EFFECTS OF KC-10 DIVESTMENT ON DAILY COMPETITION SORTIE REQUIREMENTS

GRADUATE RESEARCH PAPER

Aaron A. Borszich, Major, USAF

AFIT-ENS-MS-20-J-026

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT-ENS-MS-20-J-026

EFFECTS OF KC-10 DIVESTMENT ON DAILY COMPETITION SORTIE REQUIREMENTS

GRADUATE RESEARCH PAPER

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Operations Management

Aaron A. Borszich, BS, MBA

Major, USAF

June 2020

AFIT-ENS-MS-20-J-026

EFFECTS OF KC-10 DIVESTMENT ON DAILY COMPETITION SORTIE REQUIREMENTS

Aaron A. Borszich, BS, MBA

Major, USAF

Committee Membership:

Dr. Jeffery D. Weir

Chair

Abstract

The air refueling capability of the USAF has endured decrements to capacity, sweeping budget cuts, and serious years of delay during the acquisition of its new airframe, the KC-46. The concepts of how air refueling can increase the amount of time aircraft can fly without landing are intuitive. However, the measurement and connection of the value created in the act have proven difficult to express in ways that win resources. Ultimately the strategic vision for the air refueling fleet has been sacrificed in fiscal policy and forced the decision to divest the Air Force's youngest and most capable air refueling weapons system, the KC-10.

This project sought to find new ways of measuring the capacity and capability of the air refueling fleet in ways that can relate the needs of the Air Force to decision-makers that control DOD fiscal programming. Initial research could not find a usable history of refueling missions flown and how much fuel the tanker aircraft offloaded to receiver aircraft. Consequently, the logical start was to find data that could create such a record and demonstrate the utility of the information. The research used ten years of actual missions flown other than combat and a separate data set of fuel usage on over half of those missions to create a record of refueling mission effects. Then the database was analyzed to assess how many additional flights would be required if the original aircraft, the KC-10, was replaced with a smaller but more numerous KC-46. The research found that the historical schedule would have needed about 20% more flights flown by the KC-46 each year, but the claim on the required fleet size required to accomplish the increase was less certain.

To my wife and children, thank you for your support and patience throughout this academic year. I love you, and I feel your love.

Acknowledgments

Thank you to everyone who helped make this year of research the best it could be. I could not have completed a project like this without an awesome family, supportive faculty and colleagues, and experts who lend their time and talents to those who need them. This research represents another great year of learning and accomplishment for me, and I could not have made it this far without you. I'd like to acknowledge a few of you by name here.

To my talented and beautiful wife. Thank you for your inspirational drive, ambitious spirit, and dedicated support throughout our 22.9 years together. We are an exceptional team and thank you for dancing with me this year as we both completed master's degrees. I am excited to live our future together.

I am also indebted to the connections and perspective of Lt Gen Giovanni Tuck, who agreed to sponsor this research. Your team and network boosted this project at every turn. Thank you to Mr. Rowayne Schatz for encouraging me to take on this topic during our visit to the pentagon and for lending me your expert knowledge for the paper. Thank you to Mr. Bruce Busler for taking the time to talk in-depth with me on the finer points of "taskable tails." Your clarity in the delivery of complex concepts is something I will always strive to emulate. Also, a great thanks to Mr. Don Anderson, who supplied the most valuable thing a researcher can have, source data for this project. You've been an outstanding source and pathfinder for many ASAM students. Thank you to Lt Col Stew Welch and Mr. Dave LeRoy for hot-washing my conclusions and being great advocates for the importance of air refueling. And, finally, thank you to Dr. Jeff Weir, who agreed to be my academic advisor for this research and for being a great mentor in this research process. The time you dedicated to teach and demonstrate many Excel functions to our class paid dividends for me in this research. Thank you ALL for the hours of thought and conversation you dedicated to this research project and my quest for understanding.

Aaron A. Borszich

Table of Contents

Page

List of Figures

List of Tables

EFFECTS OF KC-10 DIVESTMENT ON DAILY COMPETITION SORTIE REQUIREMENTS

I. Introduction

General Issue

America's air refueling fleet is the backbone of deterrence, and it is in distress (Grismer, 2011). Years of fiscal restraint and downsizing have reduced the number of tankers in the Air Force from a high of 800 aircraft (Romero, 2015) to a current, mission-capable fleet of 396 KC-135s and 59 KC-10s (*Air Refueling Non-Mobilized Capacity*, 2020). The National Security Strategy (2017) states that, "the size of our force matters" and that instead of further reductions, we should "grow the force while modernizing and ensuring readiness."

In light of the budgetary challenges and acquisition delays of the KC-46, many have questioned how the Air Force will grow its air refueling capability (*Air Refueling Non-Mobilized Capacity*, 2020; Camerer, 2001; MacDonald, 2015; Russell, 2012; Welch & Leroy, 2019). The plan to recapitalize the aging fleet of tankers has suffered decades of delays, and further financial constraint forced the Air Force to program the divestment of its youngest and largest tanker, the KC-10 (Welch & Leroy, 2019). This year, USTRANSCOM has presented an argument to stop the divestment of the KC-10 until the KC-46 is fully mission capable to avoid an unacceptable dip in air refueling capability (*Air Refueling Aircrew and Aircraft "Balancing" in FY21 (with forecast through FY24)*, 2020).

One of the challenges for the DOD is how to justify or express its need for air refueling. The concept of air refueling is often discussed and planned in abstract terms that are difficult to translate into mutual understanding. The complexity of planning air refueling support caused many planners in the 1990s to simply state assumptions that it would "be present in adequate supply" (Romero, 2015). This research hopes to find a new way of measuring tanker capacity and aid decision-makers with varied ways to advocate for future acquisitions.

Problem Statement

To any outsider, the original plan to exchange the KC-135 as it approached 60 years of service was easy to understand. The KC-46 brought greater fuel efficiency, more fuel capacity, more cargo capacity, and better technology to the warfighter (MacDonald, 2015). However, after multiple delays in the KC-X (now the KC-46) acquisition process such as the 2008-2011 rebidding of the contract to Boeing from Airbus (Grismer, 2011), and now multiple production delays, 2020 is here and the Air Force has yet to employ a new tanker (*Air Refueling Non-Mobilized Capacity*, 2020). Everything has not gone to plan.

To compound those problems, the drastic budget cuts of sequestration forced the DOD to cut entire programs instead of finding incremental savings. From the literature, it is clear that the leaders of the DOD and the Air Force have busied themselves almost as much with finances as they have fighting wars and defending America. The recapitalization of the tanker fleet was and is the most troublesome financial setback by far because the Air Force has been discussing and failing to resolve this need since the

1990s (Camerer, 2001). In 2014, the Air Force needed options, and the KC-10 was the most expensive weapon system behind the C-5 (Schatz, 2020). There was simply not enough money to continue the acquisition of the KC-X and keep all the other aircraft, so the Air Force decided to divest the KC-10 to ensure the recapitalization of the tanker fleet continued (Schatz, 2020). Therefore, the plan to divest the KC-10 was not born from military strategy but instead conceived in fiscal necessity (Welch & Leroy, 2019). How can the Air Force prove that it does not need its largest capacity tanker?

Research Focus

This research will describe the feasibility of the Air Force's planned 2030 tanker fleet of 300 KC-135s and 179 KC-46s. There is no question that the KC-46 is an upgrade from the KC-135 and will be more than capable in a one for one replacement of that subset of the tanker fleet. However, the KC-10 replacement plan is less straightforward, and at face value appears to reduce the air refueling capacity of the USAF. For those reasons, while data is available to evaluate all KC-135 and KC-10 historical missions, this research will focus on the KC-10 missions in the datasets.

Additionally, the research will also be limited in scope to the mathematical feasibility of executing a mission schedule with a smaller but more numerous airframe. The project does not assess the secondary and tertiary impacts of higher operations tempos caused by more missions in the greater system. Possible limitations not researched here include parking limitations (Welch & Leroy, 2019) at en-route airports and increased demand for trained pilots, aircrew, and maintainers.

Research Question

Will the Air Force have enough KC-46 aircraft to replace the KC-10 divestment without reducing support for Daily Competition operations?

Investigative Questions

- How many historical KC-10 missions would have required a formation of KC-46 aircraft to accomplish the same effects?
- How will the increased number of formation missions increase the total number of mission days flown each year?
- How many KC-46 taskable tails would the Air Force have needed if the KC-46 flew the historical schedule of the KC-10?

Summary

The Air Force tanker fleet is being made smaller by budget cuts, aging aircraft, and a delayed recapitalization plan. The reduction in force, at face value, conflicts with the National Security Strategy, and the Air Force has planned to *grow and modernize* its tanker fleet with a path to replace a larger tanker with a smaller one in greater numbers. Hard numbers, metrics, and ratios will help the Air Force explain this plan and make data-driven arguments for the requirements in future tanker acquisitions. This research looks at tanker capacity by analyzing historical mission data instead of aggregate planning numbers and hopes to add a different perspective to the conversation about air refueling capacity.

