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# Factors Affecting Unsatisfactory Performance During Air-To-Air Refueling In The C-17 Pilot Checkout Course

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FACTORS AFFECTING UNSATISFACTORY PERFORMANCE DURING AIR-TO-  
AIR REFUELING IN THE C-17 PILOT CHECKOUT COURSE

by

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Bachelor of Science, United States Air Force Academy, 2004

A Thesis

Submitted to the Graduate Faculty

of the

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In partial fulfillment of the requirements

for the degree of

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2015

This thesis, submitted by Richard Smith in partial fulfillment of the requirements for the Degree of Master of Applied Economics from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done, and is hereby approved.

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This thesis is being submitted by the appointed advisory committee as having met all of the requirements of the Graduate School at the University of North Dakota and is hereby approved.

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Date

Title                      Factors Affecting Unsatisfactory Performance During Air-To-Air  
Refueling In The C-17 Pilot Checkout Course

Department              Department of Economics

Degree                    Master of Science in Applied Economics

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Richard Smith  
23 April 2015

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## ABSTRACT

In 2014, the USAF reduced its personnel by approximately 20,000. One of the areas hit hardest by the cuts were the faculty at the USAF C-17 formal training unit, where students are trained to fly the C-17 transport plane. Due to the reduction in forces, faculty staffing dropped by 30% though the number of students remained the same. Air-to-air refueling during the Pilot Checkout Course is the most commonly failed syllabus event. When a student fails to progress on a syllabus event, it requires additional instructor, simulator, and aircraft resources. In an effort to reduce the amount of failures and improve efficiency, the faculty collected data relating to how students prepared for the air refueling required for the course and applied theories on learning to analyze how number of repetitions, time between practices, and demographic factors influenced a student's ability to progress on every flight.

## CHAPTER I

### INTRODUCTION

Due to 2014 budget cuts, the Air Force needed to reduce manning by 20,000 and offered a severance package to allow people to leave the service. This reduction coincided with the airlines starting a hiring boom and caused experienced pilots to leave in droves. The C-17 community took a substantial hit, with a reduction of crew to aircraft ration from 3:1 to 2:1, a reduction in manning by a third (Losey, 2014). Additionally, two active duty squadrons will close and the assigned aircraft will be transferred to the guard and reserves (Davis, 2014). The formal training unit or schoolhouse for all C-17 training is the 58<sup>th</sup> Airlift Squadron (AS) located at Altus Air Force Base. In these cuts, the 58<sup>th</sup> AS lost approximately 30% of its instructors, yet still had to maintain the same level of student output (J. Turk, personal communication, 1 May 2014).

When the 58<sup>th</sup> AS projected a manning shortfall, it started looking at various courses and how to mitigate failures in the courses it taught. Each course ranges from three to seven flights with the last flight being an evaluation. A failed evaluation goes into a pilot's permanent record, potentially affecting future job opportunities in the Air Force as well as in the civilian airline world. Failing a training flight prior to the evaluation does not carry any such consequences. Generally, when a student fails a

training flight, he or she flies a simulator sortie with an instructor and then must re-fly failed events in the aircraft. This requires the 58<sup>th</sup> AS to provide an additional instructor for the simulator as well as generating another training flight in an already full schedule. The course with the highest rate of failures is the Pilot Checkout Course where a pilot goes from being a copilot to the aircraft commander or the captain, and the most commonly failed event is air-to-air refueling. Traditionally, between 12% and 20% of students fail a flight in this course because of air refueling and require an additional flight.

To potentially mitigate these failures, the faculty decided to collect data on how well prepared students were for this course in order to analyze its effect on performance. As students arrived for classes, they received a briefing from a faculty member. We used this as a chance to gauge how prepared students were for their courses. At the end of the briefing, students for the Pilot Checkout Course were asked a series of questions consisting of demographic information and preparation information. The questions included what squadron they were assigned, information about when and how many air refueling sorties they had done in preparation, and a couple of other questions regarding landings and night vision goggle usage. Initially, I thought that previous experience and recent experience would be key factors. I also thought some of the demographic information could influence performance because each base can make its own policy on how to prepare students for the course.

The information gathered from the survey becomes more interesting when paired with another database that tracks student performance. When a student fails a sortie, the student is placed on the Commander's Awareness Program and the reason is documented

in this database. This program is like probation; it gives the student extra attention and extra practice sessions to ensure they pass the formal evaluation. The database contained the same demographic information that the survey did which enabled a link to how well a student prepared with how they performed.

From the link between the two sets of data, I could then build a model to determine the probability that a student would pass every flight in the Pilot Checkout Course based on their practice routine. The more attempts a student had and how recently they were accomplished played a major role in determining success. In this paper, we will examine these factors and how other theories of learning apply similar factors to determine how well a task is learned and retained. Interestingly, some of the demographic information as to where and how the student was trained prior to arrival at the formal training unit appears to be of less importance than when the student practiced.

The conclusions of this research will allow for a more standardized and robust training requirement for students prior to arriving at Altus AFB for the Pilot Checkout Course. Each unit is allowed to decide what is an appropriate amount of training and waive any requirements they have created. The range of student experience can be anywhere from having never attempted air refueling to already being proficient at the task. The goal would be to have students show up closer to the proficient range to minimize the amount of additional flights required at the schoolhouse. This would alleviate the instructors from having to fly additional simulator events and flights when they are already stretched thin from the Air Force's manning cuts.

