



**TANKER FUEL EFFICIENCY:
SAVING THROUGH RECEIVER FUEL PLANNING**

GRADUATE RESEARCH PROJECT

Justin R. Capper, Major, USAF

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**DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY**

AIR FORCE INSTITUTE OF TECHNOLOGY

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Major, USAF

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Abstract

The Department of Defense (DOD) has made significant budget cuts, necessitating initiative, innovation and efficiency. The DOD is the largest consumer of fuel in the world. Jet fuel accounts for almost 3/4ths of this fuel, most being used by Air Mobility Command (AMC). A large portion of AMC's missions involve air refueling, an inherently fuel inefficient process. Adhering to the most accurate fuel plan will remove extra fuel from the tanker, lowering the tanker's weight, and reducing fuel expended and increasing the life of the tanker. Through analyzing and altering air refueling mission, the Air Force will achieve a fuel savings. This research identifies which receivers drive higher costs due to fuel inefficiency.

The missions analyzed were conducted in Fiscal Year 2012. Qualitative data was extracted from the AMC Fuel Tracker and manipulated in Excel. Deployed operations have not been included due to the dynamic planning involved in combat operations. Each tanker mission was categorized by mission design series (MDS) and then examined to determine MDS effect of planned versus actual offloaded fuel. This analysis is noteworthy because the results explain an area of fuel inefficiency in AMC's tanker fleet.

Dedication

For my wife, thank you for your love, kindness, caring and proofreading skills.

For my girls, thank you for always making me aware of what is truly important.

Acknowledgements

I sincerely appreciate the guidance, help, teaching, and understanding I have received from my advisor, Major Josh Strakos, during this study.

Colonel Keith Boone, thank you sir for your direction, and guidance on this paper. Your coordination and help was of great value and I hope I have delivered a product that will be of use for AMC and the Fuel Efficiency Division.

Mr. Chuck Stiles and Mr. Allen McCoy from AMC, thank you for helping me sort my data and fill in as many holes as we could. Thank you for your continued fight for Air Force fuel efficiency.

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Justin R. Capper, Major, USAF

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I. Introduction

The United States remains the only nation able to project and sustain large-scale military operations over extended distances. We maintain superior capabilities to deter and defeat adaptive enemies and to ensure the credibility of security partnerships that are fundamental to regional and global security. In this way, our military continues to underpin our national security and global leadership, and when we use it appropriately, our security and leadership is reinforced.

President Barack Obama

National Security Strategy, May 2010

Background & Problem Statement

The Department of Defense (DOD) is often criticized for its overwhelming size and budget. The DOD has been combating these criticisms by fostering a culture of fiscal responsibility. In 2013, the United States federal government implemented automatic spending cuts known as sequestration. This was the result of passing the Budget Control Act of 2011. Sequestration will cut an estimated \$600 billion from the DOD budget (DOD, 2014). The effects of sequestration accent the immediate need for the DOD to make significant cuts in spending. This new budget demands processes to be examined for efficiencies and wastes to be minimized or eliminated.

Immediate budget savings can be achieved by examining energy efficiencies. The DOD is the largest consumer of fuel in the world (Hoy, 2008). The DOD consumed over 116.8 million barrels of fuel at a cost of \$17 billion in 2011 (DOD, 2012). In 2007, jet fuel accounted for 71% of the petroleum used by the DOD (Hoy, 2008). Accordingly, the Air Force spends almost \$10 billion a year on energy (Starosta, 2012), 48% of DOD's energy consumption (USAF, 2013).

In fiscal year 2011, the Air Force spent \$8.3 billion on fuel (Starosta, 2012). The fuel budget, set a year in advance, may fall victim to the current, volatile price of oil. Under Secretary for Budget, Major General Frank Faykes, stated that for every \$10 per barrel increase in crude oil, the Air Force fuel bill increases \$650 million per annum (GAO, Defense Management, 2008). This equates to approximately 7-8% of the annual fuel budget depending on fuel used that year. Due to this large expenditure, fuel efficiency has become an emphasis item for the Air Force and Air Mobility Command (AMC).

AMC is responsible for command guidance in relation to large mobility aircraft. These aircraft include the large cargo-carrying C-5, C-17 and C-130; as well as the KC-10 and KC-135 tanker aircraft. Due to the size and fuel loads of these large aircraft, fuel inefficiencies often become evident due to the amount and cost of fuel wasted. The root causes of these inefficiencies, however, are not as easily recognized.

When comparing AMC's cargo mission to its air refueling mission, it becomes evident that the air refueling mission has more variability between its planned and actual fuel usage. This variability allows the greatest opportunity to find inefficiencies. Cargo missions start and end with the same amount of cargo, have a fairly direct routing, and when planned correctly can be very efficient. In contrast, cargo carried by the tanker is the fuel to be offloaded to the receiver(s), and therefore subjected to greater variation through the mission execution. For basic air refueling (AR) missions, a tanker aircraft flies to a predetermined point known as a track or anchor. The tanker will meet or rendezvous with an aircraft, the receiver, which needs the tanker's fuel to complete its mission. The tanker's orbit time and offload are affected by the receiver's operations, which may change the rendezvous time and amount of fuel requested. When the receiver(s) rendezvous with the tanker, the plan is almost irrelevant and the fuel

transfer becomes a negotiation between aircraft commanders to ensure safety and mission accomplishment for both aircraft. These ever-changing variables create a challenge for mission planners.

The quantity of operational air refueling is going to wane with the wars in Iraq and Afghanistan coming to an end. However, the capability to perform air refueling will remain the key requirement for enabling global operations. The Air Force's core missions expect airmen to provide *Global Vigilance, Global Reach and Global Power for America* (Air Force, 2013). The tanker and its air refueling mission are the essential elements that enable the capabilities of vigilance, reach and power to be "global".

In order to ensure the air refueling mission is accomplished, a well-trained force is required. Air Force flight publications state, "It is inherently dangerous to fly two aircraft in close proximity" (Boeing, 2009). Air refueling requires aircraft to come into direct contact with one another. Being prepared for and proficient at this mission is essential as our military must always be prepared to defend, assist or attack at a moment's notice.

With economic pressures, it is critical to adapt an air refueling process that will facilitate the best air refueling training at the least cost. In order to maximize cost savings, many options should be explored while maintaining an appropriate level of safety and mission effectiveness. These areas include: fuel efficiencies, simulators, AR requirements, etc. This research examines the fuel used on tanker sorties versus what was planned to find fuel inefficiencies.

According to regulation, pilots will ensure sufficient reserve fuel to meet unforeseen problems. This reserve fuel is calculated by using the aircraft's best endurance fuel rate, for a minimum of 20 minutes or up to 10% of the flight time to a maximum of 45 minutes (11-202 V3, 2010). An aircraft's zero fuel weight is the minimum fuel required for safe operation to include

fuel required for ballast and engine feeding. Fuel below this level can result in engine flameout or an unsafe center of gravity. Missions are planned to land with a minimum fuel that equals the sum of the zero fuel weight, reserve fuel, contingency fuel (defined locally) and any identified alternate/required fuel. Once this planned fuel is defined, maintenance must fuel the jet accordingly. Pilots may only accept an aircraft within 5,000 pounds of the planned fuel load (11-2KC-135V3; 11-2KC-10 V3, 2013). Typically, the planned landing fuel for both the KC-135 and the KC10 is between 16,000 and 18,000 pounds of fuel.

Carrying extra weight or fuel costs money. Former AMC Commander, General Paul Selva confirms, “For every pound of stuff you carry you burn a tenth of a pound of fuel.” (Insinna & Tadjdeh, 2013) When an aircraft lands with more fuel than planned, it generates an unnecessary expense. There are some reasons for carrying extra fuel, also known as tankering. Bad weather, divert options, contingencies, etc. are all valid reasons to tanker fuel to keep crews safe. However, in most cases the cost to carry additional fuel will outweigh the benefits. The decision to tanker fuel should only be used to mitigate risk. Tankering fuel to allow longer than needed loiter times, faster transit speeds or due to the standardizing of ramp fuel loads are fuel inefficient practices and are unacceptable reasons to tanker fuel. Poor coordination and planning are also not acceptable justifications for inaccurate fuel loads and consumption. Ensuring the most accurate prediction of fuel utilization will allow the Air Force to meet the mission requirement while maintaining the lowest fuel cost.

The air refueling mission and its complexities foster a fuel inefficient environment. Tankers only exist to assist other aircraft; therefore they are usually subservient to the needs of the receiver(s). The variability in air refueling operations leads to deviations from the initial fuel plan causing fuel inefficiencies. Conversely, predicting and accounting for elements and events

that affect this variability can lead to fuel savings. Each receiver arriving at the tanker has its own diverse mission capabilities and unique set of circumstances. This research examines the similarities and differences of fuel use by different categories of aircraft and specific MDSs during air refueling. Costs are then associated with these characteristics that deviate from mission planning. These costs include the price of fuel requested, the cost of carrying additional fuel weight and the potential cost to the tanker for taking more fuel than planned.

Research Question

The research study question thus follows:

Which receiver mission type and aircraft are causing tanker aircraft to carry extra fuel, resulting in greater fuel burn and increased fuel costs for the Air Force?

The following investigative questions are addressed:

1. What are the costs for carrying extra weight?
2. What are the average amounts of tankered fuel on KC-135 and KC-10 sorties?
3. What are the average amounts of extra fuel delivered to receivers?
4. What are the historic fuel usages for tanker missions?

After this data is captured and analyzed, the following questions are answered:

1. Do certain aircraft categories lead to tankering fuel?
2. Do certain MWSs, major weapons systems, lead to tankering fuel?
3. Do certain aircraft categories tend to take more fuel than planned?
4. Do certain MWSs tend to take more fuel than planned?

Research Objective and Focus

The current air refueling planning system results in excess fuel loads driving unnecessary fuel spending. A specific objective of this research is to show the need to develop and validate an existing, quantitative planning tool for determining the optimal fuel load for tanker missions. This study will help identify a problem that exists with the current fuel planning guidance.

The literature review will focus on several areas including the history of air refueling, air refueling requirements, planning, DOD fuel logistics, energy conservation, fuel savings initiatives, and budget concerns. This research will focus on KC-10 Extender and KC-135 Stratotanker missions not originating from the United States Central Command (CENTCOM) Area of Responsibility (AOR). While the implications of this research may have a large scope, the specific objective of this research will be to identify a planning problem. Resolving and minimizing this problem will result in fuel efficiency and money savings.

Methodology

This research utilizes historic air refueling data. The AMC Fuel Tracker data from Fiscal Year 2012 will be arranged and sorted into five categories using Microsoft Excel. These categories include: bomber, fighter, cargo, ISR, and mixed aircraft. Calculations will then be made from the data to show how much fuel was planned versus what fuel was delivered. The costs associated with receiver aircraft deviating from the planned fuel offload will then be calculated. These costs will then be compared and contrasted to each category and each vehicle designation, also known as mission design series (MDS).

Assumptions/Limitations

This research analyzes one full fiscal years' worth of tanker sorties. The decision to use FY 2012 data versus the available and more current FY 2013 data is made to eliminate the effects of sequestration from the research. A critical assumption is that the data is complete and accurate. The inputs into the fuel tracker are done by the aircrew. With very few exceptions, the data is taken as truth. When the data shows blank or unknown, data assumptions are made to fill in these blanks. If this assumption cannot be made, it remains "unknown".

The sorties analyzed in the fuel tracker do not include cancelled missions. When a sortie cancels the air refueling, the fuel tracker may or may not report the offload as zero. Therefore, the data analyzed is only as good as what was reported in the fuel tracker. This research only analyzes sorties where at least one receiver rendezvoused with the tanker.

In FY 2012, there were over 1.25 trillion pounds of fuel offloaded on 20,870 tanker sorties all over the world (USTRANSCOM, 2013). This research examines the 15,791 of these missions captured in the AMC Fuel Tracker. This research uses only operational and training missions that did not have operational control through CENTCOM. Combat missions are not included because there are a unique set of variables choosing mission effectiveness over fuel efficiency. However, the results of this study can be used to find applicable savings in future combat planning. The commander with operational control must set the balance and priority between effectiveness and efficiency. In high tempo, high demand, dynamic environments, fuel efficiency is far less important than the flexibility offered by using "full" tanker aircraft. Although combat effectiveness is of the utmost importance, it does mean that fuel efficiency cannot still be applied.

Finally, FY 2012 had four price changes for the price of a gallon of JP-8 jet fuel. This research uses \$3.50 per gallon of jet fuel. This price approximates the actual average in FY 2012. The FY 2012 varying price of fuel is not used to keep the focus on the use of fuel, not the price of the fuel.

Implications

The results of this research identify a characteristic of the air refueling mission affecting efficiency. Eliminating or minimizing the waste this research identifies has the potential to save millions of dollars. It also could return more money or hours to the tanker fleet for additional missions and training. The possibility exists to fly tankers with less fuel and less weight while still meeting mission requirements, all while decreasing wear and tear, thereby increasing the lifespan of the already aging tanker fleet.

The historic planning assumption of tanker fuel is that it will be available when needed and in the quantity demanded. This is demonstrated by the Strategic Air Command's (SAC) nickname for the tanker and its crew force: "TOADs". This term gained popularity and affection from bomber and tanker forces alike and stood for, "Take Off And Die", in reference to the nature of the tanker mission, to take off and deliver every drop of fuel the bomber could receive and then bailout, crash, or try to make a recovery field before flaming out the engines (Air Refueling Archive, 2009). These views have found their way into today's mission planning. Receiver air refueling requests are being made that are generally generic and often more than what the planner knows the receiver will take. The receiver(s) know that a tanker can orbit longer with more gas allowing them more flexibility to get gas when they want it rather than when they planned for it. Due to the restrained budget the DOD is facing, this may be the time to change this culture of tanker reliability, to tanker predictability.

II. Literature Review

“We know the need for a tanker is critical; it’s a capability our nation simply cannot do without.”

*General Arthur J. Lichte,
Former AMC Commander*

This chapter stresses the importance of air refueling and how from its dangerous beginnings has become a key ingredient in our nation’s defense. This capability to provide global effects comes with a high cost of inefficiency. As fuel prices increase and budgets decrease, energy inefficiency is becoming more costly. This chapter shows the effects of fuel price variability on budget planning and current developments in fuel efficiency, all of which show the importance of making air refueling an efficient process.

History of Air Refueling

Since the Wright brothers first powered flight in Kitty Hawk, North Carolina, on December 17, 1903, the United States and the world have been striving to achieve faster, higher, longer, and safer flight. The first flight lasted only 59 seconds and flew a distance less than the wingspan of some of today’s large aircraft. The capabilities of each generation of aircraft grow leaps and bounds over their predecessors’. As new capabilities grow, so does the price of aircraft and aviation parts (Anderton, 1989).

Aviation pioneers have paved the way for innovation and the development of today’s Air Force. The Wright Brother’s gave birth to powered flight and in their Wright Model B, Captain Charles de F. Chandler first used a Lewis machine gun from the sky (Anderton, 1989). Brigadier General Billy Mitchell changed the opinion on aircraft capabilities with the bombing of the *Ostfriesland*. Chuck Yeager pushed the envelope of flight when he flew his Bell X-1 past the

sound barrier (Anderton, 1989). The first successful air-to-air refueling took place on June 27, 1923, when a DH-4B carrying Lieutenants Virgil Hine and Frank W. Seifert, passed gasoline through a hose to another DH-4B flying beneath it, carrying Lieutenants Lowell H. Smith and John P. Richter (National Museum of the US Air Force, 2009).

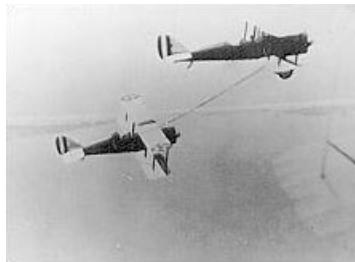


Figure 1: First Air Refueling

Six years later, on January 1 through January 7, 1929, the U.S Army Air Corps accomplished a record-breaking air-to-air refueling. Maj Carl Spaatz commanded the *Question Mark*, a Fokker C-2 tri-engine, and its five person crew. The *Question Mark* remained airborne, over the California sky for almost seven days (Wallwork, 2009). This was made possible by aerial refueling using rudimentary and hazardous techniques. Two Douglas C-1 biplanes would make contact for 7-10 minutes passing fuel through a hatch in the floor. In the end 43 contacts, including 10 at night, passed 5,700 gallons of fuel. This proof of concept mission was of great significance and its success led the Army to include an aerial refueling event in a war game just a few months later. Unfortunately, due to weather, the air refueling mission failed, and the Army put the concept of air refueling on the back burner for another 12 years (Air Refueling Archive, 2009). Of note, three of the five crewmembers, Carl Spaatz, Ira Eaker and Elwood Quesada went on to reach the general ranks, commanding units in World War II (McCarthy, 2002).



Figure 2: The Question Mark

In the years to follow, many ideas prompted the testing of aerial refueling technologies. During World War II, the expansive Pacific region saw the value of air refueling. In the European theater, fighter escorts could not stay with the bombers all the way to their targets due to lack of fuel.

The British patented a looped-hose aerial refueling system. In this system, both aircraft would trail cables with grapnel hooks. The tanker aircraft would then cross from side to side from above until the hooks connected. Once connected, a winch would reel the receiver's cable to the tanker where it was untangled and a hose was attached to the receiver's cable. The receiver would then pull the 235-foot hose to its receptacle. Once connected, it would take 18 minutes to gravity feed 1,500 gallons. This refueling system was rejected at the time because the U.S. Army did not realize a tactical need.

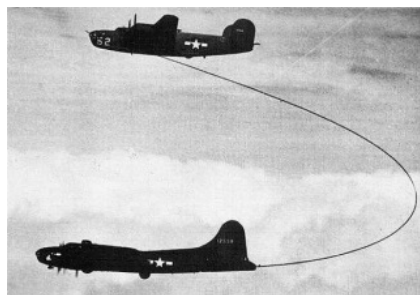


Figure 3: Air Refueling testing (1940s)

It was quickly realized that the Grappled-line looped-hose system was too difficult to operate and was unable to be used by single occupant aircraft. The next system developed was

the probe and drogue system. This system is still currently in use but has some limitations. The Navy's carrier fleet pursued the probe and drogue system and it is now its sole air refueling system. The probe and drogue is the least stable system in use and the refueling aircraft speed and fuel transfer rate is much slower than the boom method. The main reason for the Navy choosing this system is due to its size. The probe and drogue tanker system can be operated by small carrier based aircraft. This allows the carrier group to operate independently and maintain the range and loiter time that air refueling provides without Air Force tanker support.

The flying boom was developed to increase offload rates. The Air Force's Strategic Air Command's intercontinental bombers needed large offloads of fuel and preferably in a short duration. The flying boom can provide up to 8,000 pounds of fuel per minute whereas; the probe and drogue can only deliver up to 5,000 pounds per minute. When using pod mounted probe and drogue this further reduces to approximately 3,000 pounds per minute (ATP -56(B), 2010). The Air Force's fixed wing fleet has standardized to the flying boom and is now the Air Force's air refueling system of choice (Leuthy, 1998).