II. Literature Review

Chapter Overview

This chapter provides further background information on critical parts of the KC-46 transition and this research. The review begins with how other research has measured air refueling and a detailed discussion of the most recent metric found to describe tanker capacity, the "taskable tail." Then, the concept of Total Force Integration (TFI) is defined, and finally, this section introduces the research methods of sensitivity analysis and the Monte Carlo method.

How Does the DOD Measure Air Refueling?

The Air Force has been measuring, modeling, programming, and planning air refueling for decades. The majority of these efforts are justifiably focused on support for specific operations (Romero, 2015). Planning for an operation involves estimating the amount of fuel required by the fighter, intelligence, reconnaissance, and surveillance aircraft throughout the completion of stated military objectives. Then the planner works to match the number of tanker aircraft and frequency of sorties needed to support the previously stated aircraft. Over time the DOD has developed a myriad of techniques, procedures, and software that attempts the complicated feat. The Air Refueling Control Model, Theatre Battle Management Core System, Tanker Assignment Tool, Tanker Employment Tool, and the Air Refueling Control Model, are the names of just a few (MacDonald, 2015; Romero, 2015). However, these models do very little for planning the needs of the DOD in daily competition.

The Air Force needs a way to describe tanker capacity. Analysts of Desert Storm cited “Booms in the Air” as the limiting factor for air refueling effectiveness in the campaign (Romero, 2015), and it has become the only commonly understood metric for air refueling for over two decades. However, “Booms in the Air” does not urge recapitalization of the refueling fleet or explain how the Air Force can only task about 100 missions a day when it owns almost 500 tanker aircraft (*Air Refueling Non-Mobilized Capacity*, 2020). The next section discusses a newer concept of “taskable tails” and how they describe the Air Force’s ability to use its refuelers.

“Taskable Tails” and Mission Overlap

A “taskable tail” is the combination of an aircraft and an aircrew ready and available to fly a mission. Figure 1 was produced by United States Transportation Command (USTRANSCOM) to describe the relationship between aircrews and aircraft availability to fill a mission tasking. The graphic shows that the Air Force has 865 aircrews and 406 tankers available for mission taskings by USTRANSCOM in 2019. However, the red arrows show that only 368 are available if the United States fully mobilizes and goes to war. In other words, training and sustainment are no longer a concern for the DOD if America is in an all-out fight. The dotted red arrows show how the requirements of recurring training, medical appointments, professional development programs, administrative requirements, and other factors reduce the number of available crews. The surge number of 169 assumes that the Air Force is supporting a need that justifies waiving some training deadlines and return to a reduced level of operations after a short period. Then, the daily sustained number of 119 is the maximum tasking level allowable before aircrews begin to fall behind on training and medical appointments. As a final note regarding the graph for this research is that the purple section of each bar represents KC-10 tails and aircrew available for taskings.

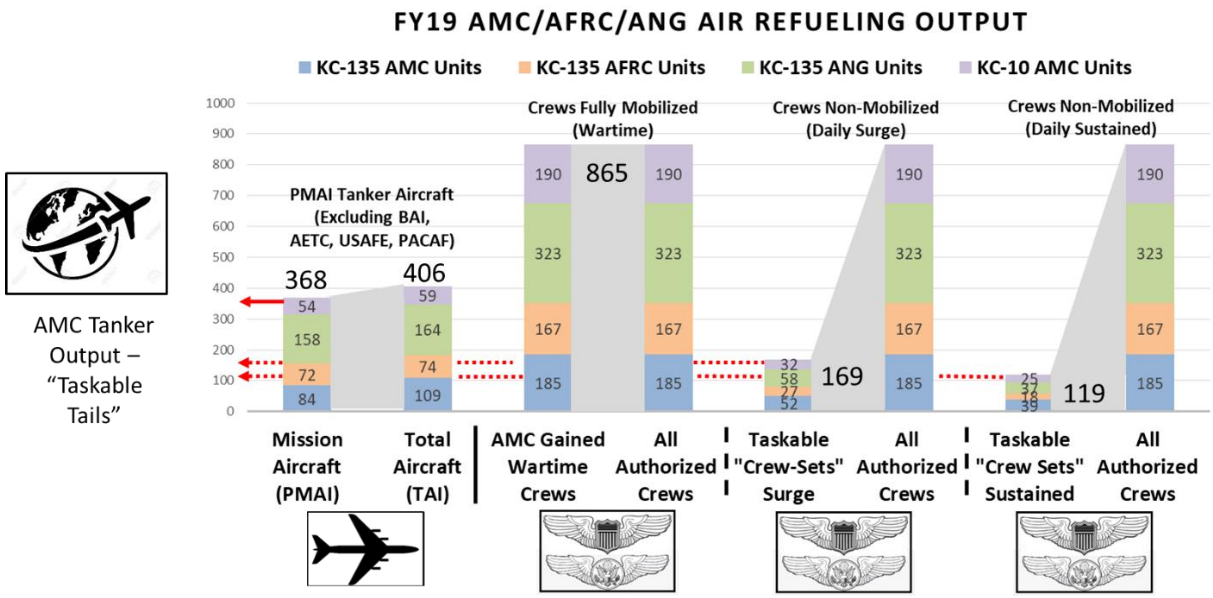


Figure 1: "Taskable Tails" Inputs (*Air Refueling Non-Mobilized Capacity*, 2020)

The "taskable tail" is the best description of bottom line air refueling capacity in the Air Force. The taskable tails are the maximum support available to all of the mission requirements pictured in Figure 2. Every day, USTRANSCOM prioritizes these mission and exercise requirements to determine which needs will go unsupported.

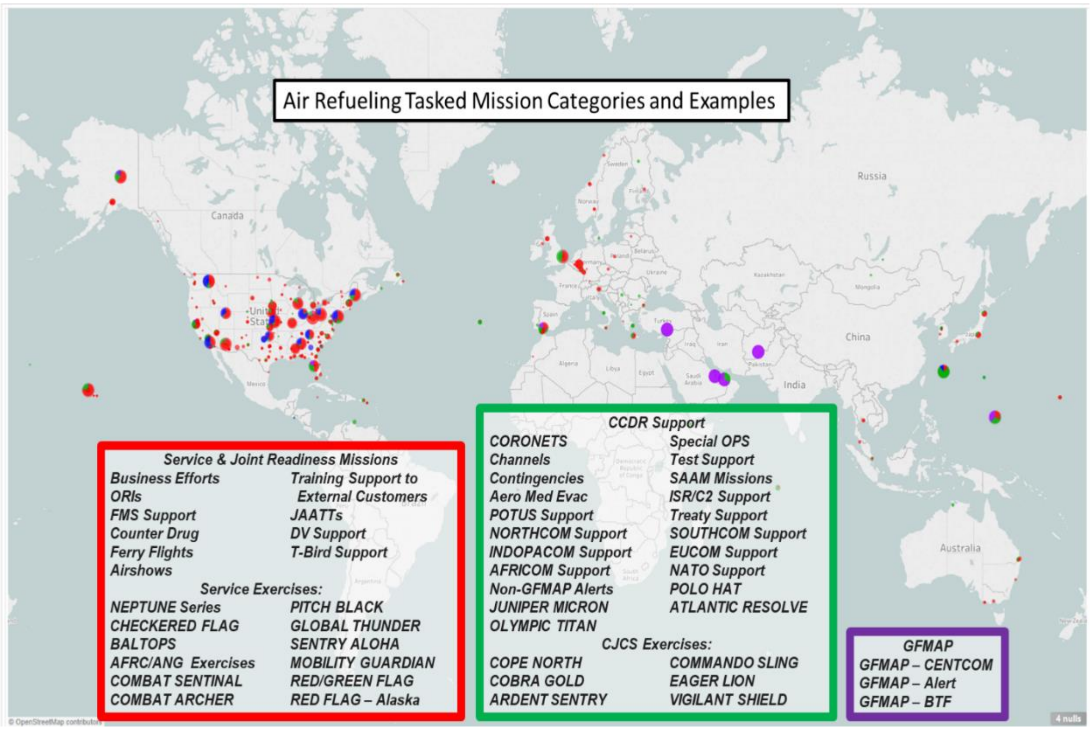


Figure 2: Tasked Mission Categories (*Air Refueling Non-Mobilized Capacity*, 2020)

The prioritization situation is not new; however, what is new is that the Air Force's newest tanker cannot support any missions until Boeing can correct critical deficiencies in its cargo and refueling systems. At the same time, the Air Force has bureaucratic inertia moving toward divestment of the KC-10, retiring some KC-135 aircraft, and cross-training of aircrews to make way for the new tanker (*Air Refueling Aircrew and Aircraft "Balancing" in FY21 (with forecast through FY24)*, 2020). The taskable tail is the best way to describe how these moves will limit the capability of the united states to meet its daily mission commitments.

As a subtopic to the taskable tail discussion, this paragraph introduces the concept of mission overlap. When the Air Force assigns a mission to a taskable tail, it is unavailable for another mission occurring at the same time. This simple concept causes many ripples and wrinkles in the planning for daily operations in the tanker fleet because weather, maintenance, aircrew sickness, and other factors can delay a mission that is in progress. If all of the sustainment level taskable tails are in use, when a delay happens, the DOD must weigh the options of canceling other missions or entering surge levels of support. The surge levels wear down the force and reduce its readiness for large scale conflict (*Air Refueling Non-Mobilized Capacity*, 2020).