In 1923, Lts. Lowell Smith and John Richter conducted the first air-to-air refueling in a De Havilland DH-4. The next month, Smith and Richter made a flight

lasting 37 hours, 15 minutes and performed sixteen air refueling events and set endurance, distance, and speed records (National Museum of the USAF, 2014). This demonstration proved that aircraft range could be unlimited with assistance from in-flight refueling, a practice very much alive and well today. Today, the KC-135 and the KC-10 are the tanker aircraft used to refuel nearly every aircraft in the U.S. Air Force and Navy. The unlimited range means fighters can engage the enemy further away and for longer; bombers can launch from the United States, hit a target on the other side of the world, and return stateside in a single flight; and cargo aircraft can deliver personnel, equipment, or supplies anywhere in the world with a moment's notice.

All C-17 formal training occurs at Altus Air Force Base in Altus, Oklahoma. The base is located in southwestern Oklahoma, approximately two and a half hours from Oklahoma City. The location is ideal for training pilots due to relatively quiet airspace, flat and open terrain, and an average 300 days a year of weather favorable for flying (97 AMW, 2014). The 58<sup>th</sup> Airlift Squadron is the formal training unit or schoolhouse for C-17 training. The 54<sup>th</sup> Air Refueling Squadron, the formal training unit for the KC-135 and the primary tanker during most air-to-air refueling, is also located at Altus, AFB. The collocation of the schoolhouses and favorable flight conditions create an environment perfect for training the next generation of mobility aircrew.

The students at the C-17 formal training unit are from twelve bases throughout the United States. Pilots come from both the active duty component as well as the reserve components consisting of the Air National Guard and the Air Force Reserves. The active versus reserve component is an interesting demographic to look at because active duty pilots are generally younger with less experience and are employed full time in the Air

Force. Active duty pilots tend to go to the next upgrade course because they have the requisite number of hours, not necessarily because they are ready. Reserve component pilots are usually older and typically have a civilian job as well. Many of these pilots were previously active duty and have already been through the Pilot Checkout Course and the more advanced instructor school. Because of this, there are fewer reserve component pilots requiring the formal training course and thus they send fewer pilots through classes. Their young pilots usually wait until they can arrange their civilian work schedules to fit in a month of training or when they are more mature.

There are two main bases, McChord AFB, WA and Charleston AFB, SC that consist of four active duty and three reserve squadrons each. These are known as the super bases. The rest of the bases are single squadron bases with at most one active duty and one reserve component squadron. Whether a student comes from a super base or a single squadron base has the potential to affect whether or not a student performs well at an upgrade course. At the super bases pilots are typically away from home anywhere from 200-300 days a year flying long haul cargo missions. These missions range from three days to three weeks in duration and are mostly cruising at 35,000 feet with a minimal workload. As a result these pilots do not get to practice the more difficult training events such as air refueling and are rarely current, let alone considered proficient.

Two bases have the KC-10 aircraft collocated and could have access to more air refueling opportunities. This is of particular interest because at the formal training unit, students only refuel with the KC-135, a much smaller aircraft with different position references. Typically, the KC-10 is easier to refuel with because of its larger size and larger operating envelope. Having the KC-10 readily available at these bases may benefit

a student because they learn the techniques for air refueling; however, it could also be a hindrance because the references for maintaining position and relative size are very different between the KC-10 and the KC-135.

The skill and experience level within all C-17 squadrons ranges from newly graduated initial qualification to highly experienced instructors. As crew positions relate to an airline, a first pilot or copilot is a first officer and aircraft commander is an airline captain. The 58<sup>th</sup> AS is unique in that it is made up entirely of instructor pilots. Instructor pilot is a higher qualification than aircraft commander and performs the teaching necessary to take a pilot to the next qualification level. The transition from first pilot to aircraft commander requires a month long course, the Pilot Checkout Course, where the student will focus on leadership, decision making, and flying skills required to execute the C-17 mission set. Up until this point, a copilot had been supervised by other pilots performing these tasks and practiced these higher level skills only occasionally. One of the harder tasks to master is known as air-to-air refueling or air refueling.

To put C-17 air refueling in perspective, there are two large passenger jets flying at roughly 400 miles per hour close enough to each other that they touch and send fuel from one to another at 6800 pounds per minute and keeping the receiver within a small envelope as depicted in

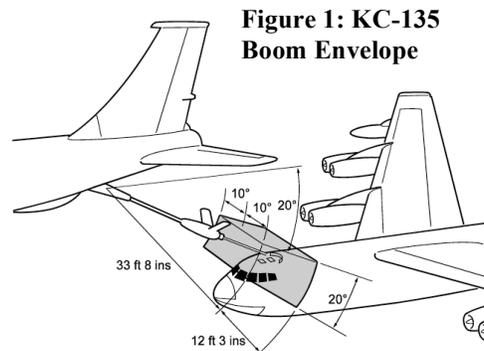


Figure 1 (NATO, 2010). Difficulty arises because the C-17 is very large and has a profound impact on how the tanker flies. Once inside a fifty-foot bubble, every time the C-17 moves, it also makes the KC-135 move. So now, a pilot is trying to also hit a

moving target that is moving because they are moving. Fighter aircraft are smaller and not susceptible to the same effects. In fact the KC-135 can move them as needed once they have made contact, thus not having the same issues as a C-17 encounters. A former F-15E pilot turned C-17 pilot, explained that during air refueling he used to eat lunch, but now he has to work (W. King, personal communication 25 Feb 2015). Immediately upon graduating the course, a pilot may be asked to on load 100,000 pounds of fuel, or roughly 15 minutes of contact time, during less than ideal conditions, an extremely arduous task.

