CIRCADIAN RHYTHM DISRUPTION: A COMPARATIVE ANALYSIS OF ENUMERATION FOR THE MOBILITY AIR FORCE

GRADUATE RESEARCH PAPER

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Abstract

Mobility Air Forces (MAF) operate in a 365/24/7 environment of shifting requirements, time zones, and levels of exertion, which can all have negative impacts on the safe execution of mission requirements. The short-notice, variability, and critical nature of airlift and tanker missions translate into circadian rhythm disruption (CRD) being a constant risk factor for MAF operations. The most serious consequences of a CRD when related to aviation, stem from impaired reaction times, lowered attention spans, diminished memory, and personal mannerisms of seclusion, all of which have been shown to increase pilot errors, incidents, and elevated aviation risk (Brown and Antuñano, 2009). This research analyzed the circadian rhythm disruptions for Active and Air Reserve Component (Reserve and Guard) aircrews across four major weapon systems (MWS) via a comparative analysis of enumeration based on over 43,000 operational sorties, across varied mission classifications. The resulting research is the first-ever empirically-based analysis of the MAF for the fleet-wide CRD, for a given year.

Senior Leaders and decision makers could be unknowingly increasing the risk to aircrews by operating them in an environment that may not adequately account for the reduced performance and alertness impacts of a CRD. Through this research, decision makers could be able to make judgments of current operating procedures and recognize the amount of MAF crews impacted by a CRD, through the assumed risk levels to the MAF.

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CIRCADIAN RHYTHM DISRUPTION: A COMPARATIVE ANALYSIS OF ENUMERATION FOR THE MOBILITY AIR FORCE

I. Introduction

Mobility Air Forces (MAF) operate in a 365/24/7 environment of shifting requirements, time zones, and levels of exertion, which can all have negative impacts on the safe execution of mission requirements. Due to the critical nature of the airlift and tanker missions, short-notice taskings are an inherent part of the risk associated with MAF operations. These combinations of factors make operating within the body's natural circadian rhythm (CR) challenging. The Federal Aviation Administration (FAA) has noted that poor management of CR leads to what this paper calls a circadian rhythm disruption (CRD), terminology used to clarify that aircrew are operating inside the window normally used for sleep, which has been linked directly to fatigue and a myriad of negative consequences associated with fatigue (Federal Aviation Administration, 2010).

In the aviation industry, a common type of a CRD is jet-lag, which stems from crossing multiple time-zones and the body's neurological fight between its inertial body clock and environmental stimuli. The most serious consequences of a CRD when related to aviation, stem from increases in reaction time, lowered attention spans, diminished memory, and personal mannerisms of seclusion, all of which have been shown to increase pilot errors, incidents, and elevated aviation risk (Brown and Antuñano, 2009).

Research has previously been conducted regarding sleep deprivation, circadian challenges, long-haul, short-haul, and fatigue that pilots grapple with during flight (Blatter and Cajochen, 2007; Brown and Antuñano, 2009; Federal Aviation Administration, 2010; Lee and Liu, 2003). This paper seeks to bridge the gap between civilian and military aviation studies through quantitative demonstration of the high levels of risk being undertaken by crews and accepted by Senior Leaders daily during MAF operations. Analysis of a year's worth of flight operations, through the lens of established home-station circadian rhythms, is an innovative approach to this field of study.

The scope of this research is to analyze MAF operations during a given year and compare the crews assumed circadian rhythm for sleep-wake cycles against their actual missions. While nobody wants crews to be operating below peak efficiency levels, this research can highlight the widespread impacts of current operations on the aircrew's CRD. Senior Leaders could use this data to make informed decisions on MAF operations and health of the force.

Background

Mobility Air Forces provide logistical capabilities that supersede anything the world has ever seen. Journeys that used to take weeks and months to accomplish, with great hazard to crew and cargo can now be accomplished in hours or days. Airlifters are able to fly non-stop/non-refueled from the CONUS to Asia or Europe while carrying thousands of pounds of cargo or troops. Through air-refueling, airplanes are able to fly direct-delivery missions from the CONUS to the Middle-East or wherever our allies and partners need assistance. The capability to fly great distances in relatively short periods of time has created its own unique problems for aircrews.

Crossing multiple time zones creates a CRD known as jet-lag, where the body clock is still operating on a previously adapted cycle (home-station), but currently functioning in a new environment (Waterhouse, et al., 2005). For mobility aircrews, who typically work office jobs from a typical 0730-1630 duty day when not flying and then fly short-notice missions, it can be challenging to attempt circadian rhythm shifts prior to a mission. While a CRD is not a new problem, research has been introduced clarifying the impacts of circadian rhythm on fatigue. Describing fatigue in layman's terms is a challenging concept due to the variability between cognitive, reflexive, and social impacts.

Researchers have used blood alcohol content (BAC) equivalency percentages to highlight the dangers of operating under fatigue, for example, stating that after 17 hours of wakefulness, subjects are operating at a minimum equivalent BAC of .05% or greater (Williamson, et al., 2000). This paper does not attempt to tie a BAC to a CRD, but BAC is mentioned because it is a standard practice for measuring equivalency to fatigue. Throughout the United States, citizens driving with a .08% BAC, minors with a .02% BAC, or commercial drivers with a .04% BAC or higher are considered driving under the influence and unlawful. Much of the world’s advanced nations have lowered the limit to .05% BAC, due to demonstrated negative effects on critical tasks, judgment, and attention spans (Fell and Voas, 2017).

Circadian rhythm disruption's consequences can have catastrophic effects when applied to million-dollar assets flying across the globe, with loads varying from hundreds of people to hundreds of thousands of pounds of cargo and fuel. Some airlines attempt to mitigate the impact of a CRD by operating with Flight Duty Periods (FDP) that are more flexible than the Basic (16 hours) and Augmented (24 hours) duty periods that MAF crews operate within, based in part upon circadian rhythm.

The Federal Aviation Administration provides the airlines a Fatigue Risk Management System (FRMS), which takes into consideration previous legs' takeoff times, alert sequences, location acclimation, and dictates pre-mission and post-mission crew rest times (Delta Master Executive Council, 2017). The United States Air Force uses the Fatigue Avoidance Scheduling Tool (FAST) to measure the effectiveness of some of its aircrews but is typically used in a post-accident investigatory role. In the FAST system, 77% efficiency is equivalent to a .05% BAC, while at 70% efficiency crews are operating at an equivalent .08% BAC, regarding cognition and reaction times. This model has been used for accident investigations in various transportation associated industries and has demonstrated a strong link between low-efficiency levels and human factor related accidents (Hursh and Eddy, 2005).

Fatigue research has exposed that humans are not effective judges of their own tiredness levels and noted that demonstrably affected individuals have stated they do not feel tired (Federal Aviation Administration, 2010). This presents a problem for the MAF because the main channel for fatigue notification is through self-confessions of the aircrews to command and control nodes. This places aircrew in the less than ideal situation of balancing the safety of flight (due to fatigue), desire to complete missions in support of national security objectives, perceived negative stigmas associated with mission cancellation, and organizational pressures for mission accomplishment. This researcher understands that there are daily tradeoffs between risk and mission accomplishment made for MAF operations such as outside user requirements, airfield operating hours, and the inherently flexible capability of mobility operations, to name a few challenges. This paper does not attempt to fix the current procedures the MAF uses operationally, but rather to highlight the spread and intensity of the CRD across the fleet, based upon current operations.

Research Questions

This paper seeks to discover and highlight the prevalence of circadian rhythm disruption faced by the MAF through answering one primary question and three investigative questions:

RESEARCH QUESTION 1: What percentage of MAF (C-5, C-17, KC-10, and KC-135) managed crews were operating an aircraft while under the impairment caused by circadian rhythm disruption during 2016?

INVESTIGATIVE QUESTION 1: Does the data show a difference for circadian rhythm management of crews based upon mission classifications (Coronet, Channel, SAAM, Refueling, etc) and the priorities allocated to those classifications?

INVESTIGATIVE QUESTION 2: Is the CRD more prevalent during takeoffs, landings, or cruise for MAF crews?

INVESTIGATIVE QUESTION 3: Are there any specific MWS, mission classifications, or bases with above-average levels of the CRD?

Assumptions

Multiple assumptions were necessary to analyze the data in a way that allowed for comparison, the establishment of normative behaviors, and a possible CRD.

Assumption # 1.

Circadian rhythm habits for crews are based upon a normally distributed population, meaning they follow the traditionally accepted work-rest, sleep-wake cycles of the population (see Figure 1). Generally accepted is 7-9 hours of sleep per night, however, to grant credibility to the data, a 6-hour sleep window of 0000 local to 0600 local was used to account for varying bedtimes and wake times in the population (Hursh and Eddy, 2005). It is understood that some people will sleep before 0000 local and some will wake up after 0600 local. This is a necessary assumption to validate that there could be fatigue amongst the crew force throughout mission classifications. It also allows for the idea of circadian peaks and valleys, as shown in Figure 1.

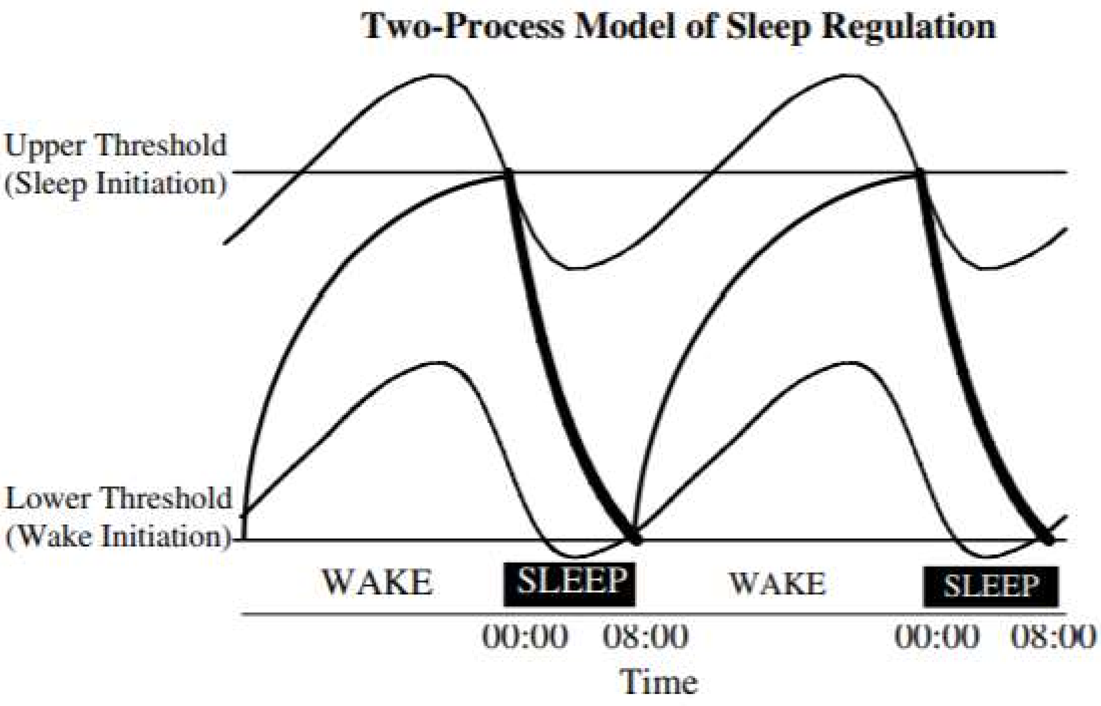


Figure 1 – Two Process Model of Sleep Regulation (Crowley, et al., 2007)

Assumption # 2.

Circadian rhythm disruption is linked to fatigue and has a negative impact on aircrews. There are many factors that contribute to fatigue, including dietary, wakefulness, sleep-debt, exertions, etc. For this research to have credibility and validity, a CRD must be assumed to contribute to fatigue.

Assumption # 3.

No circadian shifting or circadian resets were used in this research. The implication is that once a crew was on a home-station circadian rhythm, it remained on that circadian rhythm for the entirety of its mission. It also means that crews were not assumed to have had the time or capability to begin shifting their circadian rhythm prior to a mission. Longer ground times were not accounted for in the equations to try to reset a crew to new locations because it could not be determined if those times were set aside for adjustment to time-zone, maintenance delays, or continuous alert postures (with resets). While research can show possible shifts based upon East and West travel, the variability of MAF mission directions and times may not adequately allow for time zone adapting.

Assumption # 4.

Crews operate throughout missions on an established and non-shifting home station wake time, beginning at 0600 local and ending at 0000 local. For this paper, these local times were converted into Zulu Time, allowing comparison to recorded GDSS2 mission times. These times were used as the basis of the circadian rhythm disruptions, if crews alerted (were woken up) for any sortie before their biologically established 0600 home station local wake time (converted to Zulu Time), landed after their established 0000 home station local time (converted to Zulu Time), or operated through the periods of 0000-0600 (converted to Zulu Time) non-shifted body clock, then it was counted as a CRD. For this paper, local times are referencing the operating crew's home-station.

Assumption # 5.

The data analyzed at was not deciphered for scheduled versus actual sortie times (ie; maintenance delays causing a CRD) or taxi times, since the data included takeoffs and land times, not taxi operations. This means that crews could have shown as not working with a CRD because they landed prior to 0000 home station local time, but, could have been taxiing the airplane through the CRD window.

Assumption # 6.

Training sorties, functional check flights (FCF) and air shows were removed from the data because they are assumed to be scheduled through home station requirements, not managed at the enterprise levels.

Assumption # 7.

The research did not analyze whether the home station sleep times (CRD window) of 0000-0600 (local, converted to Zulu Time) took place during the day or during the night during missions. It also did not analyze the seasonality shifts of day and night for the various home stations throughout the data as a counter-balance to assumed circadian rhythms.

Assumption #8

In-flight requirements such as air refueling, tactics, airdrop, and formation flying were not analyzed in this research. While it could have happened on sorties, it could not be verified with the provided data set and therefore assumed to not be occurring. This research also did not examine or compare whether in-flight events happened, but the frequency of their occurrences. It is understood that multiple air refueling or tactical events would compound fatigue, however by not including those variables it keeps the conclusions more conservative relative to fatigue.

Limitations

This research project is limited to unclassified information. The data received from AMC/A9 and taken from Global Decision Support System 2 (GDSS2) is taken as complete and accurate data for 2016, meaning the researcher was completely reliant on provided data for analysis.

The rest of the paper will follow as a review of previously accepted literature regarding ties of circadian rhythm to fatigue, risks associated with fatigue, and the inherent risks with aviation grappling with the compounding effects of fatigue. Following the literature review, the methodology and data analysis will be unveiled, highlighting the amounts of aircrew impacted by circadian rhythm disruptions, based upon the conservative assumptions previously outlined. The conclusion will discuss implications and possible actions for Senior Leaders compared to the acceptable levels of risk to mission accomplishment.

II. Literature Review

The Literature Review section of this research paper will ultimately attempt to establish the link between circadian rhythm disruption and the risks associated with operating aircraft in the impaired state that a CRD can foster. Circadian rhythm disruption has been demonstrated to impact fatigue and nurtures itself in aviation through what is known as jet-lag. Research has demonstrated that the human body operates on a cyclical body clock, which contains performance peaks and valleys, which ties fatigue to reductions in cognitive ability and reaction time. It is with these valleys in performance and through the body clock that the CRD window of 0000-0600 local was established, times when the human body naturally performs the worst.

The research map in Figure 2 covers areas analyzed and hypothesized during this research. Circles in blue were considered measured or provided data, such as the 2016 GDSS2 data and takeoffs. Green-hued circles represent hypothesized or conjectured information for the analysis, especially what was considered the actual circadian rhythm for crews, induced fatigue, and the risks associated with that line of actions. Solid lines link items that were considered proven by research or used for empirical analysis, for example, the takeoffs, landings, and transits association to the analyzed circadian rhythm disruption. There is a conspicuous dashed line between the analyzed circadian rhythm disruption and the actual circadian rhythm, to emphasize the assumptions required to link the measured versus hypothesized results.

Overall, this research paper is focused on aviation, through the Mobility Air Force, so literature with ties to fatigue, aviation, and safety will also be examined. Through the research on different levels of task saturations during flight operations, it was decided that takeoffs and landings should be examined. The transit circadian rhythm disruptions are analyzed in the research to capture overflight of the entire CRD window, but can also provide future research data for data points outside the scope of this research paper, such as air refueling and tactics.

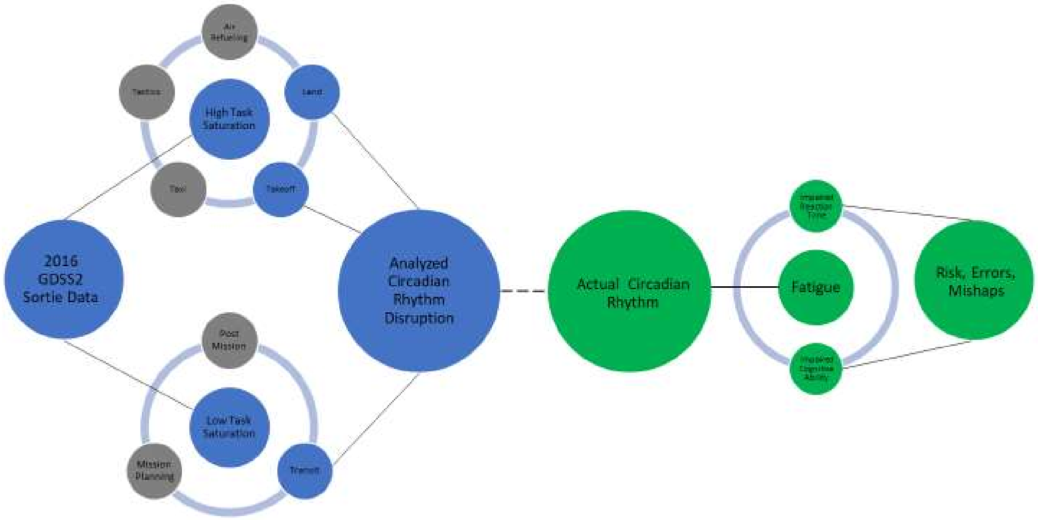


Figure 2 – Research Map

Circadian Rhythm and Fatigue

A large portion of research is dedicated to educating the workforce and its corporate structure on the tie between circadian rhythm and fatigue. The main point made through most of this research is that there are multiple factors leading to fatigue and circadian rhythmicity is one of the biological and physiological factors that is not easily mitigated without active planning (Blatter and Cajochen, 2007). There are multiple terms used to describe the out-of-phase circadian rhythm, such as circadian rhythm disruption and circadian desynchrony, but they are all allegories for the same problem. While there are many factors that can contribute to fatigue, circadian rhythm disorders have been shown to directly contribute to fatigue through the biological system (Zisapel, 2001).

Fatigue represents the measured lack of will or loss of ability to function properly, it has also been defined as a generalized reaction to stress (Holley, et al., 1981). Another definition of fatigue, according to Ivan Brown's research on fatigue with drivers, is the "reduced capacity to perform mentally or physically taxing work, or the subjective situation in which the person cannot perform a task anymore, and it results from inadequate sleep, circadian rhythm disruptions and/or time spent at work" (as cited in Yildiz, et al., 2017:100). The link established between CR and fatigue is that circadian rhythm is a known contributor to fatigue, while fatigue is not a contributor to a CRD.

The human body develops a 24-hour cyclical system for sleep, wakefulness, activity, and even body temperatures. There are troughs in the early morning and early evening times when the body is naturally in one of the minimums. Circadian rhythm follows a wavelike pattern with maximum and minimum periods of impact throughout the day, which has been measured and tied to fatigue through hours of wakefulness and performance (cognitive and vigilance) testing (Van Dongen and Dinges, 2000). Figure 3 illustrates the peaks and valleys of performance cycles throughout the day, based upon receiving 8-hours of sleep, while highlighting the major dips in effectiveness. The research on circadian rhythm's cyclical system and the sleep-wake cycles permitted this researcher to make an informed decision for the CRD windows being compared, using

0000-0600 local times, not only captured the early morning trough of performance, but since it was less than the standard 8-hour sleep block used in most sleep studies, it lends credibility and conservatism to the results of the comparative enumeration.

Based on the above-mentioned literature, circadian rhythm and fatigue are not only related, but circadian rhythm disruption has a demonstrated negative impact on performance and direct relationship to fatigue.

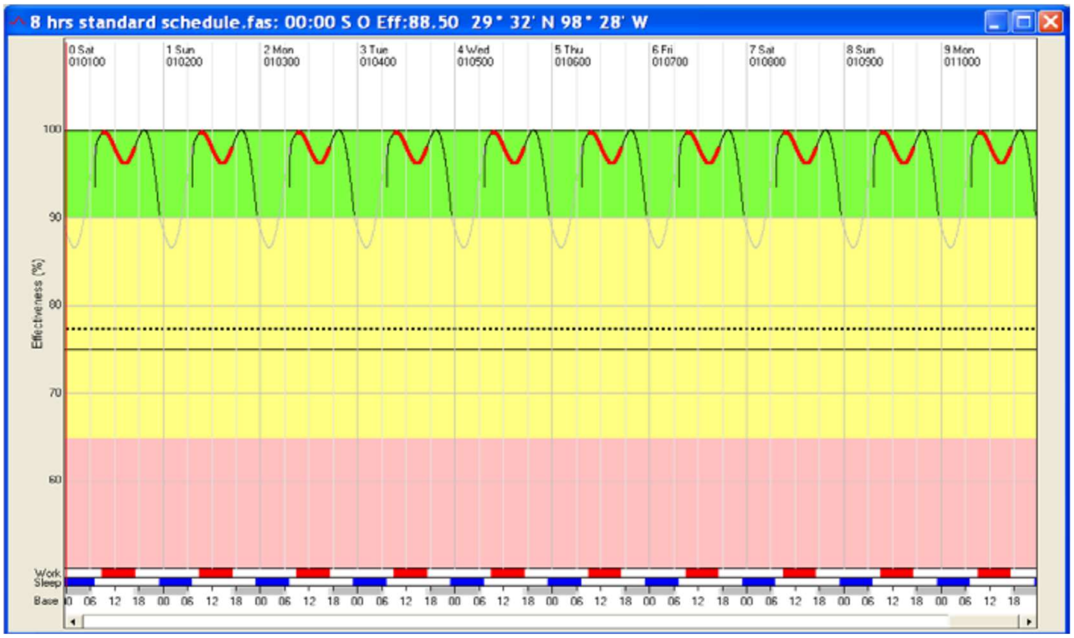


Figure 3 – Predicted Cognitive Effect for Time of Day (Hursh and Eddy, 2005)

Fatigue and Aviation

Given the inherent dangers associated with aviation and the catastrophic effects of mishaps, a large body of research has been devoted to circadian rhythm, fatigue, and aviation. The United States' Federal Aviation Administration has sponsored multiple studies and in turn, distributed advisories and regulatory packages with the findings. The conclusions have been common-sense to those operating in aviation, but they have also provided various ways to mitigate the effects of circadian rhythm and fatigue. Circadian shifts and jet lag from crossing multiple time zones, flying through day and night, and varied schedules negatively impact the ability to operate without fatigue (Federal Aviation Administration, 2010).

