargo, while the distributor's problem deals with different sized cargo. Each category is further divided into one of two sub-categories either as a two-dimensional or three-dimensional pallet packing problem, according to the similarity level of the sizes of the cargo (Wesley, 1998). Cargo size similarity makes the packing problem easier.

As a result, given a particular group of similar cargo then a solution algorithm can quickly find solutions that increase the transport aircraft space utilization. If it is possible to define a shape parameter, which gives a desirability level to select each part in a continuum, then we can use this parameter in the spare parts composition calculations as a criterion. For example assume that we have only two sizes of spare parts. We have 10 different types of spare parts of one size while we have only 2 types of the second size. Therefore our desire to select the first size spare parts to bring should be greater than the second one because it might be easier to pack. The feasibility of such a measure is not the subject of this thesis, but considering such an idea might be useful for later studies. For this research, we will use volume to capture the length, width, and height of the spare parts.

Another packing problem constraint is the length, width, and height of each pallet. These parameters define the space carrying capacity of each pallet. Although this information is available at the operational level, it is not available for spare parts composition calculations. Yet another pallet constraint is the positions of the pallets in the aircraft. The pallet position defines the height and weight limit of the pallet. Like the pallet size information, the position information of the pallets is unknown during the spare parts calculation and is beyond the scope of this thesis.

The next constraint is the weight of each spare part. This parameter has a direct relation with airlift capacity. Peterson (2000) used this parameter as a criterion in spare parts composition calculations. Recall that an aircraft's carrying capacity is a function of its cargo volume capacity (cube) and weight carrying capacity (payload). Efficient aircraft loads require a trade-off between payload and cube (Bell, 1969:5). For example we may reach the maximum weight carrying capacity of an aircraft while we fill only half of its space carrying capacity. Therefore we might use the spare part's density, (which includes both weight and the volume information) as an optimization parameter. But, because density does not consider the overall dimensions of the spare part, it is not enough for a spare parts selection algorithm (Bell, 1969:5). For capturing the trade-off between payload and cube, we need to use spare part weight and the volume separately but simultaneously.

Aircraft type, another constraint to the packing problem, is closely related to the trade-off issue between payload and cube. Different aircraft have different weight and space carrying capacities. Some can carry larger volumes of cargo, but with smaller weight capacity and vice versa. For example the C-5s have a large space carrying capacity. Therefore loading a C-5 based on volume is inefficient, since the total cargo weight we select might exceed the C-5 payload (Bell, 1969). We need to select cargo that is large and light enough not to exceed the weight limit. This requires us to use both weight and volume as simultaneous optimization criteria.

During the spare part composition calculations, we may not know which aircraft will carry the cargo depending on the planning time range. As a result the aircraft type may not be useful as an optimization criteria for spare parts. But at the same time the management might have knowledge of the probability of using a specific aircraft. For example, if C-5s are typically used for a particular deployment, management may want to base the spare parts computations on C-5s.

Another packing problem constraint is hazardous cargo. Hazardous cargo considerations have regulated loading methods. For example explosives cannot be carried on the same aircraft with flammable gases. If there are spare parts that are included in hazardous cargo class, they can be separated and considered separately. In this thesis, we will not include the hazardous cargo constraint.

In conclusion, Budget is an important resource and constraint to the RSP calculation process. Although cost is important for requirement calculation, there are situations where other factors should be considered. For example during deployment operations transportation of the required resources to deployment area is a difficult to solve. Starting from the first day of the deployment, air units require a considerable amount of ground support. Despite it being rather limited and expensive, airlift is an appropriate way to provide the fast transportation the resources need.

After the examination of candidate criteria, we concluded that weight and volume information, which Peterson, *et all.*, (2000) used in their study, are the best definitive criteria for air transportable spare parts composition calculations. This research used cost, weight, and volume criteria together in the RSP calculations.

2. <u>Exploration Of Selected Criteria</u>

Peterson, *et al.*, (2000) studied the effects of different variables for the optimization problem. They used the cost, weight, and volume criteria in their RSP calculations.

Using a deployment scenario, they calculated the cost-RSPs for 18 F-15 air superiority fighters for 30 days. They then replaced the cost data in the item database with pure weight, pure volume, and some mixture of the cost with weight and volume. The result of their study is summarized in Table 6 and shows the trade off between these variables. Some of the mixtures are promising in that they do not significantly increase cost while significantly decreasing another factor. For example, when they compare some cube-mostly cost mixture with pure cost optimization, they obtain a 6.87 percent decrease in total volume while the total cost only increases 0.46 percent (Peterson, 2000).

Table 6. Comparative Performance Measures across Optimization Methods

Optimized on	*Total Assets*	*Cost ($mill.)*	*Weight (lbs)*	*Cube (ft^3)*
Pure Weight	510	17.49	13000	1320
Mostly Weight/ Some cost	515	16.54	13300	1340
Some Weight/ Mostly Cost	535	15.37	14300	1430
Pure Cost	553	15.19	16000	1610
Some Cube/ Mostly Cost	539	15.26	14900	1510
Mostly Cube/ Some Cost	511	16.76	13000	1320
Pure Cube	485	19.18	13700	1280

(Peterson, 2000)

They concluded that for the small deployment missions the differences appear unimportant, for the large-scale deployments such as Gulf War the differences are worth consideration. They also concluded that some mixture of cost and weight or cube should be used instead of pure factors. They point out that the study was performed only on one aircraft type and a small-scale deployment model. A further study with different aircraft types and in large scale may give different results (Peterson, 2000). This thesis is built on their concept, by showing the effects of different optimization methods from a larger scale experimental design.

3. Weight And Volume Based Marginal Analysis

In Section II.A.2 and 3, we introduced cost based marginal analysis on a single site two-item model. Marginal analysis gives us the best value for a given budget or predefined aircraft availability level. Now we want to apply marginal analysis to the deployment objectives. The new objective is to minimize the RSP demand for airlift. We can achieve this objective by minimizing either total weight or total volume of the

RSPs. If we recall Equation (6), the marginal availability and cost of each item gave its marginal value. Let us define the marginal value both for weight and volume:

$$Marginal\ Value = \frac{Marginal\ Availability}{Item\ Weight}$$

or

$$Marginal\ Value = \frac{Marginal\ Availability}{Item\ Volume}$$

The two objective functions will be:

$$Minimize\left\{\sum_{l} w_l \cdot s_l\right\} \quad or \quad Minimize\left\{\sum_{l} v_l \cdot s_l\right\}$$

and

$$subject\ to\left\{\prod_{l}\left(1-\frac{EBO_l}{NAC}\right) \geq Predefined\ Availability\right\}$$

where w_l and v_l, are the weight and volume of $item_l$. S_l is the stock level of the ***lth*** item, and *NAC* is number of aircraft.

The application of the revised marginal value function may give us a different composition of the parts. We recalculated the single site two-item example given in

Section II.A.2 for weight and volume criteria. The necessary information is given in Table 7.

Table 7. Data table for weight and volume based marginal analysis example.

	Demand Rate (λ)	***BRT***	***λBRT***	***Cost ($)***	***Weight***	***Volume***
Part 1	15	0.1	1.5	30,000	5	50
Part 2	10	0.2	2	10,000	40	150

The calculations of the EBO and the availability are the same as the two-item example in Chapter II.A.2. The EBO values for different stock levels for each part were given in Table 4. The results for the cost, weight and the volume based marginal analysis are summarized in Table 8. Table 8 gives the availability level reached by the addition of each new part to the system and the cumulative cost, weight and volume values. The results of the weight and volume based analysis are very similar due to the similarity of weight and volume information for the parts we selected. The cost based analysis results on the other hand are slightly different than the other two methods. For example the cost based analysis gives 0.9646 aircraft availability for $100,000, while weight and volume based analysis give 0.9694 aircraft availability for $140,000 and $120,000, respectively. The weight and volume values for the same aircraft availability are different too. Because our example is a small scale, the differentiation of the three methods is not apparent. We expect significant differentiation across the results of larger scale calculations.

Table 8. Comparison of Cost, Weight, and Volume Based Spare Parts Calculation

Cost Based Results				Weight Based Results				Volume Based Results			
Availability (percent)	*Cost ($)*	*Weight (lbs)*	*Volume (Cu inch)*	*Availability (percent)*	*Cost ($)*	*Weight (lbs)*	*Volume (Cu inch)*	*Availability (percent)*	*Cost ($)*	*Weight (lbs)*	*Volume (Cu inch)*
68.00	-	-	-	**68.00**	-	-	-	**68.00**	-	-	-
75.35	10,000	40	150	**75.35**	30,000	5	50	**75.35**	30,000	5	50
80.40	20,000	80	300	**82.24**	60,000	10	100	**82.24**	60,000	10	100
83.15	30,000	120	450	**86.16**	70,000	50	250	**86.16**	70,000	50	250
90.75	60,000	125	500	**79.81**	80,000	90	400	**87.85**	80,000	90	400
95.07	90,000	130	550	**88.43**	110,000	95	450	**93.74**	110,000	95	450
96.46	100,000	170	700	**96.94**	140,000	100	500	**96.94**	120,000	135	600
98.36	130,000	175	750	**94.53**	150,000	140	650	**97.58**	150,000	140	650
98.88	140,000	215	900	**97.77**	180,000	145	700	**99.01**	160,000	180	800
99.53	170,000	220	950	**99.19**	190,000	185	850	**99.19**	190,000	185	850
99.70	180,000	260	1,100	**99.72**	200,000	225	1,000	**99.72**	200,000	225	1,000
99.88	210,000	265	1,150	**99.76**	230,000	230	1,050	**99.88**	210,000	265	1,150
99.93	220,000	305	1,300	**99.93**	240,000	270	1,200	**99.93**	240,000	270	1,200

4. Cost, Weight, And Volume Based Marginal Analysis

We want to include the three selected criteria: cost, weight, and volume, simultaneously in the marginal analysis. Peterson, *et al.*, (2000) achieved this implantation by replacing cost criteria with the weight-factored combinations of cost and weight, or cost and volume. Following their study, we replace the item cost with *weight-factored* cost, weight, and volume in Equation (6). The term *weight factor*, which represents the respective emphasis on each criterion, might cause confusion with the weight criteria. Therefore from now on, we will use the term *coefficient* instead of the term *weight factor*.

$$Marginal\ Value = \frac{Marginal\ Availability}{c_c \cdot cost_l + c_w \cdot weight_l + c_v \cdot volume_l} \qquad (7)$$

where c_c, c_w, and c_v are coefficients of cost, weight, and volume, and $\boldsymbol{cost_l}$, $\boldsymbol{weight_l}$, and $\boldsymbol{volume_l}$ are cost, weight, and volume of the ***lth*** item.

Using Equation (7), we can use cost, weight, and volume as simultaneous optimization criteria. Cost, weight, and volume coefficients enable us to give different emphasis to each criterion. Furthermore, by using zero in the other two criteria coefficients, we can still optimize for a single (pure) criterion. For example, if we use zero for c_w and c_v, and 1 for c_c, then we can calculate cost-based RSPs.

In this chapter, we introduced marginal cost based analysis on a simple mathematical model. Then we introduced the ASM, a more complicated model that is currently in USAF use. Finally, we evaluated different criteria to select airlift criteria to use in RSP calculations. We selected weight and volume as performance criteria in addition to a cost criterion. As a conclusion to the Chapter, we showed how to implant the three criteria in the marginal analysis method.

In the next chapter, we will introduce the methodology this study follows. We will reintroduce the 3rd and 4th research questions in more detail. Then we will look at how we use the three criteria in our computations. We follow by introducing our experimental design and analysis method.

III. Methodology

A. Introduction

In Chapter II, we explored different criteria for airlift capacity concerns in the RSP selection process, and narrowed the scope of this thesis to three criteria: cost, weight, and volume of spare parts. Now we address these three criteria in the 3rd and 4th research questions. We also introduced the mathematical implementation of cost, weight, and volume into the marginal analysis method.

In this chapter we examine the implementation of cost, weight and volume criteria and create an experimental design to answer the third and fourth research questions, which are:

- How does application of cost, weight and volume criteria affect the RSPs?
- How can we build RSPs that better suit the airlift capacity by using cost, weight, and volume?

B. Implementation Of Weight And Volume Criteria Into the RSP Selection Process

We need cost, weight and volume information for the ASM calculations. Although ASM kit databases have weight and volume fields, the ASM can only use cost information in its calculations. In Section 0 and 4, we introduced a method to put cost, weight, and volume into marginal analysis. Using this method, we can replace the denominator in Equation (6) with:

$$item\ \ cost = c_c \cdot cost_l + c_w \cdot weight_l + c_v \cdot volume_l \qquad (8)$$

where c_c, c_w, and c_v are the respective coefficients of cost, weight, and volume of l^{th} item.

This we can force ASM to use weight-factored cost, weight, and volume information in the calculations. However, this method has a disadvantage due to respective cost, weight, and volume scales. For example, costs of parts range from 333 to 95,000 dollars, weight information ranges from 1 to 470 pounds, and volume information ranges from 59 to 41,900 cubic inches for the F-16 kit database. As a result the same coefficient value used for cost, weight, and volume does not make the same effect on the final product. For example, the effect of a one-unit increase in the cost coefficient is significantly larger than the effect of a one-unit increase in the weight coefficient. In order to bring cost, weight, and volume information into closer ranges without losing the comparative information between items, we normalized cost, weight, and volume to their averages. We adopt this method from Stockman. Stockman used this method in one of his papers to graph two differently scaled data for comparison (Stockman, 1994: 15).

After normalization the respective F-16 kit database cost, weight, and volume scales reduced to ranges 0-6, 0-15, and 0-9. For better illustration, in Figure 6, we give the frequency diagrams of F-16 kit database distribution before and after normalization. The first diagram shows that cost, weight, and volume data are distributed in different ranges before the normalization. In second diagram, after normalization, the three data groups are distributed more evenly.

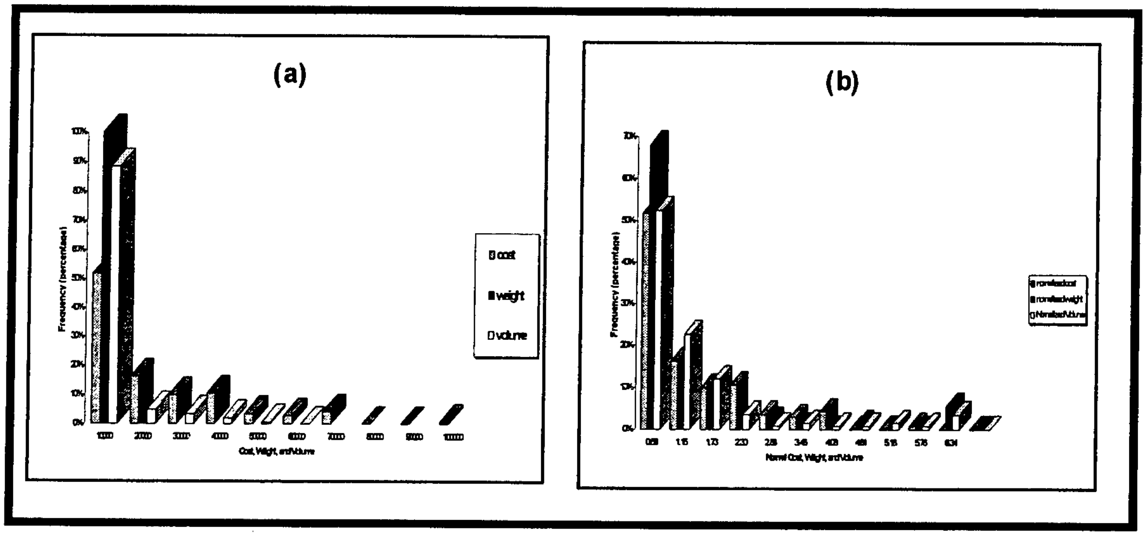


Figure 6.a. Frequency diagram for F-16 kit database distribution before normalization
b. Frequency diagram for F-16 kit database distribution after normalization

The equation below gives normalized cost as an example for normalization to average:

$$\mu_{Cost} = \sum_{l=1}^{n} \frac{Cost_l}{n} \qquad and \qquad Cost_{l\,norm} = \frac{Cost_l}{\mu_{Cost}}$$

where ***n*** is the total number of items in the kit, μ is average cost of all items, and ***l*** is the identification index of the each item.

We replace cost, weight, and volume in Equation (8) with the normalized cost, weight, and volume to obtain:

$$Item\ Cost = c_c \cdot cost_{l\,norm} + c_w \cdot weight_{l\,norm} + c_v \cdot volume_{l\,norm} \qquad (9)$$

where $cost_{l\,norm}$, $weight_{l\,norm}$, and $volume_{l\,norm}$ are normalized values of cost, weight, and volume of l^{th} item, and c_c, c_w, and c_v are the respective coefficients.

Substituting Equation (9) into Equation (7), we achieve the marginal value equation that we use in this research:

$$Marginal\ Value = \frac{Marginal\ Availability}{c_c \cdot cost_{l\,norm} + c_w \cdot weight_{l\,norm} + c_v \cdot volume_{l\,norm}} \qquad (10)$$

In order to run ASM with the cost, weight and volume criteria at the same time, we calculate Equation (9) for each item with the user defined cost, weight, and volume coefficients and replace the results with cost data in kit databases. Therefore we modify the ASM to use the three criteria simultaneously with user-defined emphasis on each.

C. Experimental Design

1. Purpose of Experiment

We now design an experiment to answer the 3rd and 4th research questions. We further expand these two research questions:

- How does different emphasis on cost, weight, and volume affect RSPs?
- Does the effect change for
  - different aircraft types,
  - shorter deployment scenarios,
  - different aircraft availability level requirements,
  - low flight hours per aircraft and low aircraft availability level requirements?
- On which criteria we should put more emphasis for RSPs that better fit a specific airlift capacity problem?
- What kind of method should we use to build better RSPs?

2. Elements of the Experiment

For our experiment elements, we used definitions from McClave (1998: 800).

Response Variables. The response variable is the variable of interest to be measured in the experiment. We also refer to the response as the independent variable.

For our experiment there are three variables of interest: Total cost, total weight and total volume from each of the ASM run. The response variables are deterministic results for each run for the same ASM parameters; such as flight schedule, number of aircraft, length of deployment, and the cost, weight, and volume coefficients that are defined in Equation (9). In most real life experiments, each experiment trial gives randomly distributed values for the response variables. In those cases, an experimental design requires multiple runs of each treatment in order to find a mean and variance for the response variables. In our case, unless the ASM parameters change, ASM gives the same shopping list for the same aircraft kit data every time we run it. As a result, the response variable values are deterministic data points. For this reason, when analyzing the results, we only need one ASM run for each treatment.

Factors. Factors are those variables whose effect on the response is of interest to the experimenter. Quantitative factors are measured on a numerical scale, whereas qualitative factors are those that are not naturally measured on a numerical scale.

In our experiment we are interested in the effect of alternative criteria on the RSP calculations for different aircraft types, deployment length, cost, weight, and volume coefficients, required aircraft availability level, and flight schedule. Of the 7 factors, aircraft type is qualitative and the other factors are quantitative.

Factor Levels. Factor levels are the values of the factors utilized in the experiment. The factor levels we use for the experiment are listed below:

Aircraft Type. KC-135, B-52, F-15, F-16

Deployment Length. 7 and 30 day deployments

Cost, weight, and volume coefficients defined in Equation(9). Integer 0-3, and 0 to 20

Required Aircraft Availability Level. 90% at day 30 for F-15, F-16, KC-135; 95% at day 7 for F-15, F-16, B-52, KC-135; 50, 70, and 90% on day 30 only for B-52; 50% at day 30 for F-16 and KC-135 with a low flight hour per aircraft per day

Flight Schedule. 5.25 hours per aircraft per day; 1,2,3, and 4 hours per aircraft per day for F-16 and KC-135

Treatments. The treatments of an experiment are the factor-level combinations utilized.

The treatments groups we utilize and their brief description are given below:

Treatment Group 1. **2** a/c type (F-16, KC-135) **x 1** deployment length (30 days) **x 21** levels cost coefficient (0-20) **x 1** level of weight coefficient (1) **x 1** level of volume coefficient (1) **x 1** a/c availability level (90%) **x 1** flight schedule (5.25 hrs/aircraft/day) = **42** treatments

Treatment Group 2. **2** a/c type (F-16, KC-135) **x 1** deployment length (30 days) **x 1** level cost coefficient (1) **x 21** levels of weight coefficient (0-20) **x 1** level of volume coefficient (1) **x 1** a/c availability level (90%) **x 1** flight schedule (5.25 hrs/aircraft/day) = **42** treatments

Treatment Group 3. **2** a/c type (F-16, KC-135) **x 1** deployment length (30 days) **x 1** level of cost coefficient (1) **x 1** level of weight coefficient (1) **x 21** levels of volume coefficient (0-20) **x 1** a/c availability level (90%) **x 1** flight schedule (5.25 hrs/aircraft/day) = **42** treatments

Treatment Group 4. **2** a/c type (F-16, KC-135) **x 1** deployment length (30 days) **x 6** different coefficient combinations **x 4** a/c availability levels and flight schedule (50% - 1 hrs, 60% – 2 hrs, 70% - 3 hrs, and 80% - 4 hrs/aircraft/day) = **48** treatments

Treatment Group 5. **1** a/c type (B-52) **x 1** deployment length (30 days) **x 4** levels of weight factor for cost **x 4** levels of weight factor for weight **x 4** levels of weight factor for volume **x 2** a/c availability level (50 and 70%) **x 1** flight schedule (5.25 hrs/aircraft/day) = **128** treatments

Treatment Group 6. **4** a/c type **x 2** deployment lengths x **4** levels of weight factor for cost **x 4** levels of weight factor for weight **x 4** levels of weight factor for volume **x 1** a/c availability level (90%) **x 1** flight schedule (5.25 hrs/aircraft/day) = **512** treatments

In the experimental runs we have 814 (42 + 42 + 42 + 48+ 128 +512*)* total treatments that each represents one ASM run.

Treatment Groups 1, *2*, and *3* help us observe the effect of each coefficient on the total cost, weight, and volume, given the other coefficient held constant. The changing coefficients for each group are defined as 21 levels starting from 0 to 20.

Treatment Group 4 is aimed for analyzing the response sensitivity of total cost, weight, and volume to different coefficient combinations at different activity levels. Activity levels are defined as availability and flight hour requirement couples.

Treatment Group 5 and the B-52, 30 day, 90 percent treatment from *Group 6*, are used to analyze the response sensitivity of three totals to aircraft availability requirements holding the flight schedules constant. The three aircraft availability levels are defined as 50, 70, and 90 percent.

Treatment Group 6, together with *Treatment Group 5* is used to evaluate the effect of coefficient combinations on the three totals, between aircraft type, deployment lengths and availability levels. *Treatment Group 5* and *6* give us total ten different deployment scenarios.