In Congressional Budget Office Testimony, Christopher Jehn states, “military pilot training is expensive” and estimates that in 1999 the cost to produce a military pilot is already over \$1 million (Jehn, 1999). This number is only to get a pilot through initial pilot training and does not include any aircraft specific qualification courses or seasoning. According to Air Force Instruction 11-2C-17 V1, to qualify to attend the Pilot Checkout Course, a C-17 pilot requires 1000 total hours and at least 400 as the primary operator in the C-17 (USAF, 2012). The cost per hour to fly the C-17 is \$23,811 (Thompson, 2013). Since the Global War on Terror, the bulk of this required seasoning time came from actual cargo missions; however, with the war winding down, more of these hours will come in the form of training missions (Rovello, 2014). More training time rather than long-haul cruise time should prepare a pilot for an upgrade better, but it will take a longer period of time because of the shorter duration of training missions.

In addition to the hour requirement, each base is allowed to decide what training must be accomplished prior to attending the formal training course. For example, the 62<sup>nd</sup> Operations Group out of McChord AFB, WA requires its pilots to accomplish one simulator and one night air refueling flight (62 OG, 2014). The 437<sup>th</sup> Operations Group

from Charleston AFB, SC requires a simulator, one day flight, one night flight, and a third flight of either day or night (437 OG, 2014). The flights can be easily waived for reasons such as not able to accomplish prior to class start date, no air refueling available within a reasonable time frame, or the tanker was unable to fly. Since there is not a C-17-wide standard requirement and the events are easily waived, it is possible to attend the course without ever having attempted an aerial refueling.

During the training course, a large portion of each flight is dedicated to air-to-air refueling. The time spent getting to and from the air refueling track plus the time practicing refueling consumes about three out of the six hours available on each of the five sorties in the Pilot Checkout Course. It takes about thirty minutes to meet the tanker; each of the two students flying together gets about an hour to practice air refueling, and then thirty minutes back before practicing landings. The Pilot Checkout Course consists of six total flights: two day air refueling flights, two night air refueling flights, a night vision goggle flight, and a day checkride (AETC, 2013). The checkride is the formal evaluation that remains in the pilot's record. Of the daily flights, the first day and the first night flights are practice, but on the second of each the student must demonstrate the ability to perform the required maneuvers such as air refueling. Proficiency is defined in the Pilot Checkout Course syllabus as approximately 5 minutes of contact where they would be receiving fuel on two separate attempts, one with the tanker's autopilot on and one with it off (AETC, 2013). The daily flights are much lower threat than the checkride and have less severe consequences for failing. Normally, a student failing to progress will receive an additional two hour simulator flight and have to repeat the aircraft flight for the events performed unsatisfactorily, both with the most experienced instructors at

the schoolhouse. In addition to the extra strain on the instructors, flying a sortie again can cost \$71, 433 to \$119, 055 depending on the length of sortie required, based on the \$23, 811 per hour (Thompson, 2013).

Because of the costs associated with training pilots, especially military pilots, much research has gone in to determining the most efficient, yet effective, methods to select, train, and season pilots. Rheinhardt (1998) examined two US Naval Academy classes' academics and demographics to determine which cadets would ultimately succeed at pilot training. Including demographic data about where a student came from may allow us to predict their success in the Pilot Checkout Course.

The idea for this research is similar to Erik Goff's thesis on the process of initial pilot training and the effect of having too many instructors has on a pilot training student's performance. Goff (2013) also determined the probability of a student passing, but he focused on the evaluation at the end of the course rather than in my research looking at passing each of the daily flights in addition to the evaluation. In initial pilot training, there are more daily flights and checkrides than there are in any formal training upgrade courses. This paper looks at pilots after they have been certified as pilots and have flown a particular plane for a couple of years and teaching them a new task. Because of the shorter duration of the course this paper focuses on, the need for preparation is imperative. The biggest difference between Goff's (2013) and my research is that he examines factors that influence training while a student is at training, but I look at how a student prepares prior to the course and how that influences the student's performance at the course.

To fully understand and model this behavior of preparing for pilot checkout, I applied theories on how humans learn a task and retain the ability to do the task after long periods of time. Another aviation related study by Wilson (1973) of the US Navy looked at experienced and inexperienced pilots performing aircraft carrier landings after an extended period of not flying and found that experienced pilots tended to retain or regain the skillset faster than the inexperienced despite longer breaks. Carrier landings can be equated to air refueling in that they are both highly complex and require intensive practice. This led me to include a time factor in the model because the pilots we are examining here are similar to Wilson's inexperienced pilots and will be affected by a longer break more drastically than the experienced pilot would.