Total Force Integration

A keen eye might have noticed in the section on taskable tails that the Air National Guard and Air Force Reserves currently own a majority of the KC-135 fleet. These aircraft are not readily taskable for two main reasons. One, directly tasking the guard or reserve, takes extra levels of red tape such as US Code Title 10 mobilization, so the majority of their participation in the USTRANSCOM mission is voluntary. Two, the aircrews often have civilian careers outside of the military and are only able to maintain their training readiness to serve as an essential crewmember in times of war (Johnson, Kniep, & Conroy, 2013). This organizational scheme saves the Air Force money but limits the responsiveness of the DOD in times of need that do not rise to the level of war declaration (Dugan-Beatovich, 1997; Robbert, 2013).

Part of the KC-46 acquisition plan is an organizational shift in the Air Force to implement Total Force Integration. In the new organization, active duty and reserve aircrew will share the same squadron buildings, mission planning areas, and be able to integrate active duty and reserve crewmembers on tasked missions easily. The aircraft owned by the two commands will also coincide at the same base. The theory is that the reserves and active duty Air Force will share ownership of most of the aircraft and allow a more fluid transfer of aircraft from reserves to active duty when needed (Johnson et al., 2013). Now the review will shift to a discussion of analysis methods.

Sensitivity and Parametric Analysis

Part of this research involves estimating formulas that govern the relationship between variables and an output. Sensitivity analysis can determine the importance of a variable to the output of the equation. In a complex system, sensitivity analysis can also be useful in screening the validity of an intermediate equation before spending extensive resources analyzing the entire system. The analysis can be performed on individual parameters in a system and plotted graphically to understand the extremes in variation that can be caused by a single parameter in a complex environment (Frey & Patil, 2002). This tool was used in the research to analyze the relationship of fuel onloads, and the overall number of missions counted as “large” before creating the Monte Carlo analysis model, reviewed next.

The Monte Carlo Method

Monte Carlo simulations are versatile and widely accepted methods of finding the likely behavior of a high-dimensional problem (Caflisch, 1998). The method is a compilation of random and deterministic flows, where an overall equation is known, but the exact values of the variables are either not known or cannot be known (Ulam, 1949). A researcher can use Microsoft Excel to set up incredibly complex relationships through cell references, without understanding or being able to solve the underlying differential equation of the system. Then by randomizing some of the inputs, the Monte Carlo method can reveal trends or convergence on a single solution to a complex problem with unknown parts.

Monte Carlo is often used in finance to test the possible outcomes of an investment strategy that depends on inputs from a basket of companies and outside influences. The researcher knows how the inputs would change the outcome but does not know what the probability of success will be with the strategy. By employing Monte Carlo analysis, multiple trials can assess if the strategy makes money in most circumstances or decide to discard plans that are too risky or result in too low of an average return on investment (Caflisch, 1998).

The method is used in this paper to find the likely workload of the tanker fleet when the historical schedule has some missions flown with an extra aircraft.

Summary

The subject of air refueling is a hot topic for the Air Force and the DOD at large in the 21st century. The literature review shows that air refueling capacity is a complex subject that is as much dependent on politics as it is on aircraft. The following methodology puts politics aside and provides an objective way to look at the Air Force's plan to divest the KC-10.

III. Methodology

Chapter Overview

The Air Force has planned to divest the KC-10 (which can carry 340,000 lbs of fuel) and provide the same mission effects with the smaller KC-46 that has a fuel capacity of 208,000 lbs (Gunzinger, Rehberg, Cohn, Walton, & Autenried, 2019). Historically, not every KC-10 mission requires a maximum fuel load, but when a mission requires more than 208,000 lbs of fuel, two KC-46 aircraft would be required to accomplish the mission. This research analyzed almost ten years of mission records to determine how many historical KC-10 missions required two KC-46 aircraft and quantified how the change in airframe might increase the total number of tails (or aircrews) in use at the same time.

This chapter begins with a discussion of assumptions and limitations that set the stage for research, followed with a description of the two data sources and then how the two records are combined. After establishing the dataset, the researcher develops the criteria that determine which missions are too large for a single KC-46. Finally, the chapter shows the creation of a “tasked tails” calendar, parametric analysis of the onload criterion, and the setup of a Monte Carlo simulation to reveal scheduling impacts on the entire mission history.

Assumptions/Limitations

Firstly, the plan to replace the KC-10 with the KC-46 assumes that the KC-135 will continue to fly to 100 years of service without degradation in mission capability (Grismer, 2011). This research also assumes that KC-46s can replace KC-135s at a one for one rate.

Also, formation flight is inherently more complicated, with more opportunities to fail, and could cause delays in the schedule (Romero, 2015). This paper assumes that the Air Force planners and aircrew can perform at a higher standard of mission complexity with the increased requirement of formation flight in the KC-46 schedule (Welch & Leroy, 2019).

Additionally, the research assumes that the KC-46 has a maximum fuel capacity of 208,000 pounds, regardless of ambient conditions such as density altitude or runway length limitations. The fact that the KC-10 typically flies to large runways mitigated the risk of this assumption skewing the results.

Then, the most significant limitation in this research is information regarding how the divestment of the KC-10 and transition to the KC-46 will affect the number of tails required in combat operations. A smaller tanker could drive a higher requirement of tails in combat, but on the other hand, the replacement of some of the KC-135 fleet with the larger KC-46 may offset the effect. This research assumed that the number of tails required in operations other than daily competition would remain proportional to the number of aircraft in the fleet.

Another limitation considers the fact that the datasets available only contain records of missions flown and does not include any tasked alerts, ground spares, or canceled missions that also prevented the use of an aircraft for another tasking. This limitation should be kept in mind when looking at totals regarding tasked missions in the results section because daily taskings include these other events regularly; however, they are less numerous than flown missions. This research assumes that a proportional amount of these other tasking events occurs regardless of the airframe considered and will not skew the conclusions of the research. In a similar fashion, the required number of KC-46 aircraft needed for training aircrew has yet to be determined and was therefore unavailable. However, the KC-46 has similar capabilities to the KC-10, such as the ability to onload fuel in flight and a cargo capability that aircrew must practice. Therefore, the training requirements are assumed to be similar to the KC-10, and the proportion of flights devoted to training and deployments will be the same for the new weapon system.

Data Overview

This research first required the creation of an estimated mission history for the KC-10 because the historical record of KC-10 missions flown with departure and arrival dates, times, and locations, alongside fuel details did not exist at Air Mobility Command (Anderson, 2019). AMC/A9 provided a complete ten-year record from the Tanker Airlift Control Center (TACC) of all missions flown by AMC, but the record did not include information about how much fuel was received from or offloaded to other aircraft. However, AMC/A9 provided another large sample of fuel information from Fuel Tracker (FT), a previous AMC fuel efficiency study, for this research.

The TACC history covers 2011 to the summer of 2019, and the FT dataset contains records from 2011 to the summer of 2016. Both records contain information on all airframes. The next step extracts 41,662 KC-10 mission records from the TACC data to scope the data file to this study. Then, 25,922 FT records were matched from the FT dataset to their corresponding mission in the TACC record to create a final dataset with 62% real-world fuel usage information.

Corrections to Source Data

The following efforts refined the final combined dataset for congruity. Close inspection found variations greater than 24 minutes in flight duration occurred in 1,472 of the TACC records that matched an FT record (5.6% of the FT records). Also, 35 TACC records (less than 1%) stated a flight duration greater than 18hrs. Of these, 24 had FT records that indicated a much shorter flight time. The researcher decided to use FT data where it was available because aircrew generated the FT entries, and was likely more accurate than the TACC data. In Excel, the following equation creates a "corrected" flight duration for each mission by favoring FT data where it was available and reducing other flight times to zero that were greater than 18hrs if no FT data was available. (By reducing the duration to zero, the mission could still be counted as flown on a given day without being counted as a mission that required two KC-46)

=IF(AND(FTflightduration="",TACCflightduration>18),0,IF(FTflightduration ="",TACCflightduration,MAX(PlannedFTflightduration,ActualFTflightduration)))

There were only two other missions modified that would have skewed the total tails tasked per day. One mission was a tail on loan to Edwards AFB for four weeks of research, and the other was a tail that returned to depot maintenance for three weeks. The researcher assigned a unique mission number to the final leg of each of these two anomalous missions, so this research would not count the tail as tasked while it was not flying at these locations. Ultimately, these corrections did not have a significant impact on the final results of the research.