D. <u>Execution Of The Experiment</u>

In our experiment, we used ASM version 6.21. There are two main inputs used in ASM. The first is the kit database of aircraft that includes item by item information that ASM. Kit databases include item specific information including national stock numbers (NSN), cost, weight, and volume information. The second input is the parameters that specify information in regards to deployment scenario. The important parameters that we used are aircraft availability levels, duration of deployment, flight schedule during deployment, and maintenance parameters.

The ASM software keeps kit data and parameters in separate computer files. F-16, B-52, F-15, and KC-135 kit databases that we access for the experiment, although containing fields for weight and volume, are missing the data. We have to collect the weight and volume information from other sources. For weight and volume information we obtain D035T database from Wright Patterson Air Force Base/Air Force Material Command (AFMC) Headquarters. D035T data is a roll-up of each Air Logistics Center's (ALC) data for the first quarter of 1995. Duplicated items are deleted from the database and there is an upper limit of 4,000 pound and 2,000,000 cubic inches to control erroneous data (Niklas, 2000).

In order to transfer weight and volume data, we import ASM kit databases and the D035T database into Microsoft Excel. Using NSNs, we match the two databases and transfer TRANSWT and TRANSCUINCH (weight and volume after packaging) of available items from the D035T database into the ASM kit databases. Although we find most of the information, the D035T database is missing some of the information. A method that has been used in Wright Patterson AFB/AFMC is applying TRANSWT=9.99 pound and TRANSCUINCH=999.99 for the missing items in the D035T (Niklas, 2000). This method would cause a bias in our experimental results because we are creating items with the same weight and volume values. Instead, we delete those items missing weight and volume information from the ASM kit databases. The statistics on items excluded are given in Table 9.

Table 9. Statistics on items used and omitted from ALC Kit databases.

	F-15	*F-16*	*B-52*	*KC-135*
Original number of items in kit database obtained from ALC	443	193	248	217
Number of items used in experiment	259	136	190	187
Number of items deleted because of missing weight and volume information	173	57	58	30
Number of items deleted by ASM due to indenture hierarchy problems	11	–	–	–
Percentage of items used in final experiment from kit databases	58%	70%	76%	86%

After transferring weight and volume information into the F-15, F-16, B-52 and KC-135 kit databases, we calculate cost, weight, and volume combinations by using Equation (9) and coefficient factor levels for each item. We multiply each result with 10,000, before we replace them with the cost information in the databases. The reason for this multiplication is that the ASM rounds the cost data to two decimal places, which is the cent portion of the cost. We lose some comparative information when the ASM round the results of Equation (9) that are close to each other. For example 2.338 is smaller than 2.339, but when we round them up to two decimals both are 2.34. In marginal analysis this causes wrong selections, if the marginal availability of the two items are equal, too. By multiplication with 10,000, we carry most of the comparative information to the left side of the decimal point.

Following the multiplication with 10,000, we replace these results with the cost information. For each combination we build a separate kit database in Excel. For example, for the F-15 aircraft and the 4-level cost, weight, and volume coefficients, we build 63 (4 x 4 x 4 –1) kit database files in Excel. We subtract 1 from 64, because when all three coefficients are zero ($c_c = c_w = c_v = 0$), the denominator of marginal value function in Equation (10) goes to zero, which is not defined.

Once we build all necessary kit databases, we import these Excel files into the ASM. While importing F-15 Excel kit database tables into ASM, we face two problems. ASM software is built with internal test modules to avoid the use of wrong kit data in the calculations. After a user builds or imports new kit data into the ASM, the ASM checks several things. One of the checks that ASM does is the hierarchy of indentures. Modern aircraft spare kits are in modular structure to increase cost effectiveness and maintainability of the aircraft. Spare parts come in two main categories: line replaceable units (LRUs) and shop replaceable units (SRUs). LRUs are mother modules that contain more than one SRU. Once an LRU fails on an aircraft, the LRU can be replaced with a functional one at the flight line. Then the failed LRU can be sent to shop for repair. SRUs use the same logic in the repair shops. If one SRU in a LRU failed, a functional SRU can be replaced with the failed one, and the failed SRU can be sent to depot for repair. SRUs are cheaper than their mother LRUs. As a result once an SRU fails in an irreparable way, it is cost effective to condemn only that SRU instead of the whole LRU. The ASM software checks the hierarchical structure of LRUs and SRUs. If ASM finds SRUs that have a missing LRU in the kit data, ASM automatically deletes that SRU. The item data we delete due to missing weight and volume information breaks the hierarchical structure of some items. The statistics of deleted items are given in Table 9.

Besides broken indenture structures, ASM checks the price of mother LRUs and their SRUs. If the price of SRU is more than price of its mother LRU, ASM changes the LRU price. Again we have this problem only in the F-15 kit database. At every transfer

ASM manipulates 3-6 LRU prices. Because the cost record of the kit items is different at each transfer file, these LRUs are different NSNs each time. We accept this as a small error because the number of these LRUs is small compared to the 259 items we use.

After importing Excel kit databases with different coefficient combinations into the ASM, we set up the ASM parameters to factor levels of experiment treatments and execute the experimental runs. Each ASM run produces a buy list that satisfies the deployment requirements in that specific run. We export buy lists back to Excel and by using original kit data, we calculate the total cost, weight, and volume of each buy list, which are the response variables of the experiment.

E. Analysis Method

In the analysis, we aim to find answers to the research questions introduced at the beginning of this chapter. First, we analyze the responses of total cost, weight, and volume to cost, weight, and volume coefficients. We use F-16 and KC-135 aircraft kit databases for the calculations. For F-16 aircraft we calculate 20 RSPs, by the use of the *treatment Group 1*, in which we change cost coefficient, while keeping weight and volume coefficients constant. We repeat the same calculations for weight and volume coefficients by using the *Treatment Group 2* and *3*. Then we repeat the process for KC-135 aircraft.

After we build all necessary RSPs, we graph the total cost, weight, and volume response to changing coefficients. From the response graphs, we interpret the coefficient effect on total cost, weight, and volume.

Following the analysis of coefficient effect on the total cost, weight, and volume, we analyze the sensitivity of the responses to deployment activity levels by using the *Treatment Group 4*. We define four levels of activity. Then using F-16 and KC-135 aircraft kit databases, we calculate RSPs for 6 randomly selected coefficient combinations for each aircraft at four different levels of activity. For activity levels, we change the aircraft availability requirements and the flight hours per day simultaneously. As analysis, we look at the response of total cost, weight, and volume to 6 coefficient combinations at each level of activity..

We next analyze the response sensitivity to aircraft availability level, holding the flight schedule constant. The treatments for this analysis are the *Treatment Group 4* and the B-52, 30 day, and 90 percent availability portion of the *Treatment Group 5*. We use B-52 aircraft kit database for the calculations and define three levels of aircraft availability (50, 70, and 90 percent) as a requirement at the end of 30-deployment. For each aircraft availability level, we calculate RSPs for 63 different coefficient combinations. Then we analyze the response of the totals to the aircraft availability levels.

After the response analyses, we define 10 different deployment scenarios by using the *Treatment Groups 5* and *6*. Then we select RSPs by using several selection objectives from each scenario. Minimizing and maximizing the total cost, weight, volume, and all three totals at the same time are our selection objectives. We use both desirable and undesirable selection objectives to observe if there are common coefficient combinations that cause the same effect in all scenarios.

We use F-16, F-15, B-52, and KC-135 aircraft for our calculations. We calculate 7 and 30-day deployment scenarios for each aircraft. We target 90 percent for 30 day and 95 percent for 7 day as aircraft availability level. For coefficients we use four levels, which give us 63 combinations for each type of deployment scenario. Besides these scenarios, we utilize the results of the *Treatment Group 4*. To summarize, by using four aircraft type and different deployment parameters, we define 10 different deployment scenarios. For each deployment scenario we calculate solution sets for 63 coefficient combinations that each give us one RSP that satisfies the same scenario requirements. The solution sets for 10 different scenarios are summarized in Appendix C.

In each scenario solution set, we locate the minimum and maximum total cost, weight, and volume. We define these minimums and maximums as *set minimums* and *set maximums*. There might be other possible minimums and maximums that are not included in our solution set. In order to find minimums and maximums that are not included in our solution sets, we should calculate RSPs using more than 4 factor levels for cost, weight, and volume coefficients. The four level coefficients give us 63-RSP solution sets. If we increase the coefficient levels, the number of RSPs in the solution sets will increase, too. Hence, the *set minimum* and *maximum* definitions are only valid for the solution set that we build. Once the solution set gets larger or smaller, the *set minimums* and *maximums* might change.

After analysis of set minimums and maximums, we change our selection objective to minimize and maximize the total cost, weight, and volume at the same time. For selection we adopt a method from spreadsheet multiple objective linear programming (MOLP).

MOLP deals with decision-making problems that have more than one objective. For example in RSP calculations, if we try to minimize only total cost, this problem is classified as a single objective optimization problem. Therefore, if we aim to minimize total cost, weight, and volume simultaneously, then we classify our problem as a multiple objective optimization problem.

A three-objective linear minimization problem can be solved in four steps. In the first three steps, we solve the problem for each of the three objectives, disregarding the other two objectives. At the end of the first three steps, we obtain the minimums of each objective in a solution set. Because of the trade-off nature of multiple objective problems, usually when one of the objectives is minimized, the other two objectives are not minimized. Since we want to minimize all three objectives simultaneously, the minimum results that we calculate are not desirable results for our purpose. The last step of the solution helps us find a solution that satisfies our objective better, although it is not as good as the minimums of each individual objective (Ragsdale, 2001: 309).

The last step of the problem substitutes the three objectives with one common objective. The new objective of the problem minimizes the sum of the deviations of three objectives from their minimum values calculated in the first three steps (Ragsdale, 2001: 309).

We adapt this method to our RSP selection process. We have 63 different RSPs for each deployment scenario. We want to select the RSP, which have the total cost, weight, and volume that has the smallest deviation from their possible minimums.

$$d_{cost_k} = \frac{Total\ Cost_k - Cost_{min}}{Cost_{min}} \cdot 100\% \quad (11)$$

$$d_{weight\,k} = \frac{Total\ Weight_k - Weight_{min}}{Weight_{min}} \cdot 100\% \quad (12)$$

$$d_{volume\,k} = \frac{Total\ Volume_k - Volume_{min}}{Volume_{min}} \cdot 100\% \quad (13)$$

where $d_{cost\,k}$, $d_{weight\,k}$, $d_{volume\,k}$ are percentage deviations from set minimums and ***Total Cost****$_k$*, ***Total Weight****$_k$*, ***Total Volume****$_k$* are the results of the k^{th} RSP; and ***weight*** $_{min}$, ***cost*** $_{min}$, and ***volume*** $_{min}$ are set minimums of the 63 RSP results.

$$d_{obj\,k} = d_{cost_k} + d_{weight_k} + d_{volume_k} \quad (14)$$

where $d_{obj\,k}$ is the total percentage deviation from set minimums of the k^{th} RSP in the solution set.

First, we locate the set minimum total cost, weight, and volume in the solution set. Then we calculate the percentage deviations of total cost, weight, and volume from the set minimums for each RSP by using Equations

(11), (12), and (13). After the percentage deviations, we calculate the total percentage deviation of each RSP by using Equation (14). This way we obtain 63 total deviations for each solution set. Finally, We simply sort the RSPs ascending according to their total percentage deviations. We obtain RSP with minimum total deviation by selecting the first RSP on the list. Similarly, the RSP with the maximum total deviation can be located at the end of the list, which we used as the undesirable selection. The data tables in Appendix C are prepared with this technique.

We remind the reader that the deviation from possible minimums is different than the deviations compared to cost based analysis. The deviation compared to cost based analysis is the deviation of selected RSP totals from the RSP totals, which is selected by the use of cost based analysis. Cost based analysis occurs where the coefficient combinations are 1,0,0 (1 for cost coefficient and 0 for weight and volume coefficients).

To conclude our analysis we show the impact of the use of cost, weight, and volume criteria in RSP calculations in terms of airlift assets and measures. We define a large-scale deployment scenario in which F-15, F-16, B-52, and KC-135 aircraft are used. We base the number of aircraft from Gulf War statistics. We utilize the RSP for 30-day, 90 percent deployment scenarios defined in the *Treatment Group 6.*

First, using the different RSP selection objectives, we select RSPs for each aircraft type. Then we calculate the overall total cost, weight, and volume of all required deployment RSPs. We assume that the RSPs are either carried by C-17 or C-141 cargo aircraft. Finally, we analyze the reduction in air cargo assets requirements in terms of cargo aircraft numbers and cost increases resulted from different RSP selection objectives compared to the current cost based RSP calculations.

In this chapter, we first used the 3rd and 4th research questions to define the scope of our experimental design. We next introduced how we implemented the three criteria into the availability based marginal analysis that ASM uses to calculate RSPs. Then, we introduced the experimental design and its execution. Finally, we presented the analysis approach that we use to answer the research questions. Chapter IV gives more detail on the analysis methods and summarizes our analysis results.

IV. Results And Analysis

A. Effect Of Coefficients On Total Cost, Weight And Volume

We examine the effect of coefficient changes on total cost, weight, and volume of shopping lists. Because we expect that the correlation level between the three criteria could change the effect of the coefficients, we first calculate the correlation between item cost, weight, and volume data for the F-16, F-15, B-52 and KC-135. Correlation results show that weight and volume data are highly correlated for the F-16 and F-15 aircraft. In B-52 and KC-135 kit databases, there are lower correlation between weight and cost data. Cost data shows low correlation with both weight and volume data in all four aircraft types (See Table 10). For our analysis, we select the F-16 and KC-135 aircraft.

Table 10. Correlation between three cost, weight, and volume information.

B-52	***cost***	***weight***	***volume***	**KC-135**	***Cost***	***Weight***	***volume***
cost	1			cost	1		
weight	0.353916	1		weight	0.302298	1	
volume	0.310087	0.460771	1	volume	0.541416	0.401137	1
F-15	***cost***	***weight***	***volume***	**F-16**	***Cost***	***Weight***	***volume***
cost	1			cost	1		
weight	0.366925	1		weight	0.377054	1	
volume	0.380839	0.821432	1	volume	0.526852	0.852718	1

To see the effect of coefficients of cost, weight, and volume data, we calculate each shopping list by holding two coefficients constant while increasing the other coefficient gradually. We repeat the experiment two more times, each time changing a different coefficient. The summary of the results can be found in Appendix A.

First, we calculate shopping lists for the KC-135. We hold weight and volume coefficients at level 1, and increase the cost coefficient from 0 to 20 by 1 (See Figure 7.a). We remind the reader that we are using normalized total cost, weight, and volume to graph them in the same scale. In response to change in cost coefficient, the total cost decreases while total weight increases, before leveling off. Total volume does not show any significant change. Total weight does not change between 6 and 15. But between 15 and 16 makes a jump. At this point we also observe a slight decrease in total cost and volume.

To find the reason for this jump in the total weight, we compare the list of items in the RSP for coefficient combinations 15,1,1 and 16,1,1. From the comparison we see that this jump is a result of two NSNs (See Table 11). The ASM omits a more expensive and larger but lighter part and adds a cheaper and smaller but heavier part.

Table 11. Comparison of number of parts in the RSPs, when the cost coefficient is 15 and 16 for the KC-135.

NSN	(15, 1, 1) A	(16, 1, 1) B	A-B	Cost	Weight	Volume
5841012827093	7	6	1	79,595	125	18,329
1680001095725FL	2	3	-1	11,713	1,746	51

We repeat the same experiment on the F-16 aircraft kit. Total cost and weight respond the same way, yet total volume is more responsive than KC-135 results. Total volume increases almost on the same path where total weight increases (See Figure 7.b).

We next calculate shopping lists for KC-135 aircraft by holding cost and volume coefficients at level 1, while increasing the weight coefficient. This time total weight decreases and total volume and cost increases. At the point where weight coefficient is 2, they all level off (See Figure 7.c).

When repeated for the F-16, total cost increases and total weight decreases while the total volume does not respond much. They all level off at point where weight coefficient is 5. Most of the change happens where the weight coefficient is between 0 and 3 (See Figure 7.d).

We now look at the effect of volume coefficient. We first calculate shopping lists for the KC-135 keeping cost and weight-coefficients constant at level 1 and increasing the volume coefficient. Total volume decreases to the point where volume coefficient is 7, total cost climbs with a low slope, and total weight increases overall with two jumps at 0-3 and 13-14 (See Figure 7.e).

To find the reason for the jump at 13-14 point, we compare the parts list of RSPs resulted at combinations 1,1,13 and 1,1,14 (See Table 12). We see that the jump is result of changes in two NSNs. ASM omits a cheaper and lighter part and adds a more expensive and heavier but smaller part. The numbers of other NSNs in two RSPs are the same.

Table 12. Comparison of number of parts in the RSPs, when the volume coefficient is 13 and 14 for the KC-135.

NSN	(15, 1, 1) A	(16, 1, 1) B	A-B	Cost	Weight	Volume
1650006408489	7	6	1	479	8	615
1680001095725FL	2	3	-1	11,713	1,746	51

We repeat the same experiment on the F-16 aircraft kit database. The total cost increases to the point where volume coefficient is 10 then levels off (See Figure 7.f). Total weight and volume decrease almost on the same path to the point where volume coefficient is 5. We interpret this as the effect of the high correlation between weight and volume data. This response is opposite to the KC-135 response, where the total weight increases in response to increasing volume coefficient (See Figure 7.e).

After a general examination of the responses, we conclude that the correlation between cost, weight, and volume data affects the response of total cost, weight, and volume. For example in the case of F-16, where weight and volume data has high correlation, an increase in the weight or volume coefficients causes a decrease or no change on total weight and volume (See Figure 7.d). Again for the F-16, because cost data has lower correlation between weight and volume data, an increase in the cost coefficient caused an increase in both total weight and volume (See Figure 7.b).

When we analyze KC-135 results, where the three types of data have low correlation, we witness that an increase in one of the coefficients causes an increase or no response on the other two totals. For example for KC-135 when we increase the weight coefficient, total cost and volume increase while total weight decreases (See Figure 7.c). This is opposite of the F-16 results exhibited in Figure 7.d.

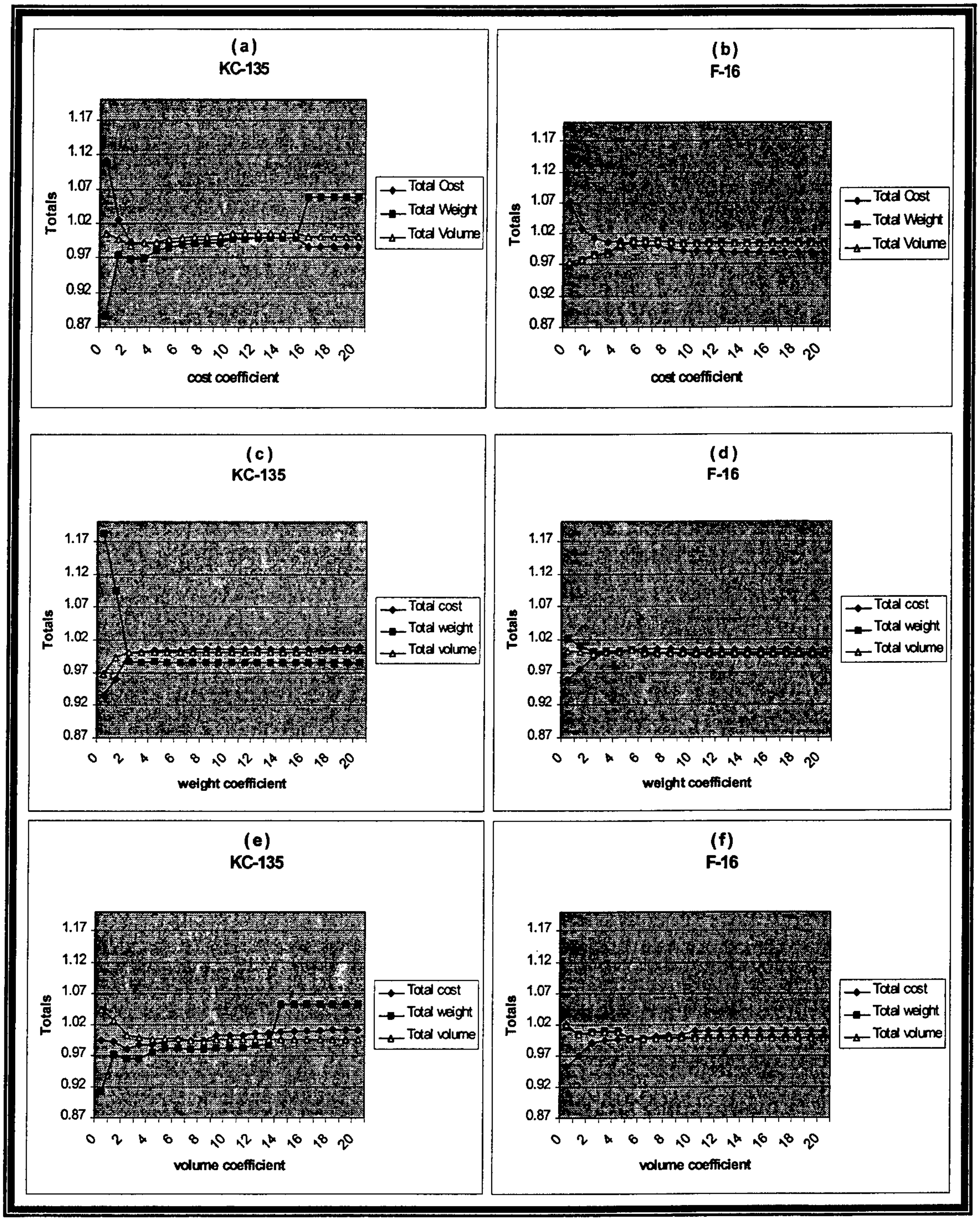


Figure 7.a. and b. Response of total cost, weight, and volume to cost coefficient.

c. and d. Response of total cost, weight, and volume to weight coefficient.

e. and f. Response of total cost, weight, and volume to volume coefficient.

Another common observation is that whichever coefficient we increase, the related response decreases. For example when we increase the cost coefficient the total cost decreases. This suggests that in order to reduce one of the totals, we need to increase the related coefficient.

The coefficients show a reducing effect on the total cost, weight, and volume. Most of the change happens between 0-5 range. Beyond this range most of the totals are unchanged. But, in few occasions we observe changes beyond 5. While interpreting the change range, we should keep in mind the fact that we use level 1 for constant coefficients. The results are only valid for this setup. Changes might occur in different ranges, if we use higher levels for the constant coefficients.

B. Sensitivity Of Coefficient Effect To Deployment Activity Level

Next we examine the effect of different activity levels on the total cost, weight, and volume response to different coefficient combinations with calculations on the KC-135 and F-16 kit databases.

Table 13. Deployment activity levels for calculations.

Level	*Aircraft Availability at Day 30 (percentage)*	*Flight Hrs per Day per Aircraft*
1	50	1
2	60	2
3	70	3
4	80	4

First, we define four activity levels for 30-day deployment scenarios. Levels are summarized in Table 13. For each activity level we calculate shopping lists for 6 different combinations of cost, weight, and volume coefficients. This part of experiment is defined in the *Treatment Group 4.* Then we calculate shopping lists for each level of activity for 6 coefficient combinations. The calculation results for the F-16 aircraft are summarized in Table 14. When we look at the first two activity level results, we see that total cost, weight, and volume does not respond to different coefficient combinations. Starting from activity level 3, total cost, weight, and volume responded to coefficient changes.