More practice attempts should provide better learning, but not if all of the practice comes at one time. As Baddeley and Longman (1978) point out, spreading out training sessions or distributing them over time yields better results than massing, or cramming all of the training into a short block. If we looked only at the number of times a student had practiced closing to make contact with the tanker it could show different results. For example, if a student makes one flight, but makes ten contact attempts, the retention of the skill would probably suffer over another student who makes the same ten attempts but over three or four flights. The former is similar to the study that showed a day between training sessions produced better retention than a twenty minute break between training sessions (Shea, Lai, Black and Park, 2000). Savion-Lemieux and Penhune also varied the length of time between sessions and found that distributed practice allowed for maximum benefit by allowing for consolidation of learning (2004). By looking at the number of air refueling flights and the number of contacts made on those flights we can

get an idea of how dense the training sessions were and if the student had time to absorb the knowledge.

Most of the research on practice and learning, however, involves a simple task such as typing. Moulton, et al, (2006) conducted study that made the link to more complex tasks when it applied the same massed and distributed practice lessons to surgical students and measured retention among the different groups. This helps us to make the leap to a task such as air refueling because surgical procedures and air refueling both require small, precise movements and a high degree of hand eye coordination. Using both air refueling flights and contact information allows us to apply the lessons from these previous studies, but one aspect not addressed is the effect of mental repetitions. The classes in Pilot Checkout Course consist of two pilots. When one pilot is physically flying, the other can be mentally performing the maneuver, thus getting extra practice. Lee, Swanson, and Hall (1991) indicate that performance will increase for somebody who watches another competent person attempt a task. This creates an interesting point that was not collected or measured in this paper, how many air refueling attempts the student had observed prior to the class. Those few students that reported never having attempted an air refueling might have witnessed enough other pilots perform that by their second flight in the course, they had figured it out.

## CHAPTER II

### THE DATA

As previously mentioned, the data for this research came from an entrance survey as students started the course as well as a performance database. This survey spanned about eighteen months, but the data presented for the purpose of this paper is the entirety of fiscal year 2014. This should smooth any variation due to an abnormal amount of failures or lack thereof in any given snapshot. The survey data yielded 195 observations. The next and most important portion of data came from a database on student performance. While each daily flight is not a formal evaluation, it gives the instructors an opportunity to evaluate how well a student is learning and performing.

The dependent variable we used is whether or not a student failed any of the sorties throughout the course. As noted with the studies about massed versus distributed learning, I included the number of air refueling sorties as a key variable of interest. When a student only has one or two flights prior to the course, the first two flights in the course represent a massed practice schedule. As the students had more flights and over a longer period of time prior to the class start date, this represents a distributed practice schedule and the first couple of flights at the course are similar to a later, fine-tuning practice session.

I also looked at the difference between when a student last attempted air refueling and when their class started. The regulation governing recurring flying training requirements states that an aircraft commander requires an aerial refueling event every forty-five days, but as the pilot gains experience the requirement eases to every sixty days (USAF, 2012). This serves as a refresher for somebody who already possesses the skill; however, a student learning the skill would require shorter times between events. Once in the Pilot Checkout Course, the student accomplishes an air refueling event about every other day, allowing for that mental absorption of the task.

Upon tabulating the failure results, the overall unsatisfactory rate of 17.95% is within the traditional rate of 15%-20% as seen in Table 1. A couple of interesting

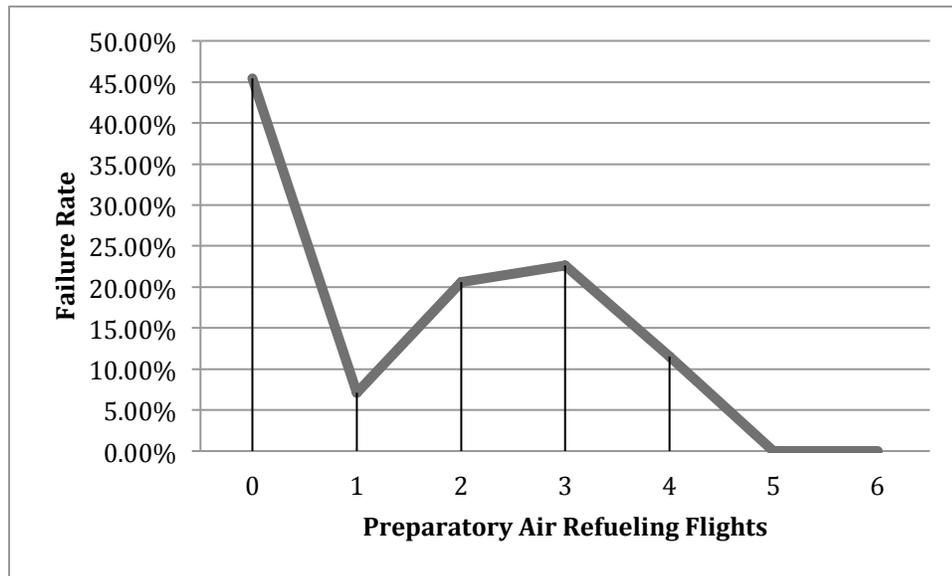
**Table 1: Failure Rates based on Air Refueling Sorties**

Air Refueling Sorties	Pass	Fail	Total	Fail Rate
0	6	5	11	45.45%
1	26	2	28	7.14%
2	50	13	63	20.63%
3	41	12	53	22.64%
4	23	3	26	11.54%
5	12	0	12	0.00%
6	2	0	2	0.00%
Total	160	35	195	17.95%

observations can be made about the data, however. The first is that after five practice flights, there was a perfect passing rate. At four sorties, the rate was outside the traditional rates. The next is that with only one flight, students tend to have a better degree of success than those with up to four flights. Figure 2 shows the non-linear relationship between failure rates and the number of preparation sorties. The group that had only one air refueling sortie prior to class actually tended to perform better

than those students with up to four attempts. While this seems to go against the theory that more practice sorties will produce better results, one explanation to this relationship may be how recently those students performed an air refueling prior to starting class. Twenty of the twenty-eight students that fall in this category had performed an air refueling within three weeks, while twenty-five had attempted with the past forty-five days. We included a nonlinear variable of air refueling sorties squared to account for this relationship.