Circadian rhythm disruption has been defined as anytime the body's normal CR is upset and jet lag has been determined to be one of the types of CRDs. One of the main symptoms of a CRD is fatigue, with jet lag being an unnatural, but common phenomenon in aviation (Brown and Antuñano, 2009). Jet lag has been a term long-associated with aviation and has been clarified to affect pilots and passengers, research clarified that while jet lag is associated with a CRD and fatigue, the exact symptoms are complex and varied. Therefore fatigue-management versus an hours-of-service type of approach is much more beneficial for airline safety. Time on duty is less important than the timing of the work (CR) and the sleep prior to operating (Caldwell, 2012). For the operators of airplanes, a CRD can be disastrous as the impacts can be reaction time increase, lowered attention spans, secondary task forgetfulness, and poor crew resource management (Brown and Antuñano, 2009).

One of the landmark studies regarding CRD, jet lag, and fatigue took a systematic approach to motivated individuals in a laboratory setting. The study showed the factors of jet lag and fatigue closely resembled each other and that the negative symptoms remained high even into day two of the study and acclimation phase of the subjects (Waterhouse, et al., 2005). This second-day finding is especially important due to the command and control (C2) of mobility operations, which usually does not give crews more than one day to attempt adjustment, but rather keep the aircraft and crews flying throughout the system. Generally agreed upon assumptions are that the body can adjust 1.5 hours per day westward and 1 hour per day when traveling eastbound (Zisapel, 2001).

Research has noted that circadian rhythm adjustment was not likely to occur in international trips with durations less than 3 days, so the best option for flight crews is to keep with their home station (domicile) sleep/wake schedules (Federal Aviation Administration, 2010).

Fatigue Related Aviation Accidents/Incidents/Mishaps

Fatigue has been measured in various transportation mishaps through the SAFTE (Sleep, Activity, Fatigue, and Task Effectiveness) model and corresponding FAST (Fatigue Avoidance Scheduling Tool) programs to discover what levels of fatigue tied into accidents. The generally accepted numbers are that above an 85% efficiency on the FAST, the mishaps were based upon other factors than fatigue, but below that there is a non-linear and higher than anticipated relationship between fatigue and mishaps. The correlation between FAST and BAC is that at 77% efficiency, the testing BAC equivalency was near a .05% BAC and at 70% efficiency, the BAC was at about .08%. Dr. Hursh, the developer of the SAFTE model demonstrated that although much work is done in the 85% efficiency area, a much higher proportion of accidents occur below the 65% efficiency on the FAST (Hursh and Eddy, 2005). To clarify, the BAC equivalency is tying fatigue towards cognitive ability and reaction times, both of which are crucial during aviation’s high task saturation periods of taking off and landing.

According to a 2007 report on Naval mishaps, “fatigue is four times more likely to contribute to workplace impairment than drugs or alcohol,” but the article discusses that fatigue is hard to track post mishap without gathering enough history to determine a valid circadian rhythm (Davenport and Lee, 2007:6). This difficulty in ascertaining accurate CR information was reiterated in the analysis of the Comair Flight 5191. The Chairman of the NTSB stated, “establishing the role that fatigue played in an accident has proven to be difficult, if not sometimes completely elusive…perhaps it is because with fatigue, we are more comfortable identifying it as a cause when everything else is ruled out” (Pruchnicki, et al., 2011:1057). The Comair Flight 5191 research concluded that CR could not be conclusively related to the accident, but through flight data recorder analysis the crew and air traffic controller demonstrated fatigue due to their CRD. A lack of accurate preceding days sleep and wake cycle information the researchers were unable to use the FAST to determine the efficiency of the aircrew, which could have made the CRD and fatigue conclusive (Pruchnicki, et al., 2011)

While this research will not be specifically analyzing mishaps during a CRD scenario, it is important to note that this research is based on the underlying theme of safety and accepted risk. These risks are especially apparent during critical phases of flight, such as the approach and landing phases. The National Aeronautics and Space Administration (NASA) sponsored research into the exact complexity associated with these phases of flight as part of its System-Wide Accident Prevention program. Under its Human Performance Modeling (HPM) umbrellas for approach and landing, aircrews were observed rapidly interpreting data from a variety of sources, making decisions on configurations, and adjusting speeds and altitudes all the way through touchdown. The intricacies of the approach and landing phases of flight cannot be overstated regarding cognitive ability, reaction time, and decision making; indeed, many airlines and aircraft manufacturers are contributing to research that reduces pilot workload in these critical phases of flight (Leiden, et al., 2002; Keller, et al., 2003). Once aircrew falls behind on an approach, it can become a compounding and debilitating problem, especially if already battling fatigue.

Fatigue's Tie to Reaction Time and Cognitive Ability

Research in the areas of sleep deprivation (fatigue) and blood alcohol content (BAC), show that at about 16-19 hours of wakefulness, subjects operated at an equivalency of .05% BAC (77% efficiency in FAST) and their equivalent BAC percentage increased the longer they were awake 18-24 hours, up to a measurable .1% BAC equivalency during certain tests (Williamson, et al., 2000). The reason the equivalency stops at .1% BAC is because that is the limit in the amount of alcohol given to the BAC test subjects. BAC research has sought to tie normalized terms that society is familiar with to calculated performance effectiveness.

One of the challenges of the BAC equivalency route is that it is extremely dependent on subjective performance (FIX individual differences, in BAC just like fatigue and CRD). The main reason for bringing BAC into the research is that it provides a direct idea to those unfamiliar with the technical aspects of FAST, CRD, wakefulness, and fatigue. It provides an estimate that can be related to everyday operations, for example, the .05% BAC makes it illegal to drive in Australia and .08% BAC is a DUI in the United States. Now imagine flying with someone who had a BAC of .05% or .08%, nobody would voluntarily place their family's safety with a pilot in that state. A main advantage of the BAC and fatigue testing is that it can help demonstrate the clear ties between fatigue and performance impact. Whether the equivalent BAC due to wakefulness is greater than .05% or .08% the research shows that there is clear hazard to the safety of flight due to fatigue (Maruff, et al., 2005).

Since CRD has been tied to fatigue, it can be inferred that through a CRD there is also a link to reaction time and cognitive ability. A joint FAA and NASA study on cockpit fatigue countermeasures noted that when the sleep/wake cycle is desynchronized (due to a CRD) the body could attempt to wake at inappropriate times, based upon the new time zone. This results in less total sleep and rapid introduction of a devastating cumulative sleep debt, leading to further decreases in cognition, reaction time, and disposition (Rosekind, et al., 1994).

A challenge in the area of reaction and cognition due to a CRD and fatigue is the variations of factors contributing to fatigue. It has been demonstrated that individuals can experience slower reaction times through the psychomotor vigilance test (PVT), based upon varying levels of fatigue and their CRD. Research has been done in efforts to mitigate some of the variability associated with fatigue testing (Van Dongen and Dinges, 2005). Through this research, ties of fatigue to reaction time and cognitive ability were successfully established.

High Task Saturation and Low Task Saturation During Flight

Multiple studies have been conducted to determine the workloads required during flight (Dussault, et al., 2005; Hankins and Wilson, 1998; Holley, et al., 1981; Keller, et al., 2003; Lee and Liu, 2003). Experiments conducted on pilots in the simulator and actual aircraft have demonstrated physiological and biological changes during different flight sequences. The consensus has been that increased physical and mental demand is required during takeoff and landing phases of flight, highlighted by spiked heart rates, changes in breathing, brain activity, and eye movements (Hankins and Wilson, 1998). The comparisons and changes noted through electroencephalography (EEG) and electrocardiography (ECG) monitoring provided quantitative evidence that the cognitive demands during takeoff, approach, and landing phases of flight were considered greater than traditional instrument flight rules (IFR) cruise (Dussault, et al., 2005). Of note, however, was that while cognitive demands were greater during the traditionally considered critical phases of flight, the physical demands were higher during cruise portions of the sortie (Lee and Liu, 2003).

The inclusion of technology to quantify the physiological and biological changes in aircrew during different phases of flight lends itself to place an emphasis on fatigue levels during critical phases of flight. This research paper uses these studies to highlight the importance of analyzing the phase of flight compared to the CRD of aircrews to demonstrate increased risk levels.

Summary of Literature Review

Fundamentally required for this research to be applicable is binding circadian rhythm to fatigue, fatigue to safety (through cognitive and performance measures), and then circadian rhythm disruption to high and low task saturating events during flight (see Figure 2 and Figure 3). The research map in Figure 2 highlights the areas considered linked together in terms of fatigue's negative impact on reaction times and cognitive abilities, thus increasing risk of errors and mishaps. It also provides a visualization of high and low task saturation, specifically tying takeoff, landing, and transit to high or low saturation, respectively. Once these links are explained, the importance of analyzing crews for their CRD becomes even more urgent. The goal of the literature review was to demonstrate the research dedicated to the linked data, measurements, and results.

III. Methodology

Research Method

To compare the CRD to phases of flight, this research used quantitative methods. Aircrews were tethered to home station circadian rhythms and then compared against specific operating windows.

This research attempted to delve into the ordinal levels of measurement, comparing not simply if a CRD occurred, but where it occurred and how often. A comparative analysis of enumeration method was used as the backdrop of the research, which focused on numbering, classifying, and comparing vast amounts of data against an established standard, in this case, the CRD windows. Experimentation of actual aircrew was not used, but could be used for further research, instead observation and analysis of the 2016 GDSS2 data set provided by AMC/A9 were used as the observable facts. For this research project, aircrews were operating with a CRD if they alerted (woken) prior to 0600 body clock time or landed during their CRD window (0000-0600 local). For example, a crew that took off at 0601 local from home station would still be considered a CRD window violation because their alert SOE broke their sleep cycle and depending on the airframe, up to 4 hours and 15 minutes prior to takeoff. For C-5 crews with a 4 hour and 15-minute alert SOE, departures prior to 1015 local were considered a CRD window violation because their circadian rhythm (sleep-wake) cycle was broken for the alert sequence.

A Comparative Analysis of Enumeration

The nomenclature for the research conducted in this paper best fits as a comparative analysis of enumeration, which is traditionally seen in the medical or nutritional frames of research (Boulassel, et al., 2015). In most comparative analysis research papers, multiple sets of bacteria are sorted and enumerated, then compared against an allowable standard in order to assess the safety of food or platelet counts (Anderson, et al., 2011).The sortie data from GDSS2 was filtered, organized, and standardized in a way that allowed for it to be lumped, classified, and counted (enumeration) for comparison against an established standard (comparative analysis), in this case, the research-informed CRD windows. Once the sortie data was counted and compared to the CRD windows, it was sorted, filtered and classified again through different mission classifications, prior to being conditionally formatted and standardized.

Data Collection and Analysis

AMC/A9 was extremely helpful in procuring and providing data for this research. The 2016 GDSS2 data was initially received and contained more than 148,000 sorties worth of data, tallying to greater than 5.9 million data cells. Through scoping, it was elected to filter out all items, except for the four MWS (C-17, C-5, KC-10, and KC-135) aircraft. From there, essential categories to determining crew home stations were filtered, aircraft operating times, and mission classifications. If it was determined that setting a home station circadian rhythm would be unreasonable, for example, C-17s based in Southwest Asia, then the data was removed. C-17 aircrews deployed to Southwest Asia are on deployment type rotations and may not have the same type of 0730-1630 office roles that home station crews may have, therefore deciding that they all go to sleep from 0000-0600 local time does not make sense. They could be on established sleep-wake cycles for flying purposes, not normally afforded at home station. In total, 43,494 sorties, 23 mission classifications, and 43 operating bases (some with multiple MWS) were set to home station circadian rhythms and included for analysis.

The categories that were analyzed for this research were departures, arrivals, and transit (cruise). Through these categories, crews were also analyzed to see if they were operating in the CRD window during critical phases of flight (takeoff or landing), any CRD window violations (takeoff, landing, or transit), and if there were any CRD window operations during departure and arrival phases of flight on the same sortie. Considering the high task saturation and fatigue discussed in the literature reviews, the sorties that contained both departures and arrivals during the CRD window could be considered the most high-risk. The categories of mission classification were kept, to inform decision makers the types of sorties with the CRD issues, compared to the expected risks associated with those classifications.

Sorting and Filtering

To begin setting the CRD windows for aircrews, the data had to be sorted and filtered. The initial 2016 GDSS2 document was filtered to remove everything that was not one of the four desired MWS aircraft. These four aircraft were specifically chosen because they represent strategic airlift and had the capability to cross multiple time zones during a single sortie, lending themselves susceptible to the long-haul challenges. Besides the initial scope of the data (four MWS), no data was paired or removed in these phases. A deliberate lack of analysis was done until the sorting phase was complete. Once the four workbooks had been created along with the sheets for each MWS, the removal of extraneous column data began.

The initial GDSS2 data contained 46 columns of data, from Mission Classification to Arrival Longitudes. This research did not require all the data provided in those columns, so each sheet was filtered down to 10 columns of data, with 8 more added for clarity and analysis. The variables in this research were Mission Classifications (see Table 1 for a list of classifications), Departure Time, and Arrival Time. To allow for lookback and possible trend findings the characteristics for each flight were also kept (Legacy Primary Mission Key, Mission ID, Tail Numbers, Flying Time, Ground Time, Departure Station, and Arrival Stations). Each MWS and base was given local CRD windows, converted into Zulu Time for comparison. Six columns were added to each individual sheet within the workbooks to facilitate the "1"/"0" and "Yes"/"No" nature of the data. The columns added were Departure CRD, Arrival CRD, Transit CRD, Critical Phase of Flight (Departure or Arrival CRD), Any CRD Busts? (Departure, Arrival or Transit violations), and Departure & Arrival CRD.

Base Level Data

Equations were developed for use in Excel, based upon the operating aircrew's home station, to see if their CRD window was violated. In other words, were they woken or operating an airplane between 0000-0600 local. The equations used for the 6 columns remained the same for the entire analysis of the data, the only changes being to the parameters of the CRD.

Three different variables were created to work with the equations. The variables were labeled as Wake, Takeoff, and Land. These variables are times that the CRD window is based upon, considering the sequence of events (SOE) required for each MWS. A 4 hour and 15-minute SOE is used for the C-5, KC-10, and KC-135 airplanes, with a 3 hour and 45-minute SOE used for the C-17. The KC-135 also has a 4 hour and 45-minute SOE based upon formation requirements, however since formation flight was not tracked in this data, 4+15 SOE was used, which means some KC-135 data could have a CRD, but was not counted as a CRD window violation using 4+15 instead of 4+45. This assumption reduces the possible CRD violations, lending the results to be more conservative. The Wake variable was tied to the 0600-local home station time that was created for each operating base. The Takeoff variable was tied to the Wake variable and SOE. If the home station wake was 0600 with a 4+15 SOE, 1015 local was the earliest a takeoff should be without breaking the sleep-wake cycle and causing a CRD. The third variable was Land and compared the arrival times for analysis. Land is based off a 0000-local home station time. The CRD window is considered the Land time through the Wake time (6-hour block).

A Departure CRD violation was triggered if the aircrew was operating with a departure time that required them to be alerted between 0000-0600 local. Each operational home station was given Wake, Takeoff, and Land times, corresponding to 0000-0600 local times. The equation used to calculate a Departure CRD violations was a comparison between the GDSS2 provided departure time and the earliest takeoff for Circadian Rhythm. The comparison had to verify that the departure time was at least after the Land time to make sure it was within the window, rather than simply any time less than the designated earliest takeoff time.

An Arrival CRD window violation occurred if the arrival times were after 0000-local home station time. The arrival window examined the provided arrival times and compared them to the CRD window's Land and Wake variables. The CRD window was violated if the arrival was between the 0000-0600 local body clock times.

The Transit CRD violations were created to capture any missions that flew directly through the CRD window, without a departure or arrival in the CRD window. For example, a mission that departs at 2359 local and lands at 0601 local would not be captured with the Departure CRD and Arrival CRD equations. To capture Transit CRD violations, a comparison was made between the departure time, arrival time, localized land time, and localized wake times. If the departure time was prior to the Land variable and arrival time was after the Wake variable, it would count as a violation since it overflew the entire CRD window.

A sortie was deemed to have a CRD violation during a critical phase of flight if it had a Departure CRD or Arrival CRD violation. The Critical Phase of Flight equation verified a violation in either the Departure CRD or Arrival CRD columns for a specific sortie.

The column labeled Any CRD Busts? examined the Departure, Arrival, and Transit CRD violation columns to determine if there is a "1" in any of those columns. If there is a "1" in any of those columns it returns a "Yes" to signify that at some point during the sortie there was a CRD violation. A bust is an aircrew centric term for violation or deviation in flight and for this research is equivalent to a violation, in this case meaning that during a sortie, were there any circadian rhythm disruptions for the crew (any phase of flight).

The final column that was added to the data is the Departure & Arrival CRD catch, in order to discover if sorties were not just violating Departure or Arrival CRD windows, but being operated with departures and arrivals during the same sortie. The literature review discussed the task saturations involved with these critical phases of flight and this research wanted to determine if crews were operating with a CRD in the double critical phase of flight zone.

The formulas used in this section formed the basis of the future analysis. A CRD window of 0000-0600 was selected for the Land and Wake variables, despite most researchers using 8-hours as the standard sleep cycle, to allow for variability in sleep distribution (Hursh and Eddy, 2005; Holley, et al., 1981; Zisapel, 2001). This research assumes a more conservative number window, meaning more crews could be impacted by a CRD than this research highlights. The CRD window also encompasses the circadian lows discussed in the literature review, which have negative impacts on performance and cognition.

Dynamic Base Data

After each base was measured individually, the capability to compare individual mission classifications was developed. A combined data and dynamic mission classification tool was created to provide the ability to visualize total sorties for the base, numbers of sorties based upon mission classification, and display the percent and numbers of sorties impacted. Each base has its own combined data table.

Each of the equations referenced in the Bases Level Data section were inputs to create the dynamic data tables. One key feature of this tool is the ability to dynamically change the mission classifications being viewed, which allows for highlighting of certain mission types that could be exceeding the expected risk, based on priority.

The dynamic data tables are helpful for understanding how the data was prepared, but a system had to be developed that allowed for comparison not only within the base, but also within the MWS, without using the dynamic function each time. A stock keeping unit (SKU) was created to allow for data visualization at the base, MWS, and MAF levels.

Stock Keeping Unit (SKU) Creation

SKU usage simplified the challenge of comparing an MWS from a location with a similar MWS from a different location while viewing either the same or different mission classifications. The SKU created is a 7-digit number that greatly reduces the workload of deciphering the data tables or relating data. The 7-digit SKU uses the MWS, Base (ICAO), and Mission Classification. The last 2 digits of the MWS comprise the first 2 digits of the SKU, for example, a C-17 is 17. The next 3 digits are the last 3 digits of the base ICAO identifier, where JB Charleston is CHS. The last 2 digits refer to the Mission Classification, where a specific key was created for any of the mission classifications that were analyzed, the number 18 is a SAAM. An example of these combined shows an SKU of 17CHS18, which translates to a C-17 from JB Charleston operating a SAAM. This becomes important when taking all the dynamic data and viewing it from a table for a specific base. The SKU legend is displayed in Table 1, below.

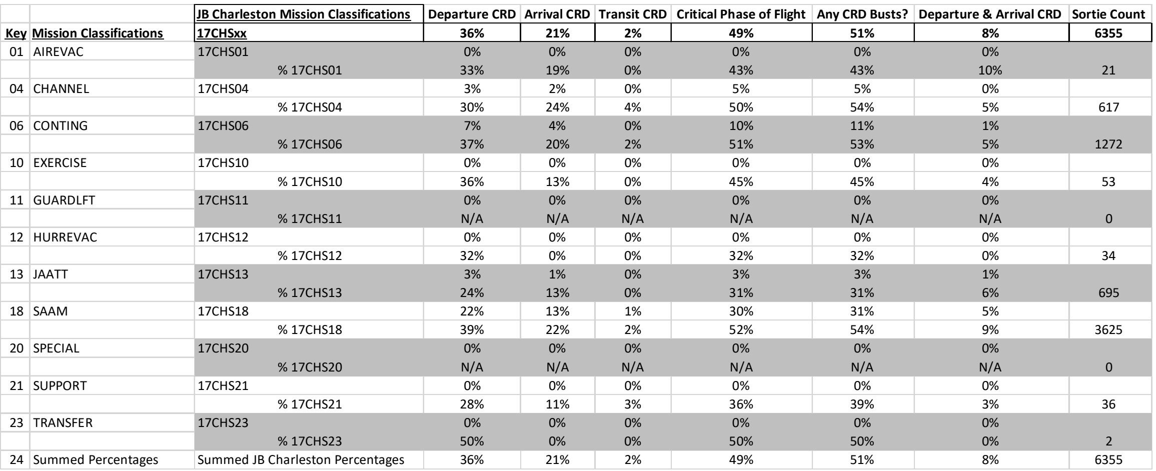
Table 1 – SKU Legend

7-DIGIT SKU Legend					
(2 DIGITS)		(3 DIGITS)		(2 DIGITS)	
MWS		**Base (ICAO)**		**Mission Classification**	
17	C-17	ADW	ANDREWS AFB	01	AEROMEDICAL EVACUATION
05	C-5	AED	JB ER	02	AIR REFUELING EXERCISE
10	KC-10	AEI	EILSON AFB, AK	03	BUSINESS EFFORT
35	KC-135	BAB	BEALE AFB	04	CHANNEL
		BGR	BANGOR ANGB, ME	05	CONTINGENCY AIR REFUELING
		BHM	BIRMINGHAM ANGB, AL	06	CONTINGENCY
		BLV	SCOTT AFB	07	CORONET
		CEF	WESTOVER ARB	08	CROSS
		CHS	JB CHARLESTON	09	DEPLOY
		DOV	DOVER AFB	10	EXERCISE
		FFO	WRIGHT-PATTERSON AFB	11	GUARD LIFT
		FOE	FORBES FIELD ANGB, KS	12	HURRICANE EVACUATION
		GSB	SEYMOUR JOHNSON AFB	13	JAATT
		GUN	RAF MILDENHALL	14	JCSEXAR
		GUS	GRISSOM ARB, IN	15	OPORD
		HIK	JB PHH	16	REDEPLOYMENT
		IAB	MCCONNELL AFB	17	REFUEL
		JAN	ALLEN C. THOMPSON FIELD ANG MS	18	SAAM
		LCK	RICKENBACKER ANGB, OH	19	SAM
		LNK	LINCOLN ANGB, NE	20	SPECIAL
		LTS	ALTUS AFB	21	SUPPORT
		MCF	MACDILL AFB	22	TANKER LIFT
		MEI	MERIDIAN, MS	23	TRANSFER
		MEM	MEMPHIS ANGB	24	*
		MKE	GENERAL MITCHELL ANGB, WI		
		MRB	SHEPHERD FIELD ANG WV		
		MTC	SELFRIDGE ANGB, MI		
		ODN	KADENA AB, JP		
		PHX	GOLDWATER ANGB, AZ		
		PIT	PITTSBURGH IA, PA		
		PSM	PEASE ANGB, NH		
		RIV	MARCH ARB		
		SKA	FAIRCHILD AFB		
		SKA	FAIRCHILD AFB		
		SKF	LACKLAND AFB		
		SLC	WRIGHT ANGB, UT		
		SUU	TRAVIS AFB		
		SUX	COL BUD DAY FIELD, IA		
		SWF	STEWART ANGB NY		
		TCM	JB LM		
		TIK	TINKER AFB		
		TYS	MCGHEE TYSON ANGB, TN		
		WRI	JB MDL		

Per Base SKU Sheet

The dynamic data combined with the SKU presented a powerful opportunity to view a base capture all at one time, while providing Mission Classifications, MWS, Locations, and the CRD percentages of the aircrews. Table 2 demonstrates JB Charleston's dynamic data with the CRD percentages, but also shows the aircrew's total and the specific mission classifications' CRD.