Figure 4: KC-97 with Flying Boom

The Air Force equipped 121, World War II era, B-29s with the flying boom. Then the Air Force procured the KC-97 tanker. Built in 1951, 780 KC-97s operated until the last one was retired in 1978 (Air Refueling Archive, 2009). Both of these tankers were propeller driven aircraft. This posed quite a problem for newer jet fighters and bombers. The need to increase

speed gave rise to the jet powered KC-135 Stratotanker. The KC-135 built in the mid-1950s and early 1960s, remains the backbone of the Air Force's tanker fleet. When the Boeing production line ended, there were 749 KC-135s built plus an additional 70 C-135 variants (Logan, 1998).

To supplement the aging KC-135 and using lessons learned over Southeast Asia, the Air Force procured the KC-10 Extender. The KC-10 was developed from the civilian DC-10. Since the KC-10 entered service in 1981, a total of 60 KC-10s were produced. The KC-10 has the ability to carry cargo or passengers while performing the air refueling mission. The KC-10 has twice the fuel capacity of the older KC-135. One of the greatest capabilities of the KC-10 is the ability to perform air refueling as both a tanker and a receiver. This ability allows the KC-10 to consolidate other tanker's excess fuel and remain on station longer for the receivers (Leuthy, 1998).



Figure 5: KC-135 refueling KC-10

Today, the Air Force operates 415 KC-135 Stratotankers and 59 KC-10 Extender aircraft. The KC-10 fleet are all receiver capable and can refuel using either the probe and drogue or with the flying boom on the same mission. There are also a few KC-10s that can mount Wing Air Refueling Pods (WARPs) on their wings to allow multiple fighters to refuel at once. The KC-135 fleet contains 54 T-model aircraft. These T-models are refurbished Q-model tankers that supported the SR-71 Blackbird. The Q now T-model tanker, allows fuel to be stored and offloaded separately from the fuel the tanker would burn. This was developed due to the SR-71

requiring a different type of fuel than other Air Force aircraft. There are also eight KC-135s that were modified to be receiver capable. Only a small number of KC-135 aircraft are Multi Point Receiver System (MPRS) capable, like WARP, allowing multiple fighter receivers to refuel at once. Unless equipped with MPRS the KC-135 is configured before flight solely as probe and drogue or flying boom. Most of the Air Force and Navy aircraft are air refueling capable with the exception of trainers, Very Important Person Special Airlift Mission (VIPSAM) aircraft and Unmanned Aerial Vehicles (UAVs) (AFA, 2013).

The United States Air Force provides the majority of the tanker fleet. The USAF's KC-135 Stratotankers are allocated throughout the force (168 Active Duty, 67 Reserve and 180 Air National Guard) and the 59 KC-10 Extenders are allocated to the active duty force (AFA, 2013). The Air Force also flies HC-130 and MC-130 aircraft for refueling special operators. There are Marine KC-130s, and Navy F-18 and S-3 aircraft that can refuel Navy and helicopter probe and drogue capable aircraft (GAO, Military Aircraft: Observations on the Air Force's Plan to Lease Aerial Refueling Aircraft, 2003). Allied nations provide air refueling, but on a much smaller scale. Japan and Italy have Boeing KC-767s. The Dutch use KDC-10s similar to the U.S. KC-10s. The Australian, Emirati and Saudi Air Forces use Airbus A330s. The French, Chilean, Singapore, and Turkish Air Force fly KC-135s (Air Refueling Archive, 2009). There are also many smaller tanker aircraft with a probe and drogue, buddy air refueling capability. Finally, the commercial sector has found opportunity in the air refueling business. Omega Air Refueling Services operate two KC-707s and one KDC-10 (Omega, 2014). Omega's fee-for-service rates are nearly the same as the cost of similar probe and drogue refueling. Omega Air supports the Navy and Marines when the Air Force is unable to meet their need (Grimser, 2011).

The tanker fleet has been successfully supporting the combat and mobility forces in nearly every operation since World War II. The buildup of the tanker fleet to support SAC bombers gave tankers an alert posture to be ready at moment's notice to engage in nuclear combat with the Soviet Union. This constant alert posture lasted until the Soviet Union's breakup in the early 1990s. In response, the tanker fleet came off alert and joined AMC. This new command and identity quickly found tanker crews out of their alert shacks and deployed globally supporting multiple contingencies.

Tankers began deploying in mass numbers to the Middle East supporting Operation Desert Storm and its aftermath, Operations Northern and Southern Watch. During the same time, Operation Allied Force required 150 KC-135s deployed to stop the ethnic cleansing occurring in Yugoslavia (Ball, 2012). Operations Desert Storm and Allied Force showed the capability of the tanker fleet by enabling stateside B-2 bombers to engage targets halfway around the world and return home nonstop. In Operations Iraqi Freedom and Enduring Freedom there were over 150 tankers deployed (GAO, 2003). During this time, tankers were also busy stateside conducting air refueling supporting Operation Noble Eagle, the homeland defense mission. In FY 2010, the KC-135 fleet delivered 255 million gallons of jet fuel to Air Force, Marine, Navy and coalition aircraft over the CENTCOM AOR (Grimser, 2011).

In 2011, the demand for air refueling increased to unprecedented levels. In addition to supporting operations in the Middle East and Afghanistan, tankers were called to support operations in Africa. The No-Fly Zone over Libya needed tankers deployed out of Moron Air Base, Spain. At the same time, tankers were supporting tsunami relief missions to Japan, an Air Expeditionary Force (AEF) swap out, a Presidential movement, in addition to their day to day missions. This committed over 200 tanker aircraft per day (HQ AMC, 2012). Today, tankers

maintain a vital role over the skies of Afghanistan, averaging 74,000 aircraft refueled per year (JCS, 2013).

Air Refueling Requirement

The United States is the only country that can employ mass lethal and nonlethal forces on a global scale (USAF, 2011). It is the tanker fleet that enables the “Global” in *Global Reach*, *Global Vigilance* and *Global Power*. Air refueling enables joint and coalition forces power projection over long distances, guaranteeing the ability to reach any location around the globe. There are three benefits tankers provide by allowing aircraft the ability to fly nonstop from the United States to their objective and back. First, tankers minimize of the need for landing rights in other countries. Second, they reduce the need for worldwide basing. Third, they maximize payloads without affecting the range of the receivers (Hazdra, 2001).

Air refueling supports many principles of war. In addition to the global **mass** effects air refueling supports, it also allows these same forces the ability to **maneuver**. Air refueling also provides **security**. Anti-access strategies can threaten forward operating bases and force the U.S. to operate from longer distances, necessitating the use of the tanker (HQ AMC, 2012). **Surprise** leverages security by attacking the enemy at a time, place or in a manner for which they are not prepared (USAF, 2011). Air refueling showcased this ability during Operation El Dorado Canyon, allowing fighters to fly from England around mainland Europe to bomb Libya. The tanker allows fighters to extend loiter time. This was critical during the initial days of Operation Desert Storm through Operations Northern and Southern Watch. The most recent actions in Operations Unified Protector and Odyssey Dawn were all dependent on tanker support.

The tenets of airpower are the guiding truths to the application of airpower. The tenets of **flexibility and versatility** are strengthened through the ability to air refuel. Flexibility allows airpower to exploit mass and maneuver simultaneously (USAF, 2011). Versatility is the ability to employ airpower effectively at the right level and in concert with joint force elements. The tanker is fundamental to flexibility and versatility. Air refueling also allows the tenet of **synergistic effects** and **persistence** by allowing application of a coordinated force at a particular time and giving airpower the speed and range to visit and revisit targets nearly at will (USAF, 2011). The principles of mass and economies of force deal with **concentration** of the right force at the right time and place. Demands for airpower likely exceed the available resources. Tankers allow greater access to airpower resources, giving commanders the ability to create **priority** and **balance**. Air assets are normally a finite resource; the tanker and the missions they support need to be prioritized and balanced in order to achieve success (USAF, 2011).

There are twelve Core Functions of the Air Force. The tanker fleet directly contributes to nine of them. The tanker force continually supports the bomber force performing **nuclear deterrence**. The combat air forces do not have the range or endurance without the tanker force to maintain **air superiority**. Air refueling supports aircraft performing **command and control** and **global integrated intelligence, surveillance, and reconnaissance**; these aircraft can extend their dwell time by air refueling. **Special operations, global precision attack, rapid global mobility** and **personnel recovery** forces, all require the tanker fleet to meet the time and range requirements to be a “Global” force. The United States has the largest tanker capability in the world by far. The sharing of these resources with other nations allows the U.S. to **build partnerships** that allow interaction and mutually beneficial effects.

There are five basic types of air refueling missions: global strike support, air bridge support, aircraft deployment support, theater support to combat air forces and special operations support. Air refueling supports both intertheater and intratheater operations. For intertheater operations, air refueling supports the long-range movement of aircraft between theaters and joint operations areas. This support provides an air bridge allowing deploying aircraft to fly nonstop to their destination, reducing closure time. Intratheater air refueling supports a global combatant commander's AOR by extending range, payload and endurance of combat and combat support aircraft (JCS, 2013).

Air refueling is a critical joint force capability that enables global operations. Without this key capability the joint war fighter cannot execute the United States' national security strategy (NSS) (Grimser, 2011). The ability to meet the NSS must be constantly examined. The Tanker Requirement Study-05 was conducted in 2000. This study was never formally completed and the NSS has changed. The latest unclassified report pertaining to tankers is the Mobility Capabilities and Requirement Study-16 (MCRS) that was conducted in 2009 (MCRS-16, 2009).

The MCRS 2016, states that the current inventory of 474 USAF aircraft (415 KC-135s/59 KC-10s) and 79 USMC KC-130s, does not satisfy all of the requirements set forth in notional strategic environments. For example, in two large scale nearly simultaneous conflicts involving land campaigns and three homeland defense operations, the tanker force would be tasked at 103% of capacity. In a second scenario where U.S. forces conduct a major air/naval campaign and respond to a significant homeland event, the tanker fleet is tasked at 120%. Only in a third hypothetical scenario where U.S. forces conduct a large land campaign using a long-term irregular warfare campaign with three homeland events does the tanker fleet meet the needed capacity. In this scenario, the tanker fleet uses 81% of its capacity. However, this is not

sustainable for long durations. The ranges of these scenarios reach from 383 KC-135/KC-10 equivalents with 66 KC-130s to the high demand of 567 KC-135/KC-10 equivalents and 79 KC-130s. The new KC-46 tanker, currently in production, should lower maintenance depot time and provide a greater capability, thus it will have more capability to meet demand (MCRS-16, 2009).

Air Refueling Planning

Air refueling missions are planned at the unit level or by mission planners at higher headquarters (HHQ). For tankers, this HHQ planning is done at the 618th Air and Space Operations Center (AOC), also known as Tanker Airlift Control Center (TACC). The TACC plans, schedules and directs air refueling missions around the world (TACC, 2008). The TACC employs mostly civilians to create and assemble mission packages for the tanker crews. Their backgrounds vary, but most are retired military pilots and navigators with relevant mission experience. These planners are certified by the FAA and even receive check rides. The packages created by TACC include flight plans, notice to airmen (NOTAMs), diplomatic clearances, weather reports, mission profiles, and fuel plans. These packages are transmitted electronically using Global Decision Support System (GDSS) (USAF, 2008).

GDSS is a single service system with joint interest that provides Mobility Air Forces (MAF) a command and control capability. This command and control allows access and information sharing across net-centric environments. GDSS is an integral part of USTRANSCOM's Defense Transportation System (Borchers, 2006). This is the system where air refueling requirements are conveyed for mission planning.

Fuel and route planning are calculated using Portable Flight Planning Software (PFPS). PFPS is a government owned and controlled suite of mission planning tools. PFPS is used for

planning for a wide variety of Air Force, Navy, Marine and foreign nation's aircraft. This software allows route and altitude selection with predicted weather effects (PFPS, 2014). It also has air refueling route planning and performance factors built in. PFPS provides the primary fuel plan based on inputs made by mission planners or aircrew.

When making a tanker fuel plan, mission planners and aircrew reference their MDS's Operations Procedure regulations. Planners begin by working backwards from their planned landing fuel. Fuel is then added to the plan via PFPS using calculated flight routes, air refueling tracks, planned air refueling offloads, contingency fuel, fuel required for weather avoidance, transition fuel and fuel for reaching an alternate or divert landing location. PFPS calculates fuel burn based on user inputs, best range, or best endurance speeds. The receiver requested offload is also input into the program. Transition fuel is the fuel for flying practice approaches, and is computed at 7.5% of the airplanes gross weight per hour (11-2KC-135V3; 11-2KC-10 V3, 2013). Once this fuel plan is calculated it is communicated to maintenance for fueling the aircraft.

Receivers calculate their fuel requests using the same PFPS software. They calculate where in their mission or on their route they will require fuel. They then request an amount of fuel that allows them to complete their mission. From this air refueling location they calculate how much fuel is required to reach a safe landing location should air refueling be unsuccessful.

Budget Concerns

Former Secretary of Defense, Robert M. Gates, called for tighter scrutiny of all defense spending, asking for \$100 billion in savings over the next five years (Grimser, 2011). Each June, the DOD submits an omnibus reprogramming request to Congress asking to move money, in

order to meet a year of execution expenses. The Air Force has a history of scrambling to pay for fuel in the final months of a fiscal year. This problem is exasperated due to rapidly changing fuel costs. When these budget shortfalls occur the Air Force has several options: slow down operations or move money around, which may require Congressional approval (Starosta, 2012).

The DOD estimates that for every \$10 increase in the price of a barrel of oil the operating costs increase by \$1.3 billion (GAO, Defense Management, 2008). The DOD's jet fuel bill increased \$5.7 billion in six years. This was a 73% increase from FY 2000's \$2.2 billion fuel bill. The wars in Iraq and Afghanistan accounted for 12% of the increase. Therefore, the bulk of the cost increases are from rising fuel prices (Lengyel, 2007). This increase occurred again between FY09 and FY 11, when the Air Force's fuel bill increased 57% in just two years (Starosta, 2012).

Table 1: Fuel Costs/Prices 2006-2012

USAF Fuel Purchases			
Fiscal Year	Dollars (In Billions)	Fiscal Year	\$ Per Gallon
2006	\$5.99	2006	2.24
2007	\$5.93	2007	2.24
2008	\$8.18	2008	3.17
2009	\$5.63	2009	2.16
2010	\$7.30	2010	2.73
2011	\$8.83	2011	3.40
TOTAL (2006-2011)	\$41.87	2012 (Oct to March)	3.93

These rising fuel costs can be confronted from several different angles. There are two main ways to decrease fuel budgets. First is finding a less expensive way to supply the DOD with fuel; the second is to reduce the fuel demand. The fuel supply is being affected by new technologies like synthetic and biomass alternative fuels as they become cheaper and more readily available. Reducing demand can be accomplished through upgrading engines, modifying operational procedures and even replacing entire weapon systems with newer more fuel efficient

systems (Blackwell, 2007). Many of these solutions are costly and must compete for the ever shrinking acquisition budget dollars.

The simulator fidelity and capability that exists today is able to provide a portion of realistic air refueling training, at a significant savings. “There is no substitute in training a fighter pilot for experiencing live gravitational forces and the kick of the afterburner and all those things, but there are parts of the training regime for those pilots and crew members that can and are better done in simulators. Over the last couple of years, ACC has done a very rigorous review of their training syllabus,” states Acting Undersecretary of the Air Force, Jamie Morin (Insinna & Tadjdeh, 2013).

The MAF Distributed Mission Operations (DMO) program raises simulator fidelity. It provides a virtual backdrop to realistic training. When this program reaches its full capability simulators will be able to link to one another. Former AMC Commander, General Paul Selva, states, “We’re on the verge of actually being able to very, very accurately simulate two airplanes refueling each other...simulators have great promise” (Insinna & Tadjdeh, 2013). There can be a tanker front end simulator linked to a boom operator weapons system trainer (BOWST) in another location. This integrated crew can then accomplish virtual air refueling with a receiver simulator linked from yet another location (HQ AMC, 2012). These high-fidelity simulator systems are very expensive, but much less expensive than the fuel and maintenance costs of an actual aircraft.

The number one recapitalization priority is replacing the 415 Eisenhower-era KC-135 Stratotankers. The Air Force calculates that the KC-135 has between 36,000 and 39,000 lifetime flying hours. It is estimated that only a few of the KC-135s will reach that limit by 2040. Currently, the average KC-135 flies approximately 435 hours per year. The USAF and Boeing

have successfully contracted to build 179 KC-46A Pegasus aircraft. These 179 aircraft will help to modernize the tanker fleet but still fall short 236 aircraft needed for replacing the legacy KC-135 (Grimser, 2011). The KC-Y and KC-Z tanker aircraft will most likely begin development near the conclusion of the KC-46A production line (HQ AMC, 2012).

The average KC-135 is over fifty years old. Even with the procurement of fifteen KC-46s per year, the last KC-135 will retire in the 2080s when it is more than 120 years old. Maintenance costs for the aging KC-135 in 2001 were \$2.2 billion. These maintenance costs keep the tanker fleet at a mission capable rate in the high 70 to low 80 percent range (GAO, 2003). The KC-135 operational readiness rate has been decreasing approximately two and-a-half percent per year (Furber, 2004). Additionally, the depot maintenance costs are expected to increase by 18 percent per aircraft per year (GAO, Military Aircraft: Observations on the Air Force's Plan to Lease Aerial Refueling Aircraft, 2003). The FY13 budget included funding KC-135 improvements that should avoid \$150 million in fuel expenses over the aircraft's lifespan (Starosta, 2012).

Due to sequestration, the Air Force has been conducting budget drills. In one such drill the KC-10 was identified as a possible item on the chopping block. Even though the KC-10 was developed and procured decades after the KC-135, it offers a greater immediate savings if cut from the budget. The KC-10 has not been modernized over time as the KC-135 has. It also has a similar mission capable rate as the KC-135. There are larger savings when an entire MWS and its support functions are eliminated than simply cutting a partial fleet. Fortunately, the value of the KC-10 in being a receiver capable tanker with dual air refueling and cargo mission capabilities has temporarily saved the aircraft from being cut from the inventory.

DoD Fuel Logistics

The Defense Energy Support Center (DESC), within the Defense Logistics Agency (DLA), finances fuel purchases through a defense working capital fund. The military services then purchase fuel from the Defense Energy Support Center (DESC) using funds appropriated for their operation and maintenance accounts. Each service has a role in planning fuel demand and for managing storage and delivery of fuel (GAO, Defense Management, 2008).

The standard price of fuel was created by the DOD to insulate the military services from the effects of the fluctuating oil market. It provides a level of budget stability for the Military Services while the working capital fund takes the effects of fluctuations. The price is set in advance of the fiscal year it is to be used. The cost of transporting, storing and managing the government fuel system, to include the war reserves, is considered when determining the standard fuel price. It is because of these factors one cannot compare the standard fuel price with that of the commercial marketplace (DLA, 2014).

Fuel expenditures have a significant impact on the DOD's operating costs but account for only three percent of the total DOD budget (GAO, Defense Management, 2008). For every \$10 increase in the price of a barrel of oil, the operating costs for the Air Force increase approximately \$650 million annually. The DOD budgets a full year ahead and one year at a time. Any increase in fuel cost must be paid by shifting resources or through emergency funding. In the past the DESC would charge one rate for an entire year. In FY 2012, they adjusted the price four times to meet the large fluctuations of the price of oil (DLA, 2014). This keeps the working capital fund viable while still providing the military services a steady price.