**Figure 2: Failure Rates and Air Refueling Sorties**



Initially, the plan was to figure out which base or squadron had the highest failure rate. As shown in Table 2, the failure rates among active duty squadrons tend to be close. The average number of failures is just over 2, with all but one squadron falling within one failure of the average. Next, I wanted to look at whether or not the reserve components had a significantly different failure rate than active duty. The thought was that guard and reserve units tend to have fewer school slots and also have fewer pilots needing to go than active duty. One of two possibilities exists for these students: they can receive a lot

of extra training and not go to the course until they are ready, or they can have a civilian job and not focus on preparing for the course. Table 3 shows the failure rates based on active duty and reserve status. The reserve rate is not significantly lower than the active rate. One additional failure would have increased the reserve rate to approximately the same as the sample mean.

**Table 2: Failure Rates by Active Duty Squadron**

Squadron	Pass	Fail	Total	Fail Rate
10 AS	12	3	15	20.00%
14 AS	13	1	14	7.14%
15 AS	12	2	14	14.29%
16 AS	9	4	13	30.77%
17 AS	9	2	11	18.18%
21 AS	11	1	12	8.33%
3 AS	7	3	10	30.00%
4 AS	12	2	14	14.29%
6 AS	10	3	13	23.08%
7 AS	7	3	10	30.00%
8 AS	13	1	14	7.14%

**Table 3: Failure Rates by Active and Reserve Components**

Status	Pass	Fail	Total	Fail Rate
Active Duty	130	30	160	18.75%
Reserve/Guard	29	6	35	17.14%

#### Assumptions

As with any survey, the data derived from this survey is susceptible to error. The most probable error is how accurately a student remembers when an event was accomplished or how many had been accomplished. Some students had a calendar with the information readily available while others knew approximate dates or timeframes. The instructor administering the survey explained that it was purely for trend analysis and

that no punishment or retribution would result from the information. A key assumption of this data is that what they provided was correct and honest. Since the survey was anonymous, there is no incentive for a student to lie about how much training he or she received prior to showing for class. Therefore, there is not a systemic error inherent with the survey. Additionally, indicator variables were used to group students based on how long it had been since their previous air-refueling sortie to account for possible reporting errors. Within the groups, the exact date of the previous air refueling attempt becomes less important because of these groups of a range of days.

Another assumption is that grading standards were applied equally to each student and from each instructor. There is some subjectivity in grading student air refueling performance. For example, one instructor may be very strict on the time requirements while another may recognize when a student has demonstrated a capability that he or she could continue the event through the required time. If there is some unforeseen circumstance such as bad weather or a maintenance problem, the instructor can deem the student was not given the full amount of time and thus grade that event as incomplete. This subjective interpretation can lead to another possible scenario called a “tactical incomplete”. When the student is struggling, but is right at the tipping point of learning the task, the instructor may find a reason to grade the flight as incomplete rather than say the student was unsatisfactory. Some instructors might feel bad about telling somebody they performed in an unsatisfactory manner or are worried that the student may not bounce back and perform better after the bad news. Other instructors see a benefit in giving a reality check and getting the student extra attention before the evaluation. Each case is different and at the time must be treated as such; it would be impossible to review

every flight for every student and determine if the exact same standard applied. If we had collected instructor data for every flight for every student, we could control for an instructor level fixed effect. However, for the purpose of this paper, we will assume that any pass meets the standards and any failure did not.

Another assumption is that the formal training unit instructor force remains relatively constant throughout the year. In a given year, about a quarter of the squadron moves and new instructors are brought in. This remains constant from year to year, but most of the turnover occurs in the spring to summer timeframe. A new instructor takes about two months to be able to fly with students, so there is a time where they are learning from the other instructors. Fiscal year 2014 was a different scenario because of the manning cuts previously mentioned. An addition quarter of the instructors would leave without replacements right away. Luckily, this happened at the end of the fiscal year, also when the data ends. There was some overlap where the departing instructors were busy with moving and not flying and the classes that started in late FY14 did not finish until FY15. During this time, the remaining instructors had to fill in, but most had been there over a year by this point, so there was not much variation in instruction.

### The Variables

The variables collected through the survey and the database and what they measure are as follows. The dependent variable is whether or not a student failed a flight. In the case of the data, it is a binary variable, however, in the model it is represented as a probability of failing a flight. Air refueling sorties is the number of refueling sorties flown as part of the pilot checkout course preparation. From the number

of air refueling sorties, we added the sorties squared variable to account for the nonlinearity as previously discussed. Day contacts and night contacts measure how many refueling attempts had been made on the air refueling sorties during the day and night, respectively. It is possible to have multiple contacts on a single flight, and this combined with the air refueling sorties will give us a glimpse into the distribution of the practice attempts.