Preparation of the Data – Finding Large Missions

Next was the development of an equation to identify which missions require more than one KC-46 to accomplish. The researcher interviewed a KC-46 pilot to determine that the maximum fuel capacity of the KC-46 was 208,000 pounds, the average fuel burn rate was 11,000 pounds per hour, and a minimum landing fuel of 15,000 pounds would be conservative and appropriate for this research (Gunzinger et al., 2019; Miller, 2020). A hypothetical fuel onload limit of 150,000 pounds was identified through parametric analysis and discussed further in the section titled "Parametric Analysis." Then, the equation can be used to evaluate each FT mission record for feasibility with a single KC-46 aircraft. Explicitly, if the minimum landing fuel, plus the corrected flight duration multiplied by the KC-46 fuel burn rate, plus the planned offload, less the fuel received in-flight (onloaded) are greater than the maximum fuel load for the KC-46 or 208,000 pounds, the mission is flagged with a "2" or otherwise, a "1." The excel formula follows this paragraph.

```
=IF((15000+(correctedflightduration*11000)
+(MAX(Plannedoffload,Actualoffload)*1000)
-(IF(MAX(plannedOnload,ActualOnload)<150,
MAX(plannedOnload,ActualOnload),0)*1000))>208000,2,1)
```

Creating a "Tasked Tails" Calendar

It is not enough to count only the days that an aircraft flew when assessing mission workload. If an aircrew flies from California to Alaska, waits one day in Alaska for a maintenance repair, waits two more days because of icy weather, then flies to Japan, and finally flies back to California, the tail only flew on three days. However, the tail and aircrew were "in use" for six days and could not be used for other taskings. Therefore, after identifying the large missions, two "calendars" are built to show how many tails are in use each day. The first version of the calendar is a representation of the mission schedule flown by the KC-10, and the second version of the calendar includes the additional KC-46 missions required to accomplish the same schedule. The calendar type record enables the researcher to count overlapping missions and determine the maximum number of tails required each day, for comparison in both scenarios.

Parametric Analysis of Onload Limit

KC-10 aircrew regularly receive fuel in flight to enable them to fly farther or offload more fuel to other aircraft during a mission. The KC-46 will also have the ability to receive fuel in flight but has less overall fuel capacity. The KC-46 simply cannot onload more than its fuel capacity of 208,000 pounds, but it would also not be a prudent plan for it to receive fuel when the aircraft only has a few thousand pounds left in its tanks before it starts the onload. That plan would be unsafe because the aircraft may run out of fuel in-flight if there is a malfunction. The Air Force has not set the maximum onload for the KC-46, but the selection of the max value could have significant impacts on the total number of missions identified as needing two KC-46s in this study. Consequently, this study used a parametric analysis to test the sensitivity of the onload variable.

The parametric analysis varied the maximum onload from 0 to 200,000 pounds and found that the number of missions identified as needing two KC-46 aircraft decreased to a plateau at 120,000 pounds onload allowed, graphed in Figure 3. The rest of the research was completed with a 150,000-pound limit because it captures a little more of the variability (96% total) in extra sorties required while still being feasible for mission planning.

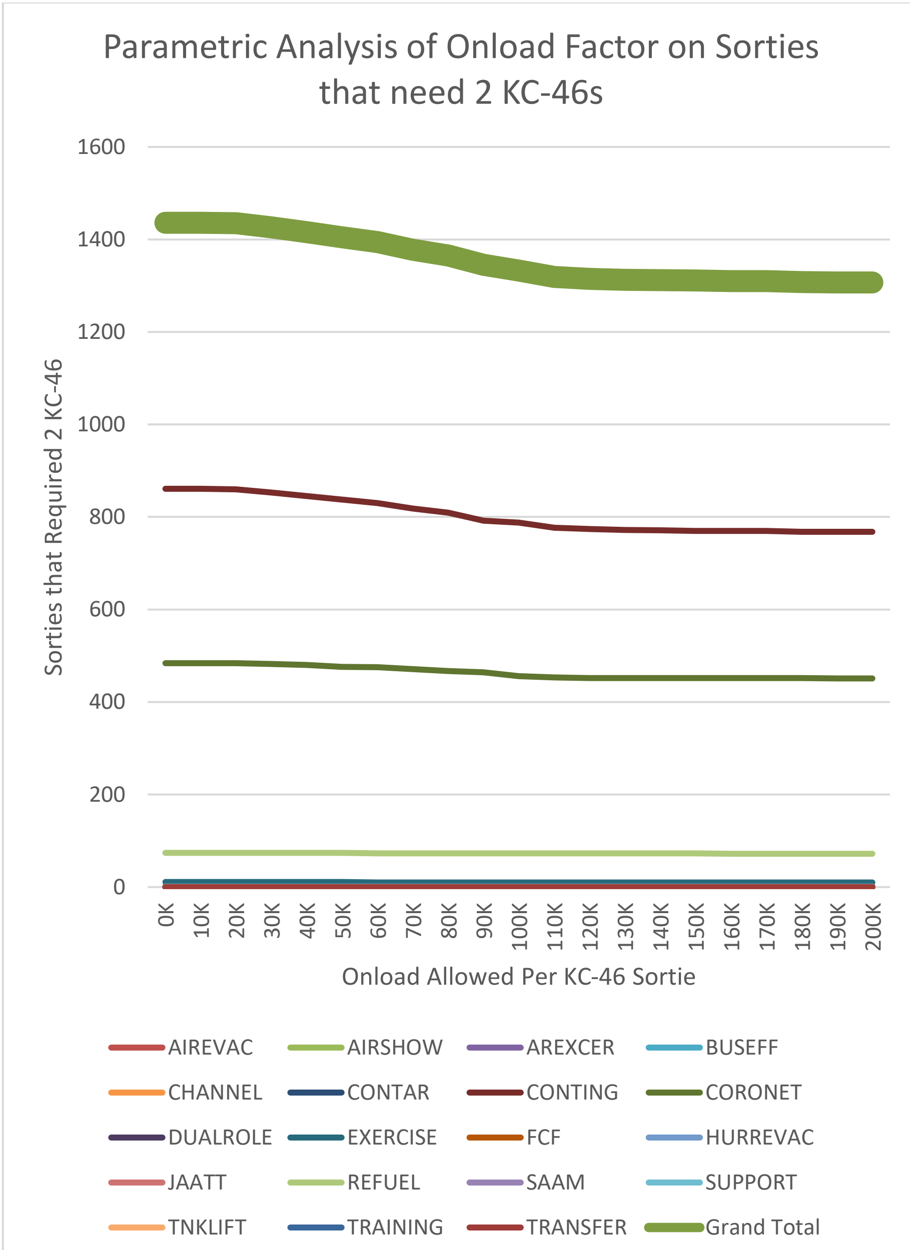


Figure 3: Parametric Analysis of Onload Limit

Monte Carlo Simulation

After the parametric analysis, the final macrolevel statistics can be observed and used to conduct a Monte Carlo analysis of probable mission calendars. The variable of interest in the Monte Carlo analysis is how many TACC records (that did not have a matching FT data record) should be counted as "large" missions and assigned two KC-46 aircraft. The following table details how many TACC missions are in each mission category, what percentage of each category has matching FT records, and how many FT records in each category need two KC-46 aircraft to accomplish.

Macro Analysis of TACC and Fuel Tracker (FT) Data					
Mission Categories	**TACC Records**	**With FT Matches**		**of Matches, needed 2 KC-46**	
AIREVAC	9	9	100%	0	0%
AIRSHOW	39	4	10%	0	0%
AREXCER	43	14	33%	0	0%
BUSEFF	355	126	35%	1	1%
CHANNEL	3054	2563	84%	0	0%
CONTAR	5	3	60%	2	67%
CONTING	7033	3976	57%	770	19%
CORONET	4575	2992	65%	452	15%
DEPLOY	7	0	0%	0	0%
DRCORNET	6	0	0%	0	0%
DUALROLE	132	93	70%	1	1%
EXERCISE	201	136	68%	10	7%
FCF	4	4	100%	0	0%
GNDALT	2	0	0%	0	0%
HURREVAC	11	10	91%	0	0%
JAATT	382	320	84%	1	0%
JCSEXAR	1	0	0%	0	0%
REFUEL	1535	723	47%	73	10%
SAAM	242	214	88%	0	0%
SUPPORT	157	111	71%	1	1%
TNKLIFT	8	8	100%	0	0%
TRAINING	23452	14390	61%	0	0%
TRANSFER	409	226	55%	0	0%
Grand Total	**41662**	**29522**	**62%**	**1311**	**5%**

Table 1: Macro Analysis of TACC and Fuel Tracker (FT) Data

There is a trend in the three mission categories that needed the most additional KC-46 aircraft: CONTING, CORONET, and REFUEL missions. Each mission in the data has a unique mission identifier number. While the exact explanation of the number is not necessary for this paper, it is important to note that the second character of the mission numbers in these categories has a high correlation with the sorties that need additional KC-46 aircraft. The following table shows how the researcher uses the mission numbers to further define each category for the Monte Carlo simulations.