Table 14. F-16 aircraft results for activity levels

	Coefficients of			Responses		
	Cost	Weight	Volume	Total Cost ($)	Total Weight (lbs)	Total Volume (inch^3)
Level 1	2	0	2	791,316.31	2,733.20	324,275.22
	1	3	3	791,316.31	2,733.20	324,275.22
	3	2	2	791,316.31	2,733.20	324,275.22
	3	3	0	791,316.31	2,733.20	324,275.22
	0	3	0	791,316.31	2,733.20	324,275.22
	3	3	2	791,316.31	2,733.20	324,275.22
Level 2	2	0	2	867,858.54	3,005.70	358,241.25
	1	3	3	867,858.54	3,005.70	358,241.25
	3	2	2	867,858.54	3,005.70	358,241.25
	3	3	0	867,858.54	3,005.70	358,241.25
	0	3	0	867,858.54	3,005.70	358,241.25
	3	3	2	867,858.54	3,005.70	358,241.25
Level 3	2	0	2	1,256,631.78	4,050.70	539,839.52
	1	3	3	1,281,442.30	4,026.20	534,544.90
	3	2	2	1,256,631.78	4,050.70	539,839.52
	3	3	0	1,256,631.78	4,050.70	539,839.52
	0	3	0	1,288,962.60	4,027.90	534,760.90
	3	3	2	1,281,442.30	4,026.20	534,544.90
Level 4	2	0	2	3,026,084.24	7,504.81	1,220,684.87
	1	3	3	3,197,758.58	7,380.21	1,203,710.58
	3	2	2	3,140,500.96	7,519.56	1,246,585.94
	3	3	0	3,067,768.69	7,470.91	1,238,421.19
	0	3	0	3,356,374.50	7,476.01	1,230,115.07
	3	3	2	3,130,830.43	7,406.01	1,216,215.24

We repeat the same calculations for the KC-135 aircraft kit database. We observe the same result. For the first two activity levels the total cost, weight, and volume are not responsive. Starting from the 3rd activity level they respond to coefficient changes. The calculation results for KC-135 aircraft are given in Appendix B.

In conclusion, as the flight hours and aircraft availability requirements increase, the total cost, weight, and volume become more responsive to coefficient changes. In our experimental calculations for the KC-135 and F-16 kit databases, total cost, weight, and volume become responsive once aircraft availability reaches 70 percent and flight hours per aircraft per day reaches 3 hours. If we increase the resolution of the flight hours and availability targets in the experiment, we might observe that response starts at some point between 60 percent availability, 2 hours flight and 70 percent availability, 3 hours flight levels.

C. Coefficient Effect Sensitivity To Aircraft Availability Requirements

We next, we examine the total cost, weight, and volume response sensitivity to coefficients at different aircraft availability levels with a constant flight schedule. We use the B-52 kit database for these calculations. We calculate shopping lists for a 30-day deployment with 5.25 hours flight per aircraft per day. We repeat the calculation for 50, 70, and 90 percent aircraft availability at the 30th day. For each coefficient we use four levels (0,1,2, and 3) resulting in 63 coefficient combinations. The results of these calculations are given in Appendix C.

Total cost, weight, and volume are responsive at all three availability levels. For the 50 percent aircraft availability level the totals are less responsive than 70 and 90 percent aircraft availability levels. If we examine the 50 percent aircraft availability results for B-52 aircraft in Appendix C, we see that there are common results between some of the coefficient combinations. Common results between some of the combinations are natural, for example 1,1,1; 2,2,2 or 3,3,3. Both 2,2,2 and 3,3,3 have common multipliers and reduce to 1,1,1. Because the marginal analysis method uses comparison to choose items, and coefficients go to the denominator of the equation, these combinations have the same effect on the results. Coefficient combination groups that cause the same effect are summarized in Table 15.

Table 15. Common Effect Coefficient Combinations.

Common Effect Groups	**Coefficient Combinations** **(c_c, c_w, c_v)**
1	(0,0,1); (0,0,2); (0,0,3)
2	(0,1,0); (0,2,0); (0,3,0)
3	(1,0,0); (2,0,0); (3,0,0)
4	(0,1,1); (0,2,2); (0,3,3)
5	(1,0,1); (2,0,2); (3,0,3)
6	(1,1,0); (2,2,0); (3,3,0)
7	(1,1,1); (2,2,2); (3,3,3)

In the 50 percent results (except from the common effect coefficient combinations summarized in Table 15), there are other combinations that have the common effect. These combination groups are summarized in Table 16. When we compare the results of 70 and 90 percent aircraft availability level calculations with 50 percent results, we see that in 70 and 90 percent availability levels, the only common results belong to common effect coefficient combinations. This suggests that at 70 and 90 percent availability levels total cost, weight, and volume are more responsive to coefficients than at the 50 percent availability level.

Table 16. Coefficient combinations gave the same results for 50 percent aircraft availability level.

Coefficients of			Responses		
Cost	**Weight**	**Volume**	**Total Cost ($)**	**Total Weight (lbs)**	**Total Volume (Cu inch)**
2	2	1	3,432,519	30,669	3,661,182
3	3	1	3,432,519	30,669	3,661,182
2	1	2	3,428,771	30,781	3,662,256
3	2	2	3,428,771	30,781	3,662,256
3	2	3	3,460,994	30,641	3,649,998
3	3	2	3,460,994	30,641	3,649,998
2	1	1	3,405,410	30,899	3,686,589
3	1	2	3,405,410	30,899	3,686,589
3	2	1	3,405,410	30,899	3,686,589

In conclusion, total cost, weight, and volume are responsive for different aircraft availability levels with a constant high flight schedule. We observe that the totals are less responsive for the 50 percent availability level. When we consider the results of Section IV.B, together with the results of this part of analysis, we conclude that total cost, weight, and volume response sensitivity to coefficients reduces or diminishes when the requirements of the deployment decreases. Because we expect high levels of requirements for actual deployment scenarios, we expect also that the total cost, weight, and volume should always remain in the sensitive region for RSP calculations.

D. Coefficient Combinations For Different Selection Criteria

In this part of the analysis we look for possible patterns in coefficient combinations that give the same result between different aircraft and deployment scenarios. Our purpose in seeking these patterns is to find ways to apply cost, weight, and volume criteria to RSP calculation to achieve desirable RSPs in other scenarios. Our question is which coefficient combination satisfies the selection objective. Selection objective might be minimizing total cost, weight, volume, or all three totals simultaneously. In addition to desirable selection objectives, for analysis purposes we use undesirable selection objectives. For example, selecting the RSP with the maximum total cost or weight in a solution set.

1. Coefficient Combinations For Possible Minimum Total Cost, Weight, And Volume

We look for the coefficient combinations where minimum total cost, weight, and volume of each solution set occur. We start the analysis with the examination of possible minimum costs. Table 17 shows where the minimum total cost of each solution set occurred. The first three columns give the deployment scenarios, followed by the coefficient combinations and the percentage change of the selected RSP totals compared to cost based marginal analysis totals.

Table 17. Possible Minimum Total Costs of Each Solution Set.

Deployment Solution Sets			**Coefficients of**			**Percentage Change Compare to Cost Based Analysis**		
A/C Type	***Dep. Days***	***Availability (percentage)***	***Cost***	***Weight***	***Volume***	***Total Cost (%)***	***Total Weight (%)***	***Total Volume (%)***
F-16	7	90	1,2,3	0	0	0.00	0.00	0.00
F-16	30	90	3	1	0	-0.36	-1.93	-1.55
KC-135	7	90	1,2,3	0	0	0.00	0.00	0.00
KC-135	30	90	3	1	1	-0.51	-13.59	-7.32
F-15	7	90	1,2,3	0	0	0.00	0.00	0.00
F-15	30	90	1,2,3	0	0	0.00	0.00	0.00
B-52	7	90	1,2,3	0	0	0.00	0.00	0.00
B-52	30	90	1,2,3	0	0	0.00	0.00	0.00
B-52	30	70	3	0	1	-0.01	-2.59	-13.02
B-52	30	50	1,2,3	0	0	0.00	0.00	0.00

Examining Table 17, we see that most minimum total costs occur at coefficient combinations 1,0,0, 2,0,0 and 3,0,0, which are all equivalent. For F-16 and KC-135 30-day and B-52 30-day 70 percent aircraft availability calculations, the minimum total costs occur at coefficient combinations different than cost based optimization results. We observe a desirable change compared to the cost based analysis result. Total cost, weight, and volume are reduced compared to the cost based optimization results. This result shows that, there are a few possible solutions that can reduce all three totals at the same time.

It is important to note that the pure cost based analysis might not always minimize the total cost of the RSPs. On occasions, it is possible to calculate cheaper RSPs by using the three optimization criteria in combination then by using the pure cost based optimization currently employed.

For the second part of our analysis, we select the set minimums for total weight. We summarized these results in Table 18. Similar to the minimum cost selection, most of the minimum weight results occur at only weight-based analysis, which is at coefficient combination 0,1,0 or equivalents 0,2,0 and 0,3,0. Other minimum weight results require some combination of cost or volume coefficients. 7-day F-15 deployments require the combination of the three criteria with more emphasis on the weight criteria.

Table 18. Possible Minimum Total Weight Results of Each Solution Set.

Deployment Solution Sets			**Coefficients of**			**Percentage Change Compare to Cost Based Analysis**		
A/C Type	***Dep. Days***	***Availability (%)***	***Cost***	***Weight***	***Volume***	***Total Cost (%)***	***Total Weight (%)***	***Total Volume (%)***
F-16	7	90	0	1,2,3	0	12.34	-4.44	-3.38
F-16	30	90	0	1,2,3	1,2,3	5.07	-4.80	-4.02
KC-135	7	90	0	1,2,3	0	18.90	-23.16	1.52
KC-135	30	90	0	1,2,3	0	9.96	-21.72	-5.54
F-15	7	90	1	3	1	4.56	-10.17	-13.93
F-15	30	90	1	3	0	5.39	-11.26	-10.84
B-52	7	90	0	1,2,3	0	10.27	-6.16	-8.72
B-52	30	90	0	1	0	8.87	-4.32	-3.45
B-52	30	70	0	1,2,3	0	19.61	-8.96	-12.29
B-52	30	50	0	1,2,3	0	23.67	-6.98	-8.81

Lastly, we examine the coefficient combinations where minimum total volume results occur. The minimum volume results are summarized in Table 19. In contrast to minimum cost and weight results, only two of the minimum total volumes occur at pure volume based calculations. Most of the minimum volume results require some combination of two or three coefficients.

Table 19. Possible Minimum Total Volume Results of Each Solution Set.

Deployment Solution Sets			**Coefficients of**			**Percentage Change Compare to Cost Based Analysis**		
A/C Type	***Dep. Days***	***Availability (%)***	***Cost***	***Weight***	***Volume***	***Total Cost (%)***	***Total Weight (%)***	***Total Volume (%)***
F-16	7	90	1	3	3	5.32	-4.20	-5.23
F-16	30	90	0	1	2	5.25	-4.71	-4.13
KC-135	7	90	1	0	3	7.42	-6.34	-9.44
KC-135	30	90	1	0	3	1.74	-0.49	-9.99
F-15	7	90	1	0	3	5.12	-9.60	-14.66
F-15	30	90	0	0	1,2,3	15.35	-5.00	-12.53
B-52	7	90	0	0	1,2,3	15.45	-2.55	-14.03
B-52	30	90	0	2	3	10.92	-2.37	-10.29
B-52	30	70	0	1	3	23.77	-4.29	-23.74
B-52	30	50	0	1	3	29.15	-5.31	-12.44

Overall, after the examination of possible minimum total cost, weight, and volume results between aircraft types and deployment requirements, we cannot find one common coefficient combination that gives the desired minimums in all cases. The required coefficient combination changes from case to case. One result is that we need to give more emphasis to related criteria, regardless of which total we want to minimize.

A notable conclusion is that although in the majority of the calculations single criterion based optimization gives the best possible minimums, for a few cases a combination of two or three criteria provides better results. Another observation is that the use of coefficient combinations instead of pure criteria optimization results in better trade-offs between the totals in few cases.

2. Coefficient Combinations For Possible Maximum Total Cost, Weight, And Volume

We now examine the coefficient combinations where the maximum total cost, weight, and volume occur. Although an RSP with a maximum is not a desirable selection, in order to expand our analysis, we use undesirable selection criteria.

First, we examine possible maximum total cost results, as introduced in Table 20. The first common observation among the maximum total cost coefficient combinations is that the cost coefficient is zero. In most of the maximum cost points, only either weight or a volume criterion is emphasized. For 7 day F-15 and KC-135, and 30-day KC-135 deployments, the maximum total cost requires a combination of non-zero weight and volume coefficients.

Table 20. Possible Maximum Total Cost Results of Each Solution Set.

Deployment Solution Sets			**Coefficients of**			**Percentage Change Compare to Cost Based Analysis**		
A/C Type	***Dep. Days***	***Availability (%)***	***Cost***	***Weight***	***Volume***	***Total Cost (%)***	***Total Weight (%)***	***Total Volume (%)***
F-16	7	90	0	1,2,3	0	12.34	-4.44	-3.38
F-16	30	90	0	1,2,3	0	6.29	-4.56	-3.07
KC-135	7	90	0	2	1	24.62	-22.55	-3.00
KC-135	30	90	0	1,2,3	1,2,3	11.62	-20.93	-6.06
F-15	7	90	0	1	2	11.38	-8.00	-12.15
F-15	30	90	0	0	1,2,3	15.35	-5.00	-12.53
B-52	7	90	0	0	1,2,3	15.45	-2.55	-14.03
B-52	30	90	0	0	1,2,3	14.57	0.62	-9.90
B-52	30	70	0	0	1,2,3	31.64	-1.50	-22.22
B-52	30	50	0	0	1,2,3	41.99	-2.90	-11.78

We then examine maximum total weight results (See Table 21). Similar to maximum total cost results, the maximum total weight occurs at combinations where the weight coefficient is zero. The majority of maximum total weight results occur where the cost coefficient was 1,2, or 3 and weight and volume coefficients are zero. Recall that this is equivalent to pure cost based calculations. This result shows that, because the USAF currently calculates the RSPs using pure cost optimization, the majority of the RSPs built are heavier than they can be.

Table 21. Maximum Total Weight Results of Each Solution Set.

Deployment Solution Sets			**Coefficients of**			**Percentage Change Compare to Cost Based Analysis**		
A/C Type	***Dep. Days***	***Availability (%)***	***Cost***	***Weight***	***Volume***	***Total Cost (%)***	***Total Weight (%)***	***Total Volume (%)***
F-16	7	90	1,2,3	0	0	0.00	0.00	0.00
F-16	30	90	1,2,3	0	0	0.00	0.00	0.00
KC-135	7	90	0	0	1,2,3	14.52	3.50	-9.25
KC-135	30	90	0	0	1,2,3	8.61	6.56	-8.71
F-15	7	90	1,2,3	0	0	0.00	0.00	0.00
F-15	30	90	1,2,3	0	0	0.00	0.00	0.00
B-52	7	90	1,2,3	0	0	0.00	0.00	0.00
B-52	30	90	0	0	1,2,3	14.57	0.62	-9.90
B-52	30	70	1,2,3	0	0	0.00	0.00	0.00
B-52	30	50	1,2,3	0	0	0.00	0.00	0.00

For KC-135 and B-52 30 day deployment calculations, the maximum total weight results require an emphasis on the volume criteria. The pure volume based calculations give an increased amount of total cost and weight compared to pure cost based analysis.

We examine the possible maximum total volumes as the last part of this analysis. The maximum total cost results are summarized in Table 22. All the maximum total volume results, except KC-135 7-day deployment results, occur at the combinations where the volume coefficient is zero. Only in KC-135 7-day deployment calculations does the maximum occur at a combination of non-zero weight and volume coefficients, with more emphasis on the weight criterion.

Table 22. Possible Maximum Total Volume Results of Each Solution Set.

Deployment Solution Sets			**Coefficients of**			**Percentage Change Compare to Cost Based Analysis**		
A/C Type	***Dep. Days***	***Availability (%)***	***Cost***	***Weight***	***Volume***	***Total Cost (%)***	***Total Weight (%)***	***Total Volume (%)***
F-16	7	90	1,2,3	0	0	0.00	0.00	0.00
F-16	30	90	1,2,3	0	0	0.00	0.00	0.00
KC-135	7	90	0	3	1	24.00	-21.02	3.64
KC-135	30	90	1,2,3	0	0	0.00	0.00	0.00
F-15	7	90	1,2,3	0	0	0.00	0.00	0.00
F-15	30	90	1,2,3	0	0	0.00	0.00	0.00
B-52	7	90	1,2,3	0	0	0.00	0.00	0.00
B-52	30	50	1,2,3	0	0	0.00	0.00	0.00
B-52	30	70	1,2,3	0	0	0.00	0.00	0.00
B-52	30	90	1,2,3	0	0	0.00	0.00	0.00

Similar to the maximum total weight results, the maximum total volume results occur at coefficient combinations 1,0,0, 2,0,0, or 3,0,0; which are all equivalent to pure cost based analysis. Again we note that using pure cost based analysis to build RSPs, probably gives the bulkiest RSPs.

In conclusion to this part of our analysis, we observe that majority of the set maximum total cost, weight, and volume happens where the related coefficients are zero. Another important observation is that the maximum weight and volume occur at pure cost based analysis, which is currently used for RSP calculations. Overall, although we observe some commonality in the coefficient combinations, the required combinations for maximum totals may vary between different scenarios and aircraft types.

3. Coefficients Combinations Where The Total Deviation From The Possible Minimums Are Minimum

In our experimental design we have 63 RSPs for each of 10 different deployment scenarios, as defined in the *Treatment Groups 5* and *6*. All of the 63 RSPs satisfy the requirements of the deployment that they belong to. We want to select the RSPs with total cost, weight, and volume that best suit our objective. Because our objectives might vary, the selection criteria will vary also. In Chapter IV.D.1 and 2, for analysis we select the RSPs with the minimum and maximum totals in an RSP solution set. The set maximums are undesirable results, although we can use the set minimums, if we are concerned only with reducing one of the totals. For example, if we want to reduce airlift payload only, then we select the RSP with the minimum total weight.

Another possible selection objective might be to minimize all three totals at the same time for a better trade-off between three optimization criteria. In this part of analysis our objective is to minimize total cost, weight, and volume of the RSPs at the same time. In addition, as an undesirable selection objective, we maximize the totals simultaneously.

In Chapter III.E we introduced a method that we adapted from spreadsheet multiple objective linear programming (MOLP). Using this method, we again analyze the results of our experiment.

In Table 23, we summarize the coefficient combinations with the minimum total deviation for 10 deployment scenarios. When we look at the percentage deviations in compare to pure cost based analysis, we see that the total cost deviation range is narrowed to 1.84 and 6.83 percent. Similarly the deviation range of total weight and volume are narrowed, too. If our objective is to reduce one of the three totals, these solutions are not the best ones. But, if we want a balanced trade-off between three totals, this selection criterion works better.

Table 23. Results with minimum total deviation from minimums

Deployment Solution Sets			**Coefficients of**			**Percentage Change Compare to Cost Based Analysis**		
A/C Type	***Dep. Days***	***Availability (%)***	***Cost***	***Weight***	***Volume***	***Total Cost (%)***	***Total Weight (%)***	***Total Volume (%)***
F-16	7	90	2	2	1	3.13	-3.89	-4.31
F-16	30	90	2	3	2	1.84	-4.07	-3.49
KC-135	7	90	2	2	3	6.83	-17.21	-8.64
KC-135	30	90	2	2	1	2.94	-18.58	-6.05
F-15	7	90	2	3	3	4.40	-9.97	-14.00
F-15	30	90	3	1	2	1.85	-8.28	-10.81
B-52	7	90	3	3	2	3.05	-4.78	-11.68
B-52	30	50	2	2	1	3.15	-5.62	-9.34
B-52	30	70	3	2	2	3.50	-5.92	-18.08
B-52	30	90	2	3	1	2.27	-3.24	-7.13

The least deviation results give a better return on investment in terms of cost increase versus decrease in total weight or volume compared to set minimums. For example for the KC-135, 7-day, 90 percent deployment scenario, if we select the RSP with the minimum total cost, we have to pay 18.90 percent more than what we normally would pay from pure cost based calculations, to reduce the total weight 23.16 percent (See Table 18). In other words for every one-percent increase in total cost we achieve a 1.22- percent reduction in total weight. If we select the RSP with the minimum total deviation for the same scenario, we pay 6.83 percent more than what we normally pay, to reduce the total weight 17.21 percent (See Table 23). I.e., for each one-percent increase in total cost we achieve a 2.51 percent reduction in total weight. 2.51 percent is a better return compared to 1.22 percent for every one-percent cost increase.

We find that no single coefficient combination gives RSPs with the least deviated total, cost, weight, and volume from their set minimums. But there is one common observation-- in all cases, the three coefficients are greater than zero.

For the worst case scenario, we select the RSPs with the most total deviations from the set minimums (See Table 24). A notable observation from the maximum deviations is that, except for one, all occur at either pure cost or pure volume optimization. For four out of ten deployment-result sets, the maximum total deviation occurs at pure cost based analysis.

When we examine the other six results, we see that they return a worse trade-off ratio than possible minimum total cost, weight, and volume results. For example for the B-52, 30-day, 70 percent deployment scenario we pay 31.64 percent more than what we normally pay from pure cost based analysis, to reduce the RSP total volume 22.22

percent (See Table 24). I.e., for each one-percent increase in total cost we obtain a 0.70-percent reduction in volume. But, if we want to reduce total volume, we would pay 23.77 percent more than we normally pay, to reduce total volume 23.74 percent, by selecting the possible minimum volume for the same scenario (See Table 19). In other words, for each one-percent increase in total cost, we obtain 0.99-percent reduction in total volume, which is better than 0.70 percent. Therefore, in maximum deviation results, we pay more for less. The same comparison can be expanded for all results in Table 24.

Table 24. Results with maximum total deviation from minimums.

Deployment Solution Sets			**Coefficients of**			**Percentage Change Compare to Cost Based Analysis**		
A/C Type	***Dep. Days***	***Availability (%)***	***Cost***	***Weight***	***Volume***	***Total Cost (%)***	***Total Weight (%)***	***Total Volume (%)***
F-16	7	90	0	3	1	12.20	-2.52	-2.87
F-16	30	90	1,2,3	0	0	0.00	0.00	0.00
KC-135	7	90	0	0	1,2,3	14.52	3.50	-9.25
KC-135	30	90	0	0	1,2,3	8.61	6.56	-8.71
F-15	7	90	1,2,3	0	0	0.00	0.00	0.00
F-15	30	90	1,2,3	0	0	0.00	0.00	0.00
B-52	7	90	1,2,3	0	0	0.00	0.00	0.00
B-52	30	50	0	0	1,2,3	41.99	-2.90	-11.78
B-52	30	70	0	0	1,2,3	31.64	-1.50	-22.22
B-52	30	90	0	0	1,2,3	14.57	0.62	-9.90

In conclusion, the method we adapt from MOLP helps us select RSPs with balanced trade-off ratios between total cost, weight, and volume. By changing the total deviation equation, we can use this method differently. For example if we exclude

$d_{weights}$ from Equation (14), we can select the RSP that has the minimum total deviation from minimum possible cost and volume. This method gives a better return on investment ratio between total cost and volume, yet with a worse return on investment ratio between total cost and weight.