Table 2 – JB Charleston SKU Sheet



		JB Charleston Mission Classifications	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
Key	Mission Classifications	17CHSxx	36%	21%	2%	49%	51%	8%	6355
01	AIREVAC	17CHS01	0%	0%	0%	0%	0%	0%	
		% 17CHS01	33%	19%	0%	43%	43%	10%	21
04	CHANNEL	17CHS04	3%	2%	0%	5%	5%	0%	
		% 17CHS04	30%	24%	4%	50%	54%	5%	617
06	CONTING	17CHS06	7%	4%	0%	10%	11%	1%	
		% 17CHS06	37%	20%	2%	51%	53%	5%	1272
10	EXERCISE	17CHS10	0%	0%	0%	0%	0%	0%	
		% 17CHS10	36%	13%	0%	45%	45%	4%	53
11	GUARDLFT	17CHS11	0%	0%	0%	0%	0%	0%	
		% 17CHS11	N/A	N/A	N/A	N/A	N/A	N/A	0
12	HURREVAC	17CHS12	0%	0%	0%	0%	0%	0%	
		% 17CHS12	32%	0%	0%	32%	32%	0%	34
13	JAATT	17CHS13	3%	1%	0%	3%	3%	1%	
		% 17CHS13	24%	13%	0%	31%	31%	6%	695
18	SAAM	17CHS18	22%	13%	1%	30%	31%	5%	
		% 17CHS18	39%	22%	2%	52%	54%	9%	3625
20	SPECIAL	17CHS20	0%	0%	0%	0%	0%	0%	
		% 17CHS20	N/A	N/A	N/A	N/A	N/A	N/A	0
21	SUPPORT	17CHS21	0%	0%	0%	0%	0%	0%	
		% 17CHS21	28%	11%	3%	36%	39%	3%	36
23	TRANSFER	17CHS23	0%	0%	0%	0%	0%	0%	
		% 17CHS23	50%	0%	0%	50%	50%	0%	2
24	Summed Percentages	Summed JB Charleston Percentages	36%	21%	2%	49%	51%	8%	6355

Notice the SKU 17CHS18 in Table 2, which has been previously discussed. Viewing it from this table allows for not just the 17CHS18 to be viewed, but all the evaluated Mission Classifications from JB Charleston. The SKU Sheet provides an instant snapshot of the base's CRD. Reading the 17CHS18 SKU lines, the top line shows the contribution toward total JB Charleston CRD, while the line below it shows the percent of CRD for a mission classification. For the top line of 17CHS18, 31% of the

"Any CRD Busts?" for JB Charleston are from the 17CHS18. Another way to view the 31% is that of the 6,355 sorties, 31% of the total CRD busts came from SAAM sorties. Taking 31% of the 6,355 shows almost 2,000 SAAM sorties were possibly impacted by a CRD. The line below it shows for the 17CHS18 SKU (SAAM), 54% of the 3,625 SAAM sorties contain CRD violations. When 54% is multiplied by 3,625, almost 2,000 sorties are also shown as impacted. The lines provide 2 different ways of consuming the data. Using the example from above, 5% of the JB Charleston "Departure & Arrival CRD" are from 17CHS18 and 9% of the 17CHS18 sorties contain a "Departure & Arrival CRD."

Removing Mission Classifications With Less Than 30

For generally accepted statistically normalized analysis of the data, at least 30 counts would be required. The guideline for this is grounded in the Central Limit Theorem, which conveys that as a sample size increases, the mean becomes more of a normal distribution. In other words, having greater than 30 repetitions allows for a more robust data analysis and could provide statistical significance to the results (Aberson, et al., 2000; Norman, 2010). To preserve the totality of the data, but provide ease of viewing, individual bases with less than 30 sorties for a given mission classification were removed. The sorties with less than 30 repetitions were kept in the overall MWS tables, for informational purposes.

Conditional Formatting

It could be feasible to scour each line over and over until numbers began to stand out, however, Excel has a Conditional Formatting function to assist. The challenge with conditional formatting is deciding what and how to highlight. There is difficulty associated with finding guidance or literature referencing the allowable CRD that crew forces can maintain. Eventually, a 3-color-scale (green, yellow, and red), where the higher numbers are red instead of traditional green was used. The actual numbers used were a 20% CRD for green, transitioning to a yellow at 35%, and completely red at a 50% CRD. While the numbers could be considered arbitrary, they highlight certain points that can provide discussion and demonstrate the variances between a CRD for a total location and the CRD for a mission classification. The conditional formatting used provides a clearer picture of a large amount of data, including where possibly higher than expected CRD is occurring in crews.

MWS Combined Tables

Once each base was sorted, filtered, and individually combined to provide the Combined Data sheets, each of those data sheets were combined to present data for the MWS, as a community. Two tables were created to provide different, but quick-to-visualize data. The first table reveals the missions in a cumulative method, which quickly highlights that the largest contributors of a CRD.

The snapshot in the combined tables provides a summary of the mission classifications used in the data, the CRD data, and sortie counts. This provides a big picture overview of the MWS and once conditionally formatted provides a glimpse of the possible CRD risk areas. One challenge to the Combined Data Table is that it does not depict the average CRD violations per specific category, rather its role is to provide the big picture sortie contributors to possible CRD. To provide a depiction of the dynamic averages of each mission classification for the MWS, a second table was created.

With the dynamic averages for each sortie, rather than seeing which mission classifications the largest contributors to the CRD are, decision makers can now realize the percent of CRD violations for specific mission classifications. While it makes it more difficult to see which mission classifications are contributing heavily to the MWS' overall CRD rate, it does make it easier to read the CRD on a specific sortie basis. The two created tables are different ways of showing similar information, one highlights bigger picture CRD contributors, while the other table highlights the percentages of CRD violations for specific mission classifications.

The conditional formatting highlights Departure CRD, Critical Phase of Flight, and the Any CRD Busts? columns. The MWS combined tables are created to provide a big-picture view of the specific crew force. When analyzing a specific mission classification, they provide a more in-depth picture of CRD. It is important to remember that for this table, the percentages are out of the total sortie count for the MWS. For the dynamic tables, the CRD violation percentages are out of the specific mission classification's sortie count.

IV. Analysis and Results

The previous sections were primers for the analysis and results. It is imperative that the link from CRD to fatigue, and then from fatigue towards risk, especially in aviation is understood. With that connection established through the literature review, viewing MAF crews on a base level then to an enterprise level through the Departure, Arrival, and Transit framework allows for a discussion of risk to take place amongst Senior Leaders.

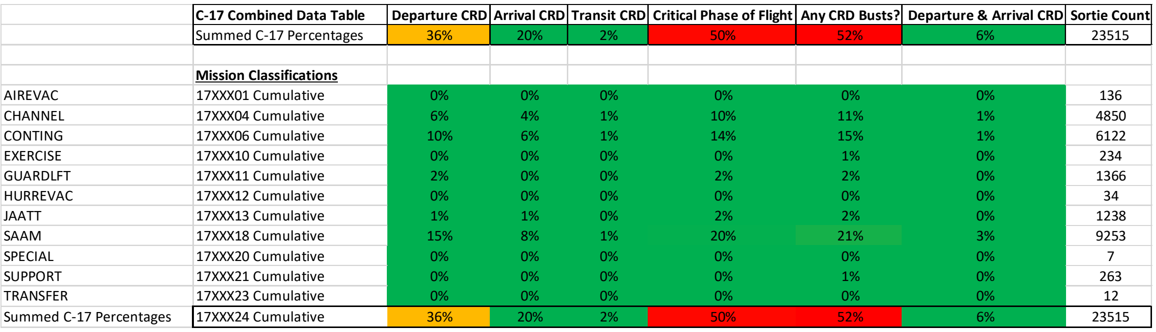
Once each base was set to home station circadian rhythms, the departure and arrival times were compared against the CRD windows. Beginning at the local level allows for observations of base level CRD, tied to specific mission classifications. After each base was analyzed, they could be combined to present a picture of each MWS and then the four MWS' combined CRD. This section will review the results of each MWS, explore a mission classification in each MWS that could be significant, and then review the results of a combined MWS and MAF comparison.

C-17 Workbook

The C-17 workbook included 14 bases and for each base a combined data table was created. From those data tables, SKU sheets were created and then filtered. The CRD window was compared against 23,515 sorties with 11 mission classifications. The C-17 Filtered Data Tables are in Appendix A.

Table 3 shows that 52% of analyzed C-17 sorties had a CRD, meaning crews could be operating fatigued a majority of the time. Channel missions accounted for 11%, Contingency for 15%, and SAAM sorties had the most contributed CRD, accounting for 21% of the busts. With a 52% CRD out of the 23,515 sorties, there is a possibility that over 10,000 C-17 sorties were impacted by a CRD during 2016.

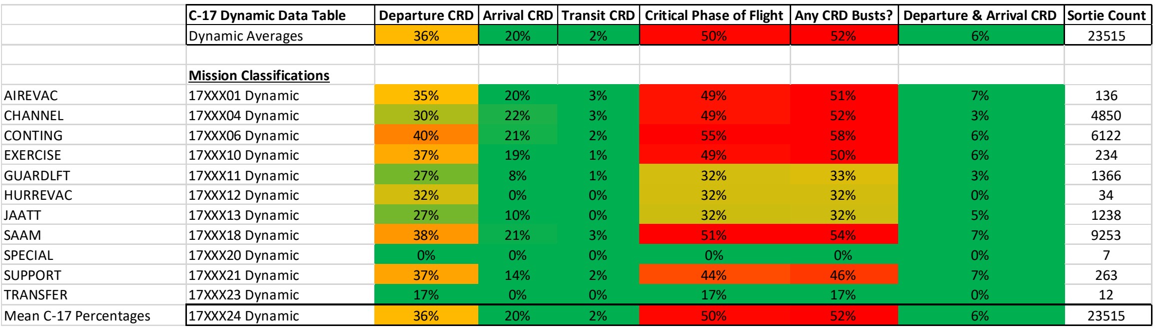
Table 3 – C-17 Combined Data Table



	C-17 Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
	Summed C-17 Percentages	36%	20%	2%	50%	52%	6%	23515
	Mission Classifications							
AIREVAC	17XXX01 Cumulative	0%	0%	0%	0%	0%	0%	136
CHANNEL	17XXX04 Cumulative	6%	4%	1%	10%	11%	1%	4850
CONTING	17XXX06 Cumulative	10%	6%	1%	14%	15%	1%	6122
EXERCISE	17XXX10 Cumulative	0%	0%	0%	0%	1%	0%	234
GUARDLFT	17XXX11 Cumulative	2%	0%	0%	2%	2%	0%	1366
HURREVAC	17XXX12 Cumulative	0%	0%	0%	0%	0%	0%	34
JAATT	17XXX13 Cumulative	1%	1%	0%	2%	2%	0%	1238
SAAM	17XXX18 Cumulative	15%	8%	1%	20%	21%	3%	9253
SPECIAL	17XXX20 Cumulative	0%	0%	0%	0%	0%	0%	7
SUPPORT	17XXX21 Cumulative	0%	0%	0%	0%	1%	0%	263
TRANSFER	17XXX23 Cumulative	0%	0%	0%	0%	0%	0%	12
Summed C-17 Percentages	17XXX24 Cumulative	36%	20%	2%	50%	52%	6%	23515

When using Table 4, the C-17 Dynamic Data Table, 54% of the 9,253 SAAM sorties had possible CRD, 58% of the 6,122 Contingency sorties contained CRD busts, and 52% of the 4,850 Channel sorties had CRD effect. If we analyze deeper into the C-17 SAAM on a base by base table, a high level of CRD on SAAM sorties is noted.

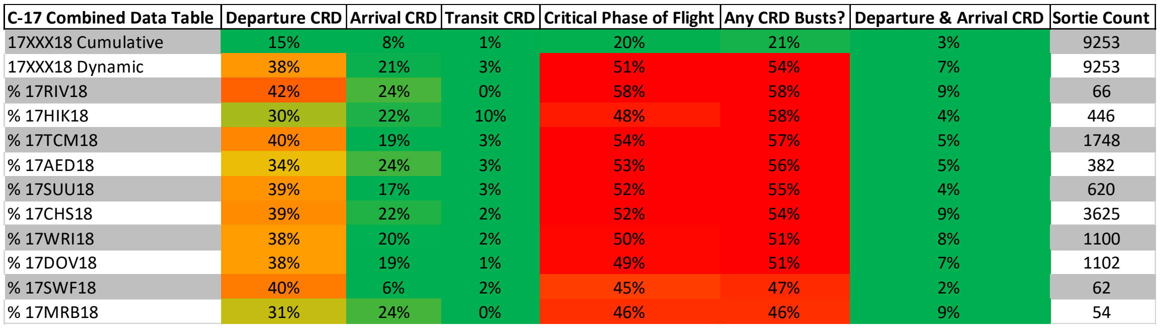
Table 4 – C-17 Dynamic Data Table



	C-17 Dynamic Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
	Dynamic Averages	36%	20%	2%	50%	52%	6%	23515
	Mission Classifications							
AIREVAC	17XXX01 Dynamic	35%	20%	3%	49%	51%	7%	136
CHANNEL	17XXX04 Dynamic	30%	22%	3%	49%	52%	3%	4850
CONTING	17XXX06 Dynamic	40%	21%	2%	55%	58%	6%	6122
EXERCISE	17XXX10 Dynamic	37%	19%	1%	49%	50%	6%	234
GUARDLFT	17XXX11 Dynamic	27%	8%	1%	32%	33%	3%	1366
HURREVAC	17XXX12 Dynamic	32%	0%	0%	32%	32%	0%	34
JAATT	17XXX13 Dynamic	27%	10%	0%	32%	32%	5%	1238
SAAM	17XXX18 Dynamic	38%	21%	3%	51%	54%	7%	9253
SPECIAL	17XXX20 Dynamic	0%	0%	0%	0%	0%	0%	7
SUPPORT	17XXX21 Dynamic	37%	14%	2%	44%	46%	7%	263
TRANSFER	17XXX23 Dynamic	17%	0%	0%	17%	17%	0%	12
Mean C-17 Percentages	17XXX24 Dynamic	36%	20%	2%	50%	52%	6%	23515

While the C-17 totals for SAAM sorties are not showing above 21% CRD for the total sortie count (see Table 3), Table 4 shows 54% for the dynamic sortie count, and Table 5 reveals how the 21% is broken out amongst the bases. This can be interpreted by observing TCM (JB LM), to see 57% CRD Busts, out of 1,748 sorties. On 57% of TCM SAAM sorties, there is CRD bust, in this case, 40% of sorties had CRD for Departure, 19% for Arrival, 3% during Transit, and 5% of the CRD window violations occurred during Departure & Arrival phases of flight. The various C-17 units sortie counts, combined with the percentages make up the 21% CRD contribution of SAAM to the 52% MWS CRD.

Table 5 – C-17 SAAM Data Table



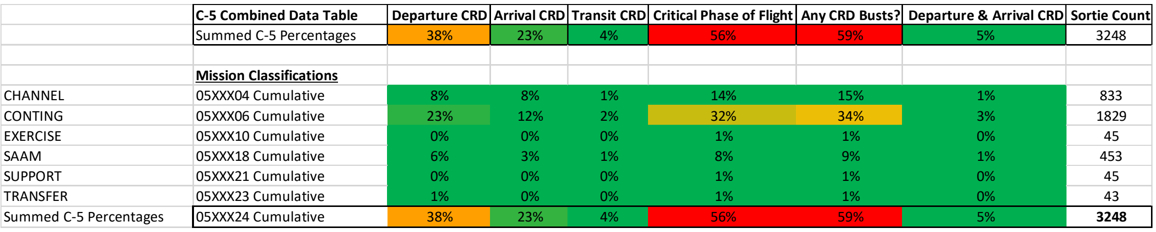
C-17 Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
17XXX18 Cumulative	15%	8%	1%	20%	21%	3%	9253
17XXX18 Dynamic	38%	21%	3%	51%	54%	7%	9253
% 17RIV18	42%	24%	0%	58%	58%	9%	66
% 17HIK18	30%	22%	10%	48%	58%	4%	446
% 17TCM18	40%	19%	3%	54%	57%	5%	1748
% 17AED18	34%	24%	3%	53%	56%	5%	382
% 17SUU18	39%	17%	3%	52%	55%	4%	620
% 17CHS18	39%	22%	2%	52%	54%	9%	3625
% 17WRI18	38%	20%	2%	50%	51%	8%	1100
% 17DOV18	38%	19%	1%	49%	51%	7%	1102
% 17SWF18	40%	6%	2%	45%	47%	2%	62
% 17MRB18	31%	24%	0%	46%	46%	9%	54

C-5 Workbook

The C-5 workbook included 4 bases and for each base, a combined data table was created. Similar to the C-17 data, from those data tables SKU sheets were created and then filtered. The CRD window was compared against 3,248 sorties with 6 mission classifications. The C-5 Filtered Data Tables are in Appendix B.

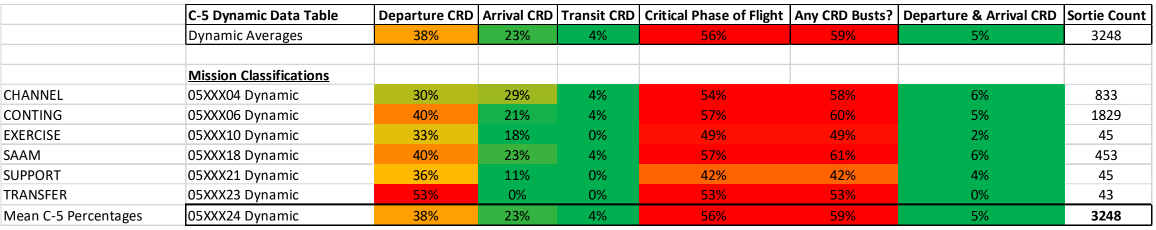
The C-5 results for the fleet in Table 6, show that 59% of its 3,248 sorties could have CRD. It appears that Contingency sorties were the most impacted by CRD, with 34% of them affected. After Contingency missions, Channel and SAAM sorties were the next highest contributors to total C-5 CRD. The combined data sheet provides the big picture of the largest contributors to CRD, but by viewing the dynamic data in Table 7, the mission classifications and their CRD contributions are more thoroughly explained.

Table 6 – C-5 Combined Data Table



	C-5 Combined Data Table	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
	Summed C-5 Percentages	38%	23%	4%	56%	59%	5%	3248
	Mission Classifications							
CHANNEL	05XXX04 Cumulative	8%	8%	1%	14%	15%	1%	833
CONTING	05XXX06 Cumulative	23%	12%	2%	32%	34%	3%	1829
EXERCISE	05XXX10 Cumulative	0%	0%	0%	1%	1%	0%	45
SAAM	05XXX18 Cumulative	6%	3%	1%	8%	9%	1%	453
SUPPORT	05XXX21 Cumulative	0%	0%	0%	1%	1%	0%	45
TRANSFER	05XXX23 Cumulative	1%	0%	0%	1%	1%	0%	43
Summed C-5 Percentages	05XXX24 Cumulative	38%	23%	4%	56%	59%	5%	**3248**

Table 7 – C-5 Dynamic Data Table



	C-5 Dynamic Data Table	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
	Dynamic Averages	38%	23%	4%	56%	59%	5%	3248
	Mission Classifications							
CHANNEL	05XXX04 Dynamic	30%	29%	4%	54%	58%	6%	833
CONTING	05XXX06 Dynamic	40%	21%	4%	57%	60%	5%	1829
EXERCISE	05XXX10 Dynamic	33%	18%	0%	49%	49%	2%	45
SAAM	05XXX18 Dynamic	40%	23%	4%	57%	61%	6%	453
SUPPORT	05XXX21 Dynamic	36%	11%	0%	42%	42%	4%	45
TRANSFER	05XXX23 Dynamic	53%	0%	0%	53%	53%	0%	43
Mean C-5 Percentages	05XXX24 Dynamic	38%	23%	4%	56%	59%	5%	**3248**

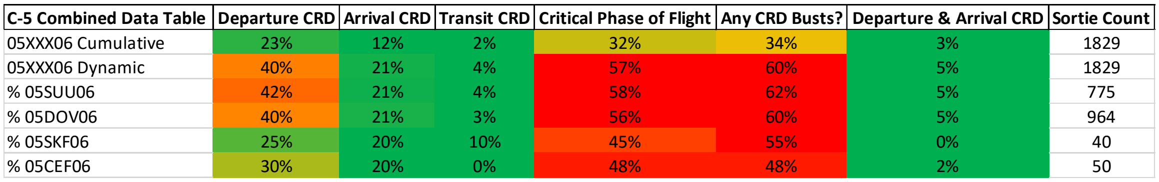
When reviewing Table 6, the Contingency sorties stand out as the largest contributor to the overall CRD of the C-5, which is exactly what the Combined Data Table is designed to highlight. However, Table 7 provides a clearer explanation of how that 34% of 3,248 sorties is executed, which shows 60% of 1,829 Contingency sorties have a CRD.

While Contingency sorties indicate 34% of the total sorties have a CRD and 15%

of the Channel missions have a CRD, the specific contributors to those disruptions at a base level can be displayed too. When viewed, some bases have a much higher percentage of CRD window violations than others. In Table 8, C-5 Contingency (05XXX06) sorties are examined. Table 8 shows that the C-5 was executing Contingency sorties with a 60% CRD bust and it appears evenly spread amongst the large bases.

Through base analysis on Table 8, SUU (Travis AFB) and DOV (Dover AFB) both show around a 40% Departure CRD and greater than 60% of their sorties having CRD busts, with about 5% of their Contingency sorties containing Departure & Arrival CRD violations.

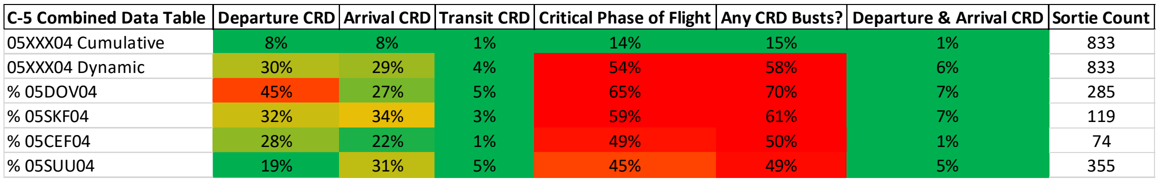
Table 8 – C-5 Contingency Data Table



C-5 Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
05XXX06 Cumulative	23%	12%	2%	32%	34%	3%	1829
05XXX06 Dynamic	40%	21%	4%	57%	60%	5%	1829
% 05SUU06	42%	21%	4%	58%	62%	5%	775
% 05DOV06	40%	21%	3%	56%	60%	5%	964
% 05SKF06	25%	20%	10%	45%	55%	0%	40
% 05CEF06	30%	20%	0%	48%	48%	2%	50

When Channel sorties are examined, the even spread of CRD across the large bases disappears in the C-5. Table 9 shows that Dover AFB had almost a 20% higher CRD on Channel sorties than Travis AFB in 2016, with Dover AFB at 70% of their Channel sorties having a CRD and Travis AFB at 49%. The dynamic data shows that 58% of the 833 Channel sorties for the C-5 contained a CRD bust.