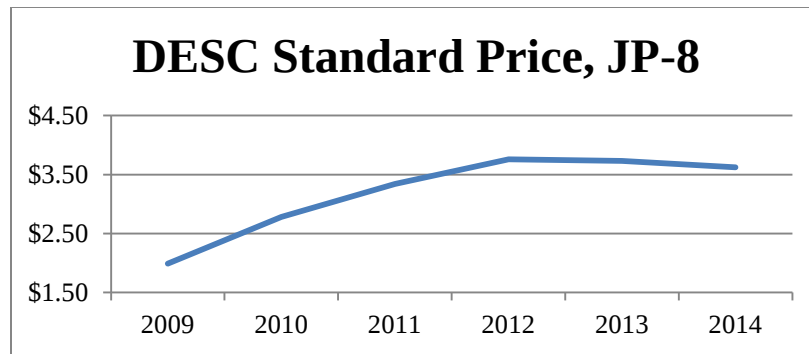


Figure 6: Standard Fuel Price JP-8 2009-2014

During air refueling, receiver aircraft pay a standard price of JP-8 when they receive fuel from a tanker. This is done primarily to keep accounting simple. The true, fully-burdened cost of the fuel coming out of the basket or boom is actually much higher. It takes approximately 8 gallons of fuel to deliver one gallon of jet fuel in flight (Hoy, 2008). When looking at the fully burdened cost of fuel analyses, the science and technology and acquisition trade space would open up significantly if we properly valued the financial costs of delivering fuel to the operator (Dipetto, 2008). This is true in mission planning as well. During training and even in some battle spaces, the fully burdened cost of energy use should be considered. For example, when air refueling's fully burdened costs outweigh the cost of mission delay, maintenance risk, etc. then air refueling should not be planned. Only when the training and operational necessity outweigh the fully burdened cost should air refueling be performed.

Energy Conservation

Trends in the energy sector suggest the cost of energy will rise as demand overtakes supply in the next 25 years. By 2030, the energy demand created by the growing economies of China and India will increase world demand 50% over that of today. In order to meet that

demand the supply would have to increase the equivalent of Saudi Arabia's production every seven years (HQ AMC, 2012).

The world's dependency on oil has allowed a small group of nations to emerge as energy power houses. The vast majority of oil reserves are controlled by national governments which control 77 percent of the world's reserves. In addition, 16 of the top 25 oil-producing companies are either majority or wholly state controlled. This gives leverage to countries that otherwise would have little (DiPeso, 2010).

By 2026, the world's liquid fuel demand is expected to increase by 20-25%. This would make the U.S. oil demand 24 million barrels per day. Jet fuel demand is also expected to increase from 95 billion gallons per year in 2007 to around 221 billion gallons per year. Aviation fuel demand has been growing 4% a year while fuel efficiencies are only growing by 1% (Hendricks, Bushnell, & Shouse, 2011).

The United States Department of Defense is the single-largest consumer of fuel in the world. Jet fuel accounts for 71% of the entire military's petroleum consumption (Hoy, 2008). The Air Force alone spent \$9 billion in 2008 to fuel aircraft and ground vehicles (Harmon, Branam, & Sandlin, 2011).

The 2013 Air Force Strategic Energy Plan added and expanded on the three pillars established by the 2011 energy plan. The pillars were to reduce demand, increase supply and create a change in culture. All of these pillars were guided by the energy vision to "Make Energy a Consideration in All We Do" (Harmon, Branam, & Sandlin, 2011). In 2013, the Air Force Energy Vision became "to sustain an assured energy advantage in air, space, and

cyberspace.” This vision no longer supported by three pillars, now has four priorities—Improve Resiliency, Reduce Demand, Assure Supply and Foster an Energy Aware Culture (USAF, 2013).

Table 2: Summary of the Intent and Expected Outcomes for the 2013 Energy Plan (USAF, 2013)

AIR FORCE ENERGY STRATEGIC PLAN		
PRIORITY	INTENT	EXPECTED OUTCOME
Improve Resiliency	➤ Identify vulnerabilities to energy and water supplies, such as physical and cyber attacks or natural disasters ➤ Mitigate impacts from disruptions in energy supplies to critical assets, installations, and priority missions	➤ Improved responsiveness to disruptions to energy and water supplies ➤ Increased ability to quickly resume normal operations and mitigate impact to the mission ➤ Prioritized response plans and solutions to mitigate risk from the tail (logistics supply chain) to the tooth (energy demand in operations)
Reduce Demand	➤ Increase energy efficiency and operational efficiency for Air Force systems and processes without losing mission capabilities	➤ Decreased amount of energy required by Air Force systems and operations ➤ Increased flexibility, range, and endurance in all operations
Assure Supply	➤ Integrate platform-compatible alternative sources of energy ➤ Diversify drop-in sources of energy ➤ Increase access to reliable and uninterrupted energy supplies	➤ Access to backup energy resources and supply chains based on asset and mission priorities ➤ Increased flexibility in all operations ➤ Increased ability to sustain mission
Foster an Energy Aware Culture	➤ Integrate communication efforts using training and education opportunities to increase awareness of energy impacts to mission ➤ Ensure the acquisition process reflects energy as a mission enabler	➤ Increased understanding and awareness of energy and its impacts to the mission ➤ Reduced energy demand through more efficient uses of energy resources ➤ Increased ability to integrate energy considerations in planning activities and other decisions

Researchers are investigating many possible solutions to fuel problems. Alternate energy sources such as solar power, fuel cells, and bio fuels are being explored by scientists and engineers working to reduce the United States’ dependency on foreign oil (Harmon, Branam, & Sandlin, 2011). Hybrid-electric and solar power are predominantly applicable to remotely piloted vehicles. Biofuels on the other hand, are being developed and tested for all aircraft requiring jet fuel.

The civilian sector and the military have been researching and testing alternative fuels. The Air Force has certified every aircraft in the inventory to fly on a 50/50 blend of petroleum based kerosene and Fischer-Tropsch synthetic paraffinic kerosene (SPK). SPK is made from coal, natural gas or natural biomass. Hydro-treated renewable jet fuel (HRJ) and alcohol-to-jet

fuel are also on their way to USAF certification. These fuels not only reduce dependency on oil, but may be considered more environmentally friendly (Starosta, 2012).

Fuel cell technology is rapidly evolving. Cars like the Nissan Leaf and Tesla Motors Model S have shown that gasoline engines are not necessarily required for transportation. These advances in the automotive industry can be a catalyst for aviation as well. Much of this research is being done in Europe where fuel prices are high and environmental impact needs to be low. So far, Pipistrel's Taurus Electro G2 is the only electric aircraft to hit the market. Until the power-to-weight ratios exceed 200 horsepower, electric-airplane applications will be limited to small aircraft. The impact of perfecting this technology has the capability to change the face of aviation; but it will be quite some time before jet fuel is not required (Pope, 2014).

The DOD has only begun to embrace the value of energy efficiency. It took two years to implement the 2009 congressionally mandated office of the Assistant Secretary of Defense – Operational Energy Plans and Programs (Andres, 2011). This office published its first Energy for the Warfighter: Operational Energy Strategy. This strategy was meant to synchronize the military services' independent energy visions by focusing on three main principles. "More Fight, Less Fuel" addressed the demand. "More Options, Less Risk" addressed diversifying the supply. Finally, "More Capability, Less Cost" drives the change in culture to include energy efficiency into operational planning (Andres, 2011).

The Air Force must continue sustaining and enhancing its capabilities, in an era of increasing fiscal constraint. The Air Force must manage its resources, including its energy consumption. To meet the goals of the National Security Strategy, the Air Force must be capable of providing Global Vigilance, Global Reach, and Global Power. By developing a robust, resilient, and ready energy posture, the Air Force will enable our warfighters, expand our

operational effectiveness in air, space, and cyberspace, and enhance national security (USAF, 2013).

Fuel Efficiency Initiatives

The DOD budgeted \$1.6 billion for operational energy initiatives for FY 2013 (DOD, 2012). The Office of the Secretary of Defense (OSD), the Joint Staff and all of the military services have been making efforts to reduce mobility energy demands in weapon systems and mobile defensive systems. OSD created a department wide Energy Security Task Force in 2006. The Joint Staff updated its policy governing the development of new weapon systems, requiring new weapon systems to consider fuel efficiency as a key performance parameter (GAO, Defense Management, 2008). Additionally, the fully burdened cost of fuel use is now considered when awarding contracts (Hills, 2011).

The Air Force budgeted \$573.5 million in FY 2013 and approximately \$2.4 billion through the Future Year Defense Program (FYDP) for operational energy initiatives. As seen in figure 7, over half of this budget is for research, development, test and evaluation, while the other half is spent on procurement and operations and maintenance (DOD, 2012). The Air Force has many energy initiatives underway, most of which focus on the demand reduction rather than supply or policy change. These initiatives include: Air Force Total Ownership Cost (AFTOC) database; aircraft engine modifications; aircraft drag reductions; vehicle, engine, material technology development; alternative fuels; and changing policies and procedures (DOD, 2012).

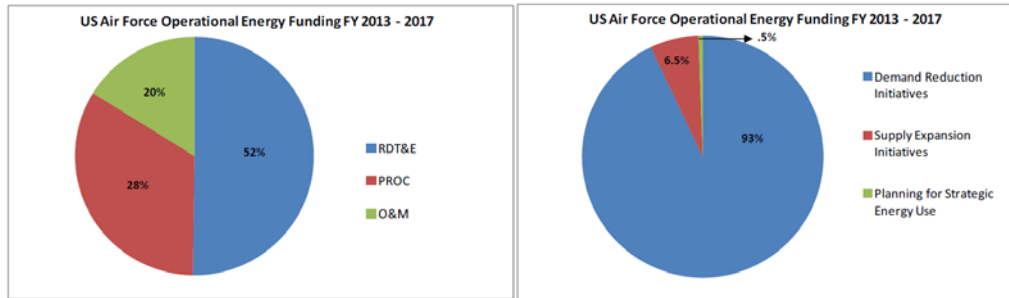


Figure 7: USAF Energy Funding

The Vice Chief of Staff of the Air Force, General Larry Spencer announced the creation of Airman Powered by Innovation, or API. This program will replace three existing programs: the Innovative Development through Employee Awareness (IDEA), Productivity Enhancing Capital Investment, and Best Practices. General Spencer states, “In this fiscally–constrained environment, we need every Airman engaged in finding smarter ways to do business.” API will piggyback on the success of the Every Dollar Counts campaign that took 302 ideas submitted by Airman and saved \$71 million and 24,000 hours annually. API will also expand the role of AFSSO21, Air Force Smart Operations for the 21st Century, the Air Force’s lean operation mechanism (AFPA, 2014).

The Air Mobility Fuel Efficiency Division (A3/A3F) celebrated its 5-year anniversary in October of 2013. The office was created in response to a sharp rise in fuel prices in 2008. Air Mobility Command had the largest fuel bill in the DOD and leadership required action. Conserving energy, primarily by focusing on fuel efficiency, is the reason for the division’s creation. The Fuel Efficiency Office (FEO) looks toward industry for expertise and best practices for lowering fuel costs. The FEO is comprised typically of contractors and Reservists with logistics and commercial airline experience. They are charged with developing tools, processes, metrics and interfaces to improve fuel conservation in the MAF (Baysmore, 2013).

The Secretary of the Air Force's current goal is to improve aviation energy efficiency by 10% by 2020. The first goal of the division was to reduce 2006-baseline fuel consumption 10% by 2015. The division helped reach this goal by 2012. Currently, there are over 70 fuel-savings initiatives (Baysmore, 2013). The FEO is also sponsoring two Advanced Studies of Air Mobility papers for the 2014 class. The FEO is helping to implement the Air Force's strategy for fuel efficiency.

The Fuel Efficiency Division's greatest and most publicized success was the removal of excess equipment and paper publications. This weight reduction has saved the MAF \$7.5 million since 2011. Removing paper from aircraft alone saves \$700,000 per year (Insinna & Tadjdeh, 2013). An additional success of the AMC fuel office was the implementation of the mission index flying optimization tool. This tool gives pilots the most fuel efficient altitude and airspeed given actual environmental conditions (Aldardice, 2012).

As fuel prices continue to rise, it is imperative that fuel efficiencies are realized and a fuel conservation culture flourishes through not only the MAF but the CAF, Air Force and DOD as well. In 2006, the USAF spent \$6.6 billion on aviation fuel; \$1.6 billion more than what was initially budgeted that year (Vann, 2009). Today, the Air Force uses 2.5 billion gallons of fuel costing roughly \$8 billion per year (HQ AMC, 2012).

It is up to the Fuel Efficiency Division to champion a fuel efficient culture change. Col Keith Boone, AMC A3F Division Chief, states "This is a cultural issue at heart. We're going back, re-learning, redoing, and implementing lessons we've discovered before. We cannot afford to return to wasteful practices. Efficiency and effectiveness are not mutually exclusive" (Baysmore, 2013).

One of AMC FEO's strategies is to learn from the aviation industry. Joel Booth, United Airline's managing director of network operations planning, standards and efficiency, states "anything we can do to use less fuel favorably affects the environmental, profitability and the efficiency of the business." (Re, 2014) United Airlines set a goal to reduce fuel expenses by \$1 billion. It has seen a 32 percent rise in fuel efficiency. Two-thirds of these fuel savings are based on modernizing their fleet with more fuel efficient aircraft. United also replaced heavy steel brakes with lighter carbon brakes. This reduction in weight saves fuel (Re, 2014). The KC-135 fleet also replaced its steel brakes with lighter, better performing carbon brakes. The remaining third of the annual fuel savings has been made through process improvements. Just like the Air Force, United Airlines stressed conserving the use of engines and auxiliary power units (APUs) during ground operations. The Air Force and industry can benefit one another through sharing lessons learned. Mr. Booth explains "I have worked with a lot of really smart people in the military and at United to learn about leadership, about fuel efficiency and how to do the best with what we've got. It's an approach of continuous improvement—always looking to get better at what we do every day." (Re, 2014)

Summary

Air refueling has solidified its role supporting military operations throughout the world. From its dangerous and courageous beginnings, air refueling has become a daily occurrence. There is no longer the need for massive quantities of tankers demanded for supporting a cold war gone hot. There is however a need to maximize the capabilities and efficiency of the tankers in the inventory.

The U.S. and its military have entered a new fiscally responsible period. Public support for unlimited budgets has vanished. This new economically sound era spotlights the need to

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embrace a culture change in the U.S. military. This new culture must adapt new procedures and policies that bring economics and efficiencies in balance with meeting mission requirements.

III. Methodology

Without the tanker, America could not execute the Air Force's core competencies of global vigilance, reach and power.

*General Raymond Johns Jr.
Former AMC Commander*

The air refueling mission is essential for accomplishing the goals of the National Security Strategy; the ability to act unilaterally to defend our nation and our interests. This research supports another NSS goal, to spend taxpayers' dollars wisely (National Security Strategy, 2010). This research supports this goal by identifying fuel inefficiencies within the air refueling mission. This chapter will discuss the methodology used to find fuel costs associated with air refueling.

Data Sources

The underlying goal of these calculations is to find a tangible amount of fuel savings for the Air Force. This research aims to find fuel inefficiencies in air refueling operations, by determining if Air Mobility Command tanker aircraft are being scheduled for greater offloads than what they are actually delivering. The main source of data is provided by the AMC Fuel Tracker. Due to variability of operations occurring from the effects of sequestration, the most recent fiscal year data was not used. Instead, Fiscal Year 2012 Fuel Tracker data was analyzed.

The data set provides 18,187 lines of data which was imported into Microsoft Excel. Each line provides a mission number, mission leg, mission class, aircraft or Mission Design Series (MDS), aircraft assigned wing, departure and arrival airport, departure and arrival date and time, flight time (hours), ramp fuel load (K lbs.), landing fuel (K lbs.), on load fuel (K lbs.), deviation remarks, average fuel burn (lbs./hour), offload scheduled (K lbs.), offload actual (K

Lbs.), number of receivers scheduled and actual, receiver unit, air refueling track, air refueling control time and date planned and actual, and cargo carried (K lbs.). See Appendix A for an example of the AMC Fuel Tracker Data.

Data Format

The following columns of data from the Fuel Tracker are not used in this research: mission leg, arrival time, planned air refueling control time and cargo carried. These items have no bearing on the research or are redundant with data used. Additional columns are created to better sort the data and clarify the results of the analysis. One column is added to show the difference between the planned fuel offload and the offload actually accomplished. This number determines if the receiver took greater, equal or less than the planned fuel. Two columns are added by taking the receiver unit and converting it to receiver MDS and receiver category. These are key data columns that group each MDS and aircraft category, in order to pin point where fuel inefficiencies are occurring. See Appendix B for columns used to manipulate the data.

Of the 18,187 lines of the data set, there are many errors and missing data points. To eliminate bad data and correct errors, each line of data is examined individually. This involves a thorough multiple step process. First, all missions missing offload data are eliminated. This immediately removes 2,396 lines of data that will no longer be used in this research. The remaining 15,791 lines of data comprise 100% of this research's data set.

A small portion of the data is missing a planned offload. In this scenario the actual offload is used for the planned offload. This has a minimal influence on the results. This occurs 58 times, or on less than 0.3% of the sorties, for a total offload of 226,200 pounds of fuel. The

minimum offload on these sorties was zero and occurred 32 times. On the remaining 26 sorties the maximum offload is 48,100 pounds and the average offload is 8,700 pounds. This conservative approach shows equal or less cost for fuel inefficiencies but still allows some of the sortie's data to be included in the analysis.

The next step in the process to complete the data is to identify the units for the receivers. In most cases the data is clear. For example, if the data states "1FW" this is easily determined to be the First Fighter Wing. Other receiver units take more effort to decipher the Fuel Tracker. Using the Air Force Portal, the 305th Operational Support Squadron from McGuire AFB and phone calls to the AMC Fuel Efficiency Division most of the receiver units are identified.

The remaining missing or unknown units are identified using mission numbers, departure time, air refueling track, plan offload and planned number of receivers. This is done in a very meticulous manner. First, each missing receiver unit entry is isolated. Then the missing receiver's air refueling track is compared to known data. This usually identifies the receiver unit through common data points. For example, if only the 1st Fighter Wing uses air refueling track "A" and the missing unit is using track "A", has the same offload and number of receivers as all of the other 1st Fighter Wing sorties, then the missing unit is labeled as 1st Fighter Wing.

Most of the missing or unknown units are determined to be small, Navy, foreign or seldom used units. Often, these missing units are input in the AMC Fuel Tracker when completing post mission paperwork after refueling these uncommon receivers. Aircrews have difficulty finding the correct unit and then leave it blank. When a receiver unit cannot be determined based on mission similarities represented in the data, the unit is left "unknown". This occurs on only 3%, or 485 missions. These lines cannot be included in MDS data but are still included in the overall averages.