E. Impact Of The Use Of Alternative Criteria

We now aim to show the impact of different selection methods based on three criteria marginal analysis, compared to the classical cost based selection method. It is easier to visualize the impact of alternative criteria on RSP selection process, if we talk in terms of airlift assets and measures.

We consider a large-scale deployment scenario in which F-15, F-16, B-52 and KC-135 aircraft get involved. Because these aircraft participated in the Gulf War, for our deployment scenario we use the numbers from Gulf War statistics (See Table 25). We simply divide the number of aircraft to fleet sizes that we use in experimental ASM calculations and round the result to define the number of fleets in our scenario.

Table 25. Aircraft Numbers for the Deployment Scenario (AFA, 1991)

Aircraft	*Number of Aircraft Joined to Gulf War*	*Fleet Size Used in This Thesis*	*Number of Fleets Used in Deployment Scenario*
KC-135	194	10	19
B-52	36	8	4
F-16	212	18	12
F-15 / F-15E	144	24	6

We make some assumptions to simplify the calculations. We assume that all deployment aircraft are deployed simultaneously. The maintenance resources of the fleets do not affect each other and there is no lateral supply chain. Each fleet has its own RSP for a 30-day period. For all fleets, the deployment requires 90 percent aircraft availability level at the end of 30-day period.

After the assumptions and definition of aircraft numbers, by using 7 different selection methods, we select RSPs for each aircraft that satisfies the scenario. Then we calculate total cost, weight, and volume of the RSPs for all-deploying aircraft. The selections methods are cost based analysis, the minimum total cost, weight and volume, the minimum deviation of totals, the minimum deviation of total cost and volume, and the minimum deviation of total cost and weight from possible minimums.

We assume that cargo is carried either with C-17 or C-141 cargo aircraft. All cargo aircraft are loaded only with deployment RSPs. The characteristics of C-17 and C-141 that we use in the analysis are summarized in Table 26. We calculate the volume capacity of the aircraft by simply multiplying the cargo compartment dimensions.

Table 26. Cargo aircraft characteristics.

Aircraft	***Cargo Compartment***			***Volume Capacity***	***Payload***
	Height	***Width***	***Length***	**(cu inch)**	***(lbs)***
C-141	9 ft 1 inch	10 ft 3 inch	93 ft 4 inch	15,015,840	68,725
C-17	12 ft 4 inch	18 ft 3 inch	85 ft 2 inch	33,125,064	168,500

For cargo loading, we use three level volume utilization rates. High utilization of cargo caused gross-out before cube-out. But, in real life, we usually expect to cube-out, before gross-out (AFELM, 2000). For a more realistic analysis, we use 100, 80, and 60 percent utilization rates for volume capacity.

After defining the airlift assets, by using the total deployment RSP cost, weight, and volume of 7 selection methods, we calculate how many C-17 or C-141 aircraft are needed for shipment. We also calculate the difference in the total cost, weight, and volume compared to cost based analysis (See Table 27).

Table 27. Deployment results and cargo aircraft requirements.

		Cost based analysis	Minimum Cost	Minimum Weight	Minimum Volume	Minimum Deviation	Minimum Deviation for Cost & Volume	Minimum Deviation for Cost & Weight
Deployment	Total Cost ($)	355,330,579	354,408,687	381,434,913	381,324,280	363,341,449	359,096,614	360,599,260
	Total Weight (lbs.)	1,247,205	1,165,543	1,084,606	1,219,904	1,111,335	1,189,597	1,115,174
	Total Volume (cu inch)	186,603,173	180,757,709	176,849,982	169,551,239	174,709,387	171,943,788	177,054,071
Compare to cost based analysis results	Cost Change ($)	-	(921,891)	26,104,334	25,993,701	8,010,870	3,766,036	5,268,681
	Weight Change (lbs.)	-	(81,661)	(162,599)	(27,301)	(135,870)	(57,608)	(132,031)
	Volume Change (cu inch)	-	(5,845,463)	(9,753,191)	(17,051,934)	(11,893,786)	(14,659,384)	(9,549,102)
100% volume utilization	# of C-17	7.40	6.92	6.44	7.24	6.60	7.06	6.62
	# of C-141	18.15	16.96	15.78	17.75	16.17	17.31	16.23
80% volume utilization	# of C-17	7.40	6.92	**6.67**	7.24	6.60	7.06	**6.68**
	# of C-141	18.15	16.96	15.78	17.75	16.17	17.31	16.23
60% volume utilization	# of C-17	**9.39**	**9.09**	**8.90**	**8.53**	**8.79**	**8.65**	**8.91**
	# of C-141	**20.71**	**20.06**	**19.63**	**18.82**	**19.39**	**19.08**	**19.65**

Note: The bolded numbers identify that aircraft cube-out, before gross-out.

When we look at the results, we see that for 100 percent volume capacity utilization all and 80 percent utilization most of the cargo load will gross-out, before it cubes-out. As a result, reducing the cargo weight is advantageous. At 60 percent volume utilization, all of the cargo load cubed-out before grossed-out. For 60 percent utilization case the selection methods that reduces the cargo volume are advantageous.

Different selection methods give some reductions in the required cargo aircraft number. For C-17, the reduction ranges from 0.16 to 0.96 aircraft at 100 percent, 0.16 to 0.81 aircraft at 80 percent, and 0.48 to 0.86 aircraft at 60 percent volume utilization. For C-141, the reduction ranges from 0.40 to 2.37 aircraft at 100 and 80 percent, and 1.06 to 1.89 aircraft at 60 percent volume utilization.

Although we have reductions in the required amount of airlift assets, there is a related cost. The cost increase ranges between $3.7 to $26.1 million. The cost increase is high compared to the decrease in the number of required cargo aircraft. Although the cost fact makes the use of alternative criteria unattractive over cost based RSP calculations the method still gives extra power to planners. There might be times that saving one cargo aircraft load is worth the added cost.

Another notable gain happens when we select RSPs with the minimum total costs. Although this selection method does not allow us to substantially reduce the number of required airlift assets, it gives us an extra reduction in the total cost, and some reduction in total weight and volume.

In this chapter, we analyzed the results of the experimental ASM calculations. We looked at the coefficient effects on the total cost, weight, and volume response variables. Then we examined the response sensitivity of these totals to different activity levels and availability levels. After this basic analysis, we looked for favorable coefficient combinations for different situations and translated the results in terms of airlift assets and measures. In Chapter IV, we summarize the general results of the research and give recommendations.

V. Conclusions And Recommendations

This thesis aims to reduce airlift load due to the readiness spare packages (RSP) by the implementation of airlift criteria into RSP selection process. We define four research questions in Chapter I and seek answers through a literature review and an experimental design with the Aircraft Sustainability Model (ASM). In this chapter, we now summarize our conclusions and recommendations.

A. Conclusions

1. Research Question 1

The first research question is "What airlift criteria affect the RSP selection in terms of airlift capacity?" To answer this question we review the methodology used for RSP selection and airlift constraints related to RSP air transportation. We look at the pallet loading problem constraints. The reason we select the pallet loading problem is its being at the operational level where the airlift information is most disaggregated. After the examination of pallet loading problem constraints, we reduced the scope of this thesis to three airlift criteria that we use in RSP selection.

We select item weight and volume as airlift criteria. We keep cost as selection criterion along with weight and volume criteria. We aim to optimize the RSPs for three objectives. These three objectives are minimizing total cost, weight, and volume of the RSPs.

2. <u>Research Question 2</u>

The second research question is "How can we apply these airlift criteria to the RSP selection process?" To implement cost, weight, and volume criteria to the RSP selection, we follow a similar approach to Peterson's study on the same subject (2000). Current mathematical models for RSP selection use a cost based marginal analysis. This methodology employs a value function based on aircraft availability and item cost. In their study, Peterson replaced the item cost with combinations of item cost, weight and volume data in the value function. By multiplying the cost, weight, and volume data with coefficients they define different emphasis for each criteria.

We use the same method to implement three airlift criteria, yet we normalize cost, weight, and volume data to their averages, before we use them in the value function. The reason we normalize the data is that the respective scales of three data type are different. The emphasis coefficients that we use would make a different effect on each, because cost, weight, and volume data ranges in different scales. By normalizing the data we reduce this undesirable effect.

3. <u>Research Question 3</u>

The third research question is "How does the application of these criteria affect the RSPs?" To answer this question, we build an experimental design in which we calculate a series of RSPs for different deployment scenario.

First, we examine the individual effect of each criterion on the total cost, weight, and volume of the RSPs. One conclusion is that the emphasis increase on the criteria causes a positive response (decrease) on the related total. For example if we increase the emphasis for weight, the total weight of the calculated RSPs reduces. Our second conclusion is that the effect of each criterion on the other two criteria changes according to correlation between the criteria. For example, if weight and volume data are highly correlated, the emphasis change on either criterion effects the total weight and volume the same way. Yet, if weight and volume data have low correlation, a trade-off happens. Then, for example an emphasis increase on weight causes an increase in total volume, and a decrease on total weight of the RSPs. At some cases where there is low correlation, the emphasis change on a criterion might not have effect on the other totals.

After the individual criterion effects, we examine the total cost, weight, and volume response to different levels of deployment activity requirements. We define the deployment activity as the combination of flight schedule and availability requirements. As a result of our analysis, we conclude that the total cost, weight, and volume are not responsive to different emphasis coefficient combinations at low activity levels. In our experiment the totals do not respond until 70 percent availability and 2 flight hours per day per aircraft. The totals start to respond over 80 percent availability and 3 flight hours per day per aircraft.

For the third part of our analysis, we examine the response of totals to changing coefficient combinations at different aircraft availability requirements, while holding the flight schedule constant. We define three availability levels as 50, 70, and 90 percent. The totals respond to changing coefficients at all availability levels, but we observe a decrease on the response at 50 percent availability level. We conclude that the response of totals to different coefficient combinations reduces or diminishes as the flight hour and/or availability requirements decrease. We expect high activity levels in actual deployment scenarios, hence for at actual deployment RSP calculations, the totals should be in the responsive region.

4. <u>Research Question 4</u>

The last research question is "How can we build RSPs that better suit the airlift capacity by using these airlift criteria?" To answer this question we define 10 different deployment scenarios. For each scenario, we build solution sets that consist 63 different RSPs, based on different coefficient combinations. Then we define some desirable and undesirable optimization objectives. We look at the coefficient combinations that give us the RSPs that satisfy the optimization objectives.

We conclude that there is not a single coefficient combination that satisfies an optimization objective in all cases. When we want to minimize total cost, weight, or volume, single (pure) criterion analysis gives the best result among the 63-RSP solution set in most cases. In a few cases some combination of two or three criteria gives the minimum totals in the solution set. This is an important finding, because this way, for some cases we can reduce total cost more than we can do with pure cost based analysis, which is the approach currently in USAF use.

We obtain a balanced trade off between three totals by employing a selection method that we adopt from multiple objectives linear programming (MOLP). This method locates the minimum total cost, weight, and volume in a solution set. Then it selects the RSP with the least deviated totals from the set minimums. This way we aim to minimize all three totals at the same time. In Chapter IV, we show that this method gives a better trade-off between three totals.

After evaluation of the selection objectives, we conclude that pure cost based optimization gives quite undesirable total weight and volume values in the solution sets. When we use three criteria at the same time we can reduce the total weight and volume of RSPs. But, there is a cost trade-off for this reduction in airlift load. We find that the increase in cost is high compared to the airlift load reduction.

With this high cost increase the use of cost, weight, and volume criteria to reduce airlift load seems unattractive. Nevertheless, we find the application of three criteria is useful to minimize the total cost of RSPs. By using three criteria based analysis, we can build some RSPs cheaper than by using pure cost based analysis. For RSP selection, we recommend a method that builds a set of RSPs that satisfy the same deployment scenario and selects the cheapest RSP in the set.

Although the use of three criteria to reduce airlift load increases cost a lot, this method gives extra power to planners. By building a set of different RSPs that satisfy the scenario, the planners can select the RSP from the set that best suits their situation. Furthermore, if the RSPs are built from items already purchased (in stock), by employing three criteria based analysis, planners can reduce airlift load without incurring extra cost.

B. Recommendations

1. Expansion of the Aircraft Sustainability Model

The ASM software is designed for cost based analysis. As a result the implementation of three simultaneous criteria requires the manipulation of the kit databases. This process takes time and, for multiple calculations with different coefficient combinations, is quite demanding.

For RSP calculations, each ASM run takes a short CPU time. Therefore, an additional code that enables the ASM to produce multiple RSPs that satisfy the same deployment requirements would be much faster than manual manipulation. Besides, this capability would permit deeper experimentation of three criteria based analysis. We highly recommend automating the ASM, for further research on the subject. This automation will save a lot of effort and research time.

2. Future Research

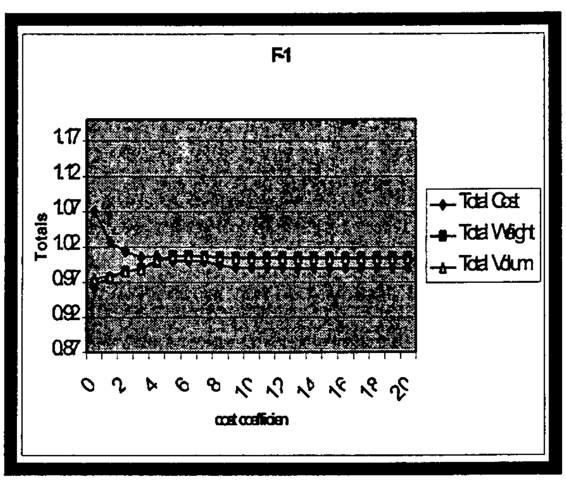
We recommend further research to focus on how three criteria based analysis can reduce RSP. Another possible research subject is to study the effect of this method, when it is used to build RSPs from items already in stock.

If the three criteria based analysis is implemented in the ASM code, more detailed analysis can be done with larger experimental designs. The statistical analysis tools such as regression or response surface methods can be used with a larger number of treatments, to define the mathematical relation of three criteria and the total cost, weight, and volume.

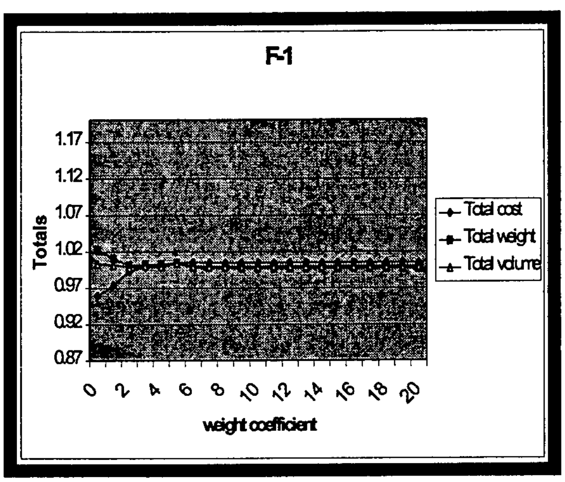
In this chapter, we summarized our answers to the research questions. Then in light of our findings, we gave our recommendations for incorporating three criteria based marginal analysis into the ASM software and conducting future research on the subject.

Appendix A: Coefficient Effects on Total Cost, Weight, And Volume

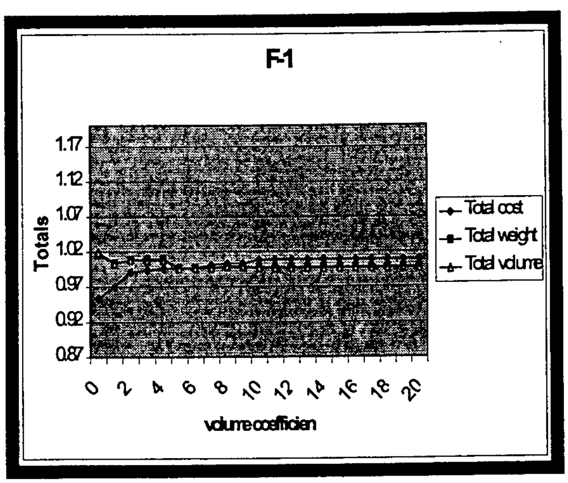
F-16 AIRCRAFT / RESPONSE OF TOTAL COST, WEIGHT, AND VOLUME TO COST COEFFICIENT								
Coefficient of			Responses			Normalized Values (Value / Average Value)		
Cost	*Weight*	*Volume*	*Total Cost ($)*	*Total Weight (lbs)*	*Total Volume (Cu inch)*	*Total Cost*	*Total Weight*	*Total Volume*
0	1	1	7,864,476	14,750	2,624,294	1.070892265	0.967477583	0.974980274
1	1	1	7,544,592	14,876	2,633,449	1.027334201	0.975724433	0.978381535
2	1	1	7,442,856	15,029	2,653,004	1.013480911	0.985789486	0.985646627
3	1	1	7,384,753	15,077	2,659,434	1.005569121	0.988954288	0.988035325
4	1	1	7,397,887	15,217	2,696,706	1.007357607	0.998097777	1.001882703
5	1	1	7,350,213	15,349	2,710,277	1.000865865	1.006742769	1.006924614
6	1	1	7,350,213	15,349	2,710,277	1.000865865	1.006742769	1.006924614
7	1	1	7,344,977	15,346	2,709,746	1.000152956	1.006598467	1.00672748
8	1	1	7,302,349	15,335	2,706,743	0.99434841	1.005844162	1.005611803
9	1	1	7,273,458	15,318	2,702,101	0.990414335	1.004729102	1.003887203
10	1	1	7,273,458	15,318	2,702,101	0.990414335	1.004729102	1.003887203
11	1	1	7,275,160	15,326	2,703,089	0.990646017	1.005253836	1.004254265
12	1	1	7,275,160	15,326	2,703,089	0.990646017	1.005253836	1.004254265
13	1	1	7,267,464	15,317	2,701,073	0.989598122	1.004663511	1.003505279
14	1	1	7,267,464	15,317	2,701,073	0.989598122	1.004663511	1.003505279
15	1	1	7,267,464	15,317	2,701,073	0.989598122	1.004663511	1.003505279
16	1	1	7,267,798	15,319	2,701,375	0.989643546	1.004814372	1.003617251
17	1	1	7,267,798	15,319	2,701,375	0.989643546	1.004814372	1.003617251
18	1	1	7,267,798	15,319	2,701,375	0.989643546	1.004814372	1.003617251
19	1	1	7,267,798	15,319	2,701,375	0.989643546	1.004814372	1.003617251
20	1	1	7,267,798	15,319	2,701,375	0.989643546	1.004814372	1.003617251
Average Value			7,343,854	15,246	2,691,638			



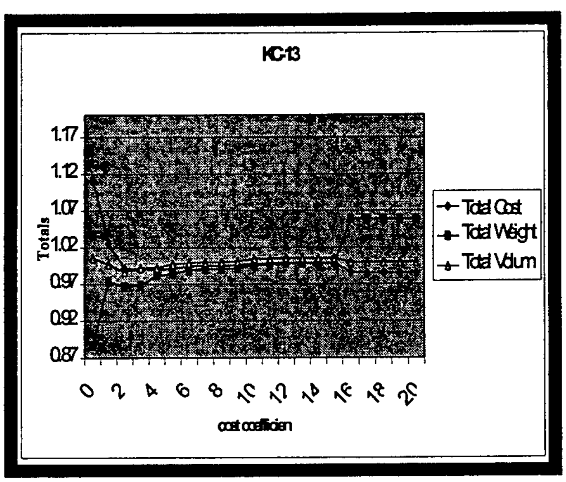
F-16 AIRCRAFT / RESPONSE OF TOTAL COST, WEIGHT, AND VOLUME TO COST COEFFICIENT								
Coefficient of			Responses			Normalized Values (Value / Average Value)		
Cost	*Weight*	*Volume*	*Total Cost ($)*	*Total Weight (lbs)*	*Total Volume (Cu inch)*	*Total Cost*	*Total Weight*	*Total Volume*
1	0	1	7,430,639	15,046	2,637,491	0.958871385	1.02234691	1.003012723
1	1	1	7,544,592	14,876	2,633,449	0.973576219	1.010745137	1.001475821
1	2	1	7,694,428	14,734	2,625,732	0.992911532	1.001090015	0.998540806
1	3	1	7,742,943	14,753	2,631,055	0.999172038	1.002419718	1.000565325
1	4	1	7,739,253	14,748	2,630,474	0.998695766	1.002059604	1.000344229
1	5	1	7,784,866	14,780	2,640,205	1.00458184	1.004240669	1.004044836
1	6	1	7,790,289	14,691	2,629,895	1.005281682	0.998213862	1.000124041
1	7	1	7,788,254	14,681	2,628,605	1.005019076	0.997514019	0.999633699
1	8	1	7,788,254	14,681	2,628,605	1.005019076	0.997514019	0.999633699
1	9	1	7,786,485	14,675	2,628,275	1.004790765	0.997133522	0.999508204
1	10	1	7,785,033	14,673	2,627,414	1.004603441	0.996950067	0.999180726
1	11	1	7,786,151	14,673	2,627,974	1.004747718	0.996977246	0.999393589
1	12	1	7,786,151	14,673	2,627,974	1.004747718	0.996977246	0.999393589
1	13	1	7,786,151	14,673	2,627,974	1.004747718	0.996977246	0.999393589
1	14	1	7,786,151	14,673	2,627,974	1.004747718	0.996977246	0.999393589
1	15	1	7,786,151	14,673	2,627,974	1.004747718	0.996977246	0.999393589
1	16	1	7,786,151	14,673	2,627,974	1.004747718	0.996977246	0.999393589
1	17	1	7,786,151	14,673	2,627,974	1.004747718	0.996977246	0.999393589
1	18	1	7,786,151	14,673	2,627,974	1.004747718	0.996977246	0.999393589
1	19	1	7,786,151	14,673	2,627,974	1.004747718	0.996977246	0.999393589
1	20	1	7,786,151	14,673	2,627,974	1.004747718	0.996977246	0.999393589
Average Value			7,749,360	14,718	2,629,569			