Table 9 – C-5 Channel Data Table



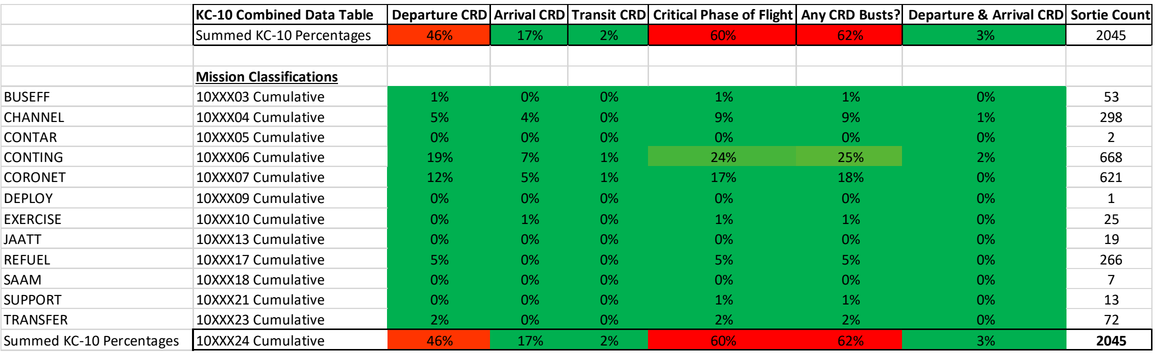
C-5 Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
05XXX04 Cumulative	8%	8%	1%	14%	15%	1%	833
05XXX04 Dynamic	30%	29%	4%	54%	58%	6%	833
% 05DOV04	45%	27%	5%	65%	70%	7%	285
% 05SKF04	32%	34%	3%	59%	61%	7%	119
% 05CEF04	28%	22%	1%	49%	50%	1%	74
% 05SUU04	19%	31%	5%	45%	49%	5%	355

The largest contributor to Dover AFB's possibly high CRD for Channel sorties was that its Departure CRD was showing 45% of its departures were violations. Table 9 shows that 27% of DOV's arrivals were operating in the CRD window, 34% of SKF and 31% of SUU's Channel sorties arrived in the CRD window.

KC-10 Workbook

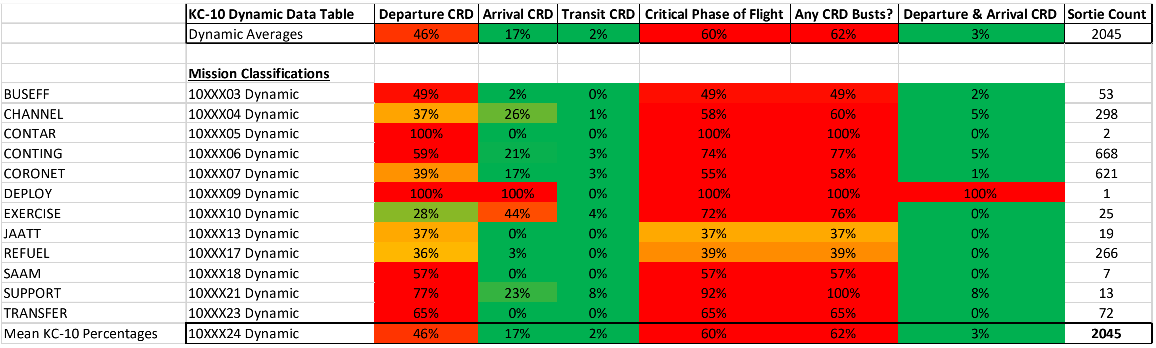
The KC-10 workbook included 2 bases and for each base, a combined data table was created. From those data tables, SKU tables were created, filtered and formatted. The CRD window was compared against 2,045 sorties with 12 mission classifications. The KC-10 Filtered Data Tables are located in Appendix C. Table 10 expresses the combined data for the KC-10 and Table 11 shows the dynamic data. The combined data shows 62% of the 2,045 sorties analyzed had a crew CRD through the parameters established, with Contingency, Coronet, and Channel sorties as the largest contributors to the KC-10's CRD. Dynamic data reveals 77% of Contingency, 58% of Coronets and 60% of Channel sorties with a CRD violation.

Table 10 – KC-10 Combined Data Table



	KC-10 Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
	Summed KC-10 Percentages	46%	17%	2%	60%	62%	3%	2045
	Mission Classifications							
BUSEFF	10XXX03 Cumulative	1%	0%	0%	1%	1%	0%	53
CHANNEL	10XXX04 Cumulative	5%	4%	0%	9%	9%	1%	298
CONTAR	10XXX05 Cumulative	0%	0%	0%	0%	0%	0%	2
CONTING	10XXX06 Cumulative	19%	7%	1%	24%	25%	2%	668
CORONET	10XXX07 Cumulative	12%	5%	1%	17%	18%	0%	621
DEPLOY	10XXX09 Cumulative	0%	0%	0%	0%	0%	0%	1
EXERCISE	10XXX10 Cumulative	0%	1%	0%	1%	1%	0%	25
JAATT	10XXX13 Cumulative	0%	0%	0%	0%	0%	0%	19
REFUEL	10XXX17 Cumulative	5%	0%	0%	5%	5%	0%	266
SAAM	10XXX18 Cumulative	0%	0%	0%	0%	0%	0%	7
SUPPORT	10XXX21 Cumulative	0%	0%	0%	1%	1%	0%	13
TRANSFER	10XXX23 Cumulative	2%	0%	0%	2%	2%	0%	72
Summed KC-10 Percentages	10XXX24 Cumulative	46%	17%	2%	60%	62%	3%	**2045**

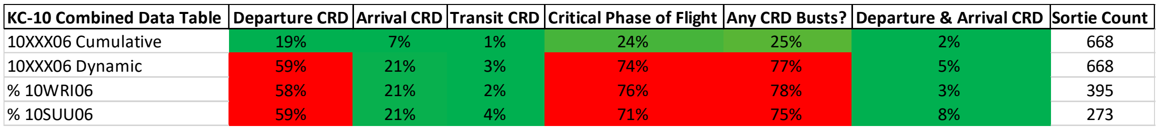
Table 11 – KC-10 Dynamic Data Table



	KC-10 Dynamic Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
	Dynamic Averages	46%	17%	2%	60%	62%	3%	2045
	Mission Classifications							
BUSEFF	10XXX03 Dynamic	49%	2%	0%	49%	49%	2%	53
CHANNEL	10XXX04 Dynamic	37%	26%	1%	58%	60%	5%	298
CONTAR	10XXX05 Dynamic	100%	0%	0%	100%	100%	0%	2
CONTING	10XXX06 Dynamic	59%	21%	3%	74%	77%	5%	668
CORONET	10XXX07 Dynamic	39%	17%	3%	55%	58%	1%	621
DEPLOY	10XXX09 Dynamic	100%	100%	0%	100%	100%	100%	1
EXERCISE	10XXX10 Dynamic	28%	44%	4%	72%	76%	0%	25
JAATT	10XXX13 Dynamic	37%	0%	0%	37%	37%	0%	19
REFUEL	10XXX17 Dynamic	36%	3%	0%	39%	39%	0%	266
SAAM	10XXX18 Dynamic	57%	0%	0%	57%	57%	0%	7
SUPPORT	10XXX21 Dynamic	77%	23%	8%	92%	100%	8%	13
TRANSFER	10XXX23 Dynamic	65%	0%	0%	65%	65%	0%	72
Mean KC-10 Percentages	10XXX24 Dynamic	46%	17%	2%	60%	62%	3%	**2045**

Contingency sorties had the highest CRD for the KC-10, contributing 25% of the total CRD, with Coronet sorties representing 18% of the CRD, and Channel sorties causing 9% of the total CRD. The dynamic data shows the breakout by mission classification (see Table 11), showing KC-10s have a 77% CRD violation for the 668 Contingency sorties, equating to 515 sorties impacted. Table 12 shows the Contingency sorties viewed at the base level, which shows a uniform spread of CRD, both above 75%.

Table 12 – KC-10 Contingency Data Table

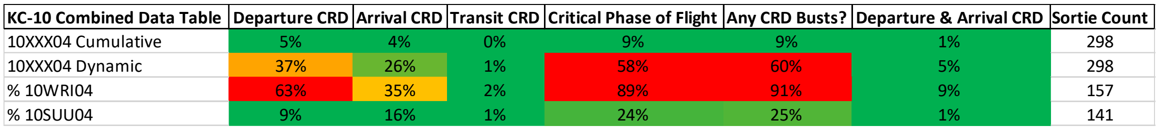


KC-10 Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
10XXX06 Cumulative	19%	7%	1%	24%	25%	2%	668
10XXX06 Dynamic	59%	21%	3%	74%	77%	5%	668
% 10WRI06	58%	21%	2%	76%	78%	3%	395
% 10SUU06	59%	21%	4%	71%	75%	8%	273

WRI and SUU both have Departure CRDs on almost 60% of the Contingency sorties, and 21% of their sorties have an Arrival CRD. A difference is that Table 12 shows SUU Departure & Arrival CRD for 8% of its Contingency sorties, compared to 3% for WRI.

The KC-10 data showed one of the largest disparities between the two bases when viewing Channel sorties at the base level. Table 13 highlights the KC-10 Channel sorties with relation to a CRD.

Table 13 – KC-10 Channel Data Table



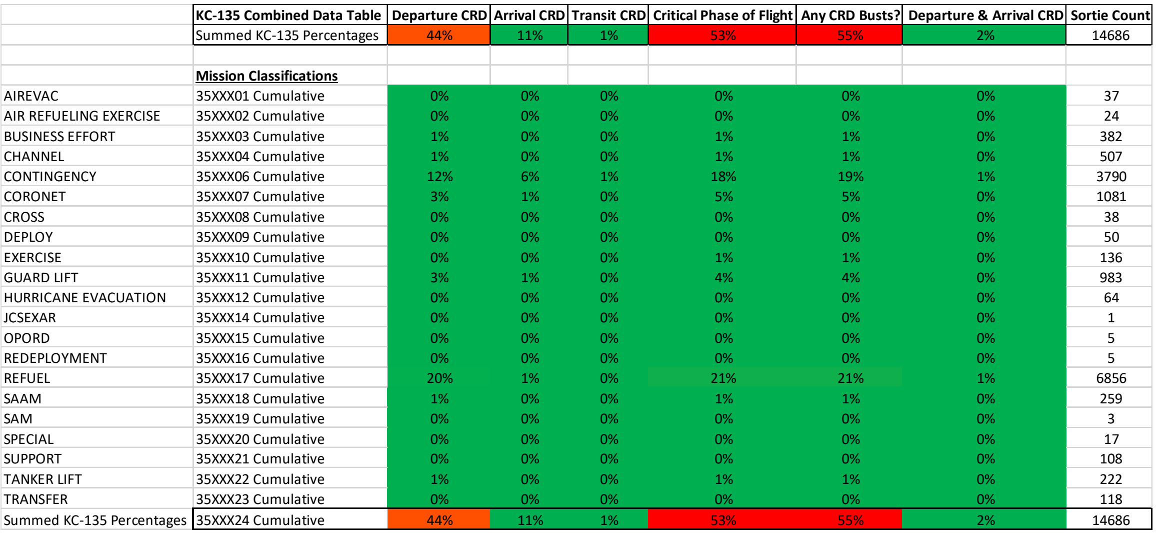
KC-10 Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
10XXX04 Cumulative	5%	4%	0%	9%	9%	1%	298
10XXX04 Dynamic	37%	26%	1%	58%	60%	5%	298
% 10WRI04	63%	35%	2%	89%	91%	9%	157
% 10SUU04	9%	16%	1%	24%	25%	1%	141

JB MDL (WRI) Channel sorties show a 91% CRD, meaning out of the 157 sorties, 143 sorties contained a CRD. Based on the assumptions and parameters for a CRD, WRI had a CRD on 63% of its departures and 35% of its arrivals. Table 13 also shows that 9% of the WRI Channel sorties had a departure and arrival during the same CRD window. To clarify, 9% of those Channel sorties had a takeoff and landing occur in the same sortie, while the crew was operating with a CRD violation.

KC-135 Workbook

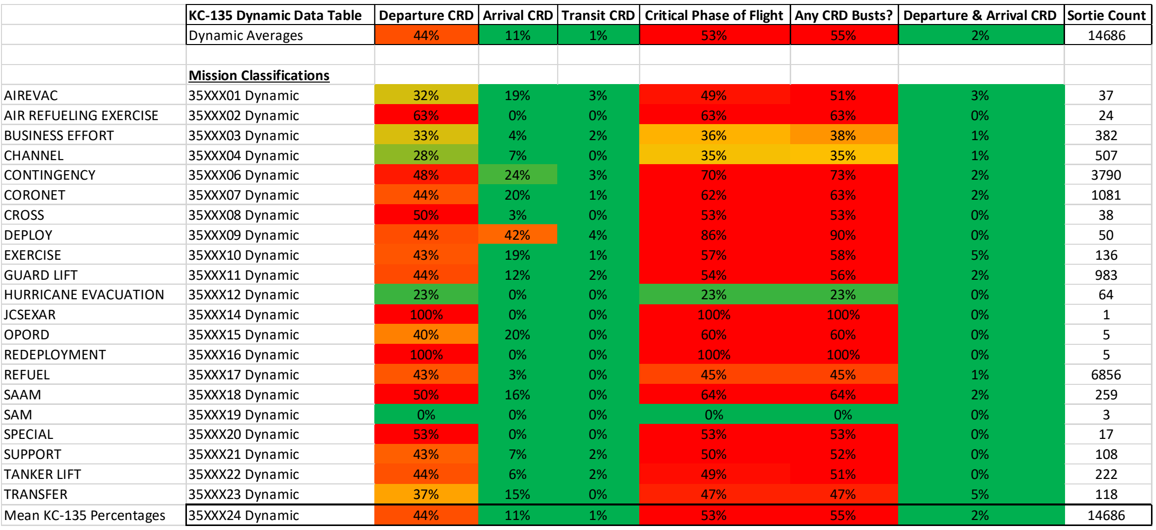
The KC-135 workbook sorted, filtered, and analyzed 29 bases. For each base a combined data table was created, then SKU tables were created for ease of data absorption. The CRD window was compared against 14,686 sorties with 21 mission classifications. The KC-135 Filtered Data Tables are in Appendix D. Table 14 contains the combined data table for the KC-135, it shows that 55% of the 14,686 sorties analyzed had a crew CRD, with the largest contributors being the Refuel and Contingency mission classifications. Using that 55% CRD, over 8,000 sorties could have been operated by crews with CRD. Table 15 shows the dynamic data for the KC-135, accenting how each of the mission classifications was affected by CRD.

Table 14 – KC-135 Combined Data Table



	KC-135 Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
	Summed KC-135 Percentages	44%	11%	1%	53%	55%	2%	14686
	Mission Classifications							
AIREVAC	35XXX01 Cumulative	0%	0%	0%	0%	0%	0%	37
AIR REFUELING EXERCISE	35XXX02 Cumulative	0%	0%	0%	0%	0%	0%	24
BUSINESS EFFORT	35XXX03 Cumulative	1%	0%	0%	1%	1%	0%	382
CHANNEL	35XXX04 Cumulative	1%	0%	0%	1%	1%	0%	507
CONTINGENCY	35XXX06 Cumulative	12%	6%	1%	18%	19%	1%	3790
CORONET	35XXX07 Cumulative	3%	1%	0%	5%	5%	0%	1081
CROSS	35XXX08 Cumulative	0%	0%	0%	0%	0%	0%	38
DEPLOY	35XXX09 Cumulative	0%	0%	0%	0%	0%	0%	50
EXERCISE	35XXX10 Cumulative	0%	0%	0%	1%	1%	0%	136
GUARD LIFT	35XXX11 Cumulative	3%	1%	0%	4%	4%	0%	983
HURRICANE EVACUATION	35XXX12 Cumulative	0%	0%	0%	0%	0%	0%	64
JCSEXAR	35XXX14 Cumulative	0%	0%	0%	0%	0%	0%	1
OPORD	35XXX15 Cumulative	0%	0%	0%	0%	0%	0%	5
REDEPLOYMENT	35XXX16 Cumulative	0%	0%	0%	0%	0%	0%	5
REFUEL	35XXX17 Cumulative	20%	1%	0%	21%	21%	1%	6856
SAAM	35XXX18 Cumulative	1%	0%	0%	1%	1%	0%	259
SAM	35XXX19 Cumulative	0%	0%	0%	0%	0%	0%	3
SPECIAL	35XXX20 Cumulative	0%	0%	0%	0%	0%	0%	17
SUPPORT	35XXX21 Cumulative	0%	0%	0%	0%	0%	0%	108
TANKER LIFT	35XXX22 Cumulative	1%	0%	0%	1%	1%	0%	222
TRANSFER	35XXX23 Cumulative	0%	0%	0%	0%	0%	0%	118
Summed KC-135 Percentages	35XXX24 Cumulative	44%	11%	1%	53%	55%	2%	14686

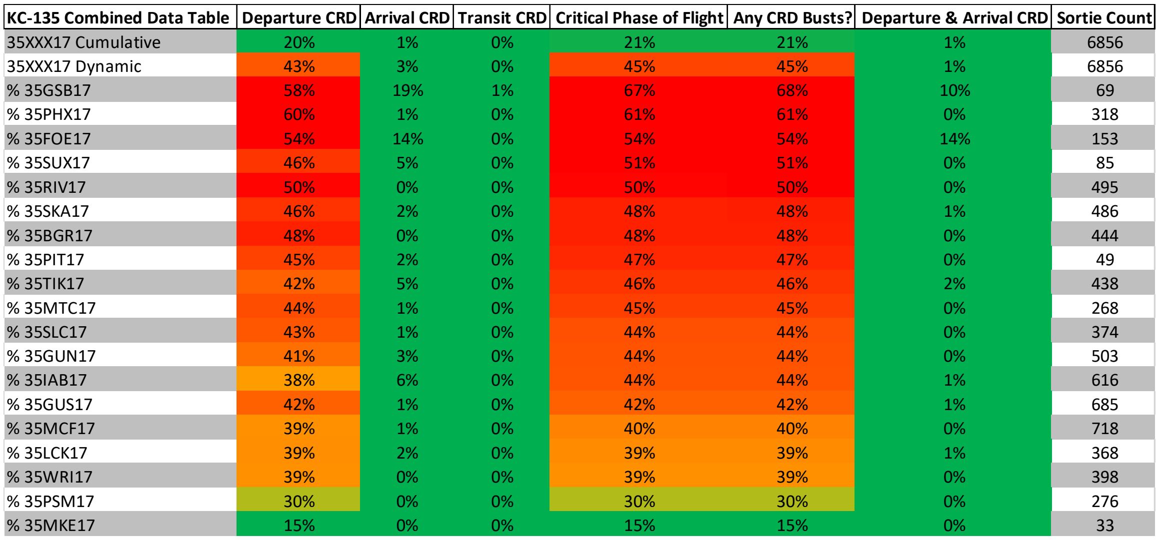
Table 15 – KC-135 Dynamic Data Table



	KC-135 Dynamic Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
	Dynamic Averages	44%	11%	1%	53%	55%	2%	14686
	Mission Classifications							
AIREVAC	35XXX01 Dynamic	32%	19%	3%	49%	51%	3%	37
AIR REFUELING EXERCISE	35XXX02 Dynamic	63%	0%	0%	63%	63%	0%	24
BUSINESS EFFORT	35XXX03 Dynamic	33%	4%	2%	36%	38%	1%	382
CHANNEL	35XXX04 Dynamic	28%	7%	0%	35%	35%	1%	507
CONTINGENCY	35XXX06 Dynamic	48%	24%	3%	70%	73%	2%	3790
CORONET	35XXX07 Dynamic	44%	20%	1%	62%	63%	2%	1081
CROSS	35XXX08 Dynamic	50%	3%	0%	53%	53%	0%	38
DEPLOY	35XXX09 Dynamic	44%	42%	4%	86%	90%	0%	50
EXERCISE	35XXX10 Dynamic	43%	19%	1%	57%	58%	5%	136
GUARD LIFT	35XXX11 Dynamic	44%	12%	2%	54%	56%	2%	983
HURRICANE EVACUATION	35XXX12 Dynamic	23%	0%	0%	23%	23%	0%	64
JCSEXAR	35XXX14 Dynamic	100%	0%	0%	100%	100%	0%	1
OPORD	35XXX15 Dynamic	40%	20%	0%	60%	60%	0%	5
REDEPLOYMENT	35XXX16 Dynamic	100%	0%	0%	100%	100%	0%	5
REFUEL	35XXX17 Dynamic	43%	3%	0%	45%	45%	1%	6856
SAAM	35XXX18 Dynamic	50%	16%	0%	64%	64%	2%	259
SAM	35XXX19 Dynamic	0%	0%	0%	0%	0%	0%	3
SPECIAL	35XXX20 Dynamic	53%	0%	0%	53%	53%	0%	17
SUPPORT	35XXX21 Dynamic	43%	7%	2%	50%	52%	0%	108
TANKER LIFT	35XXX22 Dynamic	44%	6%	2%	49%	51%	0%	222
TRANSFER	35XXX23 Dynamic	37%	15%	0%	47%	47%	5%	118
Mean KC-135 Percentages	35XXX24 Dynamic	44%	11%	1%	53%	55%	2%	14686

The KC-135 fleet had the largest spread of mission classifications and some GDSS2 mission classifications included less than 10 sorties for the fleet. This research kept the missions in the data for fleet wide statistics, but they were removed from individual bases when examining sorties with less than 30 occurrences. Table 14 shows 21% of the total CRD busts were from Refuel sorties and 19% of the total CRD busts came through Contingency sorties that violated CRD parameters. Table 15 clarifies that 45% of the 6,856 Refuel sorties and 73% of the 3,790 Contingency sorties contain CRD busts. The Refuel sorties had the largest sortie count and highest CRD, which Table 16 examines.