From squadron information, we can get a reserve component variable which is binary and indicates a 1 if the student was guard or reserves and a 0 if the student was active duty. A single squadron base variable takes on a 1 for a single squadron and 0 for a super base. Also another binary variable for KC-10 training can be found from the squadron information as well. This variable takes on a value of 1 if the students were from Travis AFB, CA or McGuire AFB, NJ, both of which have KC-10s collocated with C-17s and do a majority of their air refueling training with this aircraft rather than the KC-135. I thought learning to refuel with another aircraft could cause problems at Pilot Checkout, while other instructors thought it may help because the students have had more practice and understand the fundamentals of air refueling.

The final variable is the difference between the last air refueling sortie and the class start date. There is a slight problem with this variable, however. There are eight observations that have no date of previous accomplishment. Of the eight students with no attempted refueling, four failed a flight. When using only the difference in days, the model results were not accurate because we failed to capture that group which has an extremely high failure rate. If we made it a 0, it would negate any impact the difference from the other 187 observations had on the model. We could have made those

observations very large to emphasize the difference. Rather than this method I created five indicator dummy variables to break the difference variable into groups.

The five binary dummy variables are loosely based on the AFI 11-2C-17V1 currency requirement of forty-five days between air refueling practice (USAF, 2012). The dummy variables take on a 1 if the days since the previous air refueling attempt falls within the range for that group and a 0 if it falls outside that group's range. The ranges are one to twenty days, twenty-one to forty five days, forty-six to ninety days, greater than ninety days, and no reported difference because air refueling had not been attempted. Using these indicator dummy variables for the level of how recent an air refueling attempt had been allows us to include the not attempted group in the model as well as model the nonlinear relationship between time and failing a flight.

## CHAPTER III

### METHOD AND RESULTS

The initial investigation of the data and the problem presented in the 58<sup>th</sup> AS stopped at the surface examination of failure rates and correlation between the number of attempts and time since the last attempt with failures. The failure rates by squadron and the general trend data has been passed to the leadership on the individual squadrons. What was sent was basically the same as the anecdotal evidence that most of the instructors already knew. If a student has practiced, and practiced recently, he or she will perform better. The question of “how much better” still remains. This section looks at the model that gives insight into how much better varying degrees of preparation will influence a student’s ability to successfully pass every flight.

In the model, the dependent variable of whether or not a student fails is binary and is, therefore, not suitable for an OLS model. Instead, we will use a probit model allowing us to calculate a probability of failure based on the remaining preparation variables and demographic information. The regression equation for the probability of failure given is:

$$\Pr(\text{failure} = 1 \mid 21\text{-}45 \text{ days, } 46\text{-}90 \text{ days, } >90 \text{ days, no previous attempts, sorties, sorties}^2, \text{ day contacts, night contacts, reserve component, KC-10 trained}) = \phi(\beta_1 + \beta_2(21\text{-}45 \text{ days}) + \beta_3(46\text{-}90 \text{ days}) + \beta_4(>90 \text{ days}) + \beta_5 \text{ no previous attempts} + \beta_6 \text{ sorties} + \beta_7 \text{ sorties}^2 + \beta_8 \text{ day contacts} + \beta_9 \text{ night contacts} + \beta_{10} \text{ reserve component} + \beta_{11} \text{ KC-10 trained})$$

The results of this regression are seen in Table 4. In the model the baseline for the dummy indicator variables representing time is the group that had a previous attempted refueling up to twenty days prior to the class start date. The coefficient for the 21 to 45 day indicator is found not to be statistically significant, which indicates there is

no difference in performance between students who had practiced air refueling within 45 days of arriving to the Pilot Checkout Course. Students practicing between 46 and 90 days prior to starting training were shown to perform worse than the baseline group, with the result significant at the 5% level. The failure rate of these students increased by 65 percentage points over the baseline. Similarly, students performed worse if their previous practice was more than 90 days prior to class. The failure rate for these students was 61 percentage points more than the baseline, with the result significant at the 10% level. The poorest performing group, those who had never previously attempted air refueling, performed 75 percentage points worse than the baseline, with the result significant at the 1% level.

**Table 4: Probit Model Regression for Probability of Failure**

	Coef.	SE	Z	Marginal Effect
21 to 45 days	-0.512	0.396	-1.29	-0.093
46 to 90 days	1.911**	0.781	2.45	0.654
>90 days	1.768*	0.910	1.94	0.612
no previous attempts	2.328***	0.756	3.08	0.756
Air Refueling Sorties	1.456***	0.532	2.73	0.326
Sorties Squared	-0.273***	0.101	-2.7	-0.061
Day Contacts	0.028	0.051	0.55	0.006
Night Contacts	-0.148	0.098	-1.52	-0.033
Reserve Component	0.025	0.332	0.08	0.006
KC-10 Trained	-0.022	0.344	-0.06	-0.005
Constant	-2.500	0.688	-3.63	
Observations	195			
Pseudo R2	0.131			

\*\*\* p < 0.01, \*\*p < 0.05, \* p < 0.1

The number of air refueling sorties and the sorties squared are also significant at the 1% level. However, the marginal effects of these two variables are interesting. At

first glance, an additional sortie causes an increased probability of failure by 32 percentage points, but the sortie-squared variable produces a reduction in the probability of failure by 6%. As a student accomplishes more sorties prior to attending the course, his or her probability of failure actually increases. When the number of sorties squared becomes large enough the combine effect of the two sortie variables then decreases the probability of failure. This occurs at four or more sorties. This is similar to the performance data from Figure 1 where students with only one sortie performed well, but then the failure rates climbed until four sorties and dropped significantly after that. The nonlinear sorties squared term models this.