Composition of the Three Largest Categories								
Of 3,976 CONTING msns,	49%	1960	mission numbers began with	?P	and	761	38.83%	needed 2 KC-46s
	51%	2016		the rest		9	0.45%	
Totals	100%	3976				770		
Of 2,992 CORONET msns,	28%	847	mission numbers began with	?J	and	4	0.47%	needed 2 KC-46s
	53%	1577		?P		448	28.41%	
	19%	564		?v		0	0.00%	
Totals	100%	2988				452		
Of 723 REFUEL msns,	11%	81	mission numbers began with	?J	and	3	3.70%	needed 2 KC-46s
	75%	544		?P		64	11.76%	
	10%	73		?v		1	1.37%	
Totals	97%	698				68		

Table 2: Composition of the Largest Categories

Then, the knowledge of which missions are most likely to require two KC-46 aircraft enables the creation of a final probability framework in the Monte Carlo simulation. The simulation creates 40 unique iterations of the mission calendars. Each iteration assigns a random number to each mission record, and the random number determines if the mission is assigned one or two KC-46 aircraft. The following table shows the final probabilities used for each mission category in the simulation, and all other categories not listed have a probability of zero for needing two KC-46 aircraft.

Propotion of Missions that Require two KC-46		
Mission Category	**Subcategory**	**Proportion**
BUSEFF		0.80%
CONTAR		66.00%
CONTING	"?P" Mission	38.83%
	all else	0.45%
CORONET	"?J" Mission	0.47%
	"?P" Mission	28.41%
DUALROLE		1.10%
EXERCISE		7.40%
REFUEL	"?J" Mission	3.70%
	"?P" Mission	11.76%
	"?v" Mission	1.37%
SUPPORT		1.00%

Table 3: Final Probabilities for Monte Carlo Simulations

An equation was built for each category to evaluate the random numbers in each Monte Carlo iteration. The equation for the coronet mission category and subcategories is provided here as an example. (The cells N1, and N2 contained the probability benchmark; I240 contained FT info; J240 was the category; H240 was the mission number; B240 contained the random number; O240 was the previously evaluated result of needed 2 KC-46 based on FT data):

```
=IF(I240="",IF(J240="CORONET",IF(RIGHT(LEFT(H240,2))="P",IF(B240<=$N$2
,2,1),IF(RIGHT(LEFT(H240,2))="J",IF(B240<=$N$1,2,1),1)),""),O240)
```

Summary

This research creates a simulated calendar to depict how KC-46 aircraft could have accomplished the past ten years of daily competition missions flown by the KC-10. A large sample of fuel usage data describes the characteristics of the ten-year KC-10 mission history that did not include fuel data. Then, each mission is evaluated for feasibility by a single KC-46 that has a smaller fuel capacity than the KC-10. Finally, a Monte Carlo simulation investigates how many KC-46 aircraft are needed to fly the same historical missions as the current fleet of 59 KC-10s.

IV. Analysis and Results

Chapter Overview

This chapter presents the answer to each of the investigative questions in turn. Those answers form the foundation for the analysis of the overarching research question, “Does the Air force have enough KC-46 aircraft on order to replace the KC-10?” The next and final chapter will discuss the implications of these results and conclude the paper.

Investigative Questions Analysis

Investigative Question 1: How many historical KC-10 missions would have required a formation of KC-46 aircraft?

Short answer, 13% of KC-10 daily competition sorties needed two KC-46 aircraft. Of the 41,662 mission records, 23,452 or 56% of the missions were training missions that are not part of the taskable tails conversation. After removing the training missions, the 40 Monte Carlo experiments yielded an average of 2,312 records that need two KC-46 aircraft. Figure 4 shows the breakdown of records by year.

	Total	2011	2012	2013	2014	2015	2016	2017	2018	2019*
Total Missions Flown	41662	5811	5223	4724	5251	4857	4689	4611	4146	2350
Small Missions	39350	5337	5007	4542	4990	4627	4426	4293	3899	2229
Training Missions	23452	2584	3009	2955	2864	2871	2644	2456	2557	1512
Small Daily Competition Missions	15898	2753	1998	1587	2126	1756	1782	1837	1342	717
Large Daily Competition Missions	2312	474	216	182	261	230	263	318	247	121
Ratio of Large to Total Daily Competion	**13%**	15%	10%	10%	11%	12%	13%	15%	16%	14%

Large Daily Competition Missions Per Category	2011	2012	2013	2014	2015	2016	2017	2018	2019*
AIREVAC	0	0	0	0	0	0	0	0	0
AIRSHOW	0	0	0	0	0	0	0	0	0
AREXCER	0	0	0	0	0	0	0	0	0
BUSEFF	0	0	0	0	1	0	1	0	0
CHANNEL	0	0	0	0	0	0	0	0	0
CONTAR	0	0	0	2	0	1	0	0	0
CONTING	387	127	115	122	108	136	184	167	69
CORONET	73	74	52	126	90	101	96	55	44
DEPLOY	0	0	0	0	0	0	0	0	0
DRCORNET	0	0	0	0	0	0	0	0	0
DUALROLE	1	0	0	0	0	0	0	0	0
EXERCISE	0	0	3	1	6	1	2	1	1
FCF	0	0	0	0	0	0	0	0	0
GNDALT	0	0	0	0	0	0	0	0	0
HURREVAC	0	0	0	0	0	0	0	0	0
JAATT	0	1	0	0	0	0	0	0	0
JCSEXAR	0	0	0	0	0	0	0	0	0
REFUEL	12	13	13	10	25	24	35	23	7
SAAM	0	0	0	0	0	0	0	0	0
SUPPORT	0	1	0	0	0	0	0	0	0
TNKLIFT	0	0	0	0	0	0	0	0	0
TRAINING	0	0	0	0	0	0	0	0	0
TRANSFER	0	0	0	0	0	0	0	0	0

*2019 is only thru June of that year

Table 4: Count of Missions Flown that Required Two KC-46 Aircraft

Investigative Question 2: How will the increased number of formation missions increase the total number of mission days flown each year?

It is not enough to look at the raw number of sorties that require two KC-46 aircraft because a mission may have had multiple legs while only one sortie was large enough to need two KC-46 aircraft truly. The single large leg of a mission warrants an additional KC-46 for each leg of the mission because if the planners split the required formation leg into a separate mission, there would be positioning and de-positioning flights required to get the second KC-46 into position. An algorithm developed that investigates how many “efficiency days” might be saved by flying each additional required sortie as a separate mission found only 8% possible savings in the added mission days. The discussion of the algorithm is in Appendix A to avoid a departure from the point of this paper.

The mission days per year metric considers the entire period of days each aircraft is in use. Two examples can illustrate the point. On a local mission, a tanker can depart from its home base, refuel another set of aircraft and return to base in a single day. Another mission may require the tanker to depart its home station to meet up with a set of aircraft that need to cross an ocean. This mission might fly one leg to meet the other set of aircraft, experience bad weather on the next day that delays the mission, fly the customer aircraft across the ocean on the third day, experience a minor maintenance issue that requires the delivery of a part at the next location, delay for two days waiting for the part, and finally fly home on the sixth day. This mission would only have three recorded flights in the original data set, but the mission cost the Air Force six mission days where the tail was not available for other taskings. Therefore, the mission days are counted by tracking each mission number through the data to find the start and end of the mission and counting the total days between the two dates. The following graph shows an average twenty percent increase to mission days required each year if the KC-46 accomplished the historical KC-10 schedule, with the additional formation missions.

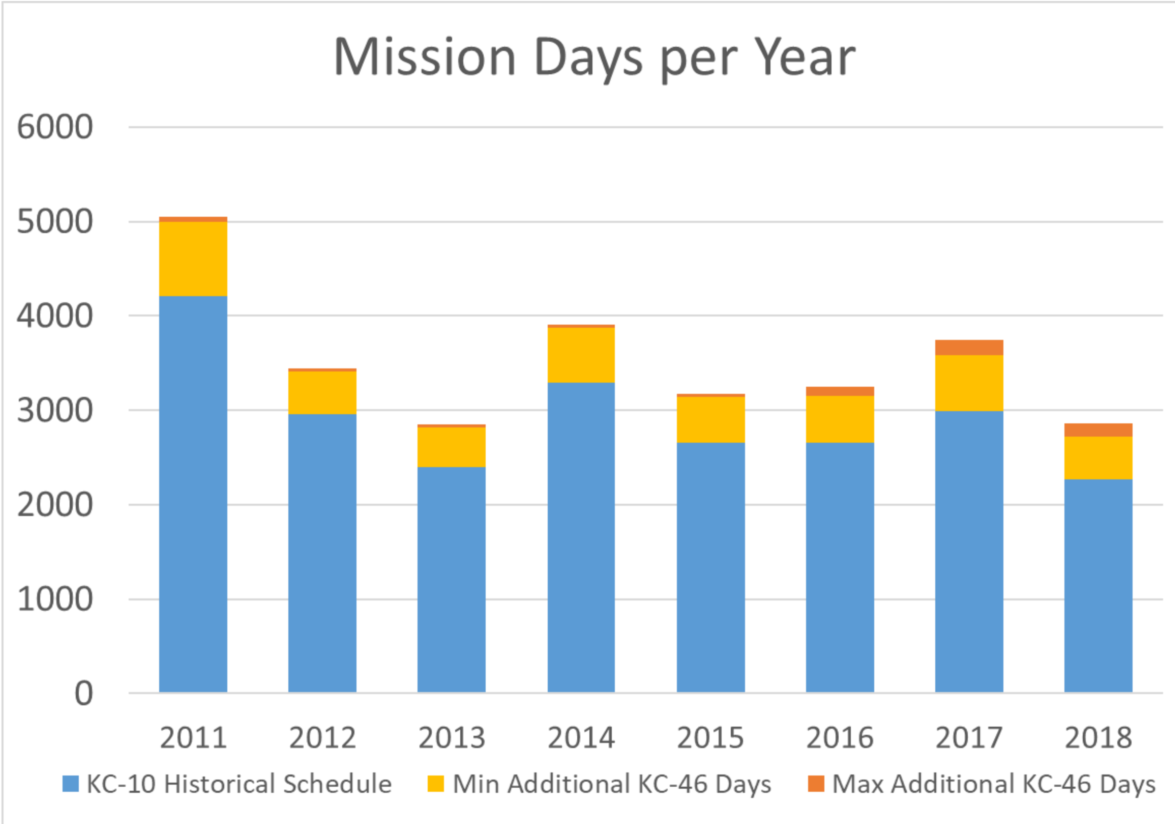


Figure 4: Mission Days Flown per Year

Investigative Question 3: How many KC-46 taskable tails would the Air Force have needed if the KC-46 flew the historical schedule of the KC-10?