Table 16 – KC-135 Refuel Data Table



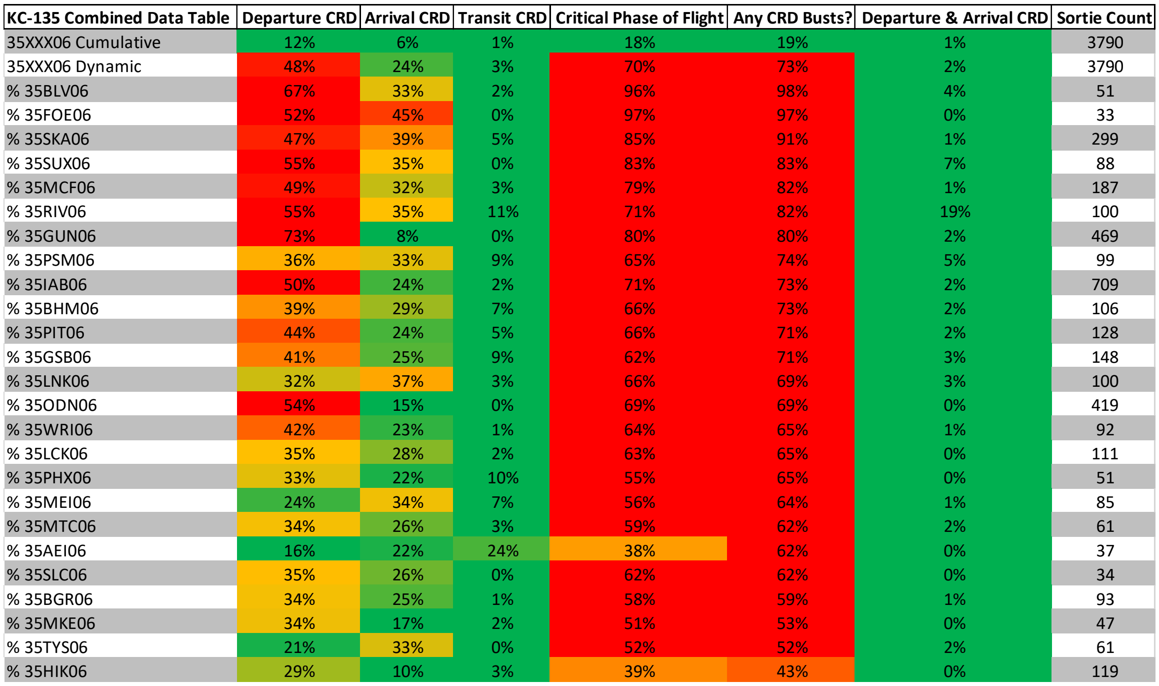
KC-135 Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
35XXX17 Cumulative	20%	1%	0%	21%	21%	1%	6856
35XXX17 Dynamic	43%	3%	0%	45%	45%	1%	6856
% 35GSB17	58%	19%	1%	67%	68%	10%	69
% 35PHX17	60%	1%	0%	61%	61%	0%	318
% 35FOE17	54%	14%	0%	54%	54%	14%	153
% 35SUX17	46%	5%	0%	51%	51%	0%	85
% 35RIV17	50%	0%	0%	50%	50%	0%	495
% 35SKA17	46%	2%	0%	48%	48%	1%	486
% 35BGR17	48%	0%	0%	48%	48%	0%	444
% 35PIT17	45%	2%	0%	47%	47%	0%	49
% 35TIK17	42%	5%	0%	46%	46%	2%	438
% 35MTC17	44%	1%	0%	45%	45%	0%	268
% 35SLC17	43%	1%	0%	44%	44%	0%	374
% 35GUN17	41%	3%	0%	44%	44%	0%	503
% 35IAB17	38%	6%	0%	44%	44%	1%	616
% 35GUS17	42%	1%	0%	42%	42%	1%	685
% 35MCF17	39%	1%	0%	40%	40%	0%	718
% 35LCK17	39%	2%	0%	39%	39%	1%	368
% 35WRI17	39%	0%	0%	39%	39%	0%	398
% 35PSM17	30%	0%	0%	30%	30%	0%	276
% 35MKE17	15%	0%	0%	15%	15%	0%	33

When reviewing Table 16, the data shows many bases at greater than a 40% CRD for Refuel sorties. A few bases had less than 30 sorties pertaining to the Refuel mission classification, so were removed from the tables. A majority of the CRD occurred during departure. Table 1 contains the SKU Legend for any unfamiliar ICAOs.

Contingency sorties accounted for almost 20% of the CRD for the KC-135. The Contingency sorties contributed 19% out of the 14,686 KC-135 CRD busts, which means they contained almost 3,000 total CRD busts. 3,790 sorties were examined as part of the Contingency mission classification and Table 17 examines the breakout of the Contingency sorties.

There is a high variability to the numbers of sorties flown per location in Table 17, with sorties ranging from 33 to a high-count of 709 out of IAB. The KC-135 Contingency sorties had the highest percentage of CRD busts across the largest cross-section of bases than any other examined MWS. The locations of BLV, FOE, and SKA each had CRD busts of greater than 90%, with BLV and FOE each having CRD window busts on departure for more than 50% of their sorties.

Table 17 – KC-135 Contingency Data Table

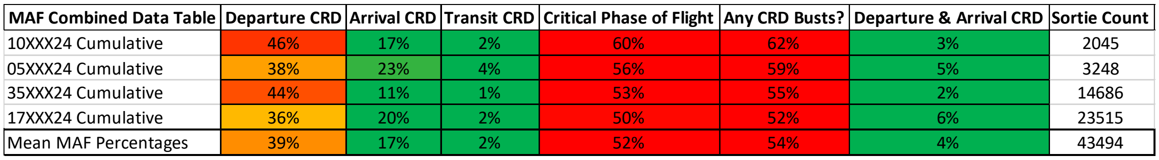


KC-135 Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
35XXX06 Cumulative	12%	6%	1%	18%	19%	1%	3790
35XXX06 Dynamic	48%	24%	3%	70%	73%	2%	3790
% 35BLV06	67%	33%	2%	96%	98%	4%	51
% 35FOE06	52%	45%	0%	97%	97%	0%	33
% 35SKA06	47%	39%	5%	85%	91%	1%	299
% 35SUX06	55%	35%	0%	83%	83%	7%	88
% 35MCF06	49%	32%	3%	79%	82%	1%	187
% 35RIV06	55%	35%	11%	71%	82%	19%	100
% 35GUN06	73%	8%	0%	80%	80%	2%	469
% 35PSM06	36%	33%	9%	65%	74%	5%	99
% 35IAB06	50%	24%	2%	71%	73%	2%	709
% 35BHM06	39%	29%	7%	66%	73%	2%	106
% 35PIT06	44%	24%	5%	66%	71%	2%	128
% 35GSB06	41%	25%	9%	62%	71%	3%	148
% 35LNK06	32%	37%	3%	66%	69%	3%	100
% 35ODN06	54%	15%	0%	69%	69%	0%	419
% 35WRI06	42%	23%	1%	64%	65%	1%	92
% 35LCK06	35%	28%	2%	63%	65%	0%	111
% 35PHX06	33%	22%	10%	55%	65%	0%	51
% 35MEI06	24%	34%	7%	56%	64%	1%	85
% 35MTC06	34%	26%	3%	59%	62%	2%	61
% 35AEI06	16%	22%	24%	38%	62%	0%	37
% 35SLC06	35%	26%	0%	62%	62%	0%	34
% 35BGR06	34%	25%	1%	58%	59%	1%	93
% 35MKE06	34%	17%	2%	51%	53%	0%	47
% 35TYS06	21%	33%	0%	52%	52%	2%	61
% 35HIK06	29%	10%	3%	39%	43%	0%	119

Combined Mobility Air Force's Data

As previously mentioned, the total count for scoped sorties that were examined was 43,494. The SKU creation and dynamic data availability enabled comparing the MAF on a fleet-wide scale for snapshots. The created tables also permitted cumulative data comparisons regarding affected sortie counts, CRD busts with base to MWS visibility, and the CRD breakouts for phases of flight. Table 18 combines the C-17, C-5, KC-10, and KC-135 data into a condensed view of the CRD in the MAF. When combined and averaged out, 54% of the 43,494 examined sorties were affected by circadian rhythm disruptions, showing more than 20,000 sorties across the MAF had a CRD violation. The KC-10 had the highest percent of CRD, with 62% of 2,045 sorties impacted, accounting for over 1,200 sorties. The MWS with the most CRD based on the parameters in the research, was the C-17, showing 52% of 23,515 sorties with CRD busts.

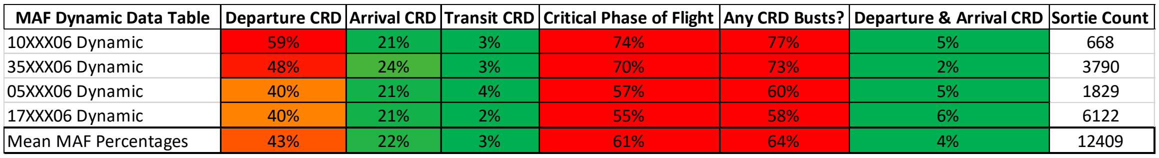
Table 18 – Mobility Air Force Combined Data Table



MAF Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
10XXX24 Cumulative	46%	17%	2%	60%	62%	3%	2045
05XXX24 Cumulative	38%	23%	4%	56%	59%	5%	3248
35XXX24 Cumulative	44%	11%	1%	53%	55%	2%	14686
17XXX24 Cumulative	36%	20%	2%	50%	52%	6%	23515
Mean MAF Percentages	39%	17%	2%	52%	54%	4%	43494

Contingency, and Channel mission classifications were consistently near the top of each MWS' CRD contributors. Table 19 provides dynamic combined data for Contingency sorties and Table 20 highlights the Channel sorties' CRD across the MAF. The data in Table 19 shows a 64% CRD for 12,409 sorties, insinuating that a CRD impacted almost 8,000 Contingency sorties in 2016. The KC-10 had a 77% CRD rate for 668 sorties. While the KC-135 had the second highest CRD rate for Contingency sorties at 73%, the number of sorties handled by the C-17, combined with its 58% CRD rate means that the C-17 had the highest number of Contingency sorties impacted by CRD.

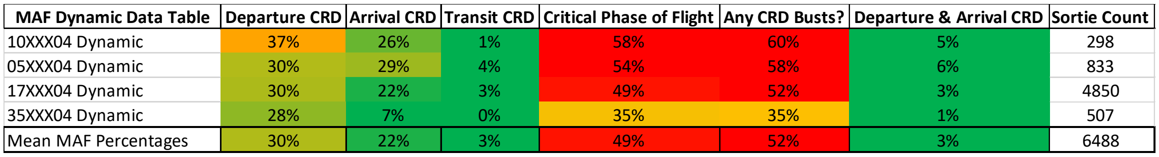
Table 19 – Mobility Air Force Dynamic Contingency Data



MAF Dynamic Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
10XXX06 Dynamic	59%	21%	3%	74%	77%	5%	668
35XXX06 Dynamic	48%	24%	3%	70%	73%	2%	3790
05XXX06 Dynamic	40%	21%	4%	57%	60%	5%	1829
17XXX06 Dynamic	40%	21%	2%	55%	58%	6%	6122
Mean MAF Percentages	43%	22%	3%	61%	64%	4%	12409

The CRD for Channel sorties averaged to 52% of the 6,488 sorties, meaning more than 3,000 sorties were operated inside the CRD window on Channel missions. The KC-10 shows the highest CRD rate, at 60% of 298 sorties and the C-17 shows 52% of 4,850 sorties impacted by CRD. The MWS specific Dynamic Data Tables are located in Appendix E.

Table 20 – Mobility Air Force Dynamic Channel Data



MAF Dynamic Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
10XXX04 Dynamic	37%	26%	1%	58%	60%	5%	298
05XXX04 Dynamic	30%	29%	4%	54%	58%	6%	833
17XXX04 Dynamic	30%	22%	3%	49%	52%	3%	4850
35XXX04 Dynamic	28%	7%	0%	35%	35%	1%	507
Mean MAF Percentages	30%	22%	3%	49%	52%	3%	6488

This research used a comparative analysis of enumeration to analyze the 2016 GDSS2 data across 4 MWS and attempted to provide a CRD discussion for senior leadership consideration. In-flight events such as specific air refueling, airdrop, or tactical events, which would increase operator fatigue, were not analyzed. KC-135 Refuel sorties were analyzed, but purely from a departure, arrival, and transit perspective, like Coronet sorties. A large contingent of C-17 sorties were removed from evaluation against the CRD windows, even though the data was available through GDSS2 because they were deployed assets, as previously discussed. Training, FCF, and air show sorties were also removed due to being controlled by the home station and not at the enterprise level.

V. Conclusions

This research attempts to inform and highlight to Senior Leaders the risks being accepted for the Mobility Air Force, specifically compared to circadian rhythm disruption and analyzed against various mission classifications. Although literature is not published discussing what enterprise-wide levels of fatigue risks are permitted, expected, and assumed, the results could be alarming if previously unknown or unaccounted for in overall MAF risk levels.

This research provides empirical research on the frequency of circadian rhythm disruptions for the major weapons systems in Air Mobility Command. Although fatigue research has been accomplished previously within the Air Force, no research to date has looked across different aircraft, mission sets, and established a model to indicate possible circadian rhythm disruptions for the entire MAJCOM. This model is based on the assumption that aircrews are on a sleep schedule and disruptions in-between 00:00 and 06:00 would create a circadian rhythm disruption. If this assumption is accurate, and circadian disruptions lead to decreased mental ability and reaction time, then the Air Force is taking considerable risk.

Further discussion is necessary to match the risk level to the priority of the mission. The next sections are broken down to further explore this research and are as follows: Senior Leader implications, mission classification tied to risk, MWS with propensity for a CRD, specific MWS basing/combinations, concluding remarks, and future research.

Senior Leader Implications

Using the data provided, Senior Leaders can have these important discussions with their staffs and action officers. Operators in the MAF will mitigate as many risks as possible while providing unparalleled support to allies and partners. It is understood that it is not reasonable or necessarily feasible to avoid all CRD, but a CRD should be part of the risk factors weighed against necessity.

An analysis of the procedures and processes currently used to assist crews in mitigating fatigue factors, weighed against the risk of mission accomplishment and failure, could incorporate circadian rhythm into the equation if it is currently not used. Relying solely on aircrews to inform C2 of personal fatigue levels through ORM has been proven to be risky (Federal Aviation Administration, 2010). When viewing results showing greater than 50% of sorties impacted by a CRD, perhaps it is time to reexamine current scheduling, operating, and fatigue policies in use. The Fatigue Risk Management System (FRMS) in use by many airlines could drastically reduce fatigue in the MAF. At a time when the Air Force is hemorrhaging experienced aviators to the airlines while looking to shorten the pilot training pipeline, some of the safeguards that have allowed the current operations tempo and parameters to succeed could be vacated.

It is understood that certain missions and priorities require mission completion with elevated levels of risk, but some mission classifications (such as Channel missions) could be a test of the FRMS. It could be and should be debated as to whether MAF missions should be planned through a contingency mindset, or if the time to transition to a planned sustainment mentality needs to occur. To be clear, military aviation differs from civilian aviation (airlines) when it comes to scheduling, flexibility, and operational necessity. The MAF would not be losing the capability to execute a Time Phased Force Deployment Data (TPFDD), rather it should be taking the time now to operate with planning and stability that enables a recharging of the force. It could be gleaned, that some of the ways civilian aviation is mitigating risk regarding fatigue could be implemented for many of the mission classifications that military operators are executing.

Senior Leaders should look at the CRD results and compare against their expected risks associated with specific mission classifications, if they are inconsistent then changes need to be made. The acceptable levels of risk associated with Channel missions should be presumed rather low, but 52% of the Channel sorties analyzed had a CRD for the aircrew (see Table 20). If operational necessity is dictating this type of execution plan, then Senior Leaders are at least aware of the risks, but if the risks are not matching the needs, then changes should be enacted.

Mission Classifications Tied to Risk

This researcher does not know what the Senior Leaders expected levels of risk for mission classifications are, but by looking at the dynamic and combined data tables for the MAF some high levels of risk are evident (see Table 18, Table 19, and Table 20). When examining the "Departure & Arrival CRD" columns, 4% of the 43,494 sorties had a takeoff and a landing during the CRD window, which lends to 1,779 of these dangerous sorties. Future research could examine these high-risk sorties against safety audits or the airplane's data tracking software for unsafe trends during the flight.

The Contingency missions analyzed and dynamically displayed in Table 19 highlight 64% of sorties as having a CRD, but dependent upon airframe, the KC-10s showed up to 77% of their sorties impacted by a CRD, to include 5% of their sorties containing “Departures & Arrival CRD” violations. It is worth reevaluating the risk intended for these missions and judging the operational necessity of the execution plan. The discussion in this paper is not whether missions should go by air or at all (a separate and equally valid discussion), but rather what risk should be taken for the mission classifications being examined.

Channel missions that were analyzed showed a 52% CRD, with a low of 35% CRD (KC-135) and a high of 60% (KC-10) (see Table 20). Many external factors could cause this, besides airfield hours, the proliferation of KC-135 bases (compared to the two KC-10 bases), and the destinations of the cargo. The mission classification for Channel sorties showed a 52% CRD, which was lower than the Contingency sortie CRD, but the general understanding of Channel and Contingency mission priorities would lend itself to that hypothesis. Channel missions are generally considered routine, pre-planned, and established. If that is the case, it would be expected that a much lower threshold for a CRD would be established.

MWS with Propensity for a CRD

Another discussion that should take place revolves around the MWS with the highest percent of CRD. When examining Table 18, it seems that all four MWS have greater than a 50% CRD, with the KC-10 and C-5 near 60%. The C-17 and KC-135 both have a lesser percentage, but because of the actual sortie counts of the C-17 and KC-135, they have the highest number of impacted sorties. A data point that quickly becomes visible through the analysis is the strategic alignment and basing of resources. The KC-10 and C-5 are relatively low-density assets, with a preponderance of forces located at main coastal hubs. The basing plan, combined with the long-legs afforded to the KC-10 and C-5 could prime them for an unnecessary CRD (based upon mission classification), without careful planning. This should not be taken as presuming the C-17 and KC-135 are being handled properly, to the contrary the sheer numbers of sorties impacted by a CRD should be distressing.

Specific MWS/Basing Combinations

After analyzing the data at the macro level of the MAF, to MWS, and then to locations, some combinations had a CRD rate worth highlighting even against the backdrop of an already elevated level of risk to the MAF.

An analysis of the C-5 Channel mission data set shows a large split in the CRD between Dover AFB and Travis AFB crews, with Dover AFB crews operating at a 70% CRD (see Table 9). The 45% Departure CRD for Dover AFB compared to the 19% Departure CRD for Travis AFB crews could provide an area for planners to examine. An examination of the Channel sorties flown by Dover AFB crews with a CRD highlighted a specific and repeated mission with vulnerabilities to a CRD. The crews start at KDOV (Dover AFB), fly to KWRI (JB MDL) for cargo on-loading and then operate477 a night-flight with quick-turn from EGUN (RAF Mildenhall) to ETAR (Ramstein AB). Once crew rest is completed at ETAR, the crews fly to and quick-turn EGUN, for a destination of KDOV. With a 70% CRD and a 7% "Departure & Arrival CRD" on Dover AFB C-5 Channel sorties, a large level of risk is being absorbed by Senior Leaders and aircrew for what should be considered routine missions to established bases.

While the C-5 Channels contained other locations, including into the USCENTCOM area of responsibility (AOR), the KC-10 data set had one of the more alarming results in the research. For the Channel mission classifications out of JB MDL, 91% of the sorties had a CRD, with a 9% "Departure & Arrival CRD" out of 157 sorties (see Table 13). Perhaps more surprising is that almost all the JB MDL Channel missions were the same as the Dover AFB missions the C-5 crews struggle with, minus the start or end legs at KDOV. When analyzing the specific EGUN to ETAR or ETAR to EGUN sorties, 53 out of the 54 occurrences contained a CRD. These numbers stood out for multiple reasons, the 91% was the highest CRD of any mission classification, MWS, and had greater than 30 repetitions.

Many factors can influence the times of day that crews are flying into and out of airfields, including airfield hours, bird-watch conditions, transient services, quiet-hours, but consistently having crews operate multiple legs with a CRD on established Channel sorties could be a risk that Senior Leaders should revisit.

Considering these CRD numbers are for routine and established missions, the way these missions are executed or prepared warrants an examination. While this paper did not examine the validity of Channel missions via other means besides military airlift, weekly missions with an elevated risk of CRD to multiple aircraft for established locations could lend themselves to a reexamination. A side-effect of this line of thinking would be the saving of military crews for actual missions requiring military expertise and risk, where civilian operations will not or simply cannot operate.

Closing Thoughts

A specific challenge with this research was ensuring the evaluation of data remained as unbiased and objective as possible, otherwise whatever data was produced could be dismissed. Steps taken to lend credibility to the analysis included shrinking the generally allotted 8-hour sleep window to only 6-hours to account for variations in individuals, while still capturing the important early morning trough for circadian rhythm disruption. If it was determined that crews did not operate on a standardized home station circadian rhythm, they were removed from the data, such as the C-17 crews deployed to Southwest Asia.

Training sorties were removed because their controlling authority for departure and arrivals is through home station and there are specific training requirements that only night-time sorties can accomplish, which generally would have caused a CRD bust. Even on day-time sorties, the first launch of the day would usually result in crews being alerted inside the 0000-0600 CRD windows. While not analyzed in this paper, analyzing early morning and late-night training sorties could lend itself to compelling CRD discussions.

Many assumptions were required to provide scope and feasibility for comparative analysis of the data, even if there is disagreement on all the assumptions, the results of the data analysis could and probably should warrant a discussion. Using the stated assumptions and data provided by AMC/A9, this research was able to enumerate and analyze a large section of Mobility Air Force operations for 2016. By analyzing not only the percent of CRD for the MAF, but also at how that translates into actual sorties, a compelling argument for a discussion of planning, procedures, and acceptable levels of risk has hopefully been created. With 43,494 sorties scoped, filtered, enumerated, and then compared to home station CRD windows it was determined that over 20,000 MAF sorties were impacted.

When this researcher chose to use conditional formatting, one of the areas that could be overlooked is the column of sorties containing a departure and an arrival bust due to the crew operating in their CRD windows. They would not generally highlight as anything other than green, because of the 20% required to begin shifting colors. The formatting was intentionally left at the original gates of 20%, 35%, and 50% to keep the tables uniform and clear. When the dynamic or cumulative tables are evaluated for the Departure & Arrival CRD busts against total sortie counts, there are 5% of 3,248 (C-5), 3% of 2,045 (KC-10), 6% of 23,515 (C-17), and 2% of 14,686 (KC-135) sorties possibly affected. When converted to numbers of sorties operating in this zone, over 1,700 sorties are impacted by crews operating aircraft in their CRD window and doing two separate critical phases of flight. These are physically and mentally demanding sorties, as backed up by literature review regarding task saturation, cognitive impairment, and reaction time impairment from CRD.

Fatigue and circadian rhythm disruption should be viewed by Senior Leaders through the lens of risk. Mission classifications should be given appropriate risk-levels and the CRD of aircrews should be a weighted factor. With the preponderance of the MAF-wide CRD, it would appear that it is not currently used in the planning or execution processes. Some mission classifications may lend themselves to an FRMS framework for operations, which would ease scheduling burden and drastically mitigate fatigue risk from C2, home stations, and aircrew perspectives. Analysis of the 2016 GDSS2 sortie list showed that over 20,000 sorties were impacted by a CRD, for Senior Leaders that should be an alarming call to action.

Overarching Problem Statement

This researcher had a goal of providing Senior Leaders with information regarding the diffusion of circadian rhythm disruption throughout the MAF (four MWS). By understanding another variable in the risk equation of mobility operations, decision-makers could have a better understanding of the accepted levels of risk during the execution of various missions. A large set of data was scoped down into separate MWS, mission classifications, and CRD categories, with the goal of this researcher to arm the decision makers with enough evidence to make informed and accurate decisions regarding acceptable levels of risk for the MAF. The data showed 54% of MAF sorties for 2016 had a CRD, unmitigated, over 20,000 sorties were at risk for CRD.