After the units are identified, the units must be matched to the air refuelable MDS flown by the unit. There are 618 receiver units and receiver unit combinations in the data. Again using the Air Force Portal, AF webpage, the 305 OSS and AMC's Fuel Efficiency Division, each unit is matched to the air refuelable aircraft assigned to the unit. In most cases, each unit has only one MDS. In the case where there are multiple air refuelable MDSs, a similar procedure for identifying the unit is used to match known data with unknown data. For example, there are multiple wings that fly both the F-16 and the A-10 aircraft. Fortunately, each of these receiver MDSs use very different AR tracks. When the A-10 or F16 sortie compares the AR track flown with known MDSs and units that use that AR track, and all of them are A-10 units, then the F-16 or A-10 MDS unit is labeled as A-10. Again, when the MDS cannot be identified it remains mixed, F-16/A-10. This allows the sortie to be included with the Fighter data but not MDS specific data.

This same procedure is done with mixed units. For example, when 366FW and 4FW are on the same sortie and both the 366th Fighter Wing and the 4th Fighter Wing both fly F-15s. For all Navy and Marine assets, with the exception of the E-6B TACAMO, the MDS is matched to "USN". Additionally, all foreign units are matched as "Foreign", without regard to the aircraft flown. The only exceptions for foreign aircraft are those identified as a "Heavy" aircraft. In this case the sortie is matched to the actual MDS flown. If the sortie supports a bomber and a fighter on the same sortie it is categorized as a MIXED MDS to be included in the overall analysis only. From the 618 receiver units they are matched to 31 MDS types.

Once the 31 MDS type are identified, they are again organized into six broad aircraft categories. These categories include: Fighter, Bomber, Heavy, Intelligence Surveillance and Reconnaissance (ISR), Mixed and Unknown. MDS data with multiple receivers and those

identified as mixed or unknown fighter, bomber or heavy can then be lumped into their respective category. This allows more data to be analyzed when looking at each overarching category. This leaves 181, or 1.1% of the missions that can only be included in the Unknown category. This data is still used as part of the overall analysis.

Table 3: Aircraft Categories and MDSs Used

FIGHTER	BOMBER	HEAVY	ISR	MIXED	UNKNOWN
A-10	B-1	C-130	E-3	C-17/E-3	UNKNOWN
A-10/F-16	B-2	C-5	E-4	Mixed	
F-15	B-52	C-17	E-8		
F-16	Mix'd Bombr	C-32	RC-135		
F-22		KC-10	RC-135/E4		
USN		KC-135	TACAMO		
Foreign		C-17/KC-10			
Mix'd Fightr		C-17/C-5			
		C5/C17/KC10			
		Mix'd Heavy			

Data Analysis

In 2008, Cyintech completed a study identifying a cost of weight (CoW) for AMC aircraft (Cyintech, 2008). This CoW is given as a percentage. This percentage represents the amount of fuel it takes to burn 100 pounds of fuel. For example, a 5.3% CoW translates to a tanker carrying 100 pounds will take 5.3 lbs. of fuel per hour of flight. The CoW differs for short, medium and long duration sorties. In this research, the KC-10 uses less than 3.4 and greater than 6.6 hours and the KC-135 uses less than 2.6 and greater than 5.5 hours as the sortie duration discriminators. This is calculated by taking the half-way point between the median flight time ranges given in the study. Once this is determined, the operational CoW from Cyintech is matched to the associated sortie duration for both the KC-10 and the KC-135.

Table 4: Sortie Duration CoW Range Factors

	KC-135		KC-10	
	Sortie Duration	CoW Factor	Sortie Duration	CoW Factor
Short	<2.6 hrs.	6.88%	<3.4 hrs.	8.19%
Medium	2.6-5.5 hrs.	5.34%	3.4-6.6 hrs.	6.12%
Long	>5.5 hrs.	1.71%	>6.6 hrs.	3.64%

Once the CoWs, MDSs, and Categories are integrated with the data, the difference between the planned air refueling amount and the actual amount of fuel taken is calculated. This is done with Equation 1, a simple subtraction problem. When there is zero difference in the planned and the actual amount of fuel the sortie is labeled ETP, Equal To Plan. When the result is positive or the receiver takes less than the plan, the sortie is labeled LTP, Less Than Plan. Finally, when Equation 1 results in a negative number or the receiver takes more fuel than the plan the sortie is labeled GTP, Greater Than Plan. The percentage of ETP, LTP and GTP sorties are calculated for each MDS and category.

$$\text{Fuel Difference (Klbs)} = \text{Planned offload} - \text{Actual offload} \quad (1)$$

$$\text{Ex. } 36 \text{ Klbs} = 78 \text{ Klbs} - 42 \text{ Klbs}$$

Equation 1: Fuel Difference

Next, the cost of the fuel not taken by the receiver is calculated by taking the answer of Equation 1 and multiplying it by \$3.50, the cost of fuel used in this research. This \$3.50 per gallon of JP-8 jet fuel is used because it is an even fuel price that approaches the average price for FY 2012.

Following this calculation, the gallons of extra fuel are determined for each LTP sortie. This is done through the use of Equation 2. Each sortie's CoW factor, determined by tanker's sortie duration, is multiplied by the sortie duration. Then it is multiplied by the fuel difference determined by Equation 1. This number is then divided by 6.7 pounds per gallon, the weight of a

gallon of JP-8 fuel. This is used to get results in gallons of fuel instead of pounds of fuel.

Finally, the \$3.50 price per gallon is then multiplied by the fuel used to carry the LTP fuel. This is done using Equation 3.

$$\text{Fuel Used to Carry LTP Fuel} = \frac{(\text{Sortie Duration} \times \text{CoW} \times \text{Fuel Difference})}{6.7 \text{ lbs/gal}} \quad (2)$$

$$\text{Ex. } 2920.4 \text{ Gallons} = \frac{7.9 \text{ hrs} \times .0688 \times 36K \text{ lbs}}{6.7 \text{ lbs/gal}}$$

Equation 2: Fuel Used to Carry LTP Fuel

$$\text{Cost of Fuel} = \text{Gallons of Fuel} \times \text{Price of Fuel} \quad (3)$$

$$\text{Ex. } \$10,221.42 = 2920.4 \text{ gal} \times \$3.50$$

Equation 3: Cost of Fuel

The cost for taking more than the planned amount of fuel is examined in terms of cost of fuel and equivalent tanker flight hours. The fuel difference for GTP sorties calculated from Equation 1 is divided by the average tanker fuel burn rate, represented in Equation 4. This burn rate is input by crewmembers in the Fuel Tracker. This is equivalent to tanker flight hours in terms of an average tanker burn rate. This is computed for KC-135 or KC-10 hours, by dividing by the average fuel burn rate of the respective tanker. However, in this report it is left as average tanker hours.

$$\text{Equivalent Tanker Hours} = \frac{\text{Fuel Difference}}{\text{Tanker Fuel Burn Rate}} \quad (4)$$

$$\text{Ex. } .6 \text{ hrs} = \frac{6.1 \text{ Klbs}}{10,000 \text{ lbs/hr}}$$

Equation 4: Cost in Equivalent Tanker Hours

The same fuel in difference in GTP sorties is divided by the weight of fuel, 6.7 pounds per gallon, to calculate gallons of fuel over the plan. This result is then multiplied by the cost of fuel, \$3.50 per gallon, to get the cost of fuel taken in excess of the plan.

Finally, the data is sorted by category and then by MDS. The information is then gathered into summary charts (See Chapter 4 and Appendices H-K). These charts are made for each type of tanker and each receiver category and MDS. Each summary chart displays the number and percentage of ETP, LTP and GTP sorties. It also shows the average tanker fuel burn rates and landing fuel. The number of planned and actual receivers for both LTP and GTP sorties are also displayed. The calculated cost for the fuel, the cost to carry and the cost in tanker hours for planning versus actual air refueling are shown. The costs associated with each Category and MDS are then compared and contrasted against each other to show which aircraft affect AMC's fuel bill the most.

IV. Analysis and Results

Simply put, America's National Security Strategy, built on the imperative of world-wide engagement, demands nothing less than the best global transportation system the world has ever known, one capable of projecting U.S. strength and resolve—anywhere, anytime.

General Charles T. Robertson Jr.

*Former Commander Air Mobility Command and
US Transportation Command*

The fuel not burned or offloaded during a sortie is unnecessary weight. Former AMC Commander, General Paul Selva confirms, “For every pound of stuff you carry you burn a tenth of a pound of fuel.” (Insinna & Tadjdeh, 2013) The factor with the most impact on air refueling fuel waste is the inability to adhere to the mission plan. This research identifies over \$26 million of fuel purchased for receivers that never made its way to their tanks. The cost of carrying this fuel exceeds \$5 million. Additionally, some receivers took 13.8 million pounds of fuel over their original plan. This fuel, taken from the tanker's usable fuel, equals over \$7 million. This money or fuel could have been used for an additional missions or training. These fuel deviations introduce more volatility in air refueling planning and budgeting.

Sortie Fuel Predictability

Using the 15,719 sorties from the FY 2012 AMC Fuel tracker, the research finds that on 49.1% of sorties, the receiver aircraft fails to take the full amount of requested fuel. These sorties are labeled LTP or less than plan sorties. On 17.4% of the sorties, the receiver(s) took more fuel than they had requested. These are labeled GTP for greater than plan sorties. Therefore, on ETP or equal to plan sorties, receivers took the planned offload on 33.5% of the sorties.

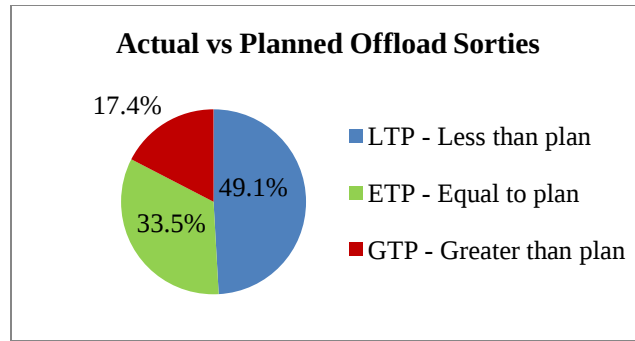


Figure 8: Actual vs Planned Offload Sorties

The differences between the planned and actual fuel offload incur a cost. This cost includes the direct cost of carrying the additional weight of fuel, or indirectly, the mission effectiveness and training lost. This loss of training and mission effectiveness is due to the receiver taking fuel allocated to the tanker, therefore shorting follow on tanker mission objectives after air refueling.

In 2008, Cyintech conducted a study that calculates the Cost of Weight (CoW) for all mobility aircraft (Cyintech, 2008). Each tanker is analyzed based upon the median long, medium or short duration of their sorties. The KC-10's average sortie duration for FY12 was 4.9 hours. There are 2,371 KC-10 sorties classified into 330 long, 1,685 medium and 356 short duration sorties. The CoW for KC-10s is 3.64% on long duration sorties and 6.12% and 8.19% on medium and short duration sorties. The KC-135's average sortie duration for the same time period was 3.7 hours. The 13,420 KC-135 sorties break down into 1,032 long, 9,839 medium and 2,549 short duration sorties. The CoW for KC-135s is 1.71% on long duration sorties and 5.34% and 6.88% on medium and short duration sorties. The cost of weight is greater on short duration sorties compared to long duration sorties. This can be likened to city versus highway gas mileage.

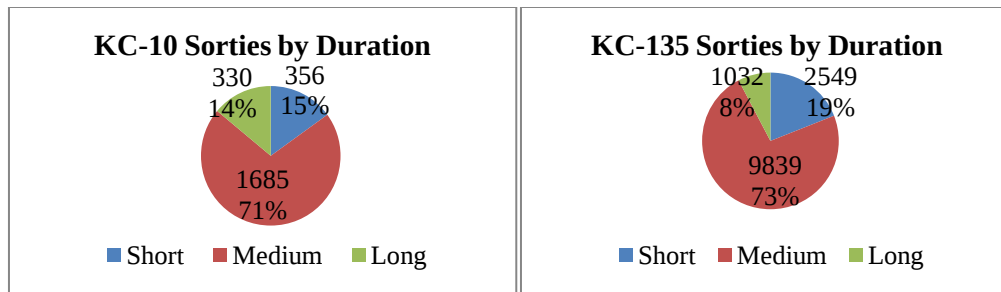


Figure 9: Tanker Sorties by Duration

When examining fuel use in both tankers, sortie length does affect air refueling fuel efficiency. On long GTP sorties the average additional fuel taken by receivers is over two times greater than short and medium length sorties. See appendix G for details on KC-10 and KC-135 short, medium and long length sorties. This makes sense because most of these long sorties are deployment, coronet, contingency, etc. missions that require an oceanic crossing. Fighter aircrews will often maximize their onloads at each air refueling to ensure adequate fuel is available in case something goes wrong. A Hill AFB, F-16 pilot states “when I have one engine and I’m out of gliding distance from the shore, the last thing I want to think about is fuel!” Therefore tankers are usually directed to carry more fuel than what an ideal fuel plan would entail.

According to a member of KC-10 squadron leadership, there are multiple reasons that long length sorties carry more fuel than necessary. When performing a channel (cargo) mission with no air refueling KC-10s almost always land at the required and desired landing fuel. On Coronet (fighter movement) sorties the tanker is often directed by TACC to carry the maximum amount of fuel. This is usually driven by the amount of fuel that a KC-10 can carry. The extra fuel allows them to carry forward or launch early to facilitate the fighter movement if one of the other tankers breaks. On these missions it is also common for KC-135s to deliver any excess fuel to the KC-10 so that the KC-135 lands at their planned landing fuel. When the receiver(s) does not need or take this fuel, the KC-10 ends up landing with large excess

amounts of fuel. Additionally in fiscal year 2012, TACC authorized the tankering of gas when flying near Egypt. This was due to constant unplanned reroutes. All of these reasons contribute to large amounts of air refueling inefficiency, specifically on long duration tanker sorties (Fish, 2014).

During fiscal year 2012, the average planned offload was 20.8K pounds, but the average actual offload was 18.6K pounds. On one sortie this 2,000 pounds of fuel is not very significant. When 2,000 pounds of fuel is multiplied over 15,719 sorties, the amount is quite substantial. The total planned offload for FY 2012 is 329,110,900 pounds while receivers only unloaded 293,062,100 pounds. This 36,048,800 pounds of JP-8 fuel short of the plan cost \$18,831,462.69 using the price of \$3.50 per gallon. This fuel will eventually be used by the tanker fleet or downloaded upon landing for future use. However, the Air Force begins paying for that fuel at the time of purchase with funds it could use elsewhere. It is also unknown when that fuel will actually get used. This could be beneficial if the price of fuel increases dramatically, but most likely the Air Force ends up paying for “warehousing” the fuel.

When all tanker sorties are analyzed together, Greater Than Planned (GTP) sorties’ additional onloads cancel out a large portion of fuel that is shorted by Less Than Planned (LTP) sorties. This creates the need to look at the GTP, LTP and Equal To Plan (ETP) sorties separately. Examining the entire 49.1% of LTP sorties reveals the largest amount of air refueling fuel waste. These sorties short the planned offload by 49.8M pounds. This shorted fuel, when calculated at \$3.50 per gallon, equals \$26,028,768.66 of fuel purchased for delivery to receiver aircraft but never delivered to the planned receiver.

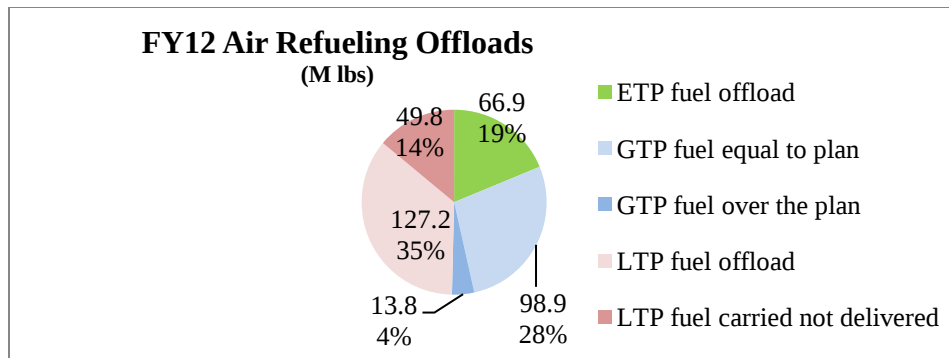


Figure 10: FY12 Air Refueling Fuel Usage

Additionally, on the 17.4% of GTP sorties, 13.8M pounds of fuel were provided over the original requests of 98.9M pounds. This additional fuel costs \$7,197,305.97 at \$3.50 per gallon. When receiver units take extra fuel they are billed accordingly. Using this same 13.8M pounds of fuel, with an average tanker fuel burn rate of 11,083.8 pounds per hour, this additional fuel equates to 1,243.0 average tanker flight hours. This can also be expressed as 1,388.9 KC-135 flight hours at a burn rate of 9,920 pounds per hour or as 779.5 KC-10 flight hours at a burn rate of 17,673 pounds per hour.

The goal for both the KC-135 and the KC-10 is to land with their planned landing fuel. This is equal to the minimum fuel directed in the tanker's technical data plus any reserves for mission or weather alternate requirements. This normally equals 16,000 lbs. for the KC-135 and 16,500 lbs. for the KC-10 in good weather. The AMC Fuel Tracker reports the average landing fuel for the entire tanker fleet as 29,100 lbs.

The KC-10 has an atrocious landing fuel average of 46,100 lbs. The KC-135 averages much better, but still a large 26,100 lbs. of fuel on landing. This amount shows a massive amount of extra fuel being carried on each and every sortie. The KC-10 lands with more fuel than the KC-135 for a variety of reasons. One reason is that all KC-10s are air refuelable. When there are multiple tankers flying, often excess fuel is offloaded to the KC-10 tanker allowing KC-135s to land at their planned landing weight. Another reason for this high average is the

requirement for “Heavy” air refueling. Most large air refuelable aircraft do not have this training requirement. The KC-10 however does, and accomplishes this training by swapping large amounts of fuel back and forth between KC-10s. If this fuel cannot be transferred to other aircraft, the KC-10s are forced to land with this traded extra fuel. This extra fuel at landing costs the Air Force money in CoW carrying costs. Any amount of fuel remaining in the tanker’s fuel tanks after landing can be used on the next tanker sortie or downloaded for future use.

The cost of carrying extra weight is calculated by multiplying the flight time by the CoW factor multiplied by the difference of fuel planned and the fuel delivered. The total cost for carrying the fuel requested but not taken by receiver aircraft is \$5,293,785.18. This amount is calculated from 10,133,817 lbs. of fuel not taken priced at \$3.50 per gallon.

The inaccuracy between fuel requests and fuel delivered is only one element of air refueling affecting efficiency. The number of receivers planned to air refuel has a variability that affects efficiency as well. In most cases, when refueling heavy aircraft such as cargo, bomber or ISR aircraft, there is one receiver scheduled and one receiver that shows up. Sorties refueling fighter aircraft on the other hand average 5.56 aircraft scheduled and 6.07 aircraft refueled. In FY 2012, there were 41,306 receivers scheduled for time on the tanker, and according to the AMC Fuel Tracker, 44,360 receivers actually came to the tanker. There were 485 receiver aircraft less than planned on LTP sorties and 2,932 receivers more than planned on GTP sorties. With only 2%, or 485 receivers less than planned on LTP sorties, the amount of receivers coming to the tanker does not have a large effect on the receiver(s) not meeting the fuel plan. On GTP sorties this is not true. There is a 32.6% or 2,932 receiver difference than the plan on GTP sorties. This large increase in receivers over the plan is a partial reason for GTP sorties.