The remaining variables: the number of day and night contacts prior on the air refueling sorties and the demographic information of reserve component and KC-10 trained were all found to not be significant at even the 10% level. When the variable measuring single squadron bases was included in the model, it was statistically insignificant and provided a change of less than one quarter of one percent in the probability of failing, and was dropped. These variables that are still in the model provide some interesting details about some preconceived notions, however.

We gathered the squadron data so that we could look at the difference in performance from a guard or reserve pilot would have compared to an active duty pilot. The model confirms what the initial analysis showed, but against what I originally thought. Reserve component pilots do not have a substantial advantage over active duty pilots and perform the same throughout the course. Perhaps the most intriguing finding about the demographics was that a student who learned to refuel primarily with a different aircraft, the KC-10, was insignificant and when the marginal effect is examined,

it shows a .5% decrease in the probability of failure. Also squadron level data was analyzed to see if being from a particular squadron was an advantage or disadvantage to include a local policy bias, but no squadron was significant and most were dropped for predicting the model too perfectly.

A few considerations about the model are what it cannot predict or does not incorporate. Altus Air Force Base is a training base for the KC-135 pilots and the boom operators as well. So we have a pilot learning how to fly behind the tanker, which is being piloted by a student learning to fly that aircraft while a student boom operator tries to fly the boom to the fuel receptacle on the C-17, complicating matters. Bad weather, such as turbulence or thunderstorms, can also make air refueling extremely difficult. The last, but most common and important issue pilots face is the possibility of a slump. It may be hard to believe, but just like in sports or any other dynamic environment, pilots can temporarily perform poorly. Even the best pilots have bad days and may fail to maintain the proper position during air refueling.

## CHAPTER IV

### SUMMARY

This research focused on the factors that influence success and failure for learning and performing air-to-air refueling for a C-17 pilot. Specifically, the purpose was to determine how a student's preparation for the Pilot Checkout Course affected his or her overall performance throughout the course. Minimizing the amount of failures can save over \$100,000 per prevented failure and given the current fiscal constraints the United States is facing, this is a good thing.

First we examined the data to find general trends. The most obvious was that if a student flew four or more air refueling attempts, he or she would have an increased probability of passing every flight. Going further and building the model, we confirmed that four flights was the tipping point as well, but the most important factor was how recently a student had flown an air refueling flight prior to starting the class, more specifically within forty-five days of starting class.

We also saw that some possible factors were not significant, such as active versus guard, single squadron bases versus super bases, and KC-135 versus KC-10 training. Some of these factors could spur future research options as the guard and reserves absorb the active duty's excess pilots. Almost all of the formal training unit instructors that left

active duty, and drove this discussion in the first place, found a job in the guard or reserves increasing the knowledge pool even further at these units. The active duty squadrons will continue to be manned with younger instructors, with a rare previous schoolhouse instructor in the mix.

As the wars draw down, the C-17 will be in less demand for hauling cargo, but pilots still require a certain amount of seasoning before they upgrade. It will be interesting to see how the reduction in hours affects upgrade timelines as well as the quality of the students. Logging seasoning time while crossing the ocean can build hours quickly, but the quality of those hours suffers compared to a pilot who earns a majority of the hours flying frequent local proficiency sorties with plenty of air refueling practice. The fail rate could drop to nearly zero. Obviously, there will still be blunders, but not at a rate of almost a fifth of the students failing.

Ideally, preparation would consist of four or more flights with at least one of those within forty-five of the class start date; this would create a very well prepared student that should already be able to refuel and the event would be fresh in his or her mind. A more cost and time efficient idea would be to require every student to complete only one sortie and it must be within forty-five days prior to class. The model shows these would be the two optimized inputs to reduce the probability of failing. Since each flight costs around \$100,000, the bases may argue \$400,000 to prepare a student for a course is too much and to just let them fail a flight; students rarely fail twice, so it's a \$300,000 savings. Some bases already require three flights; adding one more flight will cost the same dollar amount, but they can prepare multiple pilots as well as maintain proficiency for the other pilots in the units. Every unit has a flying hours program that

should be used for proficiency and training new and upgrading pilots. Any hours unused can be turned back in; the fewer flights the 58<sup>th</sup> AS has to do over, the more it can turn back to allow the other units more training time.

Additionally, when a student fails a ride in the Pilot Checkout Course, it puts extra strain on the formal training unit personnel, aircraft, and simulators and it delays his or her timeline to get home. When the student does not return on time, another pilot at home picks up the workload and may miss an air refueling opportunity just prior to that pilot starting Pilot Checkout and, therefore, decreasing probability of passing every flight at the course. In this way, each student can severely impact the future students.

Most units do not have the luxury that schoolhouse does of having their tankers parked next to them with similar requirements and funding, so the bases may have a hard time finding the resources to refuel against. One solution that has been attempted in the past is to send a student to Altus a week early and fly with the 58<sup>th</sup> AS instructors on their proficiency sorties. These sorties are to allow the instructors to practice flying events they don't normally get to fly when they are instructing. Adding an extra pilot on these flights does not have a large impact on the instructors' training, but allows the student a couple of additional attempts at air refueling, and very close in time to the class start date. If that program started again, it could make for interesting comparisons to students who had not shown up early.