Future Research Considerations

During the accomplishment of data analysis, other avenues for research were discovered, but due to time constraints and scope not pursued in this paper. Possible areas for future research include:

Is there a correlation between a CRD and an MFOQA or LOSA violation?

Does the data change if other in-flight activities are added to the analysis, for example, refueling or tactics?

How severe are the CRD violations and is a departure more serious than an arrival violation, for example, are crews landing within 30 minutes of their arrival CRD window or at the very end of it?

What is are the hours of wakefulness associated with missions? If body clocks naturally wake crews at 0600, how long from 0600 until eventual sortie land time have they been awake?

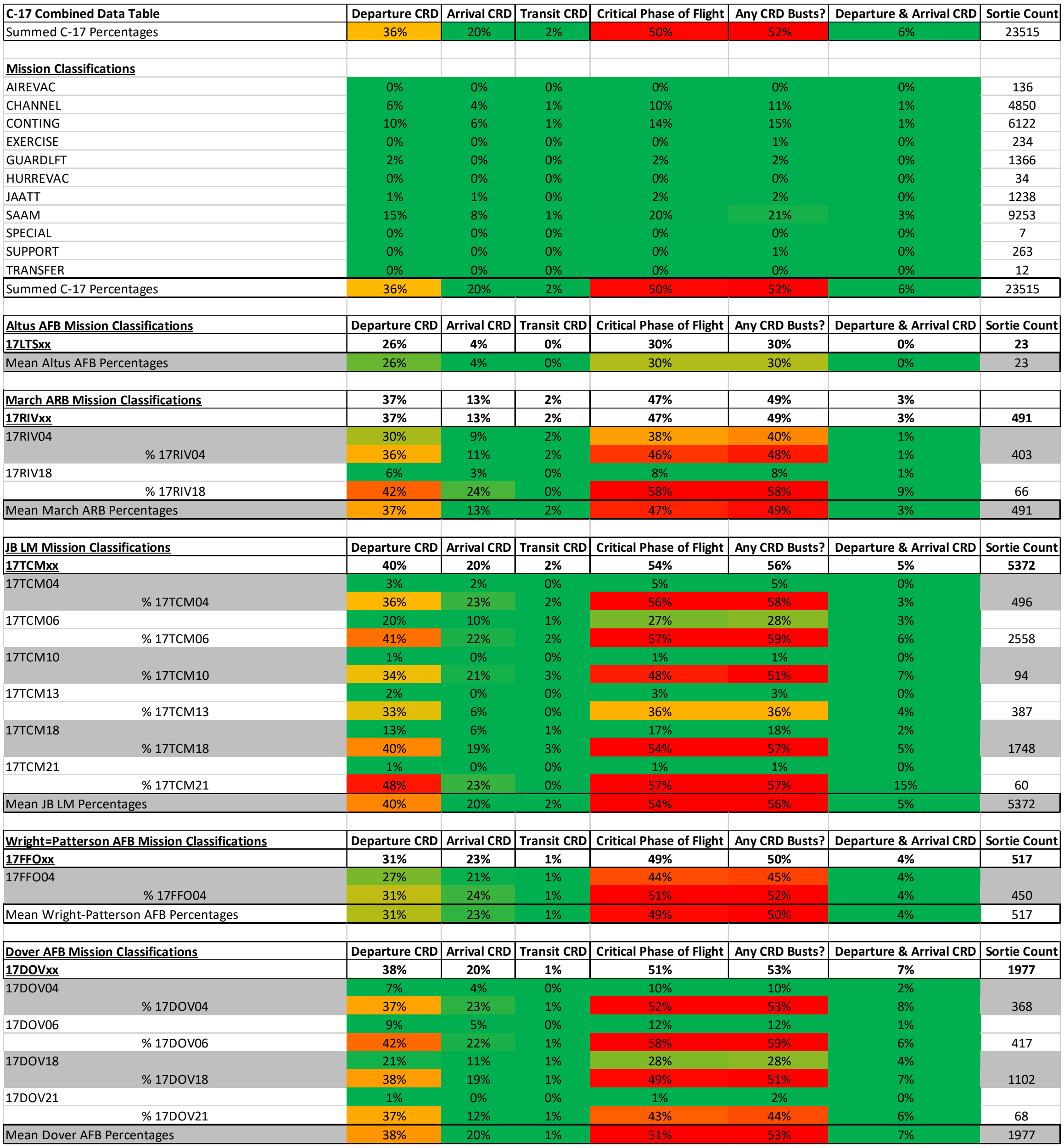
Should ORM categories for show time and health/fatigue levels be updated to include newer guidance and are crews themselves always the best determinants of their own fatigue?

How much ground time should crews be afforded after crossing multiple time zones to effectively reduce or combat CRD?

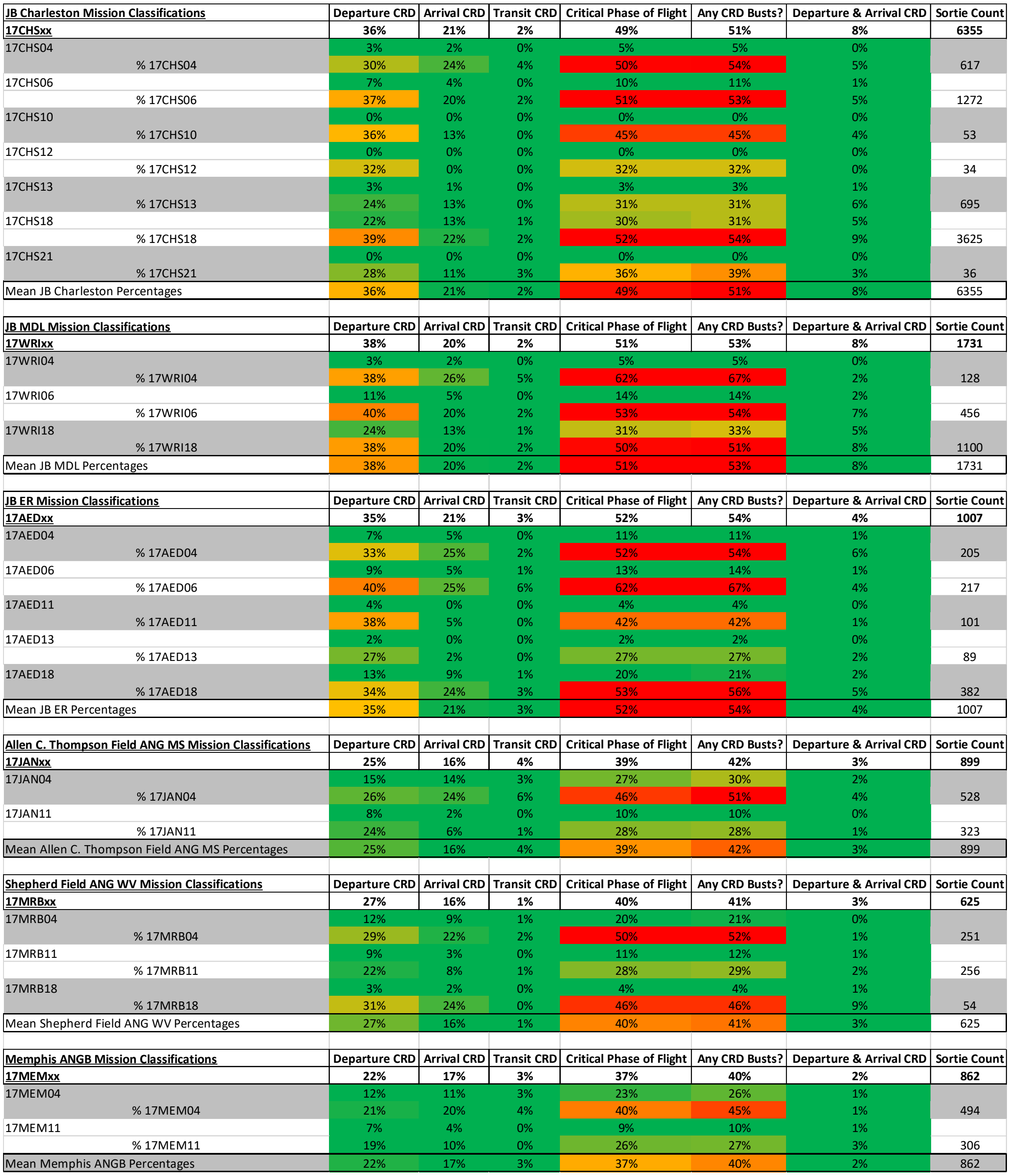
Taking a smaller subset of the data, such as Channel missions, how could operating procedures be changed to reduce the CRD levels amongst MAF crews?

This research examined data from a mission classification perspective, perhaps a *different way would be based on JCS mission priorities and whether they are still valid means of determining military versus civilian logistics.*

Appendix A – C-17 Data



C-17 Combined Data Table	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
Summed C-17 Percentages	36%	20%	2%	50%	52%	6%	23515
Mission Classifications							
AIREVAC	0%	0%	0%	0%	0%	0%	136
CHANNEL	6%	4%	1%	10%	11%	1%	4850
CONTING	10%	6%	1%	14%	15%	1%	6122
EXERCISE	0%	0%	0%	0%	1%	0%	234
GUARDLFT	2%	0%	0%	2%	2%	0%	1366
HURREVAC	0%	0%	0%	0%	0%	0%	34
JAATT	1%	1%	0%	2%	2%	0%	1238
SAAM	15%	8%	1%	20%	21%	3%	9253
SPECIAL	0%	0%	0%	0%	0%	0%	7
SUPPORT	0%	0%	0%	0%	1%	0%	263
TRANSFER	0%	0%	0%	0%	0%	0%	12
Summed C-17 Percentages	36%	20%	2%	50%	52%	6%	23515
Altus AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17LTSxx	**26%**	**4%**	**0%**	**30%**	**30%**	**0%**	**23**
Mean Altus AFB Percentages	26%	4%	0%	30%	30%	0%	23
March ARB Mission Classifications	**37%**	**13%**	**2%**	**47%**	**49%**	**3%**	
17RIVxx	**37%**	**13%**	**2%**	**47%**	**49%**	**3%**	**491**
17RIV04	30%	9%	2%	38%	40%	1%	
% 17RIV04	36%	11%	2%	46%	48%	1%	403
17RIV18	6%	3%	0%	8%	8%	1%	
% 17RIV18	42%	24%	0%	58%	58%	9%	66
Mean March ARB Percentages	37%	13%	2%	47%	49%	3%	491
JB LM Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17TCMxx	**40%**	**20%**	**2%**	**54%**	**56%**	**5%**	**5372**
17TCM04	3%	2%	0%	5%	5%	0%	
% 17TCM04	36%	23%	2%	56%	58%	3%	496
17TCM06	20%	10%	1%	27%	28%	3%	
% 17TCM06	41%	22%	2%	57%	59%	6%	2558
17TCM10	1%	0%	0%	1%	1%	0%	
% 17TCM10	34%	21%	3%	48%	51%	7%	94
17TCM13	2%	0%	0%	3%	3%	0%	
% 17TCM13	33%	6%	0%	36%	36%	4%	387
17TCM18	13%	6%	1%	17%	18%	2%	
% 17TCM18	40%	19%	3%	54%	57%	5%	1748
17TCM21	1%	0%	0%	1%	1%	0%	
% 17TCM21	48%	23%	0%	57%	57%	15%	60
Mean JB LM Percentages	40%	20%	2%	54%	56%	5%	5372
Wright=Patterson AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17FFOxx	**31%**	**23%**	**1%**	**49%**	**50%**	**4%**	**517**
17FFO04	27%	21%	1%	44%	45%	4%	
% 17FFO04	31%	24%	1%	51%	52%	4%	450
Mean Wright-Patterson AFB Percentages	31%	23%	1%	49%	50%	4%	517
Dover AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17DOVxx	**38%**	**20%**	**1%**	**51%**	**53%**	**7%**	**1977**
17DOV04	7%	4%	0%	10%	10%	2%	
% 17DOV04	37%	23%	1%	52%	53%	8%	368
17DOV06	9%	5%	0%	12%	12%	1%	
% 17DOV06	42%	22%	1%	58%	59%	6%	417
17DOV18	21%	11%	1%	28%	28%	4%	
% 17DOV18	38%	19%	1%	49%	51%	7%	1102
17DOV21	1%	0%	0%	1%	2%	0%	
% 17DOV21	37%	12%	1%	43%	44%	6%	68
Mean Dover AFB Percentages	38%	20%	1%	51%	53%	7%	1977



JB Charleston Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17CHSxx	**36%**	**21%**	**2%**	**49%**	**51%**	**8%**	**6355**
17CHS04	3%	2%	0%	5%	5%	0%	
% 17CHS04	30%	24%	4%	50%	54%	5%	617
17CHS06	7%	4%	0%	10%	11%	1%	
% 17CHS06	37%	20%	2%	51%	53%	5%	1272
17CHS10	0%	0%	0%	0%	0%	0%	
% 17CHS10	36%	13%	0%	45%	45%	4%	53
17CHS12	0%	0%	0%	0%	0%	0%	
% 17CHS12	32%	0%	0%	32%	32%	0%	34
17CHS13	3%	1%	0%	3%	3%	1%	
% 17CHS13	24%	13%	0%	31%	31%	6%	695
17CHS18	22%	13%	1%	30%	31%	5%	
% 17CHS18	39%	22%	2%	52%	54%	9%	3625
17CHS21	0%	0%	0%	0%	0%	0%	
% 17CHS21	28%	11%	3%	36%	39%	3%	36
Mean JB Charleston Percentages	36%	21%	2%	49%	51%	8%	6355

JB MDL Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17WRIxx	**38%**	**20%**	**2%**	**51%**	**53%**	**8%**	**1731**
17WRI04	3%	2%	0%	5%	5%	0%	
% 17WRI04	38%	26%	5%	62%	67%	2%	128
17WRI06	11%	5%	0%	14%	14%	2%	
% 17WRI06	40%	20%	2%	53%	54%	7%	456
17WRI18	24%	13%	1%	31%	33%	5%	
% 17WRI18	38%	20%	2%	50%	51%	8%	1100
Mean JB MDL Percentages	38%	20%	2%	51%	53%	8%	1731

JB ER Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17AEDxx	**35%**	**21%**	**3%**	**52%**	**54%**	**4%**	**1007**
17AED04	7%	5%	0%	11%	11%	1%	
% 17AED04	33%	25%	2%	52%	54%	6%	205
17AED06	9%	5%	1%	13%	14%	1%	
% 17AED06	40%	25%	6%	62%	67%	4%	217
17AED11	4%	0%	0%	4%	4%	0%	
% 17AED11	38%	5%	0%	42%	42%	1%	101
17AED13	2%	0%	0%	2%	2%	0%	
% 17AED13	27%	2%	0%	27%	27%	2%	89
17AED18	13%	9%	1%	20%	21%	2%	
% 17AED18	34%	24%	3%	53%	56%	5%	382
Mean JB ER Percentages	35%	21%	3%	52%	54%	4%	1007

Allen C. Thompson Field ANG MS Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17JANxx	**25%**	**16%**	**4%**	**39%**	**42%**	**3%**	**899**
17JAN04	15%	14%	3%	27%	30%	2%	
% 17JAN04	26%	24%	6%	46%	51%	4%	528
17JAN11	8%	2%	0%	10%	10%	0%	
% 17JAN11	24%	6%	1%	28%	28%	1%	323
Mean Allen C. Thompson Field ANG MS Percentages	25%	16%	4%	39%	42%	3%	899

Shepherd Field ANG WV Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17MRBxx	**27%**	**16%**	**1%**	**40%**	**41%**	**3%**	**625**
17MRB04	12%	9%	1%	20%	21%	0%	
% 17MRB04	29%	22%	2%	50%	52%	1%	251
17MRB11	9%	3%	0%	11%	12%	1%	
% 17MRB11	22%	8%	1%	28%	29%	2%	256
17MRB18	3%	2%	0%	4%	4%	1%	
% 17MRB18	31%	24%	0%	46%	46%	9%	54
Mean Shepherd Field ANG WV Percentages	27%	16%	1%	40%	41%	3%	625

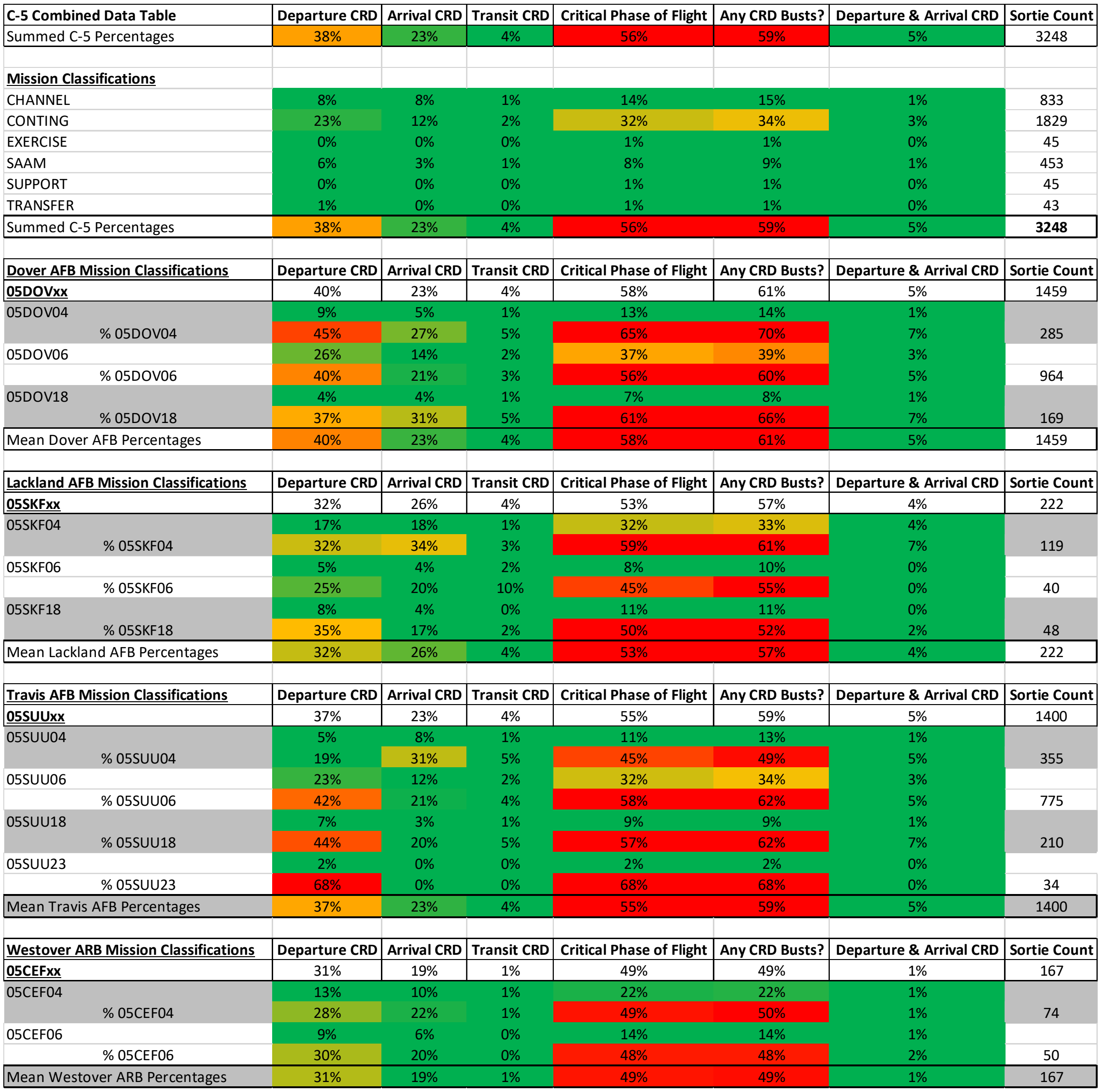
Memphis ANGB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17MEMxx	**22%**	**17%**	**3%**	**37%**	**40%**	**2%**	**862**
17MEM04	12%	11%	3%	23%	26%	1%	
% 17MEM04	21%	20%	4%	40%	45%	1%	494
17MEM11	7%	4%	0%	9%	10%	1%	
% 17MEM11	19%	10%	0%	26%	27%	3%	306
Mean Memphis ANGB Percentages	22%	17%	3%	37%	40%	2%	862

JB PHH Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17HIKxx	**35%**	**20%**	**5%**	**50%**	**56%**	**4%**	**1089**
17HIK04	6%	5%	0%	10%	10%	1%	
% 17HIK04	30%	25%	2%	52%	54%	3%	210
17HIK06	7%	4%	1%	10%	11%	1%	
% 17HIK06	38%	23%	3%	54%	57%	6%	208
17HIK11	8%	1%	0%	8%	8%	1%	
% 17HIK11	48%	8%	0%	51%	51%	6%	170
17HIK13	1%	0%	0%	1%	1%	0%	
% 17HIK13	30%	8%	3%	35%	38%	3%	37
17HIK18	12%	9%	4%	20%	24%	1%	
% 17HIK18	30%	22%	10%	48%	58%	4%	446
Mean JB PHH Percentages	35%	20%	5%	50%	56%	4%	1089

Stewart ANGB NY Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17SWFxx	**27%**	**16%**	**3%**	**41%**	**44%**	**2%**	**821**
17SWF04	15%	12%	2%	26%	29%	1%	
% 17SWF04	25%	19%	4%	42%	46%	1%	511
17SWF11	7%	3%	0%	9%	9%	1%	
% 17SWF11	27%	10%	1%	35%	36%	2%	210
17SWF18	3%	0%	0%	3%	4%	0%	
% 17SWF18	40%	6%	2%	45%	47%	2%	62
Mean Stewart ANGB NY Percentages	27%	16%	3%	41%	44%	2%	821