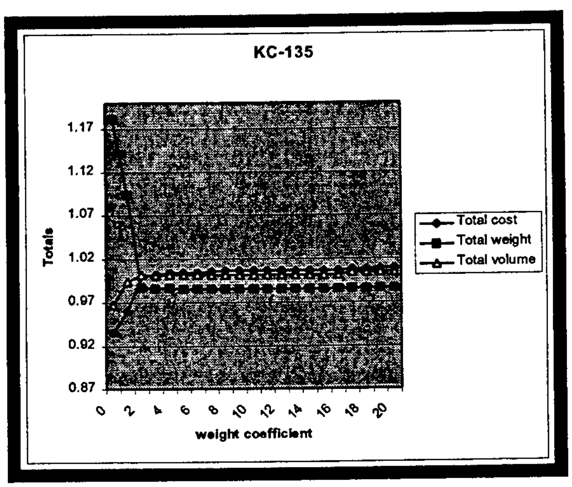
F-16 AIRCRAFT / RESPONSE OF TOTAL COST, WEIGHT, AND VOLUME TO VOLUME COEFFICIENT								
Coefficient of			**Responses**			**Normalized Values (Value / Average Value)**		
Cost	***Weight***	***Volume***	***Total Cost ($)***	***Total Weight (lbs)***	***Total Volume (Cu inch)***	***Total Cost***	***Total Weight***	***Total Volume***
1	1	0	7,413,294	15,060	2,675,400	0.953126219	1.015629149	1.019595415
1	1	1	7,544,592	14,876	2,633,449	0.970007228	1.003220169	1.003607931
1	1	2	7,703,185	14,940	2,645,423	0.990397498	1.007549824	1.008171243
1	1	3	7,724,827	14,958	2,643,517	0.993180038	1.008797466	1.007444826
1	1	4	7,744,722	14,964	2,645,029	0.99573794	1.009181874	1.008021049
1	1	5	7,750,156	14,771	2,615,075	0.996436583	0.996165933	0.996605576
1	1	6	7,750,156	14,771	2,615,075	0.996436583	0.996165933	0.996605576
1	1	7	7,782,348	14,779	2,615,075	1.000575503	0.996696687	0.996605576
1	1	8	7,799,005	14,793	2,620,700	1.002717028	0.997640849	0.998749264
1	1	9	7,799,005	14,793	2,620,700	1.002717028	0.997640849	0.998749264
1	1	10	7,843,493	14,784	2,615,696	1.008436815	0.997060864	0.996842239
1	1	11	7,843,493	14,784	2,615,696	1.008436815	0.997060864	0.996842239
1	1	12	7,848,560	14,790	2,615,865	1.009088303	0.997465504	0.996906645
1	1	13	7,848,560	14,790	2,615,865	1.009088303	0.997465504	0.996906645
1	1	14	7,848,560	14,790	2,615,865	1.009088303	0.997465504	0.996906645
1	1	15	7,848,560	14,790	2,615,865	1.009088303	0.997465504	0.996906645
1	1	16	7,848,560	14,790	2,615,865	1.009088303	0.997465504	0.996906645
1	1	17	7,848,560	14,790	2,615,865	1.009088303	0.997465504	0.996906645
1	1	18	7,848,560	14,790	2,615,865	1.009088303	0.997465504	0.996906645
1	1	19	7,848,560	14,790	2,615,865	1.009088303	0.997465504	0.996906645
1	1	20	7,848,560	14,790	2,615,865	1.009088303	0.997465504	0.996906645
Average Value			7,777,872	14,828	2,623,982			



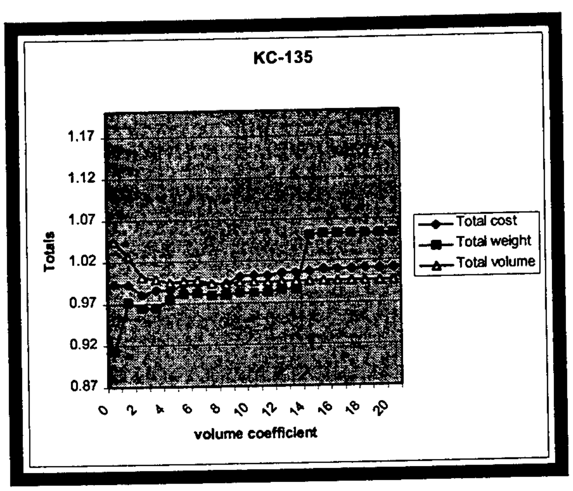
KC-135 AIRCRAFT / RESPONSE OF TOTAL COST, WEIGHT, AND VOLUME TO COST COEFFICIENT								
Coefficient of			**Responses**			**Normalized Values (Value / Average Value)**		
Cost	***Weight***	***Volume***	***Total Cost ($)***	***Total Weight (lbs)***	***Total Volume (Cu inch)***	***Total Cost***	***Total Weight***	***Total Volume***
0	1	1	6,070,394	23,693	3,534,853	1.111658393	0.886022487	1.005490332
1	1	1	5,598,866	26,048	3,504,474	1.025308476	0.974106275	0.99684911
2	1	1	5,418,176	25,847	3,469,251	0.992219049	0.966584026	0.986829845
3	1	1	5,410,918	25,894	3,487,311	0.99088993	0.96832295	0.991967048
4	1	1	5,407,768	26,235	3,489,135	0.990313079	0.981075059	0.992485886
5	1	1	5,414,662	26,324	3,504,946	0.991575543	0.984403322	0.996983331
6	1	1	5,428,387	26,457	3,510,726	0.994089048	0.989377018	0.998627454
7	1	1	5,435,791	26,493	3,514,466	0.995444822	0.990723282	0.999691299
8	1	1	5,432,165	26,490	3,514,136	0.994780826	0.990611093	0.99959743
9	1	1	5,438,415	26,511	3,519,761	0.995925396	0.991396414	1.001197464
10	1	1	5,449,443	26,642	3,531,476	0.99794486	0.996295317	1.004529889
11	1	1	5,449,443	26,642	3,531,476	0.99794486	0.996295317	1.004529889
12	1	1	5,453,857	26,688	3,534,052	0.998753216	0.998015543	1.005262633
13	1	1	5,453,857	26,688	3,534,052	0.998753216	0.998015543	1.005262633
14	1	1	5,453,857	26,688	3,534,052	0.998753216	0.998015543	1.005262633
15	1	1	5,453,857	26,688	3,534,052	0.998753216	0.998015543	1.005262633
16	1	1	5,385,974	28,309	3,515,774	0.986322032	1.058634804	1.000063226
17	1	1	5,379,534	28,306	3,515,646	0.985142705	1.058522616	1.000026816
18	1	1	5,379,534	28,306	3,515,646	0.985142705	1.058522616	1.000026816
19	1	1	5,379,534	28,306	3,515,646	0.985142705	1.058522616	1.000026816
20	1	1	5,379,534	28,306	3,515,646	0.985142705	1.058522616	1.000026816
Average Value			5,460,665	26,741	3,515,551			



KC-135 AIRCRAFT / RESPONSE OF TOTAL COST, WEIGHT, AND VOLUME TO WEIGHT COEFFICIENT								
Coefficient of			**Responses**			**Normalized Values (Value / Average Value)**		
Cost	***Weight***	***Volume***	***Total Cost ($)***	***Total Weight (lbs)***	***Total Volume (Cu inch)***	***Total Cost***	***Total Weight***	***Total Volume***
1	0	1	5,455,305	28,143	3,410,928	0.935310809	1.18186562	0.967246314
1	1	1	5,598,866	26,048	3,504,474	0.959924258	1.093900487	0.993773527
1	2	1	5,832,028	23,515	3,532,072	0.999899811	0.987525942	1.001599591
1	3	1	5,841,813	23,477	3,528,648	1.00157749	0.985913328	1.000628583
1	4	1	5,852,585	23,486	3,531,673	1.00342421	0.986295484	1.00148639
1	5	1	5,853,880	23,463	3,531,630	1.003646306	0.985330016	1.001474197
1	6	1	5,853,880	23,463	3,531,630	1.003646306	0.985330016	1.001474197
1	7	1	5,864,062	23,462	3,531,006	1.005392052	0.98529222	1.001297247
1	8	1	5,868,350	23,455	3,531,266	1.006127168	0.984998254	1.001370976
1	9	1	5,868,350	23,455	3,531,266	1.006127168	0.984998254	1.001370976
1	10	1	5,868,350	23,455	3,531,266	1.006127168	0.984998254	1.001370976
1	11	1	5,868,350	23,455	3,531,266	1.006127168	0.984998254	1.001370976
1	12	1	5,868,350	23,455	3,531,266	1.006127168	0.984998254	1.001370976
1	13	1	5,868,350	23,455	3,531,266	1.006127168	0.984998254	1.001370976
1	14	1	5,868,350	23,455	3,531,266	1.006127168	0.984998254	1.001370976
1	15	1	5,868,350	23,455	3,531,266	1.006127168	0.984998254	1.001370976
1	16	1	5,868,350	23,455	3,531,266	1.006127168	0.984998254	1.001370976
1	17	1	5,877,059	23,473	3,542,114	1.007620312	0.985754167	1.004447262
1	18	1	5,877,059	23,473	3,542,114	1.007620312	0.985754167	1.004447262
1	19	1	5,881,588	23,480	3,543,687	1.008396808	0.986027135	1.004893322
1	20	1	5,881,588	23,480	3,543,687	1.008396808	0.986027135	1.004893322
Average Value			5,832,612	23,812	3,526,431			



KC-135 AIRCRAFT / RESPONSE OF TOTAL COST, WEIGHT, AND VOLUME TO VOLUME COEFFICIENT								
Coefficient of			**Responses**			**Normalized Values (Value / Average Value)**		
Cost	***Weight***	***Volume***	***Total Cost ($)***	***Total Weight (lbs)***	***Total Volume (Cu inch)***	***Total Cost***	***Total Weight***	***Total Volume***
1	1	0	5,603,203	24,476	3,563,867	0.993632946	0.913158435	1.044449839
1	1	1	5,598,866	26,048	3,504,474	0.992863872	0.971806094	1.027043691
1	1	2	5,529,585	25,853	3,418,196	0.980578048	0.964506802	1.001758317
1	1	3	5,563,060	25,859	3,409,229	0.986514232	0.964726918	0.99913039
1	1	4	5,560,691	26,150	3,396,101	0.986094107	0.97558352	0.995283014
1	1	5	5,596,520	26,319	3,403,459	0.992447781	0.981888556	0.997439397
1	1	6	5,600,480	26,327	3,404,299	0.993150118	0.982220597	0.997685573
1	1	7	5,599,116	26,259	3,391,668	0.992908189	0.97967172	0.993983961
1	1	8	5,602,225	26,274	3,387,267	0.993459466	0.980231339	0.992694175
1	1	9	5,649,585	26,322	3,396,035	1.001857964	0.982022118	0.995263782
1	1	10	5,656,778	26,332	3,397,229	1.003133474	0.982395198	0.995613616
1	1	11	5,655,725	26,322	3,394,963	1.0029469	0.982022118	0.994949638
1	1	12	5,669,842	26,443	3,398,493	1.005450264	0.986536375	0.995984162
1	1	13	5,669,842	26,443	3,398,493	1.005450264	0.986536375	0.995984162
1	1	14	5,681,075	28,181	3,397,929	1.007442296	1.05137752	0.995818816
1	1	15	5,695,797	28,210	3,398,889	1.010052968	1.052459449	0.996100159
1	1	16	5,695,797	28,210	3,398,889	1.010052968	1.052459449	0.996100159
1	1	17	5,695,797	28,210	3,398,889	1.010052968	1.052459449	0.996100159
1	1	18	5,699,091	28,215	3,399,249	1.010637058	1.052645989	0.996205663
1	1	19	5,699,091	28,215	3,399,249	1.010637058	1.052645989	0.996205663
1	1	20	5,699,091	28,215	3,399,249	1.010637058	1.052645989	0.996205663
Average Value			5,639,108	26,804	3,412,196			



Appendix B: Sensitivity of coefficient effect to deployment activity level

KC-135 Aircraft Results

Fleet Size	10		
1st Analysis Day	5	2nd Analysis Day	30

Level	Aircraft Availability at 30th Day	Flight Hours per Day
Level 1	50 percent aircraft availability	1 hrs per aircraft per day
Level 2	60 percent aircraft availability	2 hrs per aircraft per day
Level 3	70 percent aircraft availability	3 hrs per aircraft per day
Level 4	80 percent aircraft availability	4 hrs per aircraft per day

	Coefficients of			Responses		
	Cost	*Weight*	*Volume*	*Total Cost ($)*	*Total Weight (lbs)*	*Total Volume (Cu inch)*
Level 1	2	0	2	308,454	7,679	1,012,853
	1	3	3	308,454	7,679	1,012,853
	3	2	2	308,454	7,679	1,012,853
	3	3	0	308,454	7,679	1,012,853
	0	3	0	308,454	7,679	1,012,853
	3	3	2	308,454	7,679	1,012,853
Level 2	2	0	2	308,454	7,679	1,012,853
	1	3	3	308,454	7,679	1,012,853
	3	2	2	308,454	7,679	1,012,853
	3	3	0	308,454	7,679	1,012,853
	0	3	0	308,454	7,679	1,012,853
	3	3	2	308,454	7,679	1,012,853
Level 3	2	0	2	458,548	8,007	1,061,996
	1	3	3	515,275	8,057	1,069,738
	3	2	2	458,548	8,007	1,061,996
	3	3	0	459,993	8,018	1,066,222
	0	3	0	515,459	7,944	1,060,093
	3	3	2	458,548	8,007	1,061,996
Level 4	2	0	2	2,301,160	16,302	1,859,041
	1	3	3	2,436,967	12,269	1,865,078
	3	2	2	2,320,022	12,664	1,874,830
	3	3	0	2,358,607	12,535	1,934,802
	0	3	0	2,537,555	12,161	1,901,483
	3	3	2	2,310,169	12,529	1,868,440

Appendix C: Experimental Deployment Scenario Results

F-16

Fleet Size	**18**		
1st Analysis Day	**4**	**2nd Analysis Day**	**7**
1st NMCS Target	**0.9**	**2nd NMCS Target**	**0.9**
1st Availability	**95%**	**2nd Availability**	**95%**

Flight **0-30 days; 5.25 hrs x 18 F-16s for each day**

Coefficients of			Responses			Percentage Deviation from Set Minimums			Total Deviation
Cost	Weight	Volume	Total Cost	Total Weight	Total Volume	d_1	d_2	d_3	d_t
2	2	1	$ 3.860.421	8.251	1.345.778	3.13%	0.58%	0.97%	4.67%
3	2	2	$ 3.860.421	8.251	1.345.778	3.13%	0.58%	0.97%	4.67%
3	3	2	$ 3.860.421	8.251	1.345.778	3.13%	0.58%	0.97%	4.67%
1	2	1	$ 3.884.925	8.231	1.340.866	3.78%	0.33%	0.60%	4.71%
2	3	1	$ 3.858.001	8.247	1.348.039	3.06%	0.54%	1.14%	4.73%
3	2	1	$ 3.851.526	8.258	1.350.380	2.89%	0.67%	1.31%	4.87%
1	1	1	$ 3.865.203	8.258	1.346.294	3.26%	0.66%	1.00%	4.92%
2	2	2	$ 3.865.203	8.258	1.346.294	3.26%	0.66%	1.00%	4.92%
3	2	3	$ 3.865.203	8.258	1.346.294	3.26%	0.66%	1.00%	4.92%
3	3	3	$ 3.865.203	8.258	1.346.294	3.26%	0.66%	1.00%	4.92%
2	3	3	$ 3.907.888	8.226	1.336.722	4.40%	0.28%	0.29%	4.96%
2	1	3	$ 3.874.910	8.286	1.339.645	3.51%	1.01%	0.51%	5.03%
2	2	3	$ 3.905.225	8.232	1.338.270	4.32%	0.35%	0.40%	5.08%
2	0	3	$ 3.876.100	8.291	1.339.289	3.55%	1.07%	0.48%	5.09%
2	3	2	$ 3.889.501	8.241	1.343.401	3.90%	0.46%	0.79%	5.15%
2	3	0	$ 3.855.484	8.260	1.353.373	3.00%	0.69%	1.54%	5.22%
3	1	1	$ 3.799.460	8.350	1.358.669	1.50%	1.80%	1.93%	5.23%
1	0	1	$ 3.873.597	8.294	1.342.033	3.48%	1.11%	0.68%	5.27%
2	0	2	$ 3.873.597	8.294	1.342.033	3.48%	1.11%	0.68%	5.27%
3	0	3	$ 3.873.597	8.294	1.342.033	3.48%	1.11%	0.68%	5.27%
1	2	2	$ 3.920.082	8.232	1.336.542	4.72%	0.36%	0.27%	5.35%
1	3	1	$ 3.915.813	8.230	1.340.031	4.61%	0.33%	0.53%	5.47%
1	0	2	$ 3.896.026	8.291	1.337.438	4.08%	1.07%	0.34%	5.49%
1	1	2	$ 3.926.340	8.237	1.336.063	4.89%	0.42%	0.24%	5.54%
1	3	3	$ 3.942.546	8.224	1.332.910	5.32%	0.25%	0.00%	5.57%
1	3	2	$ 3.933.241	8.224	1.336.446	5.07%	0.26%	0.27%	5.60%
3	1	3	$ 3.881.293	8.303	1.344.049	3.69%	1.22%	0.84%	5.74%
1	1	0	$ 3.857.818	8.272	1.358.098	3.06%	0.83%	1.89%	5.78%
2	2	0	$ 3.857.818	8.272	1.358.098	3.06%	0.83%	1.89%	5.78%
3	3	0	$ 3.857.818	8.272	1.358.098	3.06%	0.83%	1.89%	5.78%
1	1	3	$ 3.946.830	8.231	1.333.891	5.44%	0.34%	0.07%	5.85%
1	2	3	$ 3.946.830	8.231	1.333.891	5.44%	0.34%	0.07%	5.85%
3	3	1	$ 3.872.023	8.272	1.354.421	3.44%	0.83%	1.61%	5.88%
1	2	0	$ 3.875.238	8.275	1.355.474	3.52%	0.87%	1.69%	6.09%
1	3	0	$ 3.902.369	8.263	1.352.701	4.25%	0.73%	1.48%	6.46%
3	0	2	$ 3.840.773	8.384	1.364.639	2.60%	2.21%	2.38%	7.19%
2	1	2	$ 3.904.959	8.339	1.352.843	4.32%	1.65%	1.50%	7.46%
3	1	0	$ 3.799.080	8.412	1.380.524	1.49%	2.55%	3.57%	7.61%
1	0	3	$ 3.989.302	8.310	1.336.336	6.57%	1.30%	0.26%	8.13%
2	1	0	$ 3.816.601	8.418	1.381.985	1.96%	2.62%	3.68%	8.26%
3	1	2	$ 3.885.097	8.397	1.367.929	3.79%	2.36%	2.63%	8.78%
3	2	0	$ 3.838.318	8.452	1.390.383	2.54%	3.03%	4.31%	9.88%
1	0	0	$ 3.743.340	8.584	1.406.451	0.00%	4.65%	5.52%	10.16%
2	0	0	$ 3.743.340	8.584	1.406.451	0.00%	4.65%	5.52%	10.16%
3	0	0	$ 3.743.340	8.584	1.406.451	0.00%	4.65%	5.52%	10.16%
0	1	2	$ 4.075.554	8.289	1.336.807	8.87%	1.05%	0.29%	10.22%
0	2	3	$ 4.075.554	8.289	1.336.807	8.87%	1.05%	0.29%	10.22%
2	0	1	$ 3.831.000	8.530	1.384.778	2.34%	3.99%	3.89%	10.22%
2	1	1	$ 3.903.981	8.426	1.376.207	4.29%	2.71%	3.25%	10.25%
3	0	1	$ 3.819.180	8.554	1.391.681	2.03%	4.27%	4.41%	10.71%
0	1	1	$ 4.080.714	8.300	1.342.597	9.01%	1.18%	0.73%	10.92%
0	2	2	$ 4.080.714	8.300	1.342.597	9.01%	1.18%	0.73%	10.92%
0	3	3	$ 4.080.714	8.300	1.342.597	9.01%	1.18%	0.73%	10.92%
0	1	3	$ 4.121.237	8.376	1.344.646	10.10%	2.11%	0.88%	13.08%
0	1	0	$ 4.205.318	8.203	1.358.878	12.34%	0.00%	1.95%	14.29%
0	2	0	$ 4.205.318	8.203	1.358.878	12.34%	0.00%	1.95%	14.29%
0	3	0	$ 4.205.318	8.203	1.358.878	12.34%	0.00%	1.95%	14.29%
0	0	1	$ 4.155.527	8.404	1.347.087	11.01%	2.45%	1.06%	14.53%
0	0	2	$ 4.155.527	8.404	1.347.087	11.01%	2.45%	1.06%	14.53%
0	0	3	$ 4.155.527	8.404	1.347.087	11.01%	2.45%	1.06%	14.53%
0	3	2	$ 4.166.339	8.348	1.358.375	11.30%	1.76%	1.91%	14.98%
0	2	1	$ 4.196.909	8.365	1.365.091	12.12%	1.98%	2.41%	16.51%
0	3	1	$ 4.200.125	8.368	1.366.144	12.20%	2.01%	2.49%	16.71%
Set Maximums			$ 4.205.318	8.584	1.406.451	12.34%	4.65%	5.52%	16.71%
Set Minimums			$ 3.743.340	8.203	1.332.910	0.00%	0.00%	0.00%	4.67%
Difference			$ 461.978	381	73.541	12.34%	4.65%	5.52%	12.04%

F-16

Fleet Size	**18**		
1st Analysis Day	**5**	**2nd Analysis Day**	**30**
1st NMCS Target	**0.9**	**2nd NMCS Target**	**1.8**
1st Availability	**95%**	**2nd Availability**	**90%**