After finding the answers to questions one and two, it is possible to assess how many aircraft the Air Force needs in a fleet of KC-46 aircraft to support the same mission requirements as the KC-10. The concept of mission overlap, discussed previously, drives the math required to calculate the number of tails in use at any given moment. A graph of the daily fleet utilization looks like an earthquake seismograph and is included in the appendix if the reader finds it useful. Trendlines and regressions fail to capture the peaks in usage that the Air Force is concerned about when assessing risk and overall capability and are therefore not useful in the results of this research. The researcher uses a different approach to present the findings here.

The following graph, Figure 5, reduces the granularity in the daily data by showing the maximum number of tails in use at the same time in each month. Large mission taskings tend to come in waves and can compound to create large demand surges in the calendar. This research is concerned with having enough capacity available when it is needed and not as concerned with the days that the fleet is underutilized. In the graph, the blue section of each bar shows the historical monthly maximum of simultaneously supported KC-10 taskings, as flown. Then the orange and red bars show the minimum and maximum variability in additional KC-46 taskings required each month. The years after 2016 did not have any real-world fuel data available and showed higher variability in the Monte Carlo iteration results.

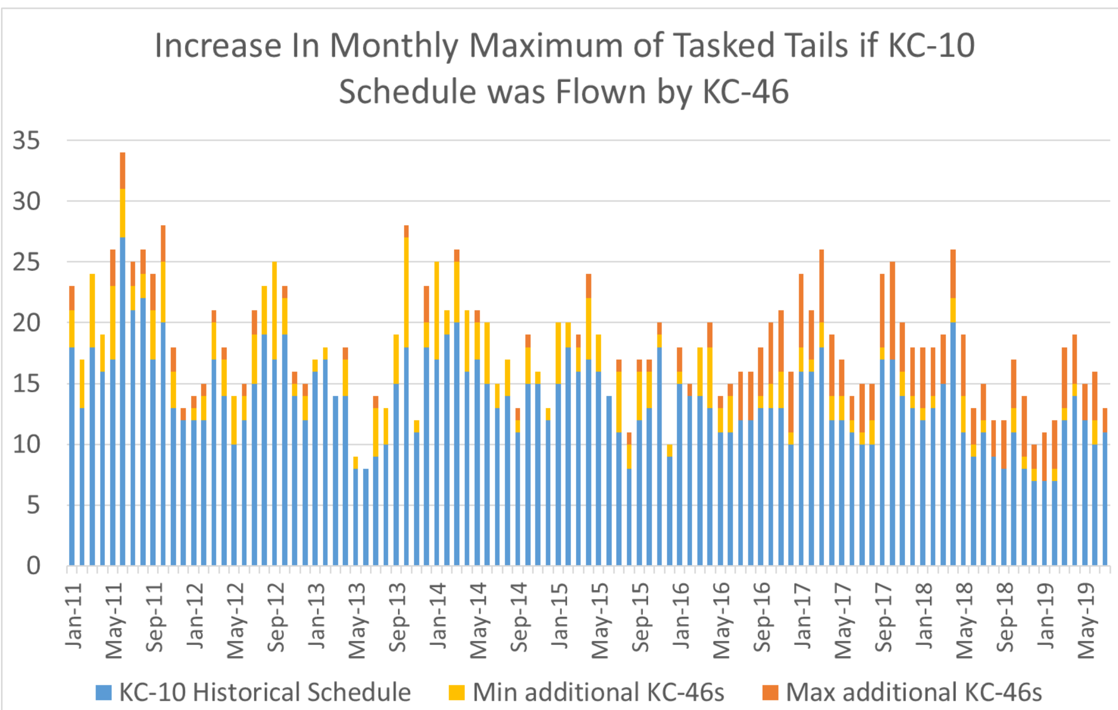


Figure 5: Maximum Tails Tasked per Month

Another useful depiction can help our senior leaders assess risk by showing how many days a smaller fleet would be unable to meet the historical mission requirements. In the following box and whisker plot, the minimum whisker shows that the historical KC-10 schedule had days where no aircraft flew, such as Christmas day. However, on average, the KC-10 supported seven tasked missions a day and had a maximum usage of 27 tasked missions in progress on a single day. It is important to reiterate here that this data set only contains missions that actually flew and does not include any tasked alerts, ground spares, or canceled missions that prevented the use of an aircraft for another tasking.

In the middle of the graph, there is a single simulated KC-46 schedule from the Monte Carlo iterations depicted, and then the highest values for each quartile from the 40 Monte Carlo runs combined to form the plot on the right. The maximum plot represents a plausible worst-case schedule.

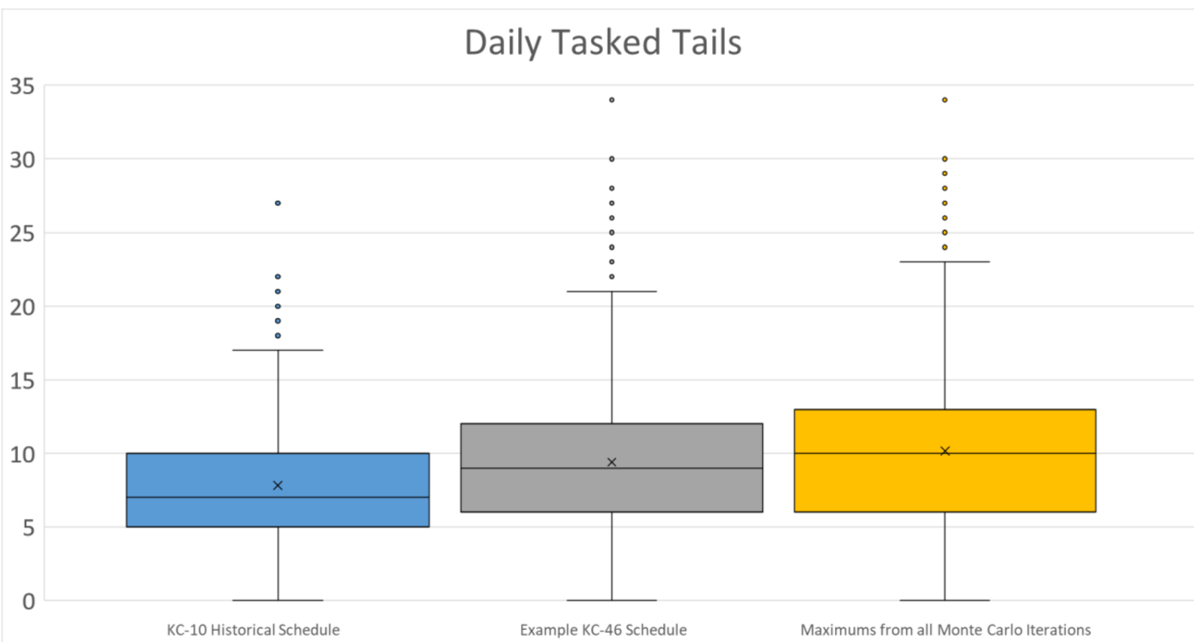


Figure 6: Box and Whisker Plot of Daily Tasked Tails

Research Question Analysis

Will the Air Force have enough KC-46 aircraft to replace the KC-10 divestment without reducing support for Daily Competition operations?

Now that the increases required to meet the historical mission contribution of the KC-10 are known, a final transformation speculates the fleet of KC-46s required. The Air Force programmed an increase in the number of tanker aircraft in its fleet from a mix of 396 KC-135 and 59 KC-10 aircraft to a new total of 479 aircraft composed of 300 KC-135 and 179 KC-46 aircraft (*Air Refueling Non-Mobilized Capacity*, 2020). This research assumed that the KC-46 could be a one for one substitute for the KC-135 in daily competition missions. Therefore, we can compare the future fleet to the 2019 fleet, where 96 of the 179 KC-46 aircraft can replace KC-135s, and the remaining 83 KC-46 aircraft replace the fleet of 59 KC-10s. Proportions based on the previously discussed assumptions can then assess whether a fleet of 83 KC-46 aircraft can support the same mission as 59 KC-10s.