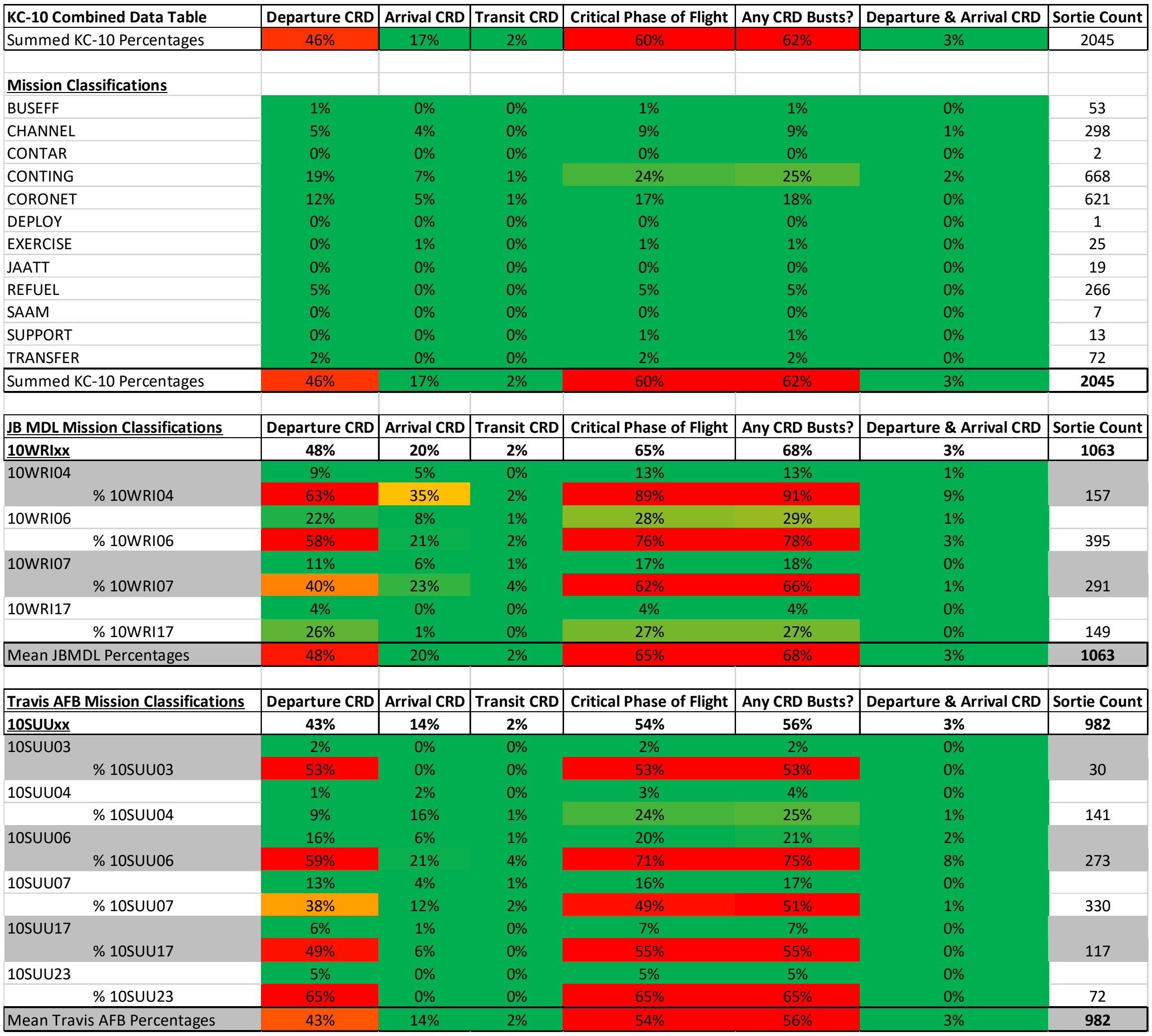
Travis AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
17SUUxx	**38%**	**20%**	**3%**	**53%**	**56%**	**5%**	**1746**
17SUU04	3%	2%	0%	5%	5%	0%	
% 17SUU04	28%	21%	3%	47%	50%	2%	187
17SUU06	20%	11%	2%	28%	30%	3%	
% 17SUU06	39%	21%	3%	55%	58%	5%	884
17SUU18	14%	6%	1%	18%	19%	1%	
% 17SUU18	39%	17%	3%	52%	55%	4%	620
Mean Travis AFB Percentages	38%	20%	3%	53%	56%	5%	1746

Appendix B – C-5 Data



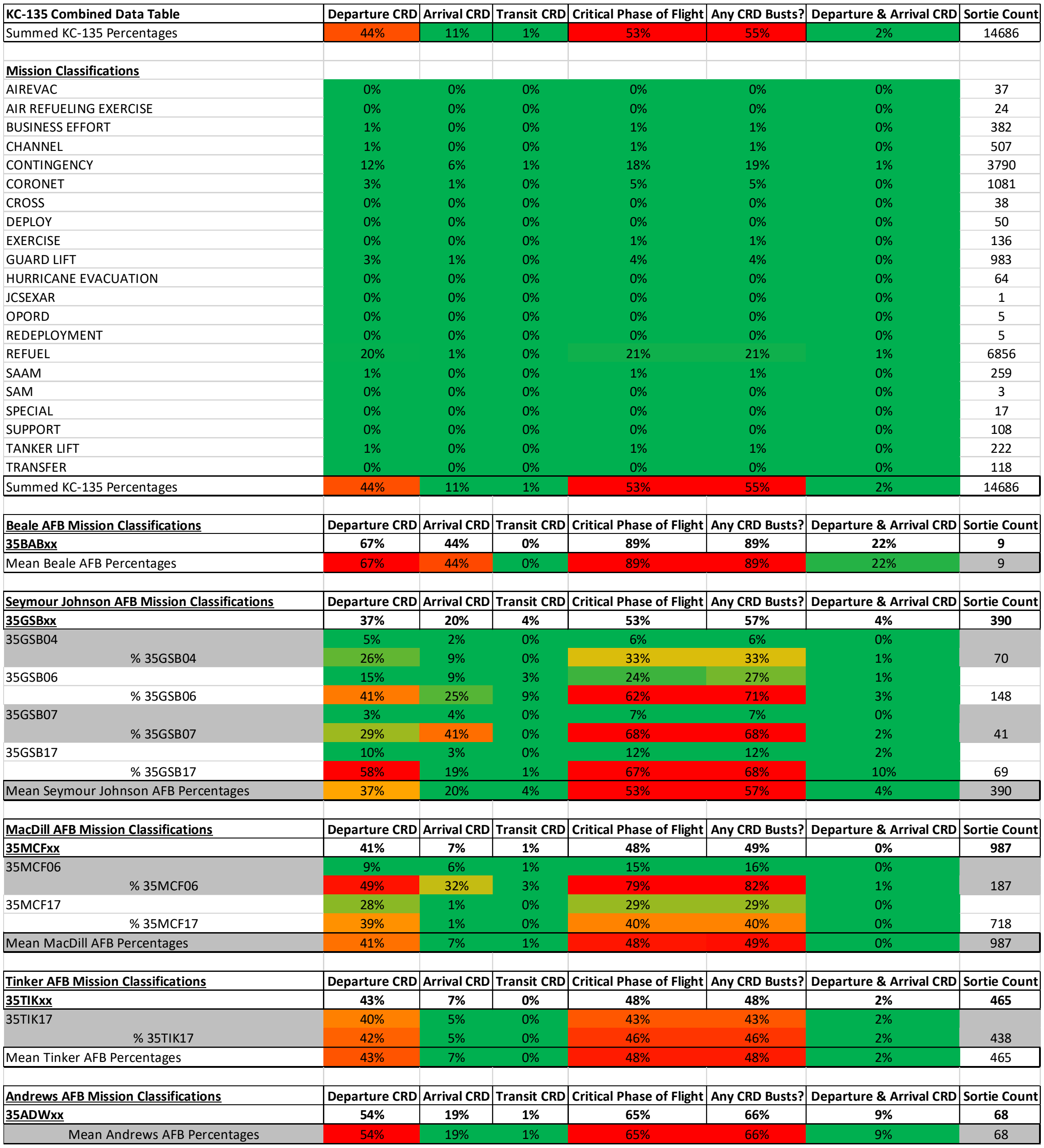
C-5 Combined Data Table	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
Summed C-5 Percentages	38%	23%	4%	56%	59%	5%	3248
Mission Classifications							
CHANNEL	8%	8%	1%	14%	15%	1%	833
CONTING	23%	12%	2%	32%	34%	3%	1829
EXERCISE	0%	0%	0%	1%	1%	0%	45
SAAM	6%	3%	1%	8%	9%	1%	453
SUPPORT	0%	0%	0%	1%	1%	0%	45
TRANSFER	1%	0%	0%	1%	1%	0%	43
Summed C-5 Percentages	38%	23%	4%	56%	59%	5%	**3248**
Dover AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
05DOVxx	40%	23%	4%	58%	61%	5%	1459
05DOV04	9%	5%	1%	13%	14%	1%	
% 05DOV04	45%	27%	5%	65%	70%	7%	285
05DOV06	26%	14%	2%	37%	39%	3%	
% 05DOV06	40%	21%	3%	56%	60%	5%	964
05DOV18	4%	4%	1%	7%	8%	1%	
% 05DOV18	37%	31%	5%	61%	66%	7%	169
Mean Dover AFB Percentages	40%	23%	4%	58%	61%	5%	1459
Lackland AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
05SKFxx	32%	26%	4%	53%	57%	4%	222
05SKF04	17%	18%	1%	32%	33%	4%	
% 05SKF04	32%	34%	3%	59%	61%	7%	119
05SKF06	5%	4%	2%	8%	10%	0%	
% 05SKF06	25%	20%	10%	45%	55%	0%	40
05SKF18	8%	4%	0%	11%	11%	0%	
% 05SKF18	35%	17%	2%	50%	52%	2%	48
Mean Lackland AFB Percentages	32%	26%	4%	53%	57%	4%	222
Travis AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
05SUUxx	37%	23%	4%	55%	59%	5%	1400
05SUU04	5%	8%	1%	11%	13%	1%	
% 05SUU04	19%	31%	5%	45%	49%	5%	355
05SUU06	23%	12%	2%	32%	34%	3%	
% 05SUU06	42%	21%	4%	58%	62%	5%	775
05SUU18	7%	3%	1%	9%	9%	1%	
% 05SUU18	44%	20%	5%	57%	62%	7%	210
05SUU23	2%	0%	0%	2%	2%	0%	
% 05SUU23	68%	0%	0%	68%	68%	0%	34
Mean Travis AFB Percentages	37%	23%	4%	55%	59%	5%	1400
Westover ARB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
05CEFxx	31%	19%	1%	49%	49%	1%	167
05CEF04	13%	10%	1%	22%	22%	1%	
% 05CEF04	28%	22%	1%	49%	50%	1%	74
05CEF06	9%	6%	0%	14%	14%	1%	
% 05CEF06	30%	20%	0%	48%	48%	2%	50
Mean Westover ARB Percentages	31%	19%	1%	49%	49%	1%	167

Appendix C – KC-10 Data

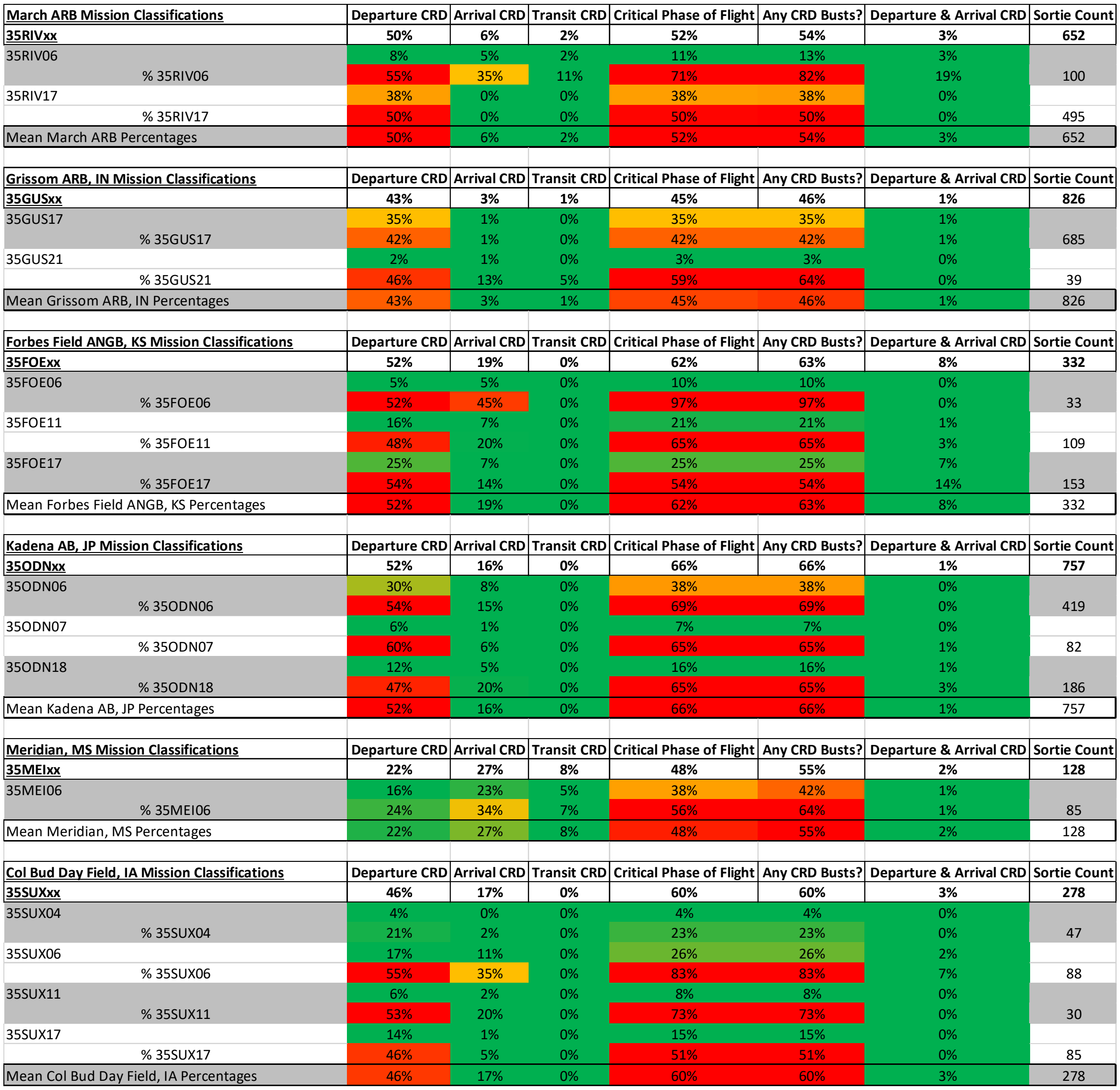


KC-10 Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
Summed KC-10 Percentages	46%	17%	2%	60%	62%	3%	2045
Mission Classifications							
BUSEFF	1%	0%	0%	1%	1%	0%	53
CHANNEL	5%	4%	0%	9%	9%	1%	298
CONTAR	0%	0%	0%	0%	0%	0%	2
CONTING	19%	7%	1%	24%	25%	2%	668
CORONET	12%	5%	1%	17%	18%	0%	621
DEPLOY	0%	0%	0%	0%	0%	0%	1
EXERCISE	0%	1%	0%	1%	1%	0%	25
JAATT	0%	0%	0%	0%	0%	0%	19
REFUEL	5%	0%	0%	5%	5%	0%	266
SAAM	0%	0%	0%	0%	0%	0%	7
SUPPORT	0%	0%	0%	1%	1%	0%	13
TRANSFER	2%	0%	0%	2%	2%	0%	72
Summed KC-10 Percentages	46%	17%	2%	60%	62%	3%	**2045**
JB MDL Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
10WRIxx	**48%**	**20%**	**2%**	**65%**	**68%**	**3%**	**1063**
10WRI04	9%	5%	0%	13%	13%	1%	
% 10WRI04	63%	35%	2%	89%	91%	9%	157
10WRI06	22%	8%	1%	28%	29%	1%	
% 10WRI06	58%	21%	2%	76%	78%	3%	395
10WRI07	11%	6%	1%	17%	18%	0%	
% 10WRI07	40%	23%	4%	62%	66%	1%	291
10WRI17	4%	0%	0%	4%	4%	0%	
% 10WRI17	26%	1%	0%	27%	27%	0%	149
Mean JBMDL Percentages	48%	20%	2%	65%	68%	3%	**1063**
Travis AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
10SUUxx	**43%**	**14%**	**2%**	**54%**	**56%**	**3%**	**982**
10SUU03	2%	0%	0%	2%	2%	0%	
% 10SUU03	53%	0%	0%	53%	53%	0%	30
10SUU04	1%	2%	0%	3%	4%	0%	
% 10SUU04	9%	16%	1%	24%	25%	1%	141
10SUU06	16%	6%	1%	20%	21%	2%	
% 10SUU06	59%	21%	4%	71%	75%	8%	273
10SUU07	13%	4%	1%	16%	17%	0%	
% 10SUU07	38%	12%	2%	49%	51%	1%	330
10SUU17	6%	1%	0%	7%	7%	0%	
% 10SUU17	49%	6%	0%	55%	55%	0%	117
10SUU23	5%	0%	0%	5%	5%	0%	
% 10SUU23	65%	0%	0%	65%	65%	0%	72
Mean Travis AFB Percentages	43%	14%	2%	54%	56%	3%	**982**

Appendix D – KC-135 Data



KC-135 Combined Data Table	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
Summed KC-135 Percentages	44%	11%	1%	53%	55%	2%	14686
Mission Classifications							
AIREVAC	0%	0%	0%	0%	0%	0%	37
AIR REFUELING EXERCISE	0%	0%	0%	0%	0%	0%	24
BUSINESS EFFORT	1%	0%	0%	1%	1%	0%	382
CHANNEL	1%	0%	0%	1%	1%	0%	507
CONTINGENCY	12%	6%	1%	18%	19%	1%	3790
CORONET	3%	1%	0%	5%	5%	0%	1081
CROSS	0%	0%	0%	0%	0%	0%	38
DEPLOY	0%	0%	0%	0%	0%	0%	50
EXERCISE	0%	0%	0%	1%	1%	0%	136
GUARD LIFT	3%	1%	0%	4%	4%	0%	983
HURRICANE EVACUATION	0%	0%	0%	0%	0%	0%	64
JCSEXAR	0%	0%	0%	0%	0%	0%	1
OPORD	0%	0%	0%	0%	0%	0%	5
REDEPLOYMENT	0%	0%	0%	0%	0%	0%	5
REFUEL	20%	1%	0%	21%	21%	1%	6856
SAAM	1%	0%	0%	1%	1%	0%	259
SAM	0%	0%	0%	0%	0%	0%	3
SPECIAL	0%	0%	0%	0%	0%	0%	17
SUPPORT	0%	0%	0%	0%	0%	0%	108
TANKER LIFT	1%	0%	0%	1%	1%	0%	222
TRANSFER	0%	0%	0%	0%	0%	0%	118
Summed KC-135 Percentages	44%	11%	1%	53%	55%	2%	14686
Beale AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35BABxx	**67%**	**44%**	**0%**	**89%**	**89%**	**22%**	**9**
Mean Beale AFB Percentages	67%	44%	0%	89%	89%	22%	9
Seymour Johnson AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35GSBxx	**37%**	**20%**	**4%**	**53%**	**57%**	**4%**	**390**
35GSB04	5%	2%	0%	6%	6%	0%	
% 35GSB04	26%	9%	0%	33%	33%	1%	70
35GSB06	15%	9%	3%	24%	27%	1%	
% 35GSB06	41%	25%	9%	62%	71%	3%	148
35GSB07	3%	4%	0%	7%	7%	0%	
% 35GSB07	29%	41%	0%	68%	68%	2%	41
35GSB17	10%	3%	0%	12%	12%	2%	
% 35GSB17	58%	19%	1%	67%	68%	10%	69
Mean Seymour Johnson AFB Percentages	37%	20%	4%	53%	57%	4%	390
MacDill AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35MCFxx	**41%**	**7%**	**1%**	**48%**	**49%**	**0%**	**987**
35MCF06	9%	6%	1%	15%	16%	0%	
% 35MCF06	49%	32%	3%	79%	82%	1%	187
35MCF17	28%	1%	0%	29%	29%	0%	
% 35MCF17	39%	1%	0%	40%	40%	0%	718
Mean MacDill AFB Percentages	41%	7%	1%	48%	49%	0%	987
Tinker AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35TIKxx	**43%**	**7%**	**0%**	**48%**	**48%**	**2%**	**465**
35TIK17	40%	5%	0%	43%	43%	2%	
% 35TIK17	42%	5%	0%	46%	46%	2%	438
Mean Tinker AFB Percentages	43%	7%	0%	48%	48%	2%	465
Andrews AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35ADWxx	**54%**	**19%**	**1%**	**65%**	**66%**	**9%**	**68**
Mean Andrews AFB Percentages	54%	19%	1%	65%	66%	9%	68



March ARB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35RIVxx	**50%**	**6%**	**2%**	**52%**	**54%**	**3%**	**652**
35RIV06	8%	5%	2%	11%	13%	3%	
% 35RIV06	55%	35%	11%	71%	82%	19%	100
35RIV17	38%	0%	0%	38%	38%	0%	
% 35RIV17	50%	0%	0%	50%	50%	0%	495
Mean March ARB Percentages	50%	6%	2%	52%	54%	3%	652

Grissom ARB, IN Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35GUSxx	**43%**	**3%**	**1%**	**45%**	**46%**	**1%**	**826**
35GUS17	35%	1%	0%	35%	35%	1%	
% 35GUS17	42%	1%	0%	42%	42%	1%	685
35GUS21	2%	1%	0%	3%	3%	0%	
% 35GUS21	46%	13%	5%	59%	64%	0%	39
Mean Grissom ARB, IN Percentages	43%	3%	1%	45%	46%	1%	826

Forbes Field ANGB, KS Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35FOExx	**52%**	**19%**	**0%**	**62%**	**63%**	**8%**	**332**
35FOE06	5%	5%	0%	10%	10%	0%	
% 35FOE06	52%	45%	0%	97%	97%	0%	33
35FOE11	16%	7%	0%	21%	21%	1%	
% 35FOE11	48%	20%	0%	65%	65%	3%	109
35FOE17	25%	7%	0%	25%	25%	7%	
% 35FOE17	54%	14%	0%	54%	54%	14%	153
Mean Forbes Field ANGB, KS Percentages	52%	19%	0%	62%	63%	8%	332

Kadena AB, JP Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35ODNxx	**52%**	**16%**	**0%**	**66%**	**66%**	**1%**	**757**
35ODN06	30%	8%	0%	38%	38%	0%	
% 35ODN06	54%	15%	0%	69%	69%	0%	419
35ODN07	6%	1%	0%	7%	7%	0%	
% 35ODN07	60%	6%	0%	65%	65%	1%	82
35ODN18	12%	5%	0%	16%	16%	1%	
% 35ODN18	47%	20%	0%	65%	65%	3%	186
Mean Kadena AB, JP Percentages	52%	16%	0%	66%	66%	1%	757

Meridian, MS Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35MEIxx	**22%**	**27%**	**8%**	**48%**	**55%**	**2%**	**128**
35MEI06	16%	23%	5%	38%	42%	1%	
% 35MEI06	24%	34%	7%	56%	64%	1%	85
Mean Meridian, MS Percentages	22%	27%	8%	48%	55%	2%	128

Col Bud Day Field, IA Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35SUXxx	**46%**	**17%**	**0%**	**60%**	**60%**	**3%**	**278**
35SUX04	4%	0%	0%	4%	4%	0%	
% 35SUX04	21%	2%	0%	23%	23%	0%	47
35SUX06	17%	11%	0%	26%	26%	2%	
% 35SUX06	55%	35%	0%	83%	83%	7%	88
35SUX11	6%	2%	0%	8%	8%	0%	
% 35SUX11	53%	20%	0%	73%	73%	0%	30
35SUX17	14%	1%	0%	15%	15%	0%	
% 35SUX17	46%	5%	0%	51%	51%	0%	85
Mean Col Bud Day Field, IA Percentages	46%	17%	0%	60%	60%	3%	278

Pittsburgh IA, PA Mission Classifications	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
35PITxx	**40%**	**14%**	**2%**	**53%**	**55%**	**1%**	**412**
35PIT04	5%	0%	0%	5%	5%	0%	
% 35PIT04	40%	0%	0%	40%	40%	0%	52
35PIT06	14%	8%	1%	21%	22%	0%	
% 35PIT06	44%	24%	5%	66%	71%	2%	128
35PIT07	6%	3%	0%	8%	8%	0%	
% 35PIT07	44%	21%	0%	63%	63%	2%	52
35PIT17	5%	0%	0%	6%	6%	0%	
% 35PIT17	45%	2%	0%	47%	47%	0%	49
35PIT22	8%	1%	0%	9%	9%	0%	
% 35PIT22	37%	7%	1%	44%	45%	0%	86
Mean Pittsburgh IA, PA Percentages	40%	14%	2%	53%	55%	1%	412