Flight Schedule **0-30 days; 5.25 hrs x 18 F-16s for each day**

Coefficients of			Responses			Percentage Deviation from Set Minimums			Total Deviation
Cost	Weight	Volume	Total Cost	Total Weight	Total Volume	d1	d2	d3	ds
2	3	2	$ 9.410.872	17.703	3.162.391	2.21%	0.76%	0.67%	3.65%
2	1	1	$ 9.276.653	17.893	3.175.290	0.75%	1.84%	1.08%	3.68%
3	1	2	$ 9.276.653	17.893	3.175.290	0.75%	1.84%	1.08%	3.68%
1	0	2	$ 9.303.086	17.886	3.169.336	1.04%	1.80%	0.89%	3.74%
2	3	1	$ 9.408.538	17.717	3.165.429	2.19%	0.84%	0.77%	3.80%
1	1	0	$ 9.270.168	17.866	3.186.572	0.68%	1.69%	1.44%	3.82%
2	2	0	$ 9.270.168	17.866	3.186.572	0.68%	1.69%	1.44%	3.82%
3	3	0	$ 9.270.168	17.866	3.186.572	0.68%	1.69%	1.44%	3.82%
2	0	3	$ 9.297.630	17.896	3.173.845	0.98%	1.86%	1.04%	3.88%
1	0	1	$ 9.297.964	17.898	3.174.146	0.99%	1.87%	1.05%	3.91%
2	0	2	$ 9.297.964	17.898	3.174.146	0.99%	1.87%	1.05%	3.91%
3	0	3	$ 9.297.964	17.898	3.174.146	0.99%	1.87%	1.05%	3.91%
1	1	2	$ 9.468.529	17.710	3.151.448	2.84%	0.81%	0.32%	3.97%
2	3	0	$ 9.389.789	17.732	3.175.297	1.98%	0.93%	1.08%	4.00%
3	1	3	$ 9.301.017	17.902	3.176.735	1.02%	1.89%	1.13%	4.04%
3	2	2	$ 9.297.775	17.905	3.178.370	0.98%	1.91%	1.18%	4.08%
2	1	2	$ 9.305.593	17.912	3.179.270	1.07%	1.95%	1.21%	4.23%
3	2	3	$ 9.305.593	17.912	3.179.270	1.07%	1.95%	1.21%	4.23%
3	1	1	$ 9.281.244	17.930	3.184.355	0.80%	2.06%	1.37%	4.23%
2	2	3	$ 9.464.963	17.738	3.162.655	2.80%	0.96%	0.68%	4.44%
1	3	1	$ 9.591.968	17.570	3.149.691	4.18%	0.00%	0.27%	4.45%
1	3	2	$ 9.591.968	17.570	3.149.691	4.18%	0.00%	0.27%	4.45%
1	2	1	$ 9.592.301	17.572	3.149.992	4.18%	0.02%	0.28%	4.48%
1	2	2	$ 9.592.301	17.572	3.149.992	4.18%	0.02%	0.28%	4.48%
1	2	3	$ 9.596.492	17.583	3.147.145	4.23%	0.08%	0.19%	4.50%
3	2	1	$ 9.314.432	17.919	3.183.995	1.16%	1.99%	1.36%	4.52%
2	1	3	$ 9.341.076	17.912	3.179.486	1.45%	1.95%	1.22%	4.63%
1	3	3	$ 9.613.495	17.576	3.148.134	4.41%	0.04%	0.22%	4.67%
2	1	0	$ 9.235.556	17.961	3.209.384	0.31%	2.23%	2.17%	4.71%
3	3	2	$ 9.329.612	17.933	3.186.610	1.33%	2.07%	1.44%	4.85%
3	3	1	$ 9.325.548	17.934	3.187.976	1.29%	2.08%	1.49%	4.85%
2	2	1	$ 9.333.367	17.941	3.188.876	1.37%	2.12%	1.52%	5.01%
1	2	0	$ 9.456.981	17.753	3.180.749	2.71%	1.05%	1.26%	5.02%
1	3	0	$ 9.599.563	17.615	3.166.517	4.26%	0.26%	0.80%	5.33%
1	1	3	$ 9.562.539	17.751	3.154.888	3.86%	1.03%	0.43%	5.33%
2	3	3	$ 9.521.779	17.762	3.167.532	3.42%	1.10%	0.84%	5.35%
2	0	1	$ 9.286.044	18.066	3.199.867	0.86%	2.83%	1.87%	5.55%
0	1	1	$ 9.709.294	17.569	3.145.107	5.45%	0.00%	0.12%	5.58%
0	2	2	$ 9.709.294	17.569	3.145.107	5.45%	0.00%	0.12%	5.58%
0	3	2	$ 9.709.294	17.569	3.145.107	5.45%	0.00%	0.12%	5.58%
0	3	3	$ 9.709.294	17.569	3.145.107	5.45%	0.00%	0.12%	5.58%
3	1	0	$ 9.207.182	18.097	3.225.731	0.00%	3.00%	2.69%	5.69%
0	1	2	$ 9.725.305	17.584	3.141.248	5.63%	0.08%	0.00%	5.71%
3	0	2	$ 9.302.715	18.071	3.200.924	1.04%	2.86%	1.90%	5.79%
0	1	3	$ 9.729.551	17.603	3.141.992	5.67%	0.19%	0.02%	5.89%
0	2	3	$ 9.730.347	17.605	3.146.593	5.68%	0.20%	0.17%	6.06%
0	2	1	$ 9.721.081	17.599	3.153.622	5.58%	0.17%	0.39%	6.15%
0	3	1	$ 9.723.415	17.611	3.158.347	5.61%	0.24%	0.54%	6.39%
1	1	1	$ 9.427.871	17.968	3.197.051	2.40%	2.27%	1.78%	6.44%
2	2	2	$ 9.427.871	17.968	3.197.051	2.40%	2.27%	1.78%	6.44%
3	3	3	$ 9.427.871	17.968	3.197.051	2.40%	2.27%	1.78%	6.44%
3	2	0	$ 9.315.043	18.060	3.221.052	1.17%	2.79%	2.54%	6.51%
0	0	1	$ 9.770.198	17.664	3.141.831	6.11%	0.54%	0.02%	6.68%
0	0	2	$ 9.770.198	17.664	3.141.831	6.11%	0.54%	0.02%	6.68%
0	0	3	$ 9.770.198	17.664	3.141.831	6.11%	0.54%	0.02%	6.68%
3	0	1	$ 9.281.477	18.200	3.233.260	0.81%	3.59%	2.93%	7.33%
1	0	3	$ 9.546.579	18.011	3.187.796	3.69%	2.52%	1.48%	7.68%
0	1	0	$ 9.821.359	17.613	3.176.187	6.67%	0.25%	1.11%	8.03%
0	2	0	$ 9.821.359	17.613	3.176.187	6.67%	0.25%	1.11%	8.03%
0	3	0	$ 9.821.359	17.613	3.176.187	6.67%	0.25%	1.11%	8.03%
1	0	0	$ 9.240.398	18.454	3.276.683	0.36%	5.04%	4.31%	9.71%
2	0	0	$ 9.240.398	18.454	3.276.683	0.36%	5.04%	4.31%	9.71%
3	0	0	$ 9.240.398	18.454	3.276.683	0.36%	5.04%	4.31%	9.71%
Set Maximums			$ 9.821.359	18.454	3.276.683	6.67%	5.04%	4.31%	9.71%
Set Minimums			$ 9.207.182	17.569	3.141.248	0.00%	0.00%	0.00%	3.65%
Difference			$ 614.177	885	135.435	6.67%	5.04%	4.31%	6.06%

KC-135

Fleet Size	**10**		
1st Analysis Day	**4**	**2nd Analysis Day**	**7**
1st NMCS Target	**0.5**	**2nd NMCS Target**	**1**
1st Availability	**95%**	**2nd Availability**	**90%**

Flight Schedule **0-7 days; 5.25 hrs x Fleet Size**

Coefficients of			Responses			Percentage Deviation from Set Minimums			Total Deviation
Cost	Weight	Volume	Total Cost	Total Weight	Total Volume	d1	d2	d3	ds
2	2	3	$ 2,975,241	16,293	2,149,183	6.83%	7.74%	0.89%	15.47%
2	3	3	$ 2,975,241	16,293	2,149,183	6.83%	7.74%	0.89%	15.47%
1	2	2	$ 2,978,599	16,290	2,148,220	6.95%	7.73%	0.85%	15.52%
1	1	3	$ 2,985,828	16,302	2,145,261	7.21%	7.81%	0.71%	15.72%
3	1	2	$ 2,964,591	16,340	2,159,688	6.45%	8.06%	1.39%	15.89%
2	1	3	$ 2,980,299	16,324	2,153,526	7.01%	7.95%	1.10%	16.06%
2	1	2	$ 2,976,920	16,325	2,156,401	6.89%	7.96%	1.23%	16.08%
1	1	2	$ 2,986,234	16,313	2,151,130	7.22%	7.88%	0.98%	16.09%
3	1	3	$ 2,977,400	16,333	2,157,016	6.91%	8.01%	1.26%	16.18%
1	2	3	$ 3,004,148	16,292	2,146,647	7.87%	7.74%	0.77%	16.38%
1	1	1	$ 2,981,313	16,335	2,159,612	7.05%	8.02%	1.38%	16.45%
2	2	2	$ 2,981,313	16,335	2,159,612	7.05%	8.02%	1.38%	16.45%
3	2	2	$ 2,981,313	16,335	2,159,612	7.05%	8.02%	1.38%	16.45%
3	2	3	$ 2,981,313	16,335	2,159,612	7.05%	8.02%	1.38%	16.45%
3	3	3	$ 2,981,313	16,335	2,159,612	7.05%	8.02%	1.38%	16.45%
2	3	2	$ 2,986,887	16,345	2,163,437	7.25%	8.09%	1.56%	16.90%
3	3	2	$ 2,986,887	16,345	2,163,437	7.25%	8.09%	1.56%	16.90%
1	2	1	$ 2,990,086	16,350	2,163,629	7.36%	8.12%	1.57%	17.06%
1	3	3	$ 3,028,058	16,315	2,151,417	8.73%	7.89%	1.00%	17.62%
1	3	2	$ 3,021,028	16,357	2,163,760	8.47%	8.17%	1.58%	18.22%
3	1	1	$ 2,851,321	16,415	2,291,240	2.38%	8.55%	7.56%	18.49%
0	2	3	$ 3,099,043	16,273	2,134,649	11.28%	7.62%	0.21%	19.10%
0	1	3	$ 3,108,161	16,311	2,130,678	11.60%	7.87%	0.02%	19.49%
0	1	2	$ 3,118,280	16,310	2,131,587	11.97%	7.86%	0.07%	19.89%
2	1	0	$ 2,872,269	16,458	2,305,251	3.13%	8.84%	8.22%	20.19%
3	2	1	$ 2,895,107	16,440	2,296,851	3.95%	8.72%	7.82%	20.50%
0	1	1	$ 3,113,834	16,311	2,148,329	11.81%	7.87%	0.85%	20.53%
0	2	2	$ 3,113,834	16,311	2,148,329	11.81%	7.87%	0.85%	20.53%
0	3	3	$ 3,113,834	16,311	2,148,329	11.81%	7.87%	0.85%	20.53%
3	3	1	$ 2,901,652	16,440	2,299,461	4.19%	8.72%	7.95%	20.85%
3	1	0	$ 2,875,977	16,526	2,315,151	3.27%	9.29%	8.68%	21.24%
3	2	0	$ 2,910,413	16,482	2,312,376	4.50%	9.00%	8.55%	22.05%
1	2	0	$ 3,085,293	15,192	2,371,552	10.78%	0.46%	11.33%	22.58%
2	3	0	$ 3,085,293	15,192	2,371,552	10.78%	0.46%	11.33%	22.58%
1	3	0	$ 3,100,912	15,168	2,376,202	11.34%	0.31%	11.55%	23.20%
1	3	1	$ 3,129,242	15,211	2,373,421	12.36%	0.59%	11.42%	24.37%
2	1	1	$ 2,946,850	16,591	2,322,045	5.81%	9.72%	9.01%	24.53%
1	1	0	$ 2,945,322	16,587	2,324,295	5.76%	9.69%	9.11%	24.56%
2	2	0	$ 2,945,322	16,587	2,324,295	5.76%	9.69%	9.11%	24.56%
3	3	0	$ 2,945,322	16,587	2,324,295	5.76%	9.69%	9.11%	24.56%
2	2	1	$ 2,962,253	16,563	2,316,344	6.36%	9.53%	8.74%	24.64%
2	3	1	$ 3,014,929	16,655	2,330,626	8.25%	10.14%	9.41%	27.80%
1	0	1	$ 2,950,983	18,465	2,150,078	5.96%	22.11%	0.93%	29.01%
2	0	2	$ 2,950,983	18,465	2,150,078	5.96%	22.11%	0.93%	29.01%
3	0	3	$ 2,950,983	18,465	2,150,078	5.96%	22.11%	0.93%	29.01%
1	0	2	$ 2,982,052	18,445	2,132,238	7.07%	21.98%	0.10%	29.15%
1	0	3	$ 2,991,539	18,433	2,130,178	7.42%	21.90%	0.00%	29.31%
2	0	3	$ 2,984,669	18,457	2,135,449	7.17%	22.05%	0.25%	29.47%
0	1	0	$ 3,311,467	15,122	2,388,152	18.90%	0.00%	12.11%	31.01%
0	2	0	$ 3,311,467	15,122	2,388,152	18.90%	0.00%	12.11%	31.01%
0	3	0	$ 3,311,467	15,122	2,388,152	18.90%	0.00%	12.11%	31.01%
0	2	1	$ 3,470,682	15,243	2,281,771	24.62%	0.80%	7.12%	32.54%
3	0	2	$ 2,895,437	19,539	2,200,191	3.96%	29.21%	3.29%	36.46%
2	0	1	$ 2,894,859	19,558	2,205,456	3.94%	29.34%	3.53%	36.82%
0	3	2	$ 3,391,713	16,842	2,254,846	21.78%	11.38%	5.85%	39.01%
3	0	1	$ 2,803,875	19,608	2,341,469	0.68%	29.67%	9.92%	40.26%
1	0	0	$ 2,785,025	19,680	2,352,329	0.00%	30.15%	10.43%	40.57%
2	0	0	$ 2,785,025	19,680	2,352,329	0.00%	30.15%	10.43%	40.57%
3	0	0	$ 2,785,025	19,680	2,352,329	0.00%	30.15%	10.43%	40.57%
0	3	1	$ 3,453,507	15,543	2,437,960	24.00%	2.79%	14.45%	41.24%
0	0	1	$ 3,189,545	20,370	2,134,841	14.52%	34.71%	0.22%	49.45%
0	0	2	$ 3,189,545	20,370	2,134,841	14.52%	34.71%	0.22%	49.45%
0	0	3	$ 3,189,545	20,370	2,134,841	14.52%	34.71%	0.22%	49.45%
Set Maximums			$ 3,470,682	20,370	2,437,960	24.62%	34.71%	14.45%	49.45%
Set Minimums			$ 2,785,025	15,122	2,130,178	0.00%	0.00%	0.00%	15.47%
Difference			$ 685,656	5,248	307,782	24.62%	34.71%	14.45%	33.98%

KC-

Fleet Size	**10**		
1st Analysis Day	**5**	**2nd Analysis Day**	**30**
1st NMCS Target	**0.5**	**2nd NMCS Target**	**1**
1st Availability	**95%**	**2nd Availability**	**90%**

Flight **0-30 days; 5.25 hrs x Fleet Size**

Coefficients of			Responses			Percentage Deviation from Set Minimums			Total Deviation
Cost	Weight	Volume	Total Cost	Total Weight	Total Volume	d1	d2	d3	ds
2	2	1	$5,598,440	24,397	3,535,064	3.47%	4.00%	4.37%	11.84%
3	3	2	$5,612,921	24,420	3,530,936	3.73%	4.10%	4.25%	12.09%
1	3	1	$5,841,813	23,477	3,528,648	7.96%	0.08%	4.18%	12.23%
3	3	1	$5,592,290	24,444	3,545,839	3.35%	4.20%	4.69%	12.25%
1	2	1	$5,832,028	23,515	3,532,072	7.78%	0.24%	4.29%	12.31%
1	3	2	$5,866,431	23,497	3,521,005	8.42%	0.16%	3.96%	12.54%
1	3	3	$5,871,872	23,508	3,517,574	8.52%	0.21%	3.86%	12.59%
1	3	0	$5,833,409	23,493	3,546,960	7.81%	0.15%	4.73%	12.68%
1	2	0	$5,814,817	23,545	3,552,190	7.46%	0.37%	4.88%	12.71%
2	1	1	$5,418,176	25,847	3,469,251	0.13%	10.18%	2.43%	12.75%
3	2	2	$5,437,002	25,834	3,466,010	0.48%	10.13%	2.34%	12.94%
1	1	0	$5,603,203	24,476	3,563,867	3.55%	4.34%	5.22%	13.12%
2	2	0	$5,603,203	24,476	3,563,867	3.55%	4.34%	5.22%	13.12%
3	3	0	$5,603,203	24,476	3,563,867	3.55%	4.34%	5.22%	13.12%
1	1	2	$5,529,585	25,853	3,418,196	2.19%	10.21%	0.92%	13.32%
3	1	1	$5,410,918	25,894	3,487,311	0.00%	10.38%	2.96%	13.35%
3	2	3	$5,521,826	25,876	3,422,635	2.05%	10.31%	1.05%	13.41%
1	2	3	$5,756,320	24,930	3,412,587	6.38%	6.27%	0.76%	13.42%
2	2	3	$5,530,644	25,850	3,423,292	2.21%	10.20%	1.07%	13.48%
1	1	3	$5,563,060	25,859	3,409,229	2.81%	10.23%	0.66%	13.70%
3	2	0	$5,603,122	24,557	3,573,848	3.55%	4.69%	5.52%	13.76%
0	3	2	$5,950,492	23,490	3,513,939	9.97%	0.14%	3.75%	13.86%
0	2	1	$5,951,300	23,484	3,516,342	9.99%	0.11%	3.82%	13.92%
3	1	2	$5,426,543	26,177	3,466,698	0.29%	11.59%	2.36%	14.24%
0	3	1	$5,968,668	23,484	3,528,552	10.31%	0.11%	4.18%	14.60%
3	1	0	$5,418,167	26,013	3,518,632	0.13%	10.89%	3.89%	14.91%
3	2	1	$5,469,715	25,962	3,502,311	1.09%	10.67%	3.41%	15.17%
2	1	3	$5,530,849	26,316	3,421,586	2.22%	12.18%	1.02%	15.43%
0	1	0	$5,980,220	23,458	3,554,178	10.52%	0.00%	4.94%	15.46%
0	2	0	$5,980,220	23,458	3,554,178	10.52%	0.00%	4.94%	15.46%
0	3	0	$5,980,220	23,458	3,554,178	10.52%	0.00%	4.94%	15.46%
0	1	2	$5,872,124	24,987	3,401,836	8.52%	6.52%	0.44%	15.48%
2	1	0	$5,433,099	26,030	3,526,190	0.41%	10.96%	4.11%	15.49%
0	1	3	$5,880,783	25,108	3,397,710	8.68%	7.03%	0.32%	16.04%
2	1	2	$5,545,654	26,364	3,431,902	2.49%	12.39%	1.33%	16.21%
3	1	3	$5,549,598	26,379	3,432,496	2.56%	12.45%	1.35%	16.36%
2	3	2	$5,748,652	24,594	3,568,435	6.24%	4.84%	5.36%	16.44%
2	3	1	$5,736,483	24,601	3,578,725	6.02%	4.87%	5.66%	16.55%
2	3	3	$5,782,856	24,597	3,558,151	6.87%	4.86%	5.06%	16.79%
0	1	1	$6,070,394	23,693	3,534,853	12.19%	1.00%	4.37%	17.56%
0	2	2	$6,070,394	23,693	3,534,853	12.19%	1.00%	4.37%	17.56%
0	3	3	$6,070,394	23,693	3,534,853	12.19%	1.00%	4.37%	17.56%
2	3	0	$5,746,548	24,652	3,601,167	6.20%	5.09%	6.33%	17.62%
1	1	1	$5,598,866	26,048	3,504,474	3.47%	11.04%	3.47%	17.99%
2	2	2	$5,598,866	26,048	3,504,474	3.47%	11.04%	3.47%	17.99%
3	3	3	$5,598,866	26,048	3,504,474	3.47%	11.04%	3.47%	17.99%
1	2	2	$5,826,544	24,669	3,573,360	7.68%	5.16%	5.50%	18.35%
2	0	3	$5,469,212	28,085	3,400,478	1.08%	19.73%	0.40%	21.20%
1	0	1	$5,455,305	28,143	3,410,928	0.82%	19.97%	0.71%	21.50%
2	0	2	$5,455,305	28,143	3,410,928	0.82%	19.97%	0.71%	21.50%
3	0	3	$5,455,305	28,143	3,410,928	0.82%	19.97%	0.71%	21.50%
0	2	3	$6,048,572	25,478	3,473,419	11.78%	8.61%	2.55%	22.95%
2	0	1	$5,432,421	28,196	3,479,945	0.40%	20.20%	2.75%	23.34%
3	0	2	$5,474,652	28,309	3,492,797	1.18%	20.68%	3.13%	24.98%
3	0	1	$5,451,423	28,358	3,502,762	0.75%	20.89%	3.42%	25.06%
1	0	3	$5,532,916	29,819	3,386,912	2.25%	27.12%	0.00%	29.37%
1	0	2	$5,548,597	29,893	3,402,142	2.54%	27.43%	0.45%	30.43%
1	0	0	$5,438,461	29,966	3,762,787	0.51%	27.74%	11.10%	39.35%
2	0	0	$5,438,461	29,966	3,762,787	0.51%	27.74%	11.10%	39.35%
3	0	0	$5,438,461	29,966	3,762,787	0.51%	27.74%	11.10%	39.35%
0	0	1	$5,906,868	31,930	3,435,121	9.17%	36.12%	1.42%	46.71%
0	0	2	$5,906,868	31,930	3,435,121	9.17%	36.12%	1.42%	46.71%
0	0	3	$5,906,868	31,930	3,435,121	9.17%	36.12%	1.42%	46.71%
Set Maximums			$6,070,394	31,930	3,762,787	12.19%	36.12%	11.10%	46.71%
Set Minimums			$5,410,918	23,458	3,386,912	0.00%	0.00%	0.00%	11.84%
Difference			$ 659,476	8,472	375,875	12.19%	36.12%	11.10%	34.86%

F-15

Fleet Size	**24**		
1st Analysis Day	**4**	**2nd Analysis Day**	**7**
1st NMCS Target	**1.2**	**2nd NMCS Target**	**2.4**
1st Availability	**95%**	**2nd Availability**	**90%**