The difference between the numbers of receivers planned versus those that actually air refuel are the result of many factors. In some cases, tanker aircraft will take additional receivers if they have additional fuel to give. This additional fuel should not exist if the tanker and receiver(s) stick to the air refueling plan. Another cause for the difference between the numbers of receivers planned versus actual are errors input by the aircrew into the AMC Fuel Tracker. There is little standardization and training to filling out the Fuel Tracker, therefore some receivers are logged for each boom or drogue contact, rather than for completion of their refueling.

Each group of receivers; bombers, fighters, cargo, and ISR share a portion of the cost associated with inaccurate air refueling planning. The percentage of excess costs in refueling does not match the percentage of sorties refueling each category. Out of the 15,791 sorties analyzed, there are 4,979 fighter, 2,103 bomber, 6,188 heavy and 2,258 ISR supported sorties. These categories are analyzed in the following sections.

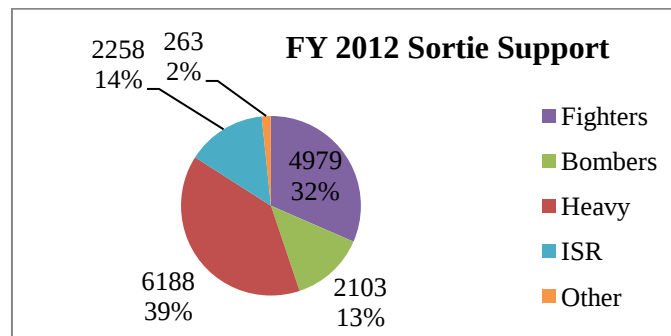


Figure 11: FY 2012 Sortie Support

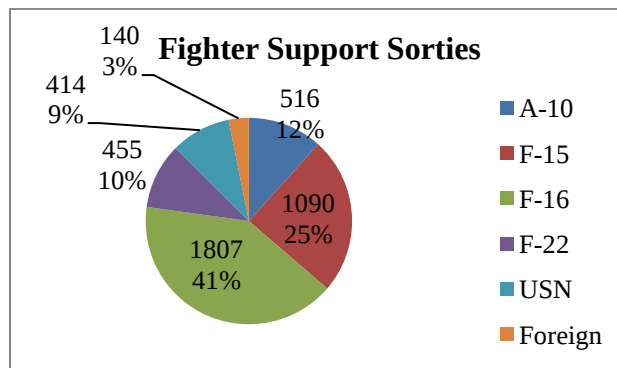
Fighters

Fighter aircraft are supported by air refueling on 4,979 of the sorties analyzed. Only 12.4% of fighter supported sorties are ETP sorties. On fighter sorties, LTP occurs most often at 59.6% of the time. This leaves 29% of the time when the receivers took greater than the planned fuel onload. During LTP fighter sorties, 17,335 of the 17,780 scheduled receivers short the

planned refueling amount by 29,293,700 pounds. At \$3.50 per gallon of JP-8 the cost of this unused fuel is \$15,302,679.10. The cost to carry this additional fuel requires just over 6M pounds of fuel that cost over \$3.15M at \$3.50 per gallon. There are also 9,862 receivers of a planned 7,101 that took an additional 7,707,300 pounds of fuel on GTP sorties. This extra fuel cost \$4,026,201.49 or the equivalent of 659.5 tanker flight hours.

Table 5: Fighter Summary

FIGHTER TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
4979		2966	616	1397
100.0%		59.6%	12.4%	28.1%
Fuel not taken		Fuel Not Taken		Fuel over
21586.4		29293.7		7707.3
Gal		Gal		Avg Burn Rate
3221850.746		4372194.03		11687.11
Price		Price		Gal
\$3.50		\$3.50		1150343.28
Cost of fuel		Cost of fuel		Price
\$11,276,477.61		\$15,302,679.10		\$3.50
Rec Plan		Rec Plan		Cost of fuel
27691		17780		\$4,026,201.49
Rec Actual		Rec Actual		Flt Hrs
30245		17335		659.5
Land fuel		Cost to Carry		Rec Plan
32.1		6031.709312	Klbs	7101
		900255.1212	gal	Rec Act
		\$3,150,892.92	Cost	9862

**Figure 12: Fighter Support Sorties**

The fighter aircraft supported sorties are subdivided into six subcategories: A-10, F-15, F-16, F-22, Navy (to include the Marines) and Foreign aircraft. The greatest overall costs due to fuel plan deviation are attributed to the F-16, primarily because it has almost two times more sorties than other fighters. However, the F-16 comes in second best (least costs) when looking at

a per sortie cost on LTP sorties. On a LTP per sortie basis, the aircraft that cost the least from best (least additional cost) to worst (most expensive) are the A-10, F-16, F-15, F-22, Foreign and finally Navy receivers.

The Navy sent 169.1% of the planned receivers to the tanker, not quite two receivers for every one planned. The F-15 is the only category that sent fewer receivers to the tanker than planned. The largest fuel shortage of the plan was by F-16s, but on a LTP per sortie basis the Navy shorts the plan the most. Additionally, the Navy and Marines also go over the fuel plan the most on a per sortie basis. On Navy supported GTP sorties, they fly 229.1% more aircraft to the tanker than the plan, over two aircraft for each one scheduled.

Table 6: Fighter Sortie Fuel Use vs. Plan

	LTP	ETP	GTP
A-10	56.8%	22.3%	20.9%
F-15	60.6%	10.6%	28.8%
F-16	59.7%	13.2%	27.1%
F-22	59.8%	12.3%	27.9%
USN	58.9%	5.6%	35.5%
Foreign	60.7%	7.9%	31.4%
Fighter Avg.	59.6%	12.4%	28.1%
Overall Avg.	49.1%	33.5%	17.4%

For GTP sorties, the order of MDSs from best (least cost) to worst is A-10, F-16, F-15, Foreign, F-22 and Navy. This leads one to believe that A-10s follow the fuel plan the closest, whereas the Navy does not. The A-10 has the least amount of costs associated with plan deviation. This cost is still \$985,902.99 to purchase the fuel and an additional \$234,889.93 to carry it on LTP sorties. The A-10 cost the tanker fleet 42.8 flight hours from additional fuel offloaded on GTP sorties.

The fighter category accounts for the largest amount of tanker fuel inefficiency. Fighter aircraft have half the ETP rate of the average category of aircraft. They also have over 10%

more LTP and GTP sorties than the overall rates for fiscal year 2012. Fighters account for one third of the tanker sorties but almost two thirds of the cost of LTP sorties. They also account for over half of the cost of all GTP sorties.

The Navy and Marine aircraft cause the most tanker fuel inefficiency of all fighter MDSs. The A-10 has the highest percentage of ETP sorties and in turn also has the least additional costs due to plan deviation. All individual fighter summaries can be viewed in Appendix H.

Bombers

Bomber aircraft are supported on 2,103 of the sorties analyzed. On 40.5% of bomber supported sorties the receiver is ETP. Slightly more often at 43.7% the bombers receive LTP. This leaves 15.7% GTP bomber sorties. During bomber supported sorties 1,234 of the 1,542 scheduled receivers flew LTP by 3,941,500 pounds. At \$3.50 per gallon of JP-8 the direct cost of this unused fuel is \$2,058,992.54. The cost to carry this additional fuel takes 877,584 pounds of fuel that cost \$458,439.44. There are also 491 receivers of a planned 525 that took GTP 1,631,900 pounds of fuel. This extra fuel cost \$852,485.07 or the equivalent of 164.9 tanker flight hours.

Table 7: Bomber Summary

BOMBER TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
2103		920	852	331
100.0%		43.7%	40.5%	15.7%
Fuel not taken		Fuel Not Taken		Fuel over
2309.6		3941.5		1631.9
Gal		Gal		Avg Burn Rate
344716.4179		588283.58		9899.26
Price		Price		Gal
\$3.50		\$3.50		243567.16
Cost of fuel		Cost of fuel		Price
\$1,206,507.46		\$2,058,992.54		\$3.50
Rec Plan		Rec Plan		Cost of fuel
3253		1542		\$852,485.07
Rec Actual		Rec Actual		Flt Hrs
2808		1234		164.9
Land fuel		Cost to Carry		Rec Plan
25.1		756.519724	Klbs	525
		112913.3916	gal	Rec Act
		\$395,196.87	Cost	491

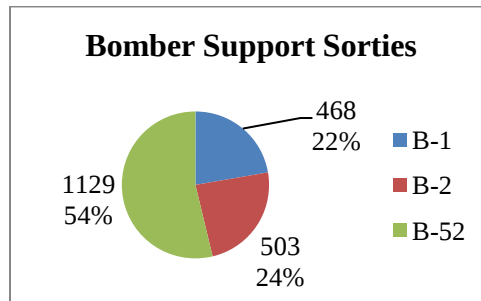


Figure 13: Bomber Support Sorties

The bomber aircraft are subdivided into three subcategories: B-1, B-2 and B-52 aircraft. The B-52 takes half of the bomber supported sorties, while the B-1 and B-2 each take approximately one quarter. Just less than one half of B-52 and B-2 sorties are ETP. The B-1 has the least amount of accuracy in receiver number and ETP fuel offloads. The bomber category is close to the overall average for all LTP, ETP and GTP sorties. The B-1 supported sorties are the only outlier flying over 60% LTP sorties. Individual bomber summaries are found in Appendix I.

Table 8: Bomber Sortie Fuel Use vs. Plan

	LTP	ETP	GTP
B-1	60.3%	27.8%	27.8%
B-2	34.6%	46.3%	46.3%
B-52	41.1%	43.2%	43.2%
Bomber Avg.	43.7%	40.5%	15.7%
Overall Avg.	49.1%	33.5%	17.4%

During bomber supporting sorties, the B-52 incurs the greatest costs due to deviation from the original air refueling plan. The B-2 has the highest per sortie cost for both LTP and GTP sorties, despite the fact that the B-2 has the highest percentage of ETP sorties. The B-52 has the least cost deviation for LTP sorties and the B-1 has the least cost for GTP sorties.

Heavy

Heavy aircraft are supported on 6,188 of the sorties analyzed. Almost half of the heavy sorties (42.6%) are ETP sorties. However, on 48.1% of the heavy supported sorties, aircraft receive LTP while only 9.3% receive GTP. During these LTP sorties, 3,760 receivers instead of the 3,382 scheduled receivers short the planned refueling amount by 8,023,400 pounds. At \$3.50 per gallon of JP-8 the direct cost of this unused fuel is \$4,191,328.36. The cost to carry this additional fuel took 1,812,783 pounds of fuel that cost \$946,976.08. There are also 699 receivers, eight more than planned, that took an additional 2,428,400 pounds of fuel. This extra fuel cost \$1,268,567.16 or the equivalent of 216 tanker flight hours.

Table 9: Heavy Summary

HEAVY TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
6188		2978	2634	576
100.0%		48.1%	42.6%	9.3%
Fuel not taken		Fuel Not Taken		Fuel over
5595		8023.4		2428.4
Gal		Gal		Avg Burn Rate
835074.6269		1197522.39		11241.19
Price		Price		Gal
\$3.50		\$3.50		362447.76
Cost of fuel		Cost of fuel		Price
\$2,922,761.19		\$4,191,328.36		\$3.50
Rec Plan		Rec Plan		Cost of fuel
6859		3382		\$1,268,567.16
Rec Actual		Rec Actual		Flt Hrs
7605		3760		216.0
Land fuel		Cost to Carry		Rec Plan
28.5		1627.067585	Klbs	691
		242845.9082	gal	Rec Act
		\$849,960.68	Cost	699

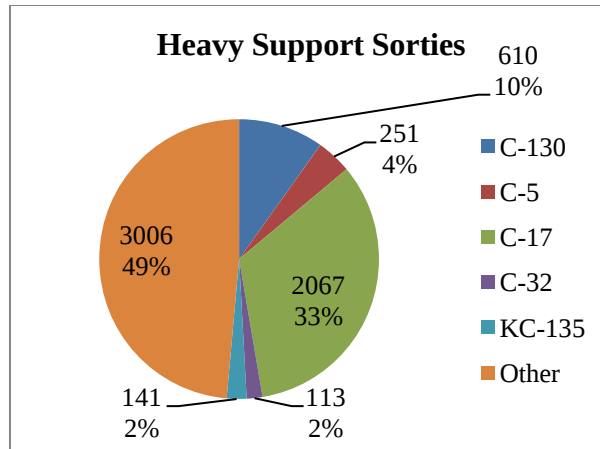


Figure 14: Heavy Support Sorties

The heavy aircraft are subdivided into six subcategories: C-130, C-5, C-17, C-32, KC-135, and the last subcategory contains all the heavy units with multiple heavy MDSs. This group does not provide enough data to isolate which MDS was supported. The largest identifiable portion of heavy aircraft is the C-17. The C-32 is the smallest supported MDS that is individually examined as a heavy aircraft. The heavy aircraft category has the most variability of data between those MDSs that are contained within. See Appendix J for Heavy MDS summaries.

On heavy LTP sorties, the C-5 uses the exact amount of receivers as planned but still manages to short the plan by 414,900 pounds of fuel. The C-130 flew only 88.9% of the planned receivers to the tanker on LTP missions. All of the other heavy aircraft flew essentially the planned amount of aircraft. The largest short of the air refueling plan was by C-17s, but on a per sortie basis the C-130 shorts the plan the most. The KC-135 took more fuel on GTP sorties than all of the other heavy MDSs.

Table 10: Heavy Aircraft Fuel Use vs Plan

	LTP	ETP	GTP
C-130	50.7%	38.7%	10.7%
C-5	54.6%	36.7%	8.8%
C-17	48.6%	43.7%	7.7%
C-32	27.4%	61.1%	11.5%
KC-135	44.7%	38.3%	17.0%
Heavy Avg.	48.1%	42.6%	9.3%
Overall Avg.	49.1%	33.5%	17.4%

The largest air refueling requirement comes from the C-17. The C-17 supported sorties cost the most at \$1,295,820.90 but at over 1,000 sorties, it also flies three times more than any other MDS. However, on a per sortie basis it has the least cost for deviating from the fuel plan. The C-130 has the greatest cost per LTP sortie.

The two bases where most of the undistinguishable receivers are located are at Travis AFB and McGuire AFB. At McGuire AFB there are KC-10s and C-17s. At Travis AFB there are KC-10s, C-17s and C-5s. These receivers all use the same AR tracks and their MDSs are not easily identified. Comparing the C-5 and C-17 LTP and ETP numbers against the heavy category totals, it is unlikely that identifying the MDS from this group will affect the analysis. When looking at GTP sorties this may not be the case.

The overall cost per sortie for the entire heavy category is much larger than any of the individual MDSs. This reveals that the KC-10 may affect the overall average of MDSs taking more fuel than planned. This makes sense due to the nature of the KC-10 mission to consolidate fuel. The KC-10 also has a “heavy” air refueling training requirement. This is probably the most expensive tanker sortie when it comes to fuel efficiency and wasted fuel. On these missions two or more KC-10 aircraft transfer large quantities of fuel back and forth between themselves. Due to the amount of fuel needed to credit the “heavy” air refueling requirement, both aircraft often land with much heavier than desired fuel loads. Depending on how the KC-10

aircrews document the fuel transfer back and forth in the AMC Fuel Tracker, this could have an impact on the heavy aircraft averages.

Intelligence, Surveillance and Reconnaissance

ISR aircraft are supported by tankers on 2,258 of the sorties analyzed. On half of the ISR sorties (50.9%) the receiver aircraft take ETP. On 32.2% the ISR aircraft receive LTP, leaving only 16.9% of the time where receivers take GTP. Due to the nature of the ISR mission it is unlikely that more than one receiver is scheduled. There are very few differences in all categories between the number of receiver aircraft planned and the aircraft that are flown. Some of these differences can be attributed to AMC Fuel Tracker errors.

LTP sorties short the planned refueling amount by 6,149,100 pounds. At \$3.50 per gallon the direct cost of this unused fuel is \$3,212,216.42. The cost to carry this additional fuel takes 1,306,785 pounds of fuel that cost \$682,648.71. There are also 586 documented receivers, just over a hundred more than planned on GTP sorties that take an additional 1,558,700 pounds of fuel. This extra fuel cost \$814,246.27 or the equivalent of 150.2 tanker flight hours.

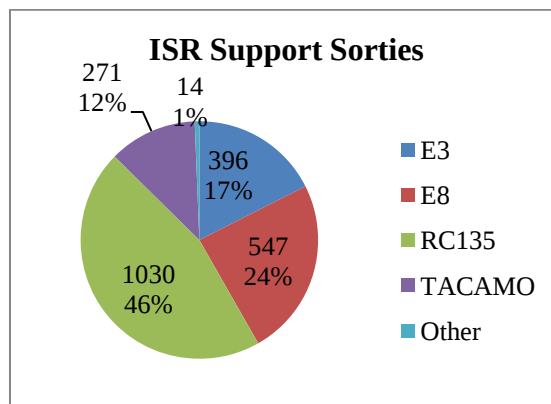


Figure 15: ISR Support Sorties

Table 11: ISR Summary

ISR TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
2258		728	1149	381
100.0%		32.2%	50.9%	16.9%
Fuel not taken		Fuel Not Taken		Fuel over
4590.4		6149.1		1558.7
Gal		Gal		Avg Burn Rate
685134.3284		917776.12		10378.54
Price		Price		Gal
\$3.50		\$3.50		232641.79
Cost of fuel		Cost of fuel		Price
\$2,397,970.15		\$3,212,216.42		\$3.50
Rec Plan		Rec Plan		Cost of fuel
2551		903		\$814,246.27
Rec Actual		Rec Actual		Flt Hrs
2687		873		150.2
Land fuel		Cost to Carry		Rec Plan
27.1		1218.481587	Klbs	481
		181862.9234	gal	Rec Act
		\$636,520.23	Cost	586

The ISR aircraft are subdivided into four subcategories: E-3, E-8, RC-135, and the Navy's TACAMO aircraft. The last subcategory contains all the ISR units that cannot be identified or that have such small numbers it is insignificant to this research. The largest identifiable portion of refueled ISR aircraft is the RC-135. The Navy operated E-6 TACAMO accounts for the smallest supported MDS individually examined as an ISR aircraft. See Appendix K for ISR MDS summaries.

Almost all of the aircraft in the ISR aircraft category operate Boeing 707 based aircraft. The air refueling tendencies however are very different. On LTP sorties, the RC-135 uses 10 more receivers planned but still manages to short the plan by 3,324,200 pounds of fuel, the most in the ISR category. This shortage of fuel, at \$3.50 per gallon, equals \$1,736,522.39. It also cost \$379,641.47 to carry the additional weight, burning an extra 726,000 pounds of fuel. On a per LTP sortie basis, the E-8 shorts the plan the least. This shortage by the E-8 still cost over \$500,000 in fuel and over \$100,000 in fuel burned carrying this unused fuel.