Another potential solution is to add two optional flights to the Pilot Checkout Course syllabus that could be used if required. Theoretically, only about 20% of the students would need the extra flights. Since the 58<sup>th</sup> AS is already flying an additional flight about 20% of the time, it should not cost anything more. The reality is that those

instructors who feel bad or tactically grade a student incomplete would potentially not hesitate to give the student another flight. Also, the bases might stop any preparation at all, resulting in more of a drain on the formal training unit because more students need the additional optional flights. This plan could also produce even more interesting numbers to analyze as a policy maker.

In conclusion, the model derived for how a Pilot Checkout student will perform confirmed what we already knew from previous years of experience. The theories on learning provided the insight to build a model that gave proper credit to how practice should be performed to learn the most the quickest. If a student practices more and spaced out for maximum consolidation to include a recent practice session, he or she will perform better.

## REFERENCES

- 437 Operations Group, *PIQ Level 4 (PrePCO-PCO)*, <https://c17ts.com>. (accessed on 30 Mar 15).
- 62 Operations Group, *Pilot Development Guide Level 3 (FPQ-FPL)*, <https://c17ts.com>. (accessed on 30 Mar 15).
- 97<sup>th</sup> Air Mobility Wing, *Altus Air Force Base Factsheet*, <http://www.altus.af.mil/library/factsheets/factsheet.asp?id=17484>, Current as of May 2014 (accessed on 30 Mar 15).
- Air Education and Training Command (2013), *Pilot Check Out (PCO) Syllabus*, Randolph AFB, TX, AETC, Apr 2013.
- Badelley, A. D. and Longman, D.J.A. (1978), *The Influence of Length and Frequency of Training Session on the Rate of Learning to Type*, *Ergonomics*, 21, 627-635.
- Davis, K (2014), *Two C-17 Squadrons to Shut Down*, *Air Force Times*, retrieved from <http://www.airforcetimes.com/story/military/2014/12/22/c17-air-force-inactivate-charleston-mcchord/20766241/> (accessed 30 Mar 15).
- Goff, Erik M. (2013) *Effects of Instructor Continuity on a Large-Scale Pilot Training Program*, Retrieved from [https://online.und.edu/webapps/portal/frameset.jsp?tab\\_tab\\_group\\_id=\\_3\\_1&url=%2Fwebapps%2Fblackboard%2Fexecute%2Flauncher%3Ftype%3DCourse%26id%3D\\_12380\\_1%26url%3D](https://online.und.edu/webapps/portal/frameset.jsp?tab_tab_group_id=_3_1&url=%2Fwebapps%2Fblackboard%2Fexecute%2Flauncher%3Ftype%3DCourse%26id%3D_12380_1%26url%3D). (accessed on 9 Jul 14).
- Jehn, C (1999), *Congressional Budget Office Testimony, Pilot Retention: Issues and Possible Solutions*, Statement before the Subcommittee on Military Personnel, Committee on Armed Service, US House of Representatives.
- Lee, T., Swanson, L., Hall, A. (1991), *What is Repeated in a Repetition? Effects of Practice Conditions on Motor Skill Acquisition*, *Physical Therapy*, 71, 150-156.
- Losey, S. (2014), *A Leaner Force: Key Changes Emerge After Tough Year of Airmen Cuts*, *Air Force Times*, retrieved from <http://www.airforcetimes.com/story/military/careers/2014/11/17/air-force-cuts-rank-afsc/19161847/>, (accessed 30 Mar 15).

- Moulton, C.E., Dubrowski, A., MacRae, H., Graham, B., Grober, E., Reznick, R. (2006), *Teaching Surgical Skills: What Kind of Practice Makes Perfect?*, *Annals of Surgery*, 244, 400-409.
- National Museum of the Air Force, *First Air-to-Air Refueling Fat Sheet*, <http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=745>, Current as of Oct 2014 (accessed on 30 Mar 15).
- North Atlantic Treaty Organization (2010), *Air-to-Air Refueling*, ATP-56(B), NATO, 22 Jan 2010.
- Reinhart, P.M. (1998), *Determinants of Flight Training Performance: Naval Academy Classes of 1995 and 1996*, Naval Postgraduate School, Monterey, CA.
- Rovello, F. (2014), *Estimating C-17 Aircrew Seasoning Given a Prediction of Flying Austerity*, Air Force Institute of Technology
- Savion-Lemieux, T. and Penhune, V. (2004), *The Effects of Practice and Delay on Motor Skills Learning and Retention*, Department of Psychology, Laboratory for Motor Learning, Cognitive Learning, and Neural Plasticity, Concordia University, Springer-Verlag.
- Shea, C.H., Lai, Q., Black, C., and Park J.H. (2000), *Spacing Practice Sessions Across Days Benefits the Learning of Motor Skills*, *Human Movement Science*, 19, 737-760.
- Thompson, M. (2013), *Costly Flight Hours*, *Time Magazine*, retrieved from <http://nation.time.com/2013/04/02/costly-flight-hours/>. (accessed 30 Mar 2015).
- United States Air Force (2012) *C-17 Aircrew Training*. AFI 11-2C-17 Volume 1, Scott AFB, IL, Air Mobility Command.
- Wilson, Wayne B. (1973), *The Effect of Prolonged Non-flying Periods on Pilot Skill in Performance of a Simulated Carrier Landing Task*, Naval Postgraduate School, Monterey, California.