Flight **0-30 days; 5.25 hrs x Fleet Size**

Coefficients of			Responses			Percentage Deviation from Set Minimums			Total Deviation
Cost	Weight	Volume	Total Cost	Total Weight	Total Volume	d1	d2	d3	ds
2	3	3	$ 7,426,780	11,981	1,802,394	4.40%	0.23%	0.77%	5.40%
2	3	2	$ 7,420,560	11,981	1,804,186	4.32%	0.23%	0.87%	5.41%
1	3	1	$ 7,438,191	11,954	1,803,892	4.56%	0.00%	0.85%	5.41%
1	2	1	$ 7,431,909	11,973	1,803,380	4.47%	0.16%	0.82%	5.46%
2	2	3	$ 7,426,343	11,991	1,803,022	4.40%	0.31%	0.80%	5.51%
1	2	2	$ 7,444,878	11,982	1,802,020	4.66%	0.23%	0.75%	5.64%
2	0	3	$ 7,404,365	12,025	1,805,825	4.09%	0.59%	0.96%	5.64%
1	1	2	$ 7,438,544	11,992	1,803,230	4.57%	0.32%	0.81%	5.70%
1	2	3	$ 7,457,081	11,987	1,799,713	4.83%	0.28%	0.62%	5.73%
1	1	1	$ 7,408,883	12,007	1,809,398	4.15%	0.45%	1.16%	5.76%
2	2	2	$ 7,408,883	12,007	1,809,398	4.15%	0.45%	1.16%	5.76%
3	3	3	$ 7,408,883	12,007	1,809,398	4.15%	0.45%	1.16%	5.76%
1	0	3	$ 7,477,781	12,030	1,788,685	5.12%	0.64%	0.00%	5.76%
1	0	2	$ 7,434,551	12,025	1,800,374	4.51%	0.60%	0.65%	5.76%
3	2	2	$ 7,396,141	12,019	1,810,955	3.97%	0.55%	1.25%	5.77%
2	3	1	$ 7,405,236	11,991	1,813,325	4.10%	0.31%	1.38%	5.79%
2	1	3	$ 7,435,360	12,005	1,804,346	4.52%	0.43%	0.88%	5.83%
3	2	3	$ 7,412,899	12,011	1,809,567	4.21%	0.48%	1.17%	5.85%
3	1	3	$ 7,397,023	12,040	1,811,334	3.98%	0.72%	1.27%	5.97%
2	2	1	$ 7,411,177	12,015	1,811,924	4.18%	0.51%	1.30%	6.00%
3	3	2	$ 7,411,177	12,015	1,811,924	4.18%	0.51%	1.30%	6.00%
2	1	2	$ 7,411,568	12,016	1,811,828	4.19%	0.52%	1.29%	6.00%
1	2	0	$ 7,403,901	11,990	1,819,701	4.08%	0.30%	1.73%	6.12%
1	3	0	$ 7,413,297	11,985	1,819,303	4.21%	0.26%	1.71%	6.19%
3	3	1	$ 7,393,392	12,029	1,818,685	3.93%	0.63%	1.68%	6.24%
1	1	3	$ 7,488,401	12,021	1,797,650	5.27%	0.56%	0.50%	6.33%
1	0	1	$ 7,407,065	12,054	1,814,014	4.13%	0.84%	1.42%	6.38%
2	0	2	$ 7,407,065	12,054	1,814,014	4.13%	0.84%	1.42%	6.38%
3	0	3	$ 7,407,065	12,054	1,814,014	4.13%	0.84%	1.42%	6.38%
3	1	2	$ 7,407,911	12,057	1,814,846	4.14%	0.86%	1.46%	6.46%
2	3	0	$ 7,411,589	12,021	1,826,152	4.19%	0.56%	2.09%	6.85%
2	1	1	$ 7,406,128	12,063	1,822,401	4.11%	0.92%	1.88%	6.91%
1	3	2	$ 7,518,509	11,981	1,806,891	5.69%	0.22%	1.02%	6.93%
3	2	1	$ 7,420,768	12,043	1,823,342	4.32%	0.75%	1.94%	7.01%
1	1	0	$ 7,393,880	12,042	1,832,966	3.94%	0.74%	2.48%	7.15%
2	2	0	$ 7,393,880	12,042	1,832,966	3.94%	0.74%	2.48%	7.15%
3	3	0	$ 7,393,880	12,042	1,832,966	3.94%	0.74%	2.48%	7.15%
3	0	2	$ 7,409,925	12,087	1,826,082	4.17%	1.11%	2.09%	7.37%
1	3	3	$ 7,536,574	12,002	1,809,476	5.95%	0.40%	1.16%	7.51%
2	0	1	$ 7,337,109	12,162	1,840,140	3.14%	1.74%	2.88%	7.76%
2	1	0	$ 7,327,555	12,183	1,854,400	3.01%	1.91%	3.67%	8.60%
3	2	0	$ 7,344,152	12,168	1,853,980	3.24%	1.79%	3.65%	8.68%
3	1	1	$ 7,445,961	12,115	1,837,300	4.67%	1.35%	2.72%	8.74%
0	2	3	$ 7,802,145	12,189	1,831,483	9.68%	1.97%	2.39%	14.04%
0	1	1	$ 7,829,289	12,193	1,838,806	10.06%	2.00%	2.80%	14.86%
0	2	2	$ 7,829,289	12,193	1,838,806	10.06%	2.00%	2.80%	14.86%
0	3	3	$ 7,829,289	12,193	1,838,806	10.06%	2.00%	2.80%	14.86%
0	1	3	$ 7,824,609	12,270	1,836,372	10.00%	2.65%	2.67%	15.31%
0	3	1	$ 7,869,285	12,164	1,852,567	10.62%	1.76%	3.57%	15.95%
0	0	1	$ 7,897,265	12,345	1,822,919	11.02%	3.27%	1.91%	16.20%
0	0	2	$ 7,897,265	12,345	1,822,919	11.02%	3.27%	1.91%	16.20%
0	0	3	$ 7,897,265	12,345	1,822,919	11.02%	3.27%	1.91%	16.20%
0	1	0	$ 7,862,297	12,128	1,866,020	10.53%	1.46%	4.32%	16.30%
0	2	0	$ 7,862,297	12,128	1,866,020	10.53%	1.46%	4.32%	16.30%
0	3	0	$ 7,862,297	12,128	1,866,020	10.53%	1.46%	4.32%	16.30%
0	2	1	$ 7,891,232	12,197	1,851,753	10.93%	2.03%	3.53%	16.49%
0	3	2	$ 7,899,322	12,209	1,850,505	11.05%	2.13%	3.46%	16.63%
0	1	2	$ 7,922,912	12,243	1,841,305	11.38%	2.42%	2.94%	16.74%
3	0	1	$ 7,381,954	12,751	1,906,185	3.77%	6.66%	6.57%	17.01%
3	1	0	$ 7,271,888	12,495	1,984,904	2.23%	4.53%	10.97%	17.72%
1	0	0	$ 7,113,591	13,307	2,095,911	0.00%	11.32%	17.18%	28.50%
2	0	0	$ 7,113,591	13,307	2,095,911	0.00%	11.32%	17.18%	28.50%
3	0	0	$ 7,113,591	13,307	2,095,911	0.00%	11.32%	17.18%	28.50%
Set Maximums			$ 7,922,912	13,307	2,095,911	11.38%	11.32%	17.18%	28.50%
Set Minimums			$ 7,113,591	11,954	1,788,685	0.00%	0.00%	0.00%	5.40%
Difference			$ 809,322	1,354	307,226	11.38%	11.32%	17.18%	23.10%

F-15

Fleet Size	**24**		
1st Analysis Day	**10**	**2nd Analysis Day**	**30**
1st NMCS Target	**1.2**	**2nd NMCS Target**	**2.4**
1st Availability	**95%**	**2nd Availability**	**90%**

Flight Schedule **0-30 days; 5.25 hrs x Fleet Size**

Coefficients of			Responses			Percentage Deviation from Set Minimums			Total Deviation
Cost	Weight	Volume	Total Cost	Total Weight	Total Volume	d1	d2	d3	ds
3	1	2	$ 11,387,743	18,968	3,210,519	1.85%	3.35%	1.97%	7.18%
2	3	1	$ 11,675,508	18,526	3,209,394	4.43%	0.95%	1.94%	7.31%
1	3	0	$ 11,783,280	18,353	3,209,441	5.39%	0.00%	1.94%	7.33%
2	1	1	$ 11,444,491	18,946	3,217,506	2.36%	3.23%	2.20%	7.79%
1	2	1	$ 11,841,787	18,496	3,185,646	5.91%	0.78%	1.18%	7.88%
3	1	1	$ 11,358,830	19,025	3,234,341	1.59%	3.66%	2.73%	7.99%
3	3	2	$ 11,703,145	18,607	3,212,775	4.67%	1.39%	2.05%	8.11%
1	3	1	$ 11,932,435	18,406	3,186,114	6.72%	0.29%	1.20%	8.21%
2	3	2	$ 11,791,695	18,592	3,195,088	5.47%	1.30%	1.48%	8.25%
3	0	2	$ 11,414,820	19,097	3,219,587	2.09%	4.05%	2.26%	8.41%
1	1	1	$ 11,791,639	18,628	3,195,226	5.47%	1.50%	1.49%	8.45%
2	2	2	$ 11,791,639	18,628	3,195,226	5.47%	1.50%	1.49%	8.45%
3	3	3	$ 11,791,639	18,628	3,195,226	5.47%	1.50%	1.49%	8.45%
2	3	0	$ 11,650,840	18,560	3,248,840	4.21%	1.13%	3.19%	8.53%
1	2	3	$ 11,994,736	18,530	3,160,012	7.28%	0.97%	0.37%	8.62%
1	2	2	$ 11,973,481	18,530	3,170,513	7.09%	0.96%	0.70%	8.76%
1	1	0	$ 11,611,347	18,649	3,252,633	3.85%	1.61%	3.31%	8.78%
2	2	0	$ 11,611,347	18,649	3,252,633	3.85%	1.61%	3.31%	8.78%
3	3	0	$ 11,611,347	18,649	3,252,633	3.85%	1.61%	3.31%	8.78%
3	2	2	$ 11,538,635	18,962	3,220,085	3.20%	3.32%	2.28%	8.80%
1	1	3	$ 11,996,908	18,564	3,162,009	7.30%	1.15%	0.43%	8.88%
2	2	3	$ 11,847,818	18,647	3,189,982	5.97%	1.60%	1.32%	8.89%
1	3	2	$ 11,984,615	18,534	3,176,492	7.19%	0.99%	0.89%	9.07%
1	0	1	$ 11,550,452	19,091	3,204,716	3.31%	4.02%	1.79%	9.12%
2	0	2	$ 11,550,452	19,091	3,204,716	3.31%	4.02%	1.79%	9.12%
3	0	3	$ 11,550,452	19,091	3,204,716	3.31%	4.02%	1.79%	9.12%
2	1	3	$ 11,669,268	18,965	3,193,084	4.37%	3.34%	1.42%	9.13%
1	3	3	$ 12,004,651	18,546	3,171,570	7.37%	1.06%	0.74%	9.16%
1	1	2	$ 11,919,920	18,649	3,189,968	6.61%	1.61%	1.32%	9.55%
3	2	1	$ 11,492,850	19,014	3,247,742	2.79%	3.60%	3.16%	9.55%
2	3	3	$ 11,930,434	18,635	3,193,949	6.71%	1.54%	1.45%	9.69%
3	2	0	$ 11,381,585	19,082	3,273,732	1.80%	3.97%	3.98%	9.75%
3	1	3	$ 11,610,571	19,053	3,221,657	3.85%	3.81%	2.33%	9.99%
1	2	0	$ 11,798,989	18,577	3,253,894	5.53%	1.22%	3.35%	10.11%
2	1	2	$ 11,667,348	19,012	3,217,754	4.35%	3.59%	2.20%	10.15%
3	2	3	$ 11,667,348	19,012	3,217,754	4.35%	3.59%	2.20%	10.15%
2	1	0	$ 11,357,661	19,171	3,291,724	1.58%	4.46%	4.55%	10.60%
1	0	2	$ 11,766,969	19,074	3,193,496	5.24%	3.93%	1.43%	10.61%
2	0	3	$ 11,723,411	19,112	3,204,324	4.85%	4.14%	1.78%	10.77%
0	1	1	$ 12,369,669	18,470	3,158,641	10.64%	0.64%	0.33%	11.60%
0	2	2	$ 12,369,669	18,470	3,158,641	10.64%	0.64%	0.33%	11.60%
0	3	3	$ 12,369,669	18,470	3,158,641	10.64%	0.64%	0.33%	11.60%
0	2	1	$ 12,373,348	18,438	3,176,731	10.67%	0.46%	0.90%	12.03%
1	0	3	$ 11,925,601	19,109	3,189,464	6.66%	4.12%	1.30%	12.09%
2	0	1	$ 11,296,428	19,617	3,284,494	1.04%	6.89%	4.32%	12.25%
0	2	3	$ 12,444,702	18,539	3,157,164	11.31%	1.01%	0.28%	12.60%
2	2	1	$ 11,695,392	19,153	3,269,334	4.60%	4.36%	3.84%	12.81%
3	0	1	$ 11,284,266	19,661	3,299,480	0.93%	7.13%	4.80%	12.85%
0	3	2	$ 12,421,696	18,548	3,177,818	11.10%	1.06%	0.93%	13.10%
3	3	1	$ 11,696,544	19,161	3,282,613	4.61%	4.41%	4.26%	13.28%
0	3	1	$ 12,338,480	18,553	3,213,424	10.36%	1.09%	2.07%	13.51%
3	1	0	$ 11,284,305	19,519	3,349,228	0.93%	6.35%	6.38%	13.66%
0	1	0	$ 12,402,007	18,363	3,235,505	10.92%	0.06%	2.77%	13.75%
0	2	0	$ 12,402,007	18,363	3,235,505	10.92%	0.06%	2.77%	13.75%
0	3	0	$ 12,402,007	18,363	3,235,505	10.92%	0.06%	2.77%	13.75%
0	1	2	$ 12,572,625	18,688	3,170,339	12.45%	1.83%	0.70%	14.97%
0	1	3	$ 12,657,502	19,003	3,215,428	13.21%	3.54%	2.13%	18.88%
0	0	1	$ 12,896,743	19,646	3,148,381	15.35%	7.05%	0.00%	22.40%
0	0	2	$ 12,896,743	19,646	3,148,381	15.35%	7.05%	0.00%	22.40%
0	0	3	$ 12,896,743	19,646	3,148,381	15.35%	7.05%	0.00%	22.40%
1	0	0	$ 11,180,608	20,681	3,599,550	0.00%	12.69%	14.33%	27.02%
2	0	0	$ 11,180,608	20,681	3,599,550	0.00%	12.69%	14.33%	27.02%
3	0	0	$ 11,180,608	20,681	3,599,550	0.00%	12.69%	14.33%	27.02%
Set Maximums			$ 12,896,743	20,681	3,599,550	15.35%	12.69%	14.33%	27.02%
Set Minimums			$ 11,180,608	18,353	3,148,381	0.00%	0.00%	0.00%	7.18%
Difference			$ 1,716,135	2,328	451,169	15.35%	12.69%	14.33%	19.84%

B-52

Fleet Size	**8**		
1st Analysis Day	**4**	**2nd Analysis Day**	**7**
1st NMCS Target	**0.4**	**2nd NMCS Target**	**0.8**
1st Availability	**95%**	**2nd Availability**	**90%**

Flight Schedule **0-7 days; 5.25 hrs x Fleet Size**

Coefficients of			Responses			Percentage Deviation from Set Minimums			Total Deviation
Cost	Weight	Volume	Total Cost	Total Weight	Total Volume	d1	d2	d3	ds
3	3	2	$ 9,046,008	46,598	6,505,137	3.05%	1.47%	2.73%	7.25%
3	1	2	$ 8,983,787	46,824	6,523,611	2.34%	1.96%	3.02%	7.32%
1	1	1	$ 9,055,954	46,606	6,503,751	3.16%	1.49%	2.71%	7.36%
2	2	2	$ 9,055,954	46,606	6,503,751	3.16%	1.49%	2.71%	7.36%
3	3	3	$ 9,055,954	46,606	6,503,751	3.16%	1.49%	2.71%	7.36%
2	2	3	$ 9,117,266	46,564	6,471,730	3.86%	1.40%	2.20%	7.46%
2	2	1	$ 9,063,438	46,620	6,514,209	3.24%	1.52%	2.87%	7.64%
1	0	1	$ 8,989,631	46,953	6,523,197	2.40%	2.24%	3.02%	7.66%
2	0	2	$ 8,989,631	46,953	6,523,197	2.40%	2.24%	3.02%	7.66%
3	0	3	$ 8,989,631	46,953	6,523,197	2.40%	2.24%	3.02%	7.66%
2	1	2	$ 9,047,959	46,748	6,512,010	3.07%	1.80%	2.84%	7.71%
3	1	3	$ 9,054,467	46,753	6,512,556	3.14%	1.81%	2.85%	7.80%
3	2	2	$ 9,054,467	46,753	6,512,556	3.14%	1.81%	2.85%	7.80%
2	1	1	$ 9,012,821	46,840	6,531,963	2.67%	2.00%	3.15%	7.82%
2	1	3	$ 9,120,128	46,728	6,474,081	3.89%	1.75%	2.24%	7.89%
3	2	3	$ 9,070,283	46,751	6,510,972	3.32%	1.81%	2.82%	7.95%
1	1	2	$ 9,183,351	46,552	6,462,062	4.61%	1.37%	2.05%	8.03%
3	1	1	$ 8,917,315	47,132	6,578,129	1.58%	2.64%	3.88%	8.10%
2	3	2	$ 9,100,141	46,640	6,515,500	3.66%	1.56%	2.89%	8.12%
2	3	1	$ 9,099,853	46,648	6,517,324	3.66%	1.58%	2.92%	8.16%
1	3	1	$ 9,219,326	46,214	6,500,410	5.02%	0.64%	2.66%	8.31%
3	0	2	$ 8,921,651	47,248	6,575,015	1.63%	2.89%	3.83%	8.35%
1	3	3	$ 9,266,026	46,257	6,465,753	5.55%	0.73%	2.11%	8.39%
1	3	2	$ 9,264,773	46,246	6,468,514	5.54%	0.71%	2.15%	8.40%
1	2	1	$ 9,192,918	46,380	6,506,533	4.72%	1.00%	2.75%	8.47%
3	2	1	$ 8,972,615	46,802	6,617,326	2.21%	1.92%	4.50%	8.63%
2	3	3	$ 9,216,245	46,584	6,473,550	4.99%	1.44%	2.23%	8.66%
1	2	2	$ 9,229,185	46,600	6,476,755	5.13%	1.48%	2.28%	8.89%
3	3	1	$ 9,002,787	46,807	6,624,704	2.55%	1.93%	4.62%	9.10%
1	2	3	$ 9,249,637	46,611	6,474,413	5.37%	1.50%	2.25%	9.11%
2	0	3	$ 9,102,404	47,007	6,527,103	3.69%	2.36%	3.08%	9.13%
1	1	3	$ 9,320,353	46,770	6,405,129	6.17%	1.85%	1.15%	9.17%
2	0	1	$ 8,932,953	47,427	6,596,139	1.76%	3.28%	4.17%	9.20%
3	0	1	$ 8,934,397	47,433	6,597,517	1.77%	3.29%	4.19%	9.25%
1	0	3	$ 9,302,656	47,045	6,409,621	5.97%	2.45%	1.22%	9.64%
1	0	2	$ 9,299,856	47,049	6,411,241	5.94%	2.45%	1.25%	9.64%
1	2	0	$ 9,087,427	46,415	6,693,695	3.52%	1.07%	5.71%	10.30%
1	3	0	$ 9,216,685	46,091	6,684,685	4.99%	0.37%	5.57%	10.92%
1	1	0	$ 8,945,392	46,780	6,790,137	1.90%	1.87%	7.23%	11.00%
2	2	0	$ 8,945,392	46,780	6,790,137	1.90%	1.87%	7.23%	11.00%
3	3	0	$ 8,945,392	46,780	6,790,137	1.90%	1.87%	7.23%	11.00%
2	3	0	$ 9,044,059	46,448	6,776,321	3.02%	1.15%	7.01%	11.18%
2	1	0	$ 8,805,516	47,353	6,865,252	0.31%	3.12%	8.42%	11.84%
3	1	0	$ 8,806,347	47,355	6,865,444	0.32%	3.12%	8.42%	11.86%
3	2	0	$ 8,872,370	47,161	6,844,754	1.07%	2.70%	8.09%	11.86%
0	1	1	$ 9,631,047	46,249	6,473,929	9.71%	0.71%	2.24%	12.66%
0	2	2	$ 9,631,047	46,249	6,473,929	9.71%	0.71%	2.24%	12.66%
0	3	3	$ 9,631,047	46,249	6,473,929	9.71%	0.71%	2.24%	12.66%
0	1	2	$ 9,722,182	46,839	6,379,366	10.75%	2.00%	0.75%	13.49%
0	3	1	$ 9,774,643	45,973	6,486,139	11.35%	0.11%	2.43%	13.89%
0	2	3	$ 9,750,652	46,853	6,384,844	11.07%	2.03%	0.83%	13.93%
0	3	2	$ 9,751,034	46,319	6,487,900	11.08%	0.86%	2.46%	14.40%
0	2	1	$ 9,811,704	46,392	6,505,308	11.77%	1.02%	2.73%	15.53%
0	1	0	$ 9,680,079	45,922	6,722,979	10.27%	0.00%	6.17%	16.44%
0	2	0	$ 9,680,079	45,922	6,722,979	10.27%	0.00%	6.17%	16.44%
0	3	0	$ 9,680,079	45,922	6,722,979	10.27%	0.00%	6.17%	16.44%
0	1	3	$ 9,868,857	47,376	6,412,016	12.42%	3.17%	1.26%	16.85%
0	0	1	$ 10,135,218	47,691	6,332,185	15.45%	3.85%	0.00%	19.31%
0	0	2	$ 10,135,218	47,691	6,332,185	15.45%	3.85%	0.00%	19.31%
0	0	3	$ 10,135,218	47,691	6,332,185	15.45%	3.85%	0.00%	19.31%
1	0	0	$ 8,778,602	48,937	7,365,328	0.00%	6.57%	16.32%	22.88%
2	0	0	$ 8,778,602	48,937	7,365,328	0.00%	6.57%	16.32%	22.88%
3	0	0	$ 8,778,602	48,937	7,365,328	0.00%	6.57%	16.32%	22.88%
Set Maximums			$ 10,135,218	48,937	7,365,328	15.45%	6.57%	16.32%	22.88%
Set Minimums			$ 8,778,602	45,922	6,332,185	0.00%	0.00%	0.00%	7.25%
Difference			$ 1,356,616	3,015	1,033,144	15.45%	6.57%	16.32%	15.63%

B-52

Fleet Size	**8**		
1st Analysis Day	**5**	**2nd Analysis Day**	**30**
1st NMCS Target	**3.6**	**2nd NMCS Target**	**4**
1st Availability	**55%**	**2nd Availability**	**50%**