Table 12: ISR Aircraft Fuel Use vs Plan

	LTP	ETP	GTP
E-3	36.6%	45.7%	17.7%
E-4	39.7%	46.8%	13.5%
RC-135	30.5%	50.8%	18.7%
TACAMO	15.9%	68.6%	15.5%
ISR Avg.	32.2%	50.9%	16.9%
Overall Avg.	49.1%	33.5%	17.4%

The TACAMO mission has the highest ETP percentage at 68.6%. The GTP costs per sortie for TACAMO aircraft are the highest of all ISR aircraft, followed by the E-3, E-8 and the lowest being the RC-135. The total cost for GTP TACAMO support is the least of ISR supported sorties at \$148,880.60 or 24 tanker flight hours. The TACAMO aircraft are better than the average ISR supported sortie for LTP refueling. This is due to only 15.9% of the TACAMO sorties taking less than the planned amount of fuel.

Summary

The Heavy category aircraft have the least cost per sortie for deviating from the planned air refueling mission. This cost is over three and a half times less than the amount of fuel per sortie for fighter supported LTP sorties. Fighters have the highest propensity for LTP sorties (59.6%), whereas ISR have the least (32.2%). On LTP missions, Bombers tend to send fewer aircraft to the tanker (80%) than what they plan. Heavy aircraft are the only category that sends more receivers to the tanker than planned, even though they still short the planned refueling amount. The total fuel cost bought but not delivered to the receiver is \$26,028,768.66, with fighter support missions accounting for the bulk at \$15,302,679.10.

Table 13: Fuel LTP Summary

	Sorties Under											
	Sorties under		lbs not taken	ratio 2	gal not taken	Cost of Fuel	Rec Plan	Rec Act	Und rec %	Carry lbs	Carry gal	Cost Carry
Total	7749	49.1%	49826.5	6.43	7436791.045	\$26,028,768.66	24245	23780	98.1%	10133.82	1512510	\$5,293,785.18
Fighter	2966	59.6%	29293.7	9.88	4372194.03	\$15,302,679.10	17780	17335	97.5%	6031.709	900255.1	\$3,150,892.92
Bomber	920	43.7%	3941.5	4.28	588283.5821	\$2,058,992.54	1542	1234	80.0%	756.5197	112913.4	\$395,196.87
Heavy	2978	48.1%	8023.4	2.69	1197522.388	\$4,191,328.36	3382	3760	111.2%	1627.068	242845.9	\$849,960.68
ISR	728	32.2%	6149.1	8.45	917776.1194	\$3,212,216.42	903	873	96.7%	1218.482	181862.9	\$636,520.23

When examining GTP sorties, heavy category aircraft use 76% of the fuel the fighters use on a per sortie basis. When looking at GTP sorties bombers, ISR and Heavy aircraft all use approximately the same amount of fuel per sortie. Fighters on the other hand demand around one thousand pounds per sortie more than the other categories. The total cost of fuel delivered over the plan is \$7,197,305.97 or 1,243 average tanker flight hours. Fighter supported sorties deliver the bulk of this fuel, equal to 659.5 tanker flight hours or just over \$4M. Heavy aircraft have the lowest percentage of GTP sorties. Fighters again have the greatest percentage of GTP sorties. This can also be attributed to the fact that they flew 138.9% of the planned receivers to the tanker. In fact, bombers are the only category that flew less than the planned amount of receivers to the tanker while still managing to take more fuel than the plan.

Table 14: Fuel GTP Plan Summary

	Sorties Over											
	sorties	lbs over	per sor	gal	cost	avg burn	flt hrs	rec plan	rec actual	rec over %		
Total	2749	17.4%	13777.7	5.01	2056373	\$7,197,305.97	11083.8	1243.0	9000	11932	132.6%	
Fighter	1397	28.1%	7707.3	5.52	1150343	\$4,026,201.49	11687.11	659.5	7101	9862	138.9%	
Bomber	331	15.7%	1631.9	4.93	243567.2	\$852,485.07	9899.26	164.9	525	491	93.5%	
Heavy	576	9.3%	2428.4	4.22	362447.8	\$1,268,567.16	11241.19	216.0	691	699	101.2%	
ISR	381	16.9%	1558.7	4.09	232641.8	\$814,246.27	10378.54	150.2	481	586	121.8%	

V. Conclusions and Recommendations

“You are part of the world’s most feared and trusted force. Engage your brain before you engage your weapon.”

General James Mattis, 2003

Conclusions

The current planning and execution of air refueling missions are costing the DOD millions of dollars. During tanker sorties in FY 2012, using an average price of \$3.50 per gallon of JP-8 fuel, receiver aircraft did not take over \$26 million of fuel they requested. This fuel cost the Air Force over \$5 million in carrying costs. At the same time, additional receivers took more fuel than planned, costing the tanker fleet \$7.2 million, an equivalent of 1,243 average tanker hours. This is equal to approximately two months of flying for a tanker squadron (Fish, 2014).

The receiver unloaded fuel equal to the amount of the fuel plan (ETP) on 33.5% of the tanker sorties in FY 2012. The receiver took less fuel than planned (LTP) on the majority of tanker sorties, 49.1% of the sorties. There were also 17.4% of tanker sorties where the receiver took more than the planned (GTP) amount of fuel. Poor coordination and inaccurate planning between tanker and receiver units are the primary cause of the fuel use discrepancies.

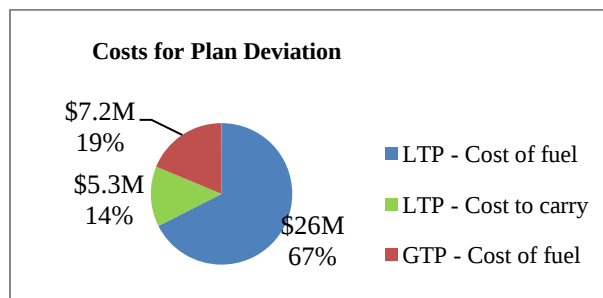


Figure 16: Cost for Plan Deviation

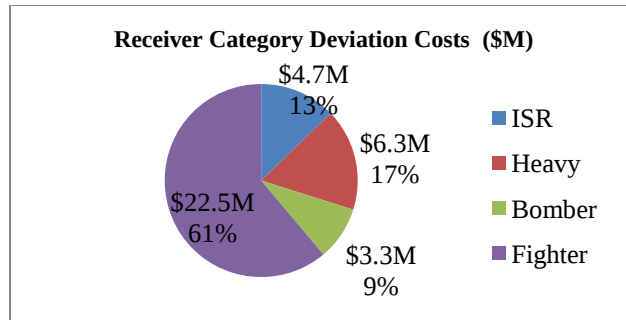


Figure 17: Overall Receiver Category Deviation Costs

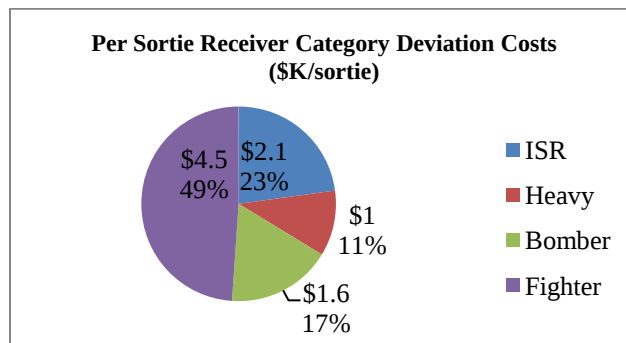


Figure 18: Per Sortie Category Deviation Costs

Table 15: Avg. offload deviation from plan

	Avg pln Offload (K lbs)	Average LTP onload as pct of plan	Average GTP onload as pct of plan
E8	21	8.79%	2.69%
E3	34.5	10.47%	2.14%
B52	11.2	9.24%	6.46%
C32	6.4	14.44%	1.31%
TACAMO	13.7	8.96%	7.68%
F22	53	13.61%	3.46%
USN	62.2	13.00%	4.30%
RC135	22.2	14.54%	2.92%
B1	15.5	14.48%	3.19%
F15	43	15.98%	3.57%
F16	27.6	16.61%	4.50%
C17	7.1	18.21%	3.39%
A10	21	17.42%	4.22%
KC135	9.1	15.64%	6.01%
Foreign	41.9	17.42%	4.29%
B2	20.9	16.38%	5.42%
C5	7.6	21.75%	2.46%
C130	8.3	34.74%	3.95%

The average costs for deviating from the fuel plan are greater on LTP sorties when compared to GTP sorties. The costs associated with LTP sorties are direct costs. The cost for carrying extra weight is immediately taken in fuel burn on the sortie. The average tanker sortie carries over \$3,350 of extra fuel. It cost the average sortie \$683 of jet fuel burned carrying this extra fuel. The aircraft with the lowest average cost of fuel carried on LTP sorties was the B-52 at \$1,315.76 per sortie. The B-52 also had the lowest cost to carry the shorted fuel at \$242.75 per sortie. The largest cost for both fuel carried and cost to carry was by the Navy. The tanker carried an extra \$7,167.64 of fuel and burned an average of \$1,611.95 per sortie carrying that fuel supporting the Navy receivers. The KC-10 did have a greater cost and cost of carrying than the Navy on their long duration sorties. This again can be attributed to the majority of these sorties being Coronet support missions, with a large excess of fuel being directed from higher headquarters.

Table 16: Average Cost per LTP Sortie

	Fuel Cost/Sortie	Carry Cost/sortie
B52	\$1,315.76	\$242.75
C17	\$1,390.26	\$260.57
Heavy	\$1,407.43	\$285.41
C5	\$1,582.04	\$299.99
KC135	\$1,664.18	\$337.95
B1	\$1,945.62	\$404.24
Bomber	\$2,238.04	\$429.56
C32	\$1,759.27	\$432.13
E8	\$2,429.47	\$447.92
C130	\$2,973.89	\$561.23
KC135	\$3,287.27	\$603.60
Total	\$3,358.98	\$683.16
KC135M	\$3,118.64	\$635.81
KC135S	\$3,284.59	\$497.04
A10	\$3,364.86	\$714.13
F16	\$4,010.53	\$765.81
TACAMO	\$4,043.04	\$860.94
ISR	\$4,412.39	\$874.34
E3	\$5,151.83	\$962.42
KC10S	\$2,736.93	\$665.92
B2	\$5,171.34	\$968.77
KC10M	\$3,168.85	\$915.87
Fighter	\$5,159.37	\$1,062.34
KC10	\$3,704.79	\$1,066.76
KC135L	\$4,737.30	\$551.95
RC135	\$5,530.33	\$1,137.57
F15	\$5,928.08	\$1,186.96
Foreign	\$6,278.49	\$1,258.90
F22	\$6,304.38	\$1,419.28
USN	\$7,167.64	\$1,611.95
KC10L	\$7,614.90	\$2,304.57

The cost of GTP sorties is not as evident. This is because the excess fuel taken rarely impacts the tanker fleet because the excess fuel, although not planned is usually on board through conservative fuel planning. In some cases, the tankers shorten their training by only gaining currency and not proficiency on maneuvers.

The C-32 only was supported on 113 sorties but it has the lowest average costs associated with air refueling GTP. On a per sortie basis, each C-32 sortie cost the tanker fleet 0.1 flying hours, taking an average of only \$381.75 of extra jet fuel. The Navy again cost the tanker fleet the most in regards to GTP sorties. The Navy cost the tanker fleet 0.6 flying hours, taking an average of \$3,938.17 of JP-8 over the plan per tanker sortie. The KC-10 missions also carried a high GTP cost on most of their missions. This can be attributed to its ability to consolidate fuel and it being the tanker of choice for Coronet missions, long intertheater fighter delivery sorties.

Table 17: Average Cost per GTP Sortie

	GTP Sorties	
	\$/sortie over	flt hr/s
C32	\$381.75	0.1
C5	\$1,113.64	0.2
C130	\$1,607.35	0.3
C17	\$1,622.67	0.3
KC135	\$1,678.17	0.3
RC135	\$1,805.35	0.3
KC135M	\$1,963.32	0.4
ISR	\$2,137.13	0.4
B1	\$2,159.51	0.4
E8	\$2,177.79	0.4
KC135	\$2,181.94	0.4
E3	\$2,182.09	0.4
Heavy	\$2,202.37	0.4
A10	\$2,214.34	0.4
KC135S	\$2,240.74	0.4
F16	\$2,400.10	0.4
B52	\$2,412.43	0.5
Bomber	\$2,575.48	0.5
Total	\$2,618.15	0.5
F15	\$2,786.13	0.5
Fighter	\$2,882.03	0.5
Foreign	\$2,987.11	0.4
B2	\$3,103.31	0.6
KC135L	\$3,178.25	0.6
F22	\$3,430.49	0.6
TACAMO	\$3,544.78	0.6
USN	\$3,938.17	0.6
KC10M	\$4,907.65	0.5
KC10	\$5,329.32	0.6
KC10L	\$5,713.56	0.6
KC10S	\$6,396.12	0.7

Recommendations

The wasted fuel in air refueling operations can be curtailed with better communication between the receiver units and the tanker units. Both receiver and tanker leadership need to have an understanding and desire to solve this problem. Their leadership is essential to driving a change in the air refueling culture. This efficiency principle must be integrated into the culture of every single Airman. Commanders and aircrew members must have clear guidance and direction. This includes the proper training and experience in filing out post mission paperwork, for example the AMC Fuel Tracker. The accuracy of efficiency information post mission is just as important to AMC as fighter debriefs. This information is valuable for gaining future efficiencies. Commanders and aircrew need to understand the importance of being efficient and the value of accomplishing the mission. More importantly they need to be armed with the knowledge and guidance to make the correct decision when these two values conflict. The solution must balance the risks of not accomplishing the mission against the costs of being energy efficient.

There are multiple courses of action (COA) that can be employed in air refueling operations. Each COA must adjust the balance point between mission risk and total cost. The COAs presented range from those that accept minimal risk to those that maximize fuel efficiency.

The air refueling COA that maximizes mission effectiveness is one where tankers minimize risk by flying at full fuel capacity. In this full tanker scenario, fuel will always be abundant and the receivers will be able to get whatever fuel they need whenever they need it. This COA is mission effective but comes at a high cost of inefficiency. This is the primary COA used in dynamic contingency operations. Tankers operating out of overseas bases supporting

operations in Afghanistan and Iraq maximize fuel loads to give the Combined Forces Air Component Commander (CFACC) and COCOM the most flexibility.

In this scenario, less than full fuel loads are used only for meeting takeoff data. This occurs when temperatures are high or the tanker needs to meet prescribed climb out rates. The only efficiencies available during these types of operations are through the use of tanker consolidation. Tanker consolidation occurs when excess fuel from a tanker can be delivered into an airborne KC-10 or refuelable KC-135. When the chain of command determines that this consolidated fuel can meet mission demand and additional tankers are not necessary, the decision is made to cancel an entire tanker sortie before it launches.

A second course of action with a high amount of risk and little flexibility is for the tanker to take the exact amount of fuel requested and only enough fuel to fly directly to the rendezvous and directly back. This COA has the least amount of wasted fuel but has little fuel to successfully complete the mission if the tanker or receiver aircraft experience maintenance issues, air traffic control delays, weather avoidance, etc. This COA is never used due to the high probability of something necessitating extra fuel and not being able to accomplish the mission.

The best air refueling solution is to find a COA that will yield a high percentage of mission success with the highest fuel efficiency achievable. The current system used in CENTCOM and in contingencies is closest to the first COA. These missions are usually very effective but as this research shows there is a large amount of waste that could be recouped.

Careful consideration must be made to avoid unwanted secondary and tertiary negative effects if the decision is made to change the current air refueling operation. Air Mobility Command delivered over 1.25 trillion pounds of fuel through its tanker fleet in FY 2012. Using \$3.50 per gallon this equals \$652 million on fuel offloads. This research identifies \$33 million in

waste, just over 5% of this expense. Senior leaders must decide if this amount is worth the cost of pursuing these savings. In order to achieve greater fuel efficiency and eliminate fuel waste, new procedures and bureaucracy will be created. These procedures must capture the savings without incurring a cost greater than the fuel trying to be saved.

The cost of fuel has been increasing and does not show any signs of reversing this trend. Eventually if not immediately, even a fraction of a percent of the fuel budget will be worth saving. It is unlikely that all inefficiencies can be removed from air refueling operations. Even with less than minimal inefficiencies, the excess costs associated with air refueling will not render the capability too costly to continue. Air refueling will always provide the enabling capabilities of “Global Vigilance, Global Reach and Global Power”. These capabilities can still be achieved with an air refueling culture changed from tanker reliability to a culture of tanker predictability.

Future Areas of Study

This research focuses on identifying the fuel inefficiencies associated with different MDSs. The causes of these inefficiencies need to be corrected. There are also multiple causes for air refueling inefficiencies. Some of these causes are universal while others only apply to a particular category or MDSs. In order to maximize air refueling efficiency there needs to be cross MAJCOM agreements addressing the balance of efficiency versus mission accomplishment.

One of the largest amounts of waste this research identifies belongs to Air Mobility Command. There are huge savings to be made by addressing the large fuel loads on KC-10 missions. The “art” of consolidation and tanker reliability is causing KC-10 aircraft to land over 20K pounds heavier on average than the ideal planned landing weight. Focusing on making

KC-10 operations more efficient not only will create immediate savings but will affect the new KC-46 that will have a similar mission and ability to be air refueled.

Air refueling training requirements should be verified and validated on a reoccurring basis. As simulators gain fidelity and realism, air refueling in the aircraft could be lessened. The training requirements should also be universal. Some of the most inefficient sorties are KC-10 heavy-weight air refueling training sorties. The KC-10 pilots require annually one onload of 10,000 pounds with an end refueling gross weight of 556,000 pounds. If the C-5 and C-17 aircraft do not need this requirement does the KC-10? The C-17 crew's air refueling requirement is currently being examined to determine what is really necessary. The C-17 crew force may remove tanker auto-pilot off air refueling, or may even cut a portion of the crew forces' air refueling qualifications. This would be a dramatic reduction in air refueling demand.

There have also been reoccurring studies on the applicability of using a working capital fund to pay for air refueling. This practice does not reduce fuel inefficiency but places the cost burden on the receiver units. This may be a way to influence receivers to be efficient if it is coming out of their own budgets.

Finally, the most vital way to ensure fuel efficiency is to drive the culture of efficiency from the COCOMs down to the aircrews. Finding the best ways to instill these money saving principles into the hearts and minds of each Airmen will have exponential effects. Each Airman will act to save fuel, time and money; while conceiving, exploring and implementing new ways to make the Air Force proficient and efficient.