The data reveals that the Air Force employed a maximum of 46% of the KC-10 fleet in simultaneous support of daily competition missions. Applying 46% to the replacement KC-46 fleet of 83 aircraft creates an available pool of 38 KC-46 aircraft. Finally, the data revealed that a maximum of 34 KC-46 aircraft was needed to support the historic daily competition schedule of the KC-10. From that rationale, the Air Force has indeed programmed enough tanker capacity in 2030 to continue its support of USTRANSCOM daily competition, with four aircraft to spare. However, that conclusion is drawn from the entire dataset and uses a peak employment level from 2011 applied to future fleet composition based on the fleet of 2019. For clarity, the bright red borders and bold font highlight the numbers from this paragraph in Table 5.

Table 5 evaluates the decisions in the previous paragraph and reveals that this research may not have the right mix of data to make a definitive claim on what the future will hold. The actual number of KC-135s has decreased since 2011, and if the researcher uses the 2011 fleet in the calculations of the previous paragraph, the Air Force would have been four tails short of their need. Without applying the method of this research to the entire set of historical KC-135 and KC-10 taskings, it is impossible to know if the fleet from 2011 “needed” the additional KC-135s when compared to the 2019 fleet. Ultimately, further investigation is required.

Historical Fleet									
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Historical Total	473	474	467	459	455	457	457	457	455
KC-135	414	415	408	400	396	398	398	398	396
KC-10	59	59	59	59	59	59	59	59	59
Max Activity for KC-10 Tasked Tails	27	19	18	20	18	15	18	20	14
(As a percentage of KC-10 Fleet)	46%	32%	31%	34%	31%	25%	31%	34%	24%
Future Fleet Applied by Year									
Future total fleet	479	479	479	479	479	479	479	479	479
KC-135	300	300	300	300	300	300	300	300	300
KC-46s to replace KC-135s	114	115	108	100	96	98	98	98	**96**
KC-46s to replace KC-10s	65	64	71	79	83	81	81	81	**83**
Yearly Availability for Tasking	46%	32%	31%	34%	31%	25%	31%	34%	24%
KC-46s available	30	21	22	27	25	21	25	27	20
needed	34	25	28	26	20	21	26	26	19
Difference	-4	-4	-6	1	5	0	-1	1	1
Max availability for Tasking	46%	46%	46%	46%	46%	46%	46%	46%	**46%**
KC-46s available	30	29	32	36	38	37	37	37	**38**
needed	**34**	25	28	26	20	21	26	26	19
Difference	-4	4	4	10	18	16	11	11	19
Average Availabiltiy for Tasking	32%	32%	32%	32%	32%	32%	32%	32%	32%
KC-46s available	21	20	23	25	26	26	26	26	26
needed	34	25	28	26	20	21	26	26	19
Difference	-13	-5	-5	-1	6	5	0	0	7

Table 5: Evaluation of Required KC-46 Fleet

Research Conclusions

The results presented in this chapter reveal that thirteen percent of KC-10 historical daily competition missions required two KC-46 aircraft to provide the same effects. Additionally, after taking into account the effect of overlapping missions that require extra KC-46 support, the research reveals that the total of mission days required would increase by 20%. Then, by tracking the peaks in overlapping missions, the results showed how 34 KC-46 taskable tails could have accomplished the same mission calendar as 27 tasked KC-10s. Finally, these results are applied to the assumptions in this research to claim that the Air Force needs a fleet of at least 74 KC-46 aircraft to continue providing the same level of support to the DOD. The future fleet could have satisfied the needs of the DOD from 2018 to 2019.

V. Conclusions and Recommendations

Air Force Implications

The results of this research are significant to the Air Force in three ways. Two insights were part of the original intent of the project, but the third is a new revelation from the analysis. This section explains the areas in order of significance to the Air Force.

The most significant implication revealed in this research is that the KC-10 has been relatively underutilized as a platform for daily competition sorties. While planners love the flexibility that a large tanker like the KC-10 can provide (Welch & Leroy, 2019), the historical record shows that most of this flexibility goes unused each year while supporting the daily competition requirements of the DOD. Given the worldwide scope of the schedule flown by the KC-10, opportunities to further combine missions in ways that better utilize the capacity of the air refueler appear unavailable. However, when the mission capacity requirement does increase, a large tanker acts as a shock absorber to the system by soaking up large requirements that would have involved multiple aircraft, aircrew, or more landings (Romero, 2015). The KC-10 provides a strategic reserve in the tanker system, but as found in the research, the Air Force has not really tapped its strategic reserve since 2011. It appears that daily competition missions more often require “a” tanker, rather than specifically “a large” tanker. Before this research, the Air Force could not demonstrate how much of its strategic refueling reserve was in use throughout history.

The capability to demonstrate capacity usage comes from the second area of significance to the Air Force, the creation of a new dataset model. By combining a complete record of duration, date, mission number, and the fuel used, offloaded or onloaded, this research demonstrates the power of these details to measure the capacity of our air refueling system. The same details should be recorded in future records for tasked ground alerts and ground spares because a tail and a crew are tasked to these missions even though they may not take off. Redundancy is a valid use of a tanker for some missions, and the tail and aircrew are not available for use. For ground alerts and spares, the planned duration and fuel is necessary for the guaranteed success of the mission. The dataset, if maintained in the future, will provide a platform for a more informed tanker procurement process.

The third area of significance is that this research tests the feasibility of the future fleet of 479 KC-135s and KC-46s to maintain the status quo. The result of the research shows senior leaders that the plan could work if the mission requirements remain the same for the next decade.

The Air Force can use this method and research to improve the quality of discussions regarding future tanker requirements and acquisitions. The impacts of new tanker designs on historical mission sets provide a compelling narrative to members of Congress regarding the necessity and cost-effectiveness of the tanker fleet. As an organization, the Air Force should maintain onload and offload fuel records that easily pair tanker missions to their effects. Data such as this can provide a clear justification of requirements for future acquisitions.

Recommendations for Future Research

Three other meaningful datasets deserve the attention of the method in this research. First, the entire KC-135 and KC-10 data available in the source data for this research should be analyzed. Such an analysis could provide a definitive answer on if the future fleet could have met the entire tanker mission accomplishment of the same period. Second, the mission records from tanker deployed locations would reveal the anticipated number of aircraft needed abroad. Third, the Mobility Capabilities and Requirements Study 2016 reported a possible refueling shortfall in two out of three scenarios (Russell, 2012). The application of this method to their data could reveal if the future KC-46 transition mitigates or amplifies the possible shortages.

This research also highlighted the importance of the taskable tails to the DOD air refueling capacity. The number of training missions required, changes in mobilized requirements, and maintenance capability to keep aircraft operationally available all factor into the taskable tails available. Further research that quantifies how these factors influence the number of taskable tails available will give the Air Force data-driven evidence regarding which supporting metrics have the most substantial control on capacity's bottom line.

Finally, just as this method created a way to assess the impact of a smaller sized tanker to an air refueling fleet, another method could be researched that looks at how valuable a larger tanker could be to the DOD. The new method, in the spirit of this research, would look at ways to combine historical missions into single sorties with a larger tanker.

Summary

In Summary, the United States tanker fleet *is* the global reach and power of its air force, and the size and composition of it have been on the decline since the 1990s (MacDonald, 2015). This research applies a new method to quantify the required size of a fleet to meet historical missions. The results highlight the fact that historical missions might not be the best metric for the size and scope of the Air Force's future needs because it does not flex its global reach every day. However, the methods demonstrate that fuel records for missions flown can reveal the workload of the fleet and show how the daily flying schedule might change with the acquisition of a new aircraft.

Appendix A: "Efficiency Days" Possible

The concept of efficiency can fit various perspectives on any subject. One researcher might look at the efficiency of air travel and say that a train uses far less fuel to get from one point to another, while another might say that air travel is the fastest way to get someplace, and it is, therefore, the most efficient use of time. Similarly, the idea of an efficient plan or schedule is up for interpretation and debate as well.