Flight Schedule **0-30 days; 5.25 hrs x Fleet Size**

Coefficients of			Responses			Percentage Deviation from Set Minimums			Total Deviation
Cost	Weight	Volume	Total Cost	Total Weight	Total Volume	d1	d2	d3	ds
2	2	1	$ 3,432,519	30,669	3,661,182	3.15%	1.47%	3.54%	8.15%
3	3	1	$ 3,432,519	30,669	3,661,182	3.15%	1.47%	3.54%	8.15%
1	0	1	$ 3,423,663	30,859	3,655,944	2.88%	2.10%	3.39%	8.37%
2	0	2	$ 3,423,663	30,859	3,655,944	2.88%	2.10%	3.39%	8.37%
3	0	3	$ 3,423,663	30,859	3,655,944	2.88%	2.10%	3.39%	8.37%
3	1	3	$ 3,423,663	30,859	3,655,944	2.88%	2.10%	3.39%	8.37%
2	1	2	$ 3,428,771	30,781	3,662,256	3.04%	1.84%	3.57%	8.44%
3	2	2	$ 3,428,771	30,781	3,662,256	3.04%	1.84%	3.57%	8.44%
2	3	1	$ 3,453,750	30,618	3,657,496	3.79%	1.30%	3.43%	8.52%
3	2	3	$ 3,460,994	30,641	3,649,998	4.00%	1.38%	3.22%	8.60%
3	3	2	$ 3,460,994	30,641	3,649,998	4.00%	1.38%	3.22%	8.60%
2	1	1	$ 3,405,410	30,899	3,686,589	2.33%	2.23%	4.25%	8.82%
3	1	2	$ 3,405,410	30,899	3,686,589	2.33%	2.23%	4.25%	8.82%
3	2	1	$ 3,405,410	30,899	3,686,589	2.33%	2.23%	4.25%	8.82%
2	0	1	$ 3,367,954	31,097	3,706,436	1.21%	2.88%	4.82%	8.91%
1	1	1	$ 3,484,300	30,586	3,644,117	4.71%	1.19%	3.05%	8.95%
2	2	2	$ 3,484,300	30,586	3,644,117	4.71%	1.19%	3.05%	8.95%
3	3	3	$ 3,484,300	30,586	3,644,117	4.71%	1.19%	3.05%	8.95%
3	0	2	$ 3,387,391	31,139	3,688,463	1.79%	3.02%	4.31%	9.12%
3	1	1	$ 3,407,304	30,927	3,694,230	2.39%	2.32%	4.47%	9.18%
3	2	0	$ 3,406,707	30,915	3,701,741	2.37%	2.28%	4.68%	9.34%
2	3	2	$ 3,504,447	30,593	3,646,772	5.31%	1.22%	3.13%	9.66%
2	3	0	$ 3,469,829	30,685	3,676,802	4.27%	1.52%	3.98%	9.77%
1	3	1	$ 3,522,660	30,491	3,646,117	5.86%	0.88%	3.11%	9.85%
1	2	1	$ 3,513,117	30,599	3,647,132	5.57%	1.24%	3.14%	9.95%
3	0	1	$ 3,372,939	31,247	3,721,035	1.36%	3.38%	5.23%	9.97%
2	1	0	$ 3,375,507	31,105	3,749,048	1.44%	2.91%	6.02%	10.37%
1	3	0	$ 3,515,455	30,541	3,668,971	5.64%	1.05%	3.76%	10.44%
1	1	0	$ 3,440,683	30,935	3,709,373	3.39%	2.35%	4.90%	10.64%
2	2	0	$ 3,440,683	30,935	3,709,373	3.39%	2.35%	4.90%	10.64%
3	3	0	$ 3,440,683	30,935	3,709,373	3.39%	2.35%	4.90%	10.64%
2	3	3	$ 3,534,689	30,664	3,653,218	6.22%	1.45%	3.31%	10.98%
3	1	0	$ 3,357,458	31,320	3,771,441	0.89%	3.62%	6.65%	11.17%
1	2	0	$ 3,527,364	30,670	3,671,961	6.00%	1.47%	3.84%	11.31%
1	2	2	$ 3,607,691	30,628	3,610,001	8.41%	1.33%	2.09%	11.84%
2	2	3	$ 3,564,752	30,772	3,656,410	7.12%	1.81%	3.40%	12.34%
2	0	3	$ 3,554,804	31,181	3,623,553	6.82%	3.16%	2.47%	12.46%
2	1	3	$ 3,588,663	30,949	3,624,773	7.84%	2.40%	2.51%	12.74%
1	3	2	$ 3,671,590	30,437	3,604,433	10.33%	0.70%	1.93%	12.97%
1	1	3	$ 3,714,660	30,876	3,567,622	11.63%	2.16%	0.89%	14.67%
1	0	3	$ 3,737,849	31,028	3,572,363	12.32%	2.66%	1.02%	16.01%
1	1	2	$ 3,695,893	31,094	3,624,019	11.06%	2.88%	2.49%	16.43%
1	2	3	$ 3,789,504	30,738	3,577,077	13.88%	1.70%	1.16%	16.73%
1	0	2	$ 3,701,709	31,246	3,638,809	11.24%	3.38%	2.90%	17.52%
1	3	3	$ 3,815,608	30,772	3,579,429	14.66%	1.81%	1.22%	17.70%
1	0	0	$ 3,327,726	32,494	4,038,331	0.00%	7.51%	14.20%	21.71%
2	0	0	$ 3,327,726	32,494	4,038,331	0.00%	7.51%	14.20%	21.71%
3	0	0	$ 3,327,726	32,494	4,038,331	0.00%	7.51%	14.20%	21.71%
0	1	0	$ 4,115,318	30,225	3,682,459	23.67%	0.00%	4.14%	27.81%
0	2	0	$ 4,115,318	30,225	3,682,459	23.67%	0.00%	4.14%	27.81%
0	3	0	$ 4,115,318	30,225	3,682,459	23.67%	0.00%	4.14%	27.81%
0	2	3	$ 4,286,226	30,551	3,550,079	28.80%	1.08%	0.39%	30.28%
0	1	3	$ 4,297,860	30,767	3,536,140	29.15%	1.79%	0.00%	30.95%
0	1	2	$ 4,315,062	30,770	3,536,679	29.67%	1.80%	0.02%	31.49%
0	1	1	$ 4,319,371	30,605	3,564,327	29.80%	1.26%	0.80%	31.85%
0	2	2	$ 4,319,371	30,605	3,564,327	29.80%	1.26%	0.80%	31.85%
0	3	3	$ 4,319,371	30,605	3,564,327	29.80%	1.26%	0.80%	31.85%
0	3	1	$ 4,266,713	30,574	3,626,681	28.22%	1.16%	2.56%	31.93%
0	2	1	$ 4,304,446	30,612	3,629,588	29.35%	1.28%	2.64%	33.28%
0	3	2	$ 4,363,259	30,693	3,579,584	31.12%	1.55%	1.23%	33.90%
0	0	1	$ 4,724,925	31,550	3,562,532	41.99%	4.38%	0.75%	47.12%
0	0	2	$ 4,724,925	31,550	3,562,532	41.99%	4.38%	0.75%	47.12%
0	0	3	$ 4,724,925	31,550	3,562,532	41.99%	4.38%	0.75%	47.12%
Set Maximums			$ 4,724,925	32,494	4,038,331	41.99%	7.51%	14.20%	47.12%
Set Minimums			$ 3,327,726	30,225	3,536,140	0.00%	0.00%	0.00%	8.15%
Difference			$ 1,397,199	2,269	502,192	41.99%	7.51%	14.20%	38.96%

B-52

Fleet Size	**8**			
1st Analysis Day	**5**		**2nd Analysis Day**	**30**
1st NMCS Target	**2**		**2nd NMCS Target**	**2.4**
1st Availability	**75%**		**2nd Availability**	**70%**

Flight Schedule **0-30 days; 5.25 hrs x Fleet Size**

Coefficients of			Responses			Percentage Deviation from Set Minimums			Total Deviation
Cost	Weight	Volume	Total Cost	Total Weight	Total Volume	d1	d2	d3	ds
3	2	2	$ 9,672,771	48,996	6,482,982	3.51%	3.33%	7.43%	14.27%
2	2	3	$ 9,987,310	48,912	6,353,984	6.88%	3.16%	5.29%	15.33%
1	1	1	$ 9,980,774	48,249	6,471,040	6.82%	1.76%	7.23%	15.80%
2	1	2	$ 9,894,329	49,481	6,389,362	5.89%	4.36%	5.88%	16.12%
3	2	3	$ 9,899,295	49,485	6,389,616	5.94%	4.36%	5.88%	16.19%
2	3	3	$10,131,649	48,777	6,343,408	8.43%	2.87%	5.11%	16.41%
2	2	2	$ 9,942,427	48,986	6,445,654	6.40%	3.31%	6.81%	16.53%
3	3	3	$ 9,942,427	48,986	6,445,654	6.40%	3.31%	6.81%	16.53%
2	3	2	$ 9,997,172	48,794	6,443,017	6.99%	2.91%	6.76%	16.66%
1	1	2	$10,267,490	49,445	6,256,091	9.88%	4.28%	3.67%	17.83%
1	2	2	$10,231,933	48,909	6,354,839	9.50%	3.15%	5.30%	17.96%
3	1	3	$ 9,940,789	49,922	6,416,203	6.39%	5.29%	6.32%	17.99%
2	1	3	$10,077,208	50,044	6,335,653	7.85%	5.54%	4.99%	18.38%
2	0	3	$10,104,935	50,430	6,291,039	8.14%	6.36%	4.25%	18.75%
3	3	2	$ 9,810,863	49,242	6,656,956	5.00%	3.85%	10.31%	19.16%
3	2	1	$ 9,469,569	49,268	6,877,928	1.34%	3.91%	13.97%	19.22%
2	0	1	$ 9,470,984	50,059	6,788,093	1.36%	5.58%	12.48%	19.42%
2	1	1	$ 9,707,553	49,811	6,671,101	3.89%	5.05%	10.54%	19.49%
2	2	1	$ 9,731,004	49,131	6,747,123	4.14%	3.62%	11.80%	19.57%
1	0	2	$10,252,764	50,838	6,198,429	9.73%	7.22%	2.71%	19.66%
3	1	2	$ 9,738,545	50,281	6,610,744	4.22%	6.04%	9.54%	19.81%
2	3	1	$ 9,839,982	48,977	6,731,984	5.31%	3.29%	11.55%	20.15%
1	3	2	$10,337,359	48,880	6,443,021	10.63%	3.09%	6.77%	20.48%
1	0	1	$10,051,180	50,117	6,491,120	7.57%	5.70%	7.56%	20.83%
3	0	1	$ 9,343,979	50,728	6,883,559	0.00%	6.99%	14.07%	21.05%
3	3	1	$ 9,632,709	49,296	6,881,763	3.09%	3.97%	14.04%	21.09%
1	2	1	$10,211,645	48,971	6,549,421	9.29%	3.28%	8.53%	21.09%
3	1	1	$ 9,433,687	50,159	6,926,476	0.96%	5.79%	14.78%	21.52%
1	3	1	$10,206,510	48,884	6,594,092	9.23%	3.10%	9.27%	21.60%
1	2	3	$10,562,012	49,396	6,303,819	13.04%	4.18%	4.46%	21.67%
2	0	2	$ 9,978,425	50,958	6,485,015	6.79%	7.47%	7.46%	21.72%
3	0	3	$ 9,978,425	50,958	6,485,015	6.79%	7.47%	7.46%	21.72%
3	0	2	$ 9,762,561	51,039	6,663,993	4.48%	7.64%	10.43%	22.55%
1	2	0	$ 9,634,199	47,971	7,162,698	3.11%	1.17%	18.69%	22.97%
1	1	3	$10,607,994	50,301	6,263,510	13.53%	6.09%	3.79%	23.40%
1	3	3	$10,643,934	49,241	6,392,212	13.91%	3.85%	5.92%	23.69%
2	3	0	$ 9,527,299	48,857	7,163,470	1.96%	3.04%	18.70%	23.71%
0	1	1	$11,229,241	48,246	6,211,389	20.18%	1.75%	2.93%	24.85%
0	2	3	$11,262,802	49,119	6,122,457	20.54%	3.59%	1.45%	25.58%
1	1	0	$ 9,525,739	48,912	7,287,194	1.95%	3.16%	20.75%	25.86%
0	2	2	$11,207,012	49,032	6,209,006	19.94%	3.41%	2.89%	26.23%
0	3	3	$11,207,012	49,032	6,209,006	19.94%	3.41%	2.89%	26.23%
0	2	1	$11,180,627	48,099	6,349,789	19.66%	1.44%	5.22%	26.32%
2	2	0	$ 9,458,951	49,803	7,279,409	1.23%	5.04%	20.62%	26.89%
3	3	0	$ 9,458,951	49,803	7,279,409	1.23%	5.04%	20.62%	26.89%
0	3	2	$11,177,585	48,941	6,296,830	19.62%	3.22%	4.34%	27.18%
1	0	3	$10,726,279	51,533	6,260,254	14.79%	8.68%	3.74%	27.21%
3	2	0	$ 9,415,072	49,946	7,383,689	0.76%	5.34%	22.35%	28.45%
1	3	0	$ 9,899,190	49,111	7,200,701	5.94%	3.58%	19.32%	28.84%
0	1	3	$11,566,413	49,846	6,034,768	23.78%	5.13%	0.00%	28.91%
0	1	2	$11,594,763	49,021	6,144,032	24.09%	3.39%	1.81%	29.29%
0	3	1	$11,234,534	48,931	6,460,953	20.23%	3.20%	7.06%	30.49%
2	1	0	$ 9,453,009	50,324	7,520,801	1.17%	6.14%	24.62%	31.93%
3	1	0	$ 9,413,811	50,705	7,539,422	0.75%	6.94%	24.93%	32.62%
0	1	0	$11,178,148	47,415	6,940,829	19.63%	0.00%	15.01%	34.64%
0	2	0	$11,178,148	47,415	6,940,829	19.63%	0.00%	15.01%	34.64%
0	3	0	$11,178,148	47,415	6,940,829	19.63%	0.00%	15.01%	34.64%
1	0	0	$ 9,345,364	52,079	7,913,808	0.01%	9.84%	31.14%	40.99%
2	0	0	$ 9,345,364	52,079	7,913,808	0.01%	9.84%	31.14%	40.99%
3	0	0	$ 9,345,364	52,079	7,913,808	0.01%	9.84%	31.14%	40.99%
0	0	1	$12,302,098	51,297	6,155,501	31.66%	8.19%	2.00%	41.84%
0	0	2	$12,302,098	51,297	6,155,501	31.66%	8.19%	2.00%	41.84%
0	0	3	$12,302,098	51,297	6,155,501	31.66%	8.19%	2.00%	41.84%
Set Maximums			$12,302,098	52,079	7,913,808	31.66%	9.84%	31.14%	41.84%
Set Minimums			$ 9,343,979	47,415	6,034,768	0.00%	0.00%	0.00%	14.27%
Difference			$ 2,958,119	4,664	1,879,040	31.66%	9.84%	31.14%	27.57%

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Fleet Size	**8**		
1st Analysis Day	**5**	**2nd Analysis Day**	**30**
1st NMCS Target	**0.4**	**2nd NMCS Target**	**0.8**
1st Availability	**95%**	**2nd Availability**	**90%**

Flight Schedule **0-30 days; 5.25 hrs x Fleet Size**

Coefficients of			Responses			Percentage Deviation from Set Minimums			Total Deviation
Cost	Weight	Volume	Total Cost	Total Weight	Total Volume	d1	d2	d3	ds
2	3	1	$ 18,928,538	80,386	12,582,841	2.27%	1.13%	3.53%	6.93%
2	2	1	$ 18,868,493	80,554	12,597,050	1.95%	1.34%	3.65%	6.94%
3	1	2	$ 18,858,084	81,186	12,532,941	1.89%	2.13%	3.12%	7.15%
1	3	2	$ 19,328,863	80,320	12,376,538	4.44%	1.04%	1.83%	7.31%
1	3	1	$ 19,237,774	80,206	12,461,898	3.94%	0.90%	2.54%	7.38%
2	1	2	$ 19,032,182	81,266	12,453,041	2.83%	2.23%	2.46%	7.53%
1	1	2	$ 19,311,030	81,348	12,266,353	4.34%	2.34%	0.93%	7.60%
1	1	1	$ 19,075,539	80,768	12,510,495	3.07%	1.61%	2.94%	7.61%
2	2	2	$ 19,075,539	80,768	12,510,495	3.07%	1.61%	2.94%	7.61%
2	1	1	$ 18,896,167	81,274	12,554,463	2.10%	2.24%	3.30%	7.64%
1	2	2	$ 19,339,258	80,546	12,380,586	4.49%	1.33%	1.87%	7.69%
3	3	2	$ 18,942,475	81,424	12,508,044	2.35%	2.43%	2.92%	7.70%
2	1	3	$ 19,273,487	81,504	12,278,998	4.14%	2.53%	1.03%	7.70%
3	2	1	$ 18,827,038	80,935	12,659,244	1.72%	1.82%	4.16%	7.70%
3	2	2	$ 18,888,733	81,676	12,509,490	2.06%	2.75%	2.93%	7.74%
1	2	3	$ 19,509,258	80,723	12,248,490	5.41%	1.55%	0.78%	7.74%
3	0	2	$ 18,883,823	81,864	12,492,026	2.03%	2.99%	2.78%	7.80%
1	2	1	$ 19,167,758	80,491	12,517,624	3.57%	1.26%	2.99%	7.82%
2	0	3	$ 19,186,958	81,882	12,294,790	3.67%	3.01%	1.16%	7.84%
3	3	3	$ 19,055,822	81,438	12,454,352	2.96%	2.45%	2.47%	7.89%
3	1	1	$ 18,748,694	81,294	12,678,831	1.30%	2.27%	4.32%	7.89%
3	2	3	$ 19,008,665	81,796	12,435,991	2.71%	2.90%	2.32%	7.93%
2	2	3	$ 19,162,076	81,549	12,379,417	3.53%	2.59%	1.86%	7.98%
2	3	2	$ 19,095,404	81,347	12,458,096	3.17%	2.34%	2.50%	8.02%
2	3	3	$ 19,172,218	81,549	12,379,195	3.59%	2.59%	1.86%	8.03%
2	0	1	$ 18,799,215	81,838	12,590,463	1.57%	2.95%	3.59%	8.12%
1	0	1	$ 19,071,385	82,049	12,394,354	3.04%	3.22%	1.98%	8.24%
2	0	2	$ 19,071,385	82,049	12,394,354	3.04%	3.22%	1.98%	8.24%
3	0	3	$ 19,071,385	82,049	12,394,354	3.04%	3.22%	1.98%	8.24%
3	3	1	$ 18,859,412	81,453	12,636,934	1.90%	2.47%	3.98%	8.35%
3	0	1	$ 18,686,999	81,768	12,729,053	0.97%	2.87%	4.73%	8.57%
1	3	3	$ 19,512,417	81,360	12,260,411	5.43%	2.35%	0.88%	8.66%
3	1	3	$ 19,006,217	82,317	12,466,369	2.69%	3.56%	2.57%	8.82%
1	0	2	$ 19,353,765	82,006	12,305,588	4.57%	3.17%	1.25%	8.99%
1	1	3	$ 19,569,000	81,674	12,298,489	5.73%	2.75%	1.19%	9.67%
1	1	0	$ 18,665,106	80,856	13,096,469	0.85%	1.72%	7.76%	10.32%
2	2	0	$ 18,665,106	80,856	13,096,469	0.85%	1.72%	7.76%	10.32%
3	3	0	$ 18,665,106	80,856	13,096,469	0.85%	1.72%	7.76%	10.32%
2	3	0	$ 18,797,391	80,537	13,082,112	1.56%	1.32%	7.64%	10.52%
1	2	0	$ 18,877,892	80,472	13,068,060	2.00%	1.23%	7.52%	10.76%
1	3	0	$ 19,047,413	80,172	13,023,096	2.92%	0.86%	7.15%	10.93%
0	3	1	$ 20,020,448	79,949	12,419,381	8.17%	0.58%	2.19%	10.94%
1	0	3	$ 19,643,602	82,252	12,338,773	6.14%	3.47%	1.52%	11.13%
2	1	0	$ 18,591,132	81,202	13,263,859	0.45%	2.15%	9.13%	11.74%
0	3	2	$ 20,282,979	80,431	12,285,481	9.59%	1.18%	1.08%	11.86%
3	2	0	$ 18,615,191	81,227	13,265,137	0.58%	2.18%	9.15%	11.91%
0	2	1	$ 20,262,539	80,421	12,372,406	9.48%	1.17%	1.80%	12.45%
0	2	3	$ 20,528,689	81,113	12,153,664	10.92%	2.04%	0.00%	12.96%
0	1	2	$ 20,563,714	81,204	12,162,848	11.11%	2.16%	0.08%	13.34%
0	2	0	$ 20,025,016	79,719	12,783,876	8.20%	0.29%	5.19%	13.67%
0	3	0	$ 20,025,016	79,719	12,783,876	8.20%	0.29%	5.19%	13.67%
0	1	1	$ 20,638,613	81,160	12,170,091	11.51%	2.10%	0.14%	13.75%
0	2	2	$ 20,638,613	81,160	12,170,091	11.51%	2.10%	0.14%	13.75%
0	3	3	$ 20,638,613	81,160	12,170,091	11.51%	2.10%	0.14%	13.75%
3	1	0	$ 18,551,284	81,831	13,449,512	0.23%	2.94%	10.66%	13.84%
0	1	3	$ 20,713,589	81,786	12,203,367	11.92%	2.89%	0.41%	15.22%
1	0	0	$ 18,507,852	83,080	13,548,183	0.00%	4.52%	11.47%	15.99%
2	0	0	$ 18,507,852	83,080	13,548,183	0.00%	4.52%	11.47%	15.99%
3	0	0	$ 18,507,852	83,080	13,548,183	0.00%	4.52%	11.47%	15.99%
0	1	0	$ 20,149,882	79,490	13,080,668	8.87%	0.00%	7.63%	16.50%
0	0	1	$ 21,204,240	83,598	12,206,415	14.57%	5.17%	0.43%	20.17%
0	0	2	$ 21,204,240	83,598	12,206,415	14.57%	5.17%	0.43%	20.17%
0	0	3	$ 21,204,240	83,598	12,206,415	14.57%	5.17%	0.43%	20.17%
Set Maximums			$ 21,204,240	83,598	13,548,183	14.57%	5.17%	11.47%	20.17%
Set Minimums			$ 18,507,852	79,490	12,153,664	0.00%	0.00%	0.00%	6.93%
Difference			$ 2,696,388	4,108	1,394,519	14.57%	5.17%	11.47%	13.24%

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 074-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
20-03-2001	Masters Thesis	Jun 2000-Mar 2001

4. TITLE AND SUBTITLE EFFECTS OF ALTERNATIVE PERFORMANCE CRITERIA UPON COMPOSITION OF AIR TRANSPORTABLE SPARE PARTS KITS	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Buyukacar, Volkan M., Lieutenant, Turkish Air Force	**5d. PROJECT NUMBER**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/ENS) 2950 P Street, Building 640 WPAFB OH 45433-7765	**8. PERFORMING ORGANIZATION** AFIT/GLM/ENS/01M-05
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A	**10. SPONSOR/MONITOR'S ACRONYM(S)**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Airlift capacity is a definitive factor in the success of large-scale military operations. History proves that the demand for airlift soon exceeds its capacity during simultaneous deployment of forces. Therefore, good solutions to the airlift capacity problem are important. This thesis contributes to the resolution of this problem by seeking ways to reduce readiness spare parts packages (RSPs) deployed for Air Force squadrons through addition of airlift criteria into the RSP selection process.

We find that item cost, weight, and volume are three important criteria for RSP computations. We then offer a method for implementing these three criteria in the RSP selection process. We evaluate our method using an experimental design based on the USAF Aircraft Sustainability Model.

The experiment results show that RSP sizes can be reduced, but typically at a high increase in cost. However, in some cases the three criteria used together can achieve smaller, cheaper RSPs than the current USAF approach (using only cost-based analysis) can produce. These results suggest that this method should be adopted for the RSP selection process, to enable cost vs. airlift requirement tradeoffs, and to achieve cost reductions on selected RSPs.

15. SUBJECT TERMS
Readiness Spares Packages, Repairable Inventory, Availability, Sustainability, ASM, Mobility, Airlift, Deployment, METRIC

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	b. ABSTRACT	c. THIS PAGE			Lt Col Alan Johnson
					19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	122	(937)-255-6565, ext 4284 (Alan.Johnson@afit.edu)

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18