Appendix A – AMC FUEL TRACKER

Example columns

MISSION_ID	LEG	MISSION_CLASS	MDS	AIRCRAFT_WING	DEP_ICAO	ARR_ICAO	DEP_TIME_ACT	ARR_TIME_ACT	FLY_TIME_ACT	RAMP_FUEL_ACT	LAND_FUEL_ACT
CP2055R1P271	700	CONTING	KC135R	18WG	RJSM	RODN	10/01/2012 05:16	10/01/2012 11:51	6.6	104.1	20.0

ONLD_FUEL_ACT	OFFLD_DEV_REASON	FUEL_BURN_RATE_ACT	OFFLD_FUEL_PLN	OFFLD_FUEL_ACT	NUM_RCVRS_PLN	NUM_RCVRS_ACT	RECEIVER_UNIT_ACT
0.0	Receiver(s) took less fuel than planned	9,181	18.0	23.5	6	8	35FW

AR_TRACK_ACT	CONTROL_TIME	CONTROL_TIME	CARGO
KARY N	10/01/2012 06:30	10/01/2012 06:40	0.0

Appendix B – Excel Working File

Legend:

	AMC Fuel Tracker
	Created Input
	Hidden AMC Fuel Tracker
	Hidden Creaetd Input
	Average
	Sum

Columns:

MISSION ID	LEG	MISSION CLASS	MDS	AIRCRAFT WING	DEP_ICAO	ARR_ICAO	DEP_TIME_ACT	ARR_TIME_ACT	FLY_TIME_ACT	Sortie Duration
8UN41TB02273	100	REFUEL	KC135T	6AMW	KMCF	KMCF	09/30/2013 23:39	10/01/2013 04:15		4.7 M
			15791							3.8

RAMP_FUEL_ACT	LAND_FUEL_ACT	ONLD_FUEL_ACT	OFFLD_DEV_REASON	FUEL_BURN_RATE_ACT	OFFLD_FUEL_PLN	OFFLD_FUEL_ACT	DIF_AR_OFLD	COW_Factor	COW%
62.3	17.4	0.0		8,468	0.0	5.1	-5.1	5.34	0.0534
91.4	29.1	15309.8		11,084	329110.9	293062.1	36048.8		0.0580

COST_FERRY	GAL_USED	\$3.50 Under	Under fuel	Ct_under	Fuel Over	Ct_over	Gal Costs OVER	\$3.50 Over	Ct =	NUM_RCVRS_PLN	plan sch	Act under
0.0	0.0	0.0	0.0	0	5.1	1	191.044	\$668.66	0	1	0	0
11890.7730910	1774742.252	\$6,211,597.88	49826.5	7749	13777.7	2749	528869.513	\$1,851,043.29	5293	41306	24245	23780

ovr plan	Ovr act	NUM_RCVRS_ACT	DIF_RCVR_NUM	RECEIVER_UNIT_ACT	RCR_MDS	RCR_CAT	AR_TRACK_ACT
1	1	1	0	1SOW	C130	HEAVY	HORSEBLANKET W151
9000	11932	44360	-3054			15791	

CONTROL_TIME_PLN	CONTROL_TIME_ACT	CARGO_ACT
10/01/2013 00:45	10/01/2013 01:57	0.0
		8217.0

Appendix C – Analysis Totals and Equal to Plan Sorties

	Totals										Equal sorties	
	Fuel price	Sorties	fuel dif	ratio	gal	costs	rec plan	rec act	rec %	Avg Lnd fuel		
Total	\$3.50	15791	36048.8	2.28	5380417.91	\$18,831,462.69	41306	44360	107.4%	29.1	5293	33.5%
KC10	\$3.50	2371	5552.6	2.34	828746.27	\$2,900,611.94	5856	9899	169.0%	46.1	659	27.8%
L	\$3.50	330	1439	4.36	214776.12	\$751,716.42	1324	3319	250.7%	47.8	44	13.3%
M	\$3.50	1685	3725.1	2.21	555985.07	\$1,945,947.76	3922	5828	148.6%	44.5	500	29.7%
S	\$3.50	356	388.5	1.09	57985.07	\$202,947.76	610	752	123.3%	51.8	115	32.3%
KC135	\$3.50	13420	30496.2	2.27	4551671.64	\$15,930,850.75	35450	34461	97.2%	26.1	4634	34.5%
L	\$3.50	1032	3077.3	2.98	459298.51	\$1,607,544.78	4607	5872	127.5%	29.5	168	16.3%
M	\$3.50	9839	22250.2	2.26	3320925.37	\$11,623,238.81	24392	22923	94.0%	25	3565	36.2%
S	\$3.50	2549	5168.7	2.03	771447.76	\$2,700,067.16	6449	5666	87.9%	29.3	901	35.3%
A10	\$3.50	516	1429.5	2.77	213358.21	\$746,753.73	2499	2668	106.8%	28.4	115	22.3%
F15	\$3.50	1090	5815	5.33	867910.45	\$3,037,686.57	6352	5661	89.1%	31.5	116	10.6%
F16	\$3.50	1807	6037.1	3.34	901059.70	\$3,153,708.96	9660	10043	104.0%	29.1	239	13.2%
F22	\$3.50	455	2448.6	5.38	365462.69	\$1,279,119.40	2441	2501	102.5%	33.7	56	12.3%
USN	\$3.50	414	2239.7	5.41	334283.58	\$1,169,992.54	2485	4202	169.1%	39.5	23	5.6%
Foreign	\$3.50	140	770	5.50	114925.37	\$402,238.81	1009	1139	112.9%	43.2	11	7.9%
Fighter	\$3.50	4979	21586.4	4.34	3221850.75	\$11,276,477.61	27691	30245	109.2%	32.1	616	12.4%
B1	\$3.50	468	818.8	1.75	122208.96	\$427,731.34	831	659	79.3%	23.8	130	27.8%
B2	\$3.50	503	1152.2	2.29	171970.15	\$601,895.52	797	690	86.6%	26.7	233	46.3%
B52	\$3.50	1129	351.3	0.31	52432.84	\$183,514.93	1616	1440	89.1%	24.9	488	43.2%
Bomber	\$3.50	2103	2309.6	1.10	344716.42	\$1,206,507.46	3253	2808	86.3%	25.1	852	40.5%
C130	\$3.50	610	1559.1	2.56	232701.49	\$814,455.22	755	720	95.4%	25.8	236	38.7%
C5	\$3.50	251	368	1.47	54925.37	\$192,238.81	262	260	99.2%	28.2	92	36.7%
C17	\$3.50	2067	2175	1.05	324626.87	\$1,136,194.03	2327	2422	104.1%	23.8	903	43.7%
C32	\$3.50	113	94.9	0.84	14164.18	\$49,574.63	113	124	109.7%	25	69	61.1%
KC135	\$3.50	141	123.6	0.88	18447.76	\$64,567.16	161	154	95.7%	24.2	54	38.3%
Heavy	\$3.50	6188	5595	0.90	835074.63	\$2,922,761.19	6859	7605	110.9%	28.5	2634	42.6%
E3	\$3.50	396	1137.6	2.87	169791.04	\$594,268.66	462	452	97.8%	28.3	181	45.7%
E8	\$3.50	547	700.7	1.28	104582.09	\$366,037.31	698	722	103.4%	25	256	46.8%
RC135	\$3.50	1030	2657.2	2.58	396597.01	\$1,388,089.55	1072	1119	104.4%	27.5	523	50.8%
TACAMO	\$3.50	271	47.8	0.18	7134.33	\$24,970.15	302	365	120.9%	27.9	186	68.6%
ISR	\$3.50	2258	4590.4	2.03	685134.33	\$2,397,970.15	2551	2687	105.3%	27.1	1149	50.9%

Appendix D – Analysis LTP Sortie Totals

	Sorties Under											
	Sorties under		lbs not taken ratio 2		gal not taken	Cost of Fuel	Rec Plan	Rec Act	Und rec %	Carry lbs	Carry gal	Cost Carry
Total	7749	49.1%	49826.5	6.43	7436791.045	\$26,028,768.66	24245	23780	98.1%	10133.82	1512510	\$5,293,785.18
KC10	1331	56.1%	9439.5	7.09	1408880.597	\$4,931,082.09	3485	5387	154.6%	2718.011	405673.3	\$1,419,856.69
L	179	54.2%	2609.3	14.58	389447.7612	\$1,363,067.16	760	1852	243.7%	789.6783	117862.4	\$412,518.54
M	961	57.0%	5829.5	6.07	870074.6269	\$3,045,261.19	2382	3147	132.1%	1684.855	251470.9	\$880,148.12
S	191	53.7%	1000.7	5.24	149358.209	\$522,753.73	343	388	113.1%	243.4781	36340.01	\$127,190.03
KC135	6418	47.8%	40387	6.29	6027910.448	\$21,097,686.57	20760	18393	88.6%	7415.806	1106837	\$3,873,928.50
L	550	53.3%	4987.7	9.07	744432.8358	\$2,605,514.93	2842	3113	109.5%	581.1208	86734.44	\$303,570.54
M	4711	47.9%	28124.5	5.97	4197686.567	\$14,691,902.99	14298	12374	86.5%	5733.831	855795.7	\$2,995,284.78
S	1157	45.4%	7274.8	6.29	1085791.045	\$3,800,268.66	3620	2906	80.3%	1100.854	164306.6	\$575,073.17
A10	293	56.8%	1887.3	6.44	281686.5672	\$985,902.99	1514	1574	104.0%	400.5444	59782.74	\$209,239.59
F15	660	60.6%	7489.7	11.35	1117865.672	\$3,912,529.85	4084	3156	77.3%	1499.634	223825.9	\$783,390.77
F16	1079	59.7%	8283.8	7.68	1236388.06	\$4,327,358.21	6134	5813	94.8%	1581.783	236087	\$826,304.42
F22	272	59.8%	3282.6	12.07	489940.2985	\$1,714,791.04	1580	1522	96.3%	738.998	110298.2	\$386,043.71
USN	244	58.9%	3347.9	13.72	499686.5672	\$1,748,902.99	1594	2226	139.6%	752.9166	112375.6	\$393,314.67
Foreign	85	60.7%	1021.6	12.02	152477.6119	\$533,671.64	732	745	101.8%	204.8415	30573.36	\$107,006.76
Fighter	2966	59.6%	29293.7	9.88	4372194.03	\$15,302,679.10	17780	17335	97.5%	6031.709	900255.1	\$3,150,892.92
B1	282	60.3%	1050.3	3.72	156761.194	\$548,664.18	515	402	78.1%	218.2227	32570.55	\$113,996.92
B2	174	34.6%	1722.5	9.90	257089.5522	\$899,813.43	311	246	79.1%	322.6828	48161.61	\$168,565.62
B52	464	41.1%	1168.7	2.52	174432.8358	\$610,514.93	716	586	81.8%	215.6143	32181.24	\$112,634.33
Bomber	920	43.7%	3941.5	4.28	588283.5821	\$2,058,992.54	1542	1234	80.0%	756.5197	112913.4	\$395,196.87
C130	309	50.7%	1759.1	5.69	262552.2388	\$918,932.84	406	361	88.9%	331.9777	49548.92	\$173,421.21
C5	137	54.6%	414.9	3.03	61925.37313	\$216,738.81	137	137	100.0%	78.67544	11742.6	\$41,099.11
C17	1004	48.6%	2672	2.66	398805.9701	\$1,395,820.90	1196	1254	104.8%	500.8065	74747.24	\$261,615.33
C32	31	27.4%	104.4	3.37	15582.08955	\$54,537.31	31	35	112.9%	25.64379	3827.431	\$13,396.01
KC135	63	44.7%	200.7	3.19	29955.22388	\$104,843.28	76	70	92.1%	40.75732	6083.182	\$21,291.14
Heavy	2978	48.1%	8023.4	2.69	1197522.388	\$4,191,328.36	3382	3760	111.2%	1627.068	242845.9	\$849,960.68
E3	145	36.6%	1430	9.86	213432.8358	\$747,014.93	198	174	87.9%	267.1399	39871.63	\$139,550.69
E8	217	39.7%	1009.2	4.65	150626.8657	\$527,194.03	307	282	91.9%	186.067	27771.19	\$97,199.17
RC135	314	30.5%	3324.2	10.59	496149.2537	\$1,736,522.39	335	345	103.0%	683.78	102056.7	\$357,198.51
TACAMO	43	15.9%	332.8	7.74	49671.64179	\$173,850.75	52	53	101.9%	70.86797	10577.31	\$37,020.58
ISR	728	32.2%	6149.1	8.45	917776.1194	\$3,212,216.42	903	873	96.7%	1218.482	181862.9	\$636,520.23

Appendix E – Analysis GTP Sortie Totals

	Sorties Over										
	sorties		lbs over	ratio 3	gal	cost	avg burn	flt hrs	rec plan	rec actual	rec over %
Total	2749	17.4%	13777.7	5.01	2056373	\$7,197,305.97	11083.8	1243.0	9000	11932	132.6%
KC10	381	16.1%	3886.9	10.20	580134.3	\$2,030,470.15	17673.15	219.9	1422	2995	210.6%
L	107	32.4%	1170.3	10.94	174671.6	\$611,350.75	18733.89	62.5	438	1269	289.7%
M	224	13.3%	2104.4	9.39	314089.6	\$1,099,313.43	17447.18	120.6	858	1570	183.0%
S	50	14.0%	612.2	12.24	91373.13	\$319,805.97	17759.41	34.5	126	156	123.8%
KC135	2368	17.6%	9890.8	4.18	1476239	\$5,166,835.82	9919.62	997.1	7578	8937	117.9%
L	314	30.4%	1910.4	6.08	285134.3	\$997,970.15	10227.04	186.8	1386	2331	168.2%
M	1563	15.9%	5874.3	3.76	876761.2	\$3,068,664.18	9782.52	600.5	4830	5239	108.5%
S	491	19.3%	2106.1	4.29	314343.3	\$1,100,201.49	10324.35	204.0	1362	1367	100.4%
A10	108	20.9%	457.8	4.24	68328.36	\$239,149.25	10705.66	42.8	509	614	120.6%
F15	314	28.8%	1674.7	5.33	249955.2	\$874,843.28	11756.58	142.4	1732	1934	111.7%
F16	489	27.1%	2246.7	4.59	335328.4	\$1,173,649.25	11180.37	201.0	2400	3077	128.2%
F22	127	27.9%	834	6.57	124477.6	\$435,671.64	11800.02	70.7	611	727	119.0%
USN	147	35.5%	1108.2	7.54	165403	\$578,910.45	13099.53	84.6	777	1780	229.1%
Foreign	44	31.4%	251.6	5.72	37552.24	\$131,432.84	13292.33	18.9	216	332	153.7%
Fighter	1397	28.1%	7707.3	5.52	1150343	\$4,026,201.49	11687.11	659.5	7101	9862	138.9%
B1	56	12.0%	231.5	4.13	34552.24	\$120,932.84	10083	23.0	100	82	82.0%
B2	96	19.1%	570.3	5.94	85119.4	\$297,917.91	10160.09	56.1	150	139	92.7%
B52	177	15.7%	817.4	4.62	122000	\$427,000.00	9698.77	84.3	269	254	94.4%
Bomber	331	15.7%	1631.9	4.93	243567.2	\$852,485.07	9899.26	164.9	525	491	93.5%
C130	65	10.7%	200	3.08	29850.75	\$104,477.61	9795.41	20.4	82	83	101.2%
C5	22	8.8%	46.9	2.13	7000	\$24,500.00	10408.8	4.5	32	30	93.8%
C17	160	7.7%	497	3.11	74179.1	\$259,626.87	9684.32	51.3	179	189	105.6%
C32	13	11.5%	9.5	0.73	1417.91	\$4,962.69	10199.56	0.9	13	13	100.0%
KC135	24	17.0%	77.1	3.21	11507.46	\$40,276.12	10551.09	7.3	31	30	96.8%
Heavy	576	9.3%	2428.4	4.22	362447.8	\$1,268,567.16	11241.19	216.0	691	699	101.2%
E3	70	17.7%	292.4	4.18	43641.79	\$152,746.27	10466.44	27.9	78	77	98.7%
E8	74	13.5%	308.5	4.17	46044.78	\$161,156.72	10332.02	29.9	122	147	120.5%
RC135	193	18.7%	667	3.46	99552.24	\$348,432.84	9996.63	66.7	214	241	112.6%
TACAMO	42	15.5%	285	6.79	42537.31	\$148,880.60	11856.22	24.0	64	114	178.1%
ISR	381	16.9%	1558.7	4.09	232641.8	\$814,246.27	10378.54	150.2	481	586	121.8%

Appendix F – KC-135 Short, Medium and Long Sortie Summary

KC135 TANKER LONG SORTIE TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
1032		550	168	314
100.0%		53.3%	16.3%	30.4%
Fuel not taken		Fuel Not Taken		Fuel over
3077.3		4987.7		1910.4
Gal		Gal		Avg Burn Rate
459298.5075		744432.84		10227.04
Price		Price		Gal
\$3.50		\$3.50		285134.33
Cost of fuel		Cost of fuel		Price
\$1,607,544.78		\$2,605,514.93		\$3.50
Rec Plan		Rec Plan		Cost of fuel
4607		2842		\$997,970.15
Rec Actual		Rec Actual		Flt Hrs
5872		3113		186.8
Land fuel		Cost to Carry		Rec Plan
29.5		581.120757	Klbs	1386
		86734.44134	gal	Rec Act
		\$303,570.54	Cost	2331

KC135 TANKER MEDIUM SORTIE TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
9839		4711	3565	1563
100.0%		47.9%	36.2%	15.9%
Fuel not taken		Fuel Not Taken		Fuel over
22250.2		28124.5		5874.3
Gal		Gal		Avg Burn Rate
3320925.373		4197686.57		9782.52
Price		Price		Gal
\$3.50		\$3.50		876761.19
Cost of fuel		Cost of fuel		Price
\$11,623,238.81		\$14,691,902.99		\$3.50
Rec Plan		Rec Plan		Cost of fuel
24394		14298		\$3,068,664.18
Rec Actual		Rec Actual		Flt Hrs
22923		12374		600.5
Land fuel		Cost to Carry		Rec Plan
25.0		5733.830874	Klbs	4830
		855795.6528	gal	Rec Act
		\$2,995,284.78	Cost	5239

KC135 TANKER SHORT SORTIE TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
2549		1157	901	491
100.0%		45.4%	35.3%	19.3%
Fuel not taken		Fuel Not Taken		Fuel over
5168.7		7274.8		2106.1
Gal		Gal		Avg Burn Rate
771447.7612		1085791.04		10324.35
Price		Price		Gal
\$3.50		\$3.50		314343.28
Cost of fuel		Cost of fuel		Price
\$2,700,067.16		\$3,800,268.66		\$3.50
Rec Plan		Rec Plan		Cost of fuel
6449		3620		\$1,100,201.49
Rec Actual		Rec Actual		Flt Hrs
5666		2906		204.0
Land fuel		Cost to Carry		Rec Plan
29.3		1100.854352	Klbs	1362
		164306.6197	gal	Rec Act
		\$575,073.17	Cost	1367

Appendix G – KC-10 Short, Medium and Long Sortie Summary

KC10 TANKER LONG SORTIE TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
330		179	44	107
100.0%		54.2%	13.3%	32.4%
Fuel not taken		Fuel Not Taken		Fuel over
1439		2609.3		1170.3
Gal		Gal		Avg Burn Rate
214776.1194		389447.76		18733.89
Price		Price		Gal
\$3.50		\$3.50		174671.64
Cost of fuel		Cost of fuel		Price
\$751,716.42		\$1,363,067.16		\$3.50
Rec Plan		Rec Plan		Cost of fuel
1324		760		\$611,350.75
Rec Actual		Rec Actual		Flt Hrs
3319		1852		62.5
Land fuel		Cost to Carry		Rec Plan
47.8		789.678344	Klbs	438
		117862.4394	gal	Rec Act
		\$412,518.54	Cost	1269