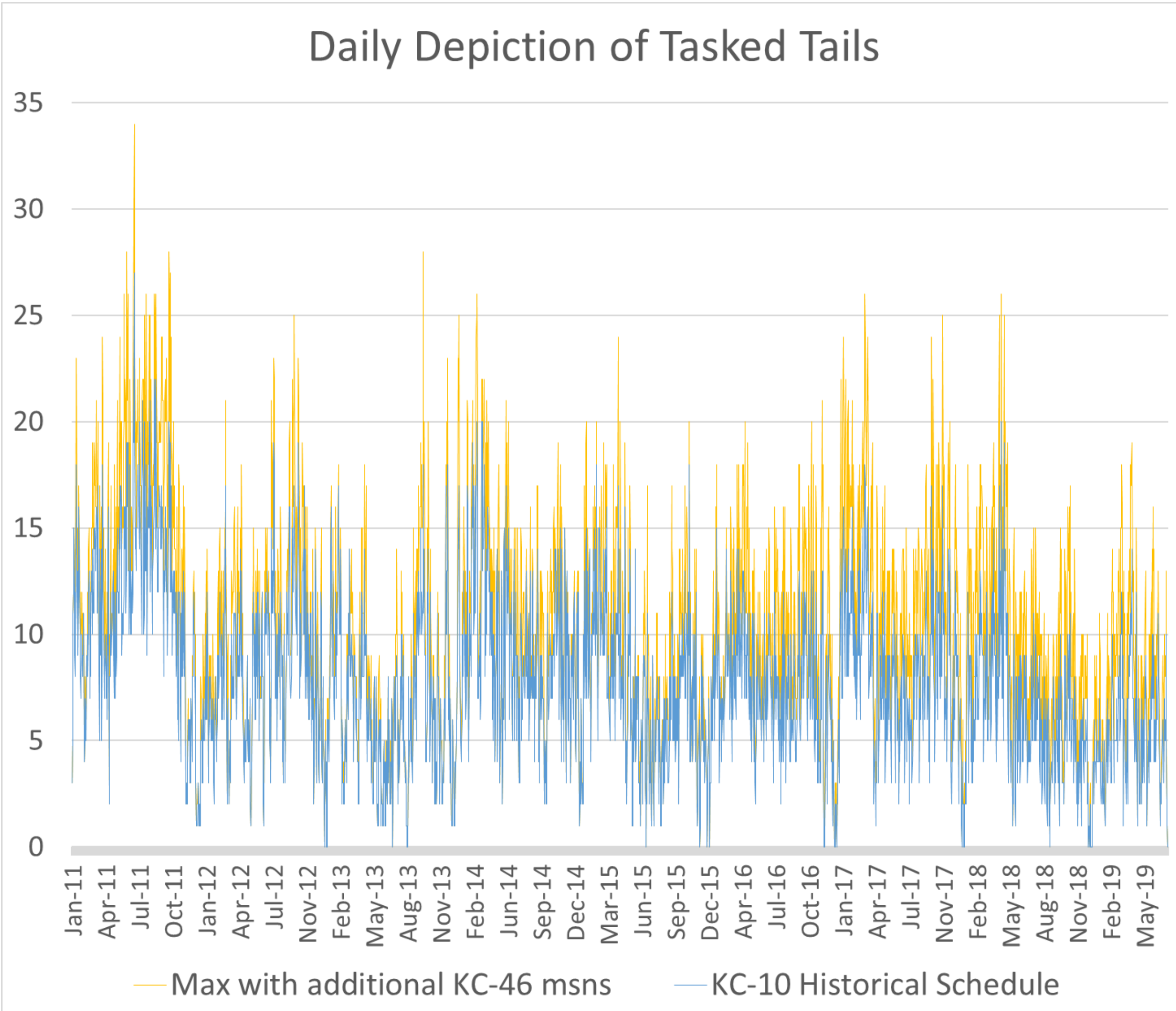
A plan can be efficient if it minimizes costs, time, or resources required, but if the same plan has a probable failure rate of over half, then the former benefits seem less efficient. In this research, there are KC-10 missions where only one leg needed two KC-46 aircraft out of a three or five leg mission. The researcher decided that it might be useful to investigate the "efficiency" of trying to fly a second KC-46 out in the system to join for only the leg that needed the pair.

The second aircraft could accomplish a mid-mission join-up by flying a positioning leg to reach the other group of aircraft, then fly the required leg, and then fly back home. In practice, planners usually include a planned day buffer between the positioning leg and mission leg for all of the aircrews and receivers to meet, brief, mission plan, and rest. Therefore, each join up would cost at least four days and three flights to accomplish. The following algorithm evaluated each mission and determines the possible reduction in the number of mission days if the schedule was planned with mid-mission join-ups instead of flying formation for the whole mission. In English, the equation states: If the mission required and extra KC-46; and either: only one leg out of the set did not need it, or duration of the entire mission minus three days minus the number of legs that required two KC-46 was less than zero, then zero efficiency days were possible by flying a join-up. Otherwise, calculate the reduction possible in the number of days subtracting the number of legs that need two KC-46 and the three days necessary to affect the join up. In Excel with the cell addresses replaced with a brief descriptive label:

=IF(*additionKC46*<>"",IF(OR((*legs*-*additionKC46*)<2,(*daysduration*-3-*additionKC46*)<0) ,0,*daysduration*-3-*additionKC46*),"")

The research calculated and totaled the efficiency days possible for each Monte Carlo run. The average savings possible was only 7.7% of the total mission days, with a standard deviation of 0.29%. The researcher believes it would not be worth the added planning complexity, and delays in the join up missions would likely cause more delays to the mission than savings.

Appendix B: Daily Depiction of Tasked Tails



Bibliography

Air Refueling Aircrew and Aircraft "Balancing" in FY21 (with forecast through FY24). (2020). Scott AFB.

Air Refueling Non-Mobilized Capacity. (2020). Scott AFB.

Anderson, D. (AMC A. (2019). *interview by the author*.

Caflisch, R. E. (1998). Monte Calro and quasi monti calro methods. *Acta Numerica*, pp. 1–49.

Camerer, M. D. (2001). *CIVILIAN CONTRACT AIR REFUELING : INNOVATIVE OR INSANE?* (April), 38.

Dugan-Beatovich, C. (1997). *The Ability of Aerial Tankers to Support Global Engagement The Ability of Aerial Tankers to Support Global Engagement*. Marine Corps University.

Frey, H. C., & Patil, S. R. (2002). Identification and Review of Sensitivity Analysis Methods. *Risk Analysis*, *22*(3), 553–578.

Grismer, M. W. (2011). Fiscally sound options for a flawed tanker recapitalization strategy. *Air and Space Power Journal*, *26*(3), 63–73.

Gunzinger, M., Rehberg, C., Cohn, J., Walton, T. A., & Autenried, L. (2019). An air force for an era of great power competition. *CSBA Center for Strategic and Budgetary Assessments*. Retrieved from https://csbaonline.org/research/publications/an-air-force-for-an-era-of-great-power-competition/publication/1 (accessed 19 July 2019)

Johnson, B. K., Kniep, S., & Conroy, S. F. (2013). The symbiotic relationship between the air force's active and reserve components ensuring the health of the total force. *Air and Space Power Journal*, *27*(1), 107–129.

MacDonald, C. R. (2015). *Next Generation Tanker: Optimizing Air Refueling Capabilities in 2030 with a Divested KC-10 Fleet*. Air University.

Miller, P. (USAF). (2020). *Interview by the Author*.

Robbert, A. A. (2013). *Costs of Flying Units in Air Force Active and Reserve Components*. https://doi.org/10.1214/07-EJS057

Romero, M. M. (2015). *Algebra of Tankers*. AIR FORCE AIR UNIVERSITY.

Russell, C. (2012). *MOBILITY CAPABILITIES: DOD ' s Mobility Study Limitations and Newly Issued Strategic Guidance Raise Questions about Air Mobility Requirements*.

Schatz, D. (HAF/A3). (2020). *Interview by the Author*.

Ulam, N. M. S. (1949). The Monte Carlo Method. *Journal of the American Statistical Association*, *44*(247), 335–341.

Welch, S., & Leroy, D. (2019). THE CASE FOR A THREE-TANKER AIR FORCE. Retrieved May 14, 2020, from https://warontherocks.com/2019/10/the-case-for-a-three-tanker-air-force/

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
15-06-2020	Graduate Research Paper	May 2019 – June 2020

4. TITLE AND SUBTITLE **Effects of KC-10 Divestment on Daily Competition Sortie Requirements**	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Borszich, Aaron A., Maj, USAF	**5d. PROJECT NUMBER**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way Wright-Patterson AFB, OH 45433-7765	**8. PERFORMING ORGANIZATION REPORT NUMBER** AFIT-ENS-MS-20-J-026
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Lt Gen Giovanni K. Tuck, Director for Logistics Joint Staff The Pentagon, Arlington, VA	**10. SPONSOR/MONITOR'S ACRONYM(S)** JCS/J4
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution Statement A. Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This project sought to find new ways of measuring the capacity and capability of the air refueling fleet in ways that can relate the needs of the Air Force to decision-makers that control DOD fiscal programming. Initial research could not find a usable history of refueling missions flown and how much fuel the tanker aircraft offloaded to receiver aircraft. Consequently, the logical start was to find data that could create such a record and demonstrate the utility of the information. The research used ten years of actual missions flown other than combat and a separate data set of fuel usage on over half of those missions to create a record of refueling mission effects. Then the database was analyzed to assess how many additional flights would be required if the original aircraft, the KC-10, was replaced with a smaller but more numerous KC-46. The research found that the historical schedule would have needed about 20% more flights flown by the KC-46 each year, but the claim on the required fleet size required to accomplish the increase was less certain.

15. SUBJECT TERMS

KC-10, KC-46, Air Refueling, Tankers, Military, Capacity, Air Force, USAF, USTRANSCOM

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Dr. Jeffery D. Weir, AFIT
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	UU	53	**19b. TELEPHONE NUMBER** *(include area code)* 937-255-3636 Ext 4523 Jeffery.Weir@afit.edu

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