KC10 TANKER MEDIUM SORTIE TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
1685		961	500	224
100.0%		57.0%	29.7%	13.3%
Fuel not taken		Fuel Not Taken		Fuel over
3725.1		5829.5		2104.4
Gal		Gal		Avg Burn Rate
555985.0746		870074.63		17447.18
Price		Price		Gal
\$3.50		\$3.50		314089.55
Cost of fuel		Cost of fuel		Price
\$1,945,947.76		\$3,045,261.19		\$3.50
Rec Plan		Rec Plan		Cost of fuel
3922		2382		\$1,099,313.43
Rec Actual		Rec Actual		Flt Hrs
5828		3147		120.6
Land fuel		Cost to Carry		Rec Plan
44.5		1684.854972	Klbs	858
		251470.8913	gal	Rec Act
		\$880,148.12	Cost	1570

KC10 TANKER SHORT SORTIE TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
356		191	115	50
100.0%		53.7%	32.3%	14.0%
Fuel not taken		Fuel Not Taken		Fuel over
388.5		1000.7		612.2
Gal		Gal		Avg Burn Rate
57985.07463		149358.21		17759.41
Price		Price		Gal
\$3.50		\$3.50		91373.13
Cost of fuel		Cost of fuel		Price
\$202,947.76		\$522,753.73		\$3.50
Rec Plan		Rec Plan		Cost of fuel
610		343		\$319,805.97
Rec Actual		Rec Actual		Flt Hrs
752		388		34.5
Land fuel		Cost to Carry		Rec Plan
51.8		243.478053	Klbs	126
		36340.00791	gal	Rec Act
		\$127,190.03	Cost	156

Appendix H – Fighter MDS Summary

A-10 FIGHTER TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
516		293	115	108
100.0%		56.8%	22.3%	20.9%
Fuel not taken		Fuel Not Taken		Fuel over
1429.5		1887.3		457.8
Gal		Gal		Avg Burn Rate
213358.209		281686.57		10705.66
Price		Price		Gal
\$3.50		\$3.50		68328.36
Cost of fuel		Cost of fuel		Price
\$746,753.73		\$985,902.99		\$3.50
Rec Plan		Rec Plan		Cost of fuel
2499		1514		\$239,149.25
Rec Actual		Rec Actual		Flt Hrs
2668		1574		42.8
Land fuel		Cost to Carry		Rec Plan
28.4		400.544363	Klbs	509
		59782.74075	gal	Rec Act
		\$209,239.59	Cost	614

F-15 FIGHTER TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
1090		660	116	314
100.0%		60.6%	10.6%	28.8%
Fuel not taken		Fuel Not Taken		Fuel over
5815		7489.7		1674.7
Gal		Gal		Avg Burn Rate
867910.4478		1117865.67		11756.58
Price		Price		Gal
\$3.50		\$3.50		249955.22
Cost of fuel		Cost of fuel		Price
\$3,037,686.57		\$3,912,529.85		\$3.50
Rec Plan		Rec Plan		Cost of fuel
6352		4084		\$874,843.28
Rec Actual		Rec Actual		Flt Hrs
5661		3156		142.4
Land fuel		Cost to Carry		Rec Plan
31.5		1499.633756	Klbs	1732
		223825.9337	gal	Rec Act
		\$783,390.77	Cost	1934

F-16 FIGHTER TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
1807		1079	239	489
100.0%		59.7%	13.2%	27.1%
Fuel not taken		Fuel Not Taken		Fuel over
6037.1		8283.8		2246.7
Gal		Gal		Avg Burn Rate
901059.7015		1236388.06		11180.37
Price		Price		Gal
\$3.50		\$3.50		335328.36
Cost of fuel		Cost of fuel		Price
\$3,153,708.96		\$4,327,358.21		\$3.50
Rec Plan		Rec Plan		Cost of fuel
9660		6134		\$1,173,649.25
Rec Actual		Rec Actual		Flt Hrs
10043		5813		201.0
Land fuel		Cost to Carry		Rec Plan
29.1		1581.782738	Klbs	2400
		236086.9758	gal	Rec Act
		\$826,304.42	Cost	3077

F-22 FIGHTER TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
455		272	56	127
100.0%		59.8%	12.3%	27.9%
Fuel not taken		Fuel Not Taken		Fuel over
2448.6		3282.6		834.0
Gal		Gal		Avg Burn Rate
365462.6866		489940.30		11800.02
Price		Price		Gal
\$3.50		\$3.50		124477.61
Cost of fuel		Cost of fuel		Price
\$1,279,119.40		\$1,714,791.04		\$3.50
Rec Plan		Rec Plan		Cost of fuel
2441		1580		\$435,671.64
Rec Actual		Rec Actual		Flt Hrs
2501		1522		70.7
Land fuel		Cost to Carry		Rec Plan
33.7		738.997958	Klbs	611
		110298.2027	gal	Rec Act
		\$386,043.71	Cost	727

USN FIGHTER TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
414		244	23	147
100.0%		58.9%	5.6%	35.5%
Fuel not taken		Fuel Not Taken		Fuel over
2239.7		3347.9		1108.2
Gal		Gal		Avg Burn Rate
334283.5821		499686.57		13099.53
Price		Price		Gal
\$3.50		\$3.50		165402.99
Cost of fuel		Cost of fuel		Price
\$1,169,992.54		\$1,748,902.99		\$3.50
Rec Plan		Rec Plan		Cost of fuel
2485		1594		\$578,910.45
Rec Actual		Rec Actual		Flt Hrs
4202		2226		84.6
Land fuel		Cost to Carry		Rec Plan
39.5		752.916647	Klbs	777
		112375.619	gal	Rec Act
		\$393,314.67	Cost	1780

Foreign FIGHTER TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
140		85	11	44
100.0%		60.7%	7.9%	31.4%
Fuel not taken		Fuel Not Taken		Fuel over
770		1021.6		251.6
Gal		Gal		Avg Burn Rate
114925.3731		152477.61		13292.33
Price		Price		Gal
\$3.50		\$3.50		37552.24
Cost of fuel		Cost of fuel		Price
\$402,238.81		\$533,671.64		\$3.50
Rec Plan		Rec Plan		Cost of fuel
1009		732		\$131,432.84
Rec Actual		Rec Actual		Flt Hrs
1139		745		18.9
Land fuel		Cost to Carry		Rec Plan
43.2		204.841503	Klbs	216
		30573.35866	gal	Rec Act
		\$107,006.76	Cost	332

Appendix I – Bomber MDS Summary

B-1 BOMBER TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
468		282	130	56
100.0%		60.3%	27.8%	12.0%
Fuel not taken		Fuel Not Taken		Fuel over
818.8		1050.3		231.5
Gal		Gal		Avg Burn Rate
122208.9552		156761.19		10083.00
Price		Price		Gal
\$3.50		\$3.50		34552.24
Cost of fuel		Cost of fuel		Price
\$427,731.34		\$548,664.18		\$3.50
Rec Plan		Rec Plan		Cost of fuel
831		515		\$120,932.84
Rec Actual		Rec Actual		Flt Hrs
659		402		23.0
Land fuel		Cost to Carry		Rec Plan
23.8		218.22267	Klbs	100
		32570.54776	gal	Rec Act
		\$113,996.92	Cost	82

B-2 BOMBER TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
503		174	233	96
100.0%		34.6%	46.3%	19.1%
Fuel not taken		Fuel Not Taken		Fuel over
1152.2		1722.5		570.3
Gal		Gal		Avg Burn Rate
171970.1493		257089.55		10160.09
Price		Price		Gal
\$3.50		\$3.50		85119.40
Cost of fuel		Cost of fuel		Price
\$601,895.52		\$899,813.43		\$3.50
Rec Plan		Rec Plan		Cost of fuel
797		311		\$297,917.91
Rec Actual		Rec Actual		Flt Hrs
690		246		56.1
Land fuel		Cost to Carry		Rec Plan
26.7		322.682765	Klbs	150
		48161.60672	gal	Rec Act
		\$168,565.62	Cost	139

B-52 BOMBER TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
1129		464	488	177
100.0%		41.1%	43.2%	15.7%
Fuel not taken		Fuel Not Taken		Fuel over
351.3		1168.7		817.4
Gal		Gal		Avg Burn Rate
52432.83582		174432.84		9698.77
Price		Price		Gal
\$3.50		\$3.50		122000.00
Cost of fuel		Cost of fuel		Price
\$183,514.93		\$610,514.93		\$3.50
Rec Plan		Rec Plan		Cost of fuel
1616		716		\$427,000.00
Rec Actual		Rec Actual		Flt Hrs
1440		586		84.3
Land fuel		Cost to Carry		Rec Plan
24.9		215.614289	Klbs	269
		32181.23716	gal	Rec Act
		\$112,634.33	Cost	254

Appendix J – Heavy MDS Summary

C-5 HEAVY TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
251		137	92	22
100.0%		54.6%	36.7%	8.8%
Fuel not taken		Fuel Not Taken		Fuel over
368		414.9		46.9
Gal		Gal		Avg Burn Rate
54925.37313		61925.37		10408.80
Price		Price		Gal
\$3.50		\$3.50		7000.00
Cost of fuel		Cost of fuel		Price
\$192,238.81		\$216,738.81		\$3.50
Rec Plan		Rec Plan		Cost of fuel
262		137		\$24,500.00
Rec Actual		Rec Actual		Flt Hrs
260		137		4.5
Land fuel		Cost to Carry		Rec Plan
28.2		78.675438	Klbs	32
		11742.60269	gal	Rec Act
		\$41,099.11	Cost	30

C-17 HEAVY TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
2067		1004	903	160
100.0%		48.6%	43.7%	7.7%
Fuel not taken		Fuel Not Taken		Fuel over
2175		2672		497.0
Gal		Gal		Avg Burn Rate
324626.8657		398805.97		9684.32
Price		Price		Gal
\$3.50		\$3.50		74179.10
Cost of fuel		Cost of fuel		Price
\$1,136,194.03		\$1,395,820.90		\$3.50
Rec Plan		Rec Plan		Cost of fuel
2327		1196		\$259,626.87
Rec Actual		Rec Actual		Flt Hrs
2422		1254		51.3
Land fuel		Cost to Carry		Rec Plan
23.8		500.806498	Klbs	179
		74747.23851	gal	Rec Act
		\$261,615.33	Cost	189

C-130 HEAVY TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
610		309	236	65
100.0%		50.7%	38.7%	10.7%
Fuel not taken		Fuel Not Taken		Fuel over
1559.1		1759.1		200.0
Gal		Gal		Avg Burn Rate
232701.4925		262552.24		9795.41
Price		Price		Gal
\$3.50		\$3.50		29850.75
Cost of fuel		Cost of fuel		Price
\$814,455.22		\$918,932.84		\$3.50
Rec Plan		Rec Plan		Cost of fuel
755		406		\$104,477.61
Rec Actual		Rec Actual		Flt Hrs
720		361		20.4
Land fuel		Cost to Carry		Rec Plan
25.8		331.977747	Klbs	82
		49548.91746	gal	Rec Act
		\$173,421.21	Cost	83

Tanker HEAVY TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
335		150	125	60
100.0%		44.8%	37.3%	17.9%
Fuel not taken		Fuel Not Taken		Fuel over
-383.5		647.4		1030.9
Gal		Gal		Avg Burn Rate
-57238.80597		96626.87		15567.55
Price		Price		Gal
\$3.50		\$3.50		153865.67
Cost of fuel		Cost of fuel		Price
-\$200,335.82		\$338,194.03		\$3.50
Rec Plan		Rec Plan		Cost of fuel
381		174		\$538,529.85
Rec Actual		Rec Actual		Flt Hrs
472		182		66.2
Land fuel		Cost to Carry		Rec Plan
70.7		154.952037	Klbs	74
		23127.1697	gal	Rec Act
		\$80,945.09	Cost	90

KC-10 HEAVY TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
194		87	71	36
100.0%		44.8%	36.6%	18.6%
Fuel not taken		Fuel Not Taken		Fuel over
-507.1		446.7		953.8
Gal		Gal		Avg Burn Rate
-75686.56716		66671.64		19213.53
Price		Price		Gal
\$3.50		\$3.50		142358.21
Cost of fuel		Cost of fuel		Price
-\$264,902.99		\$233,350.75		\$3.50
Rec Plan		Rec Plan		Cost of fuel
220		98		\$498,253.73
Rec Actual		Rec Actual		Flt Hrs
318		112		49.6
Land fuel		Cost to Carry		Rec Plan
104.5		114.194716	Klbs	43
		17043.98746	gal	Rec Act
		\$59,653.96	Cost	60

KC-135 HEAVY TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
141		63	54	24
100.0%		44.7%	38.3%	17.0%
Fuel not taken		Fuel Not Taken		Fuel over
123.6		200.7		77.1
Gal		Gal		Avg Burn Rate
18447.76119		29955.22		10551.09
Price		Price		Gal
\$3.50		\$3.50		11507.46
Cost of fuel		Cost of fuel		Price
\$64,567.16		\$104,843.28		\$3.50
Rec Plan		Rec Plan		Cost of fuel
161		76		\$40,276.12
Rec Actual		Rec Actual		Flt Hrs
154		70		7.3
Land fuel		Cost to Carry		Rec Plan
24.2		40.757321	Klbs	31
		6083.182239	gal	Rec Act
		\$21,291.14	Cost	30

Appendix K – ISR MDS Summary

E-3 ISR TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
396		145	181	70
100.0%		36.6%	45.7%	17.7%
Fuel not taken		Fuel Not Taken		Fuel over
1137.6		1430		292.4
Gal		Gal		Avg Burn Rate
169791.0448		213432.84		10466.44
Price		Price		Gal
\$3.50		\$3.50		43641.79
Cost of fuel		Cost of fuel		Price
\$594,268.66		\$747,014.93		\$3.50
Rec Plan		Rec Plan		Cost of fuel
462		198		\$152,746.27
Rec Actual		Rec Actual		Flt Hrs
452		174		27.9
Land fuel		Cost to Carry		Rec Plan
28.3		267.139901	Klbs	78
		39871.62701	gal	Rec Act
		\$139,550.69	Cost	77

E-8 ISR TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
547		217	256	74
100.0%		39.7%	46.8%	13.5%
Fuel not taken		Fuel Not Taken		Fuel over
700.7		1009.2		308.5
Gal		Gal		Avg Burn Rate
104582.0896		150626.87		10332.02
Price		Price		Gal
\$3.50		\$3.50		46044.78
Cost of fuel		Cost of fuel		Price
\$366,037.31		\$527,194.03		\$3.50
Rec Plan		Rec Plan		Cost of fuel
698		307		\$161,156.72
Rec Actual		Rec Actual		Flt Hrs
722		282		29.9
Land fuel		Cost to Carry		Rec Plan
25.0		186.066989	Klbs	122
		27771.19239	gal	Rec Act
		\$97,199.17	Cost	147

RC135 ISR TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
1030		314	523	193
100.0%		30.5%	50.8%	18.7%
Fuel not taken		Fuel Not Taken		Fuel over
2657.2		3324.2		667.0
Gal		Gal		Avg Burn Rate
396597.0149		496149.25		9996.63
Price		Price		Gal
\$3.50		\$3.50		99552.24
Cost of fuel		Cost of fuel		Price
\$1,388,089.55		\$1,736,522.39		\$3.50
Rec Plan		Rec Plan		Cost of fuel
1072		335		\$348,432.84
Rec Actual		Rec Actual		Flt Hrs
1119		345		66.7
Land fuel		Cost to Carry		Rec Plan
27.5		683.780001	Klbs	214
		102056.7166	gal	Rec Act
		\$357,198.51	Cost	241

TACAMO ISR TOTAL				
TOTAL		TOTAL UNDER	EQUAL	TOTAL OVER
Sorties		Sorties	Sorties	Sorties
271		43	186	42
100.0%		15.9%	68.6%	15.5%
Fuel not taken		Fuel Not Taken		Fuel over
47.8		332.8		285.0
Gal		Gal		Avg Burn Rate
7134.328358		49671.64		11856.22
Price		Price		Gal
\$3.50		\$3.50		42537.31
Cost of fuel		Cost of fuel		Price
\$24,970.15		\$173,850.75		\$3.50
Rec Plan		Rec Plan		Cost of fuel
302		52		\$148,880.60
Rec Actual		Rec Actual		Flt Hrs
365		53		24.0
Land fuel		Cost to Carry		Rec Plan
27.9		70.867966	Klbs	64
		10577.30836	gal	Rec Act
		\$37,020.58	Cost	114

Glossary

ACC – Air Combat Command

AMC – Air Mobility Command

AOC – Air and space Operation Center

AOR – Area of Responsibility

API – Airman Powered by Innovation

AR – Air Refueling

A3/A3F – Air Mobility Command’s Fuel Efficiency Division

BOWST – Boom Operator Weapon System Trainer

CAF – Combat Air Forces

CENTCOM – United States Central Command

COA – Course of Action

COCOM – Combatant Command

CONUS – Continental United States

CoW – Cost of Weight

DOD – Department of Defense

DESC – Defense Energy Support Center

DLA – Defense Logistics Agency

DMO – Distributed Mission Operation

ETP – Equal to Plan

FAA – Federal Aviation Administration

FEO – Fuel Efficiency Office

FY – Fiscal Year

AFIT-ENS-GRP-14-J-4

FYDP – Future Year Defense Program

GAO – Government Accountability Office

GTP – Greater than Plan

HHQ – Higher Headquarters

IDEA - Innovative Development through Employee Awareness

ISR – Intelligence, Surveillance and Reconnaissance

LTP – Less than Plan

MAF – Mobility Air Forces

MCRS – Mobility Capabilities and Requirement Study

MDS – Mission Design Series

MPRS – Multi Point Receiver System

MWS – Major Weapon System

NATO – North Atlantic Treaty Organization

NSS – National Security Strategy

OCONUS – Outside Continental United States

OSD – Office of the Secretary of Defense

OSS – Operations Support Squadron

SAC – Strategic Air Command

TACAMO – TAke Charge And Move Out, E-6A Mercury

UAV – Unmanned Aerial Vehicles

VIPSAM – Very Important Person-Special Air Mission

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14. ABSTRACT The Department of Defense (DOD) has made significant budget cuts, necessitating initiative, innovation and efficiency. The DOD is the largest consumer of fuel in the world. Jet fuel accounts for almost 3/4ths of this fuel, most being used by Air Mobility Command (AMC). A large portion of AMC's missions involve air refueling, an inherently fuel inefficient process. Adhering to the most accurate fuel plan will remove extra fuel from the tanker, lowering the tanker's weight, and reducing fuel expended and increasing the life of the tanker. Through analyzing and altering air refueling mission, the Air Force will achieve a fuel savings. This research identifies which receivers drive higher costs due to fuel inefficiency. The missions analyzed were conducted in Fiscal Year 2012. Qualitative data was extracted from the AMC Fuel Tracker and manipulated in Excel. Deployed operations have not been included due to the dynamic planning involved in combat operations. Each tanker mission was categorized by mission design series (MDS) and then examined to determine MDS effect of planned versus actual offloaded fuel. This analysis is noteworthy because the results explain an area of fuel inefficiency in AMC's tanker fleet.				
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