Eilson AFB, AK Mission Classifications	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
35AEIxx	**40%**	**13%**	**11%**	**50%**	**61%**	**3%**	**100**
35AEI06	6%	8%	9%	14%	23%	0%	
% 35AEI06	16%	22%	24%	38%	62%	0%	37
35AEI11	21%	3%	2%	22%	24%	2%	
% 35AEI11	58%	8%	6%	61%	67%	6%	36
Mean Eilson AFB, AK Percentages	40%	13%	11%	50%	61%	3%	100

Goldwater ANGB, AZ Mission Classifications	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
35PHXxx	**53%**	**6%**	**2%**	**58%**	**60%**	**1%**	**515**
35PHX06	3%	2%	1%	5%	6%	0%	
% 35PHX06	33%	22%	10%	55%	65%	0%	51
35PHX11	6%	1%	0%	7%	7%	0%	
% 35PHX11	52%	8%	0%	57%	57%	3%	61
35PHX17	37%	1%	0%	38%	38%	0%	
% 35PHX17	60%	1%	0%	61%	61%	0%	318
Mean Goldwater ANGB, AZ Percentages	53%	6%	2%	58%	60%	1%	515

Pease ANGB, NH Mission Classifications	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
35PSMxx	**35%**	**11%**	**3%**	**45%**	**48%**	**1%**	**501**
35PSM06	7%	7%	2%	13%	15%	1%	
% 35PSM06	36%	33%	9%	65%	74%	5%	99
35PSM07	3%	3%	0%	5%	5%	0%	
% 35PSM07	35%	35%	0%	70%	70%	0%	37
35PSM11	4%	1%	0%	6%	6%	0%	
% 35PSM11	47%	15%	4%	62%	66%	0%	47
35PSM17	17%	0%	0%	17%	17%	0%	
% 35PSM17	30%	0%	0%	30%	30%	0%	276
Mean Pease ANGB, NH Percentages	35%	11%	3%	45%	48%	1%	501

Lincoln ANGB, NE Mission Classifications	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
35LNKxx	**35%**	**27%**	**3%**	**59%**	**62%**	**3%**	**172**
35LNK06	19%	22%	2%	38%	40%	2%	
% 35LNK06	32%	37%	3%	66%	69%	3%	100
Mean Lincoln ANGB, NE Percentages	35%	27%	3%	59%	62%	3%	172

JB PHH Mission Classifications	**39%**	**7%**	**2%**	**46%**	**48%**	**0%**	
35HIKxx	**39%**	**7%**	**2%**	**46%**	**48%**	**0%**	**241**
35HIK06	15%	5%	2%	20%	21%	0%	
% 35HIK06	29%	10%	3%	39%	43%	0%	119
35HIK07	17%	1%	0%	18%	18%	0%	
% 35HIK07	47%	2%	0%	49%	49%	0%	87
Mean JB PHH Percentages	39%	7%	2%	46%	48%	0%	241

Wright ANGB, UT Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35SLCxx	**45%**	**3%**	**0%**	**48%**	**48%**	**1%**	**631**
35SLC04	2%	0%	0%	2%	2%	0%	
% 35SLC04	30%	8%	0%	38%	38%	0%	37
35SLC06	2%	1%	0%	3%	3%	0%	
% 35SLC06	35%	26%	0%	62%	62%	0%	34
35SLC11	12%	0%	0%	12%	12%	0%	
% 35SLC11	54%	1%	1%	54%	55%	1%	137
35SLC17	26%	0%	0%	26%	26%	0%	
% 35SLC17	43%	1%	0%	44%	44%	0%	374
Mean Wright ANGB, UT Percentages	45%	3%	0%	48%	48%	1%	631

Fairchild AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35SKAxx	**49%**	**15%**	**2%**	**63%**	**65%**	**1%**	**992**
35SKA06	14%	12%	2%	26%	27%	0%	
% 35SKA06	47%	39%	5%	85%	91%	1%	299
35SKA07	4%	1%	0%	5%	5%	1%	
% 35SKA07	49%	19%	0%	62%	62%	7%	73
35SKA17	23%	1%	0%	23%	23%	0%	
% 35SKA17	46%	2%	0%	48%	48%	1%	486
35SKA18	3%	0%	0%	3%	3%	0%	
% 35SKA18	62%	2%	0%	63%	63%	0%	52
Mean Fairchild AFB Percentages	49%	15%	2%	63%	65%	1%	992

McGhee Tyson ANGB, TN Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35TYSxx	**30%**	**24%**	**1%**	**49%**	**50%**	**5%**	**286**
35TYS06	5%	7%	0%	11%	11%	0%	
% 35TYS06	21%	33%	0%	52%	52%	2%	61
35TYS07	1%	9%	1%	9%	10%	1%	
% 35TYS07	9%	59%	5%	61%	66%	7%	44
35TYS11	12%	3%	1%	15%	15%	1%	
% 35TYS11	31%	9%	2%	38%	40%	2%	110
Mean McGhee Tyson ANGB, TN Percentages	30%	24%	1%	49%	50%	5%	286

General Mitchell ANGB, WI Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35MKExx	**35%**	**13%**	**2%**	**48%**	**50%**	**0%**	**254**
35MKE04	6%	0%	0%	6%	6%	0%	
% 35MKE04	38%	3%	0%	40%	40%	0%	40
35MKE06	6%	3%	0%	9%	10%	0%	
% 35MKE06	34%	17%	2%	51%	53%	0%	47
35MKE11	12%	5%	1%	16%	17%	0%	
% 35MKE11	45%	18%	4%	61%	66%	1%	67
35MKE17	2%	0%	0%	2%	2%	0%	
% 35MKE17	15%	0%	0%	15%	15%	0%	33
Mean General Mitchell ANGB, WI Percentages	35%	13%	2%	48%	50%	0%	254

Selfridge ANGB, MI Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35MTCxx	**39%**	**9%**	**1%**	**47%**	**48%**	**1%**	**460**
35MTC06	5%	3%	0%	8%	8%	0%	
% 35MTC06	34%	26%	3%	59%	62%	2%	61
35MTC11	7%	3%	0%	10%	10%	1%	
% 35MTC11	38%	19%	1%	54%	55%	4%	84
35MTC17	26%	1%	0%	26%	26%	0%	
% 35MTC17	44%	1%	0%	45%	45%	0%	268
Mean Selfridge ANGB, MI Percentages	39%	9%	1%	47%	48%	1%	460

Scott AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35BLVxx	**49%**	**22%**	**2%**	**68%**	**70%**	**2%**	**167**
35BLV06	20%	10%	1%	29%	30%	1%	
% 35BLV06	67%	33%	2%	96%	98%	4%	51
35BLV11	13%	5%	1%	18%	19%	0%	
% 35BLV11	40%	17%	2%	58%	60%	0%	52
Mean Scott AFB Percentages	49%	22%	2%	68%	70%	2%	167

Rickenbacker ANGB, OH Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35LCKxx	**35%**	**10%**	**1%**	**43%**	**44%**	**1%**	**687**
35LCK04	1%	0%	0%	1%	1%	0%	
% 35LCK04	22%	8%	0%	28%	28%	3%	36
35LCK06	6%	5%	0%	10%	10%	0%	
% 35LCK06	35%	28%	2%	63%	65%	0%	111
35LCK07	2%	2%	0%	4%	4%	0%	
% 35LCK07	32%	26%	2%	55%	57%	2%	47
35LCK11	3%	1%	0%	5%	5%	0%	
% 35LCK11	24%	11%	2%	34%	36%	1%	94
35LCK17	21%	1%	0%	21%	21%	1%	
% 35LCK17	39%	2%	0%	39%	39%	1%	368
Mean Rickenbacker ANGB, OH Percentages	35%	10%	1%	43%	44%	1%	687

Birmingham ANGB, AL Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35BHMxx	**40%**	**31%**	**4%**	**65%**	**69%**	**6%**	**182**
35BHM06	23%	17%	4%	38%	42%	1%	
% 35BHM06	39%	29%	7%	66%	73%	2%	106
35BHM11	8%	2%	0%	10%	10%	0%	
% 35BHM11	50%	13%	0%	63%	63%	0%	30
Mean Birmingham ANGB, AL Percentages	40%	31%	4%	65%	69%	6%	182

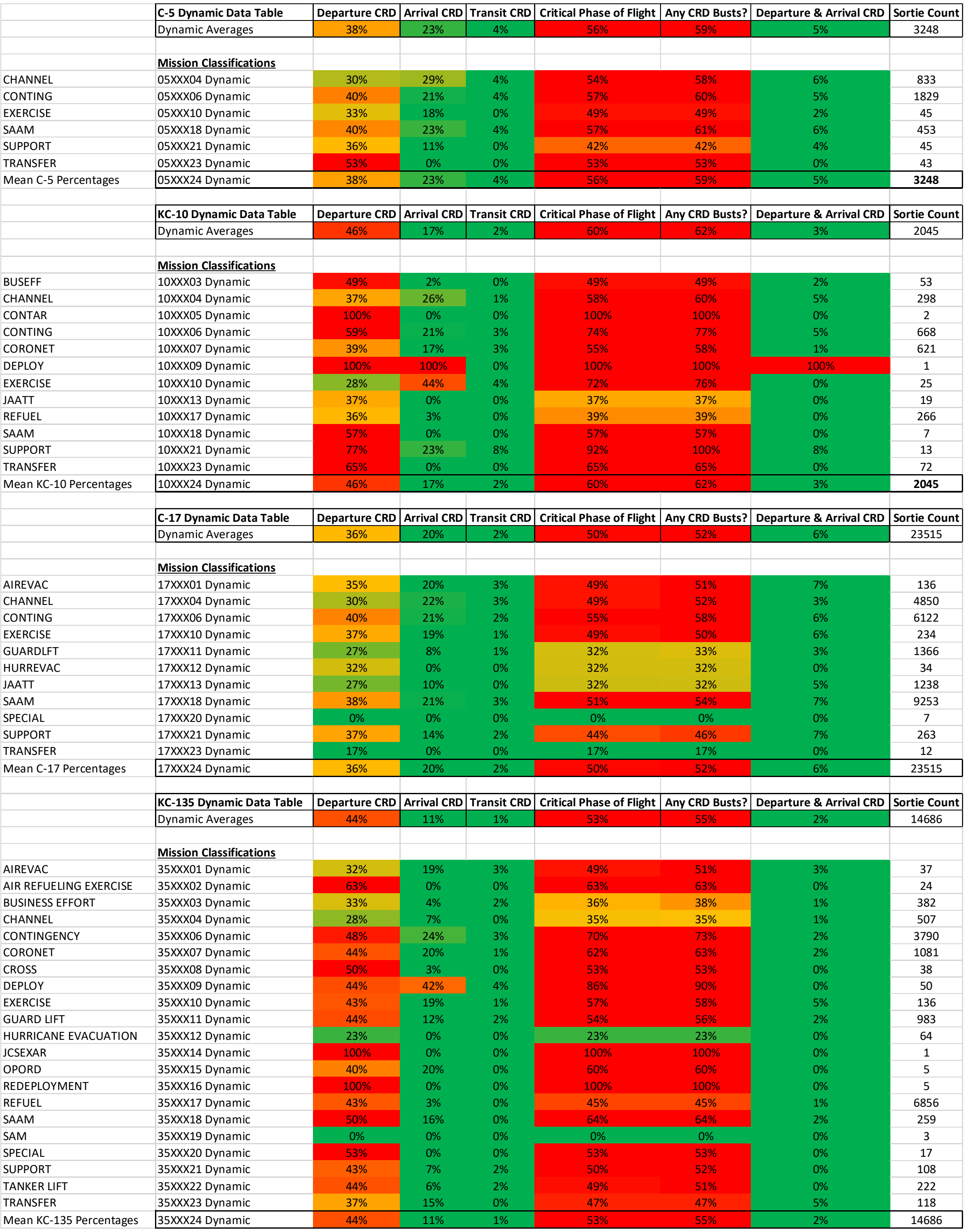
JB MDL Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35WRIxx	**39%**	**5%**	**1%**	**44%**	**44%**	**0%**	**617**
35WRI06	6%	3%	0%	10%	10%	0%	
% 35WRI06	42%	23%	1%	64%	65%	1%	92
35WRI11	4%	1%	0%	5%	5%	0%	
% 35WRI11	42%	9%	2%	51%	53%	0%	57
35WRI17	25%	0%	0%	25%	25%	0%	
% 35WRI17	39%	0%	0%	39%	39%	0%	398
Mean JB MDL Percentages	39%	5%	1%	44%	44%	0%	617

Bangor ANGB, ME Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35BGRxx	**45%**	**5%**	**1%**	**50%**	**51%**	**0%**	**614**
35BGR06	5%	4%	0%	9%	9%	0%	
% 35BGR06	34%	25%	1%	58%	59%	1%	93
35BGR17	34%	0%	0%	34%	34%	0%	
% 35BGR17	48%	0%	0%	48%	48%	0%	444
35BGR22	2%	0%	0%	2%	3%	0%	
% 35BGR22	39%	3%	3%	42%	44%	0%	36
Mean Bangor ANGB, ME Percentages	45%	5%	1%	50%	51%	0%	614

RAF Mildenhall Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35GUNxx	**57%**	**5%**	**0%**	**61%**	**61%**	**1%**	**1027**
35GUN06	33%	4%	0%	36%	36%	1%	
% 35GUN06	73%	8%	0%	80%	80%	2%	469
35GUN17	20%	1%	0%	21%	21%	0%	
% 35GUN17	41%	3%	0%	44%	44%	0%	503
Mean RAF Mildenhall Percentages	57%	5%	0%	61%	61%	1%	1027

McConnell AFB Mission Classifications	**Departure CRD**	**Arrival CRD**	**Transit CRD**	**Critical Phase of Flight**	**Any CRD Busts?**	**Departure & Arrival CRD**	**Sortie Count**
35IABxx	**42%**	**15%**	**1%**	**56%**	**57%**	**1%**	**1936**
35IAB03	2%	0%	0%	2%	2%	0%	
% 35IAB03	26%	0%	0%	26%	26%	0%	126
35IAB04	1%	0%	0%	1%	1%	0%	
% 35IAB04	34%	9%	0%	44%	44%	0%	32
35IAB06	18%	9%	1%	26%	27%	1%	
% 35IAB06	50%	24%	2%	71%	73%	2%	709
35IAB07	8%	3%	0%	11%	12%	0%	
% 35IAB07	46%	18%	1%	63%	64%	1%	350
35IAB17	12%	2%	0%	14%	14%	0%	
% 35IAB17	38%	6%	0%	44%	44%	1%	616
35IAB23	0%	0%	0%	0%	0%	0%	
% 35IAB23	18%	0%	0%	18%	18%	0%	34
Mean McConnell AFB Percentages	42%	15%	1%	56%	57%	1%	1936

Appendix E – Dynamic Data Tables



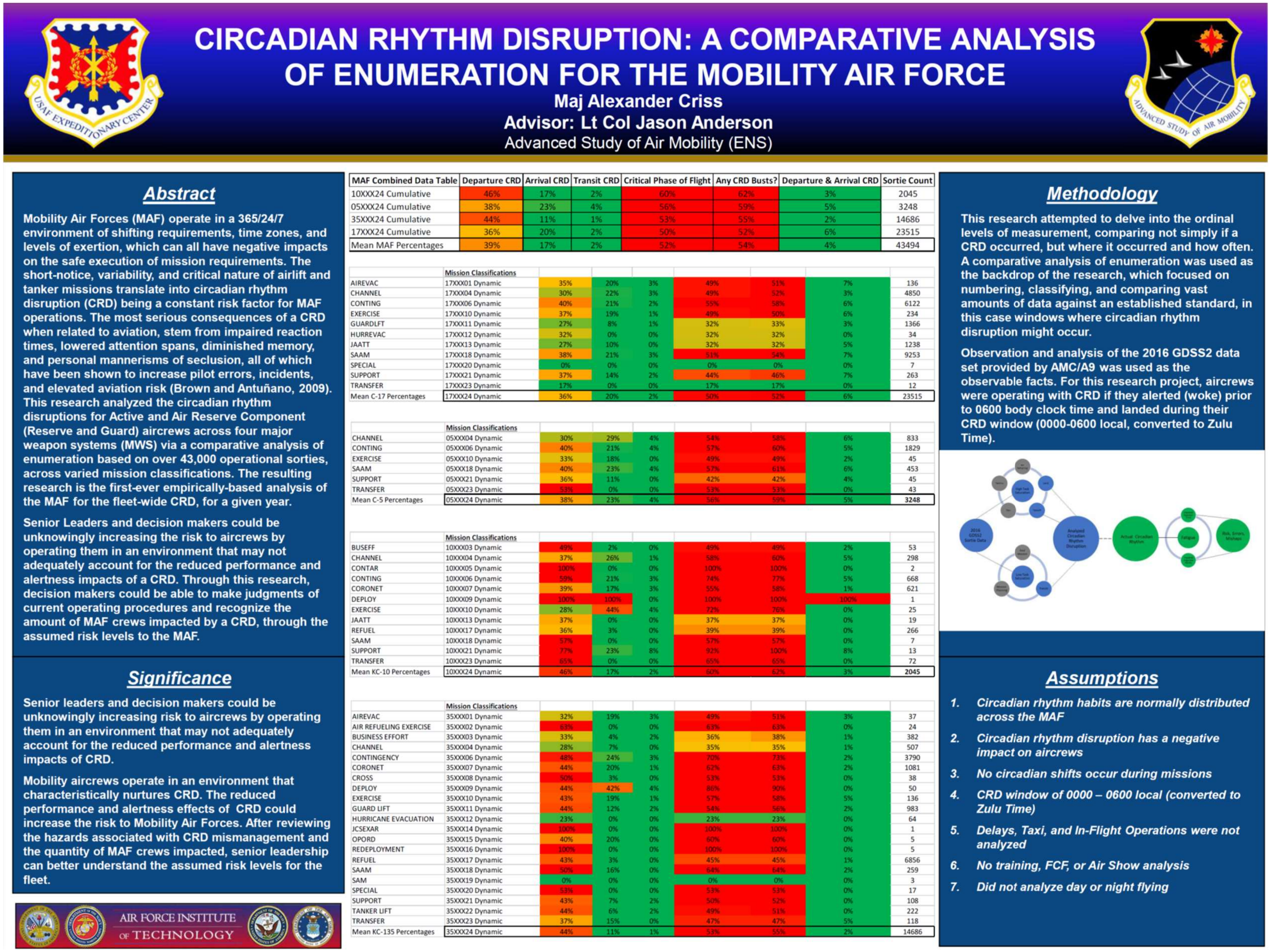
	C-5 Dynamic Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
	Dynamic Averages	38%	23%	4%	56%	59%	5%	3248
	Mission Classifications							
CHANNEL	05XXX04 Dynamic	30%	29%	4%	54%	58%	6%	833
CONTING	05XXX06 Dynamic	40%	21%	4%	57%	60%	5%	1829
EXERCISE	05XXX10 Dynamic	33%	18%	0%	49%	49%	2%	45
SAAM	05XXX18 Dynamic	40%	23%	4%	57%	61%	6%	453
SUPPORT	05XXX21 Dynamic	36%	11%	0%	42%	42%	4%	45
TRANSFER	05XXX23 Dynamic	53%	0%	0%	53%	53%	0%	43
Mean C-5 Percentages	05XXX24 Dynamic	38%	23%	4%	56%	59%	5%	**3248**

	KC-10 Dynamic Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
	Dynamic Averages	46%	17%	2%	60%	62%	3%	2045
	Mission Classifications							
BUSEFF	10XXX03 Dynamic	49%	2%	0%	49%	49%	2%	53
CHANNEL	10XXX04 Dynamic	37%	26%	1%	58%	60%	5%	298
CONTAR	10XXX05 Dynamic	100%	0%	0%	100%	100%	0%	2
CONTING	10XXX06 Dynamic	59%	21%	3%	74%	77%	5%	668
CORONET	10XXX07 Dynamic	39%	17%	3%	55%	58%	1%	621
DEPLOY	10XXX09 Dynamic	100%	100%	0%	100%	100%	100%	1
EXERCISE	10XXX10 Dynamic	28%	44%	4%	72%	76%	0%	25
JAATT	10XXX13 Dynamic	37%	0%	0%	37%	37%	0%	19
REFUEL	10XXX17 Dynamic	36%	3%	0%	39%	39%	0%	266
SAAM	10XXX18 Dynamic	57%	0%	0%	57%	57%	0%	7
SUPPORT	10XXX21 Dynamic	77%	23%	8%	92%	100%	8%	13
TRANSFER	10XXX23 Dynamic	65%	0%	0%	65%	65%	0%	72
Mean KC-10 Percentages	10XXX24 Dynamic	46%	17%	2%	60%	62%	3%	**2045**

	C-17 Dynamic Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
	Dynamic Averages	36%	20%	2%	50%	52%	6%	23515
	Mission Classifications							
AIREVAC	17XXX01 Dynamic	35%	20%	3%	49%	51%	7%	136
CHANNEL	17XXX04 Dynamic	30%	22%	3%	49%	52%	3%	4850
CONTING	17XXX06 Dynamic	40%	21%	2%	55%	58%	6%	6122
EXERCISE	17XXX10 Dynamic	37%	19%	1%	49%	50%	6%	234
GUARDLFT	17XXX11 Dynamic	27%	8%	1%	32%	33%	3%	1366
HURREVAC	17XXX12 Dynamic	32%	0%	0%	32%	32%	0%	34
JAATT	17XXX13 Dynamic	27%	10%	0%	32%	32%	5%	1238
SAAM	17XXX18 Dynamic	38%	21%	3%	51%	54%	7%	9253
SPECIAL	17XXX20 Dynamic	0%	0%	0%	0%	0%	0%	7
SUPPORT	17XXX21 Dynamic	37%	14%	2%	44%	46%	7%	263
TRANSFER	17XXX23 Dynamic	17%	0%	0%	17%	17%	0%	12
Mean C-17 Percentages	17XXX24 Dynamic	36%	20%	2%	50%	52%	6%	23515

	KC-135 Dynamic Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
	Dynamic Averages	44%	11%	1%	53%	55%	2%	14686
	Mission Classifications							
AIREVAC	35XXX01 Dynamic	32%	19%	3%	49%	51%	3%	37
AIR REFUELING EXERCISE	35XXX02 Dynamic	63%	0%	0%	63%	63%	0%	24
BUSINESS EFFORT	35XXX03 Dynamic	33%	4%	2%	36%	38%	1%	382
CHANNEL	35XXX04 Dynamic	28%	7%	0%	35%	35%	1%	507
CONTINGENCY	35XXX06 Dynamic	48%	24%	3%	70%	73%	2%	3790
CORONET	35XXX07 Dynamic	44%	20%	1%	62%	63%	2%	1081
CROSS	35XXX08 Dynamic	50%	3%	0%	53%	53%	0%	38
DEPLOY	35XXX09 Dynamic	44%	42%	4%	86%	90%	0%	50
EXERCISE	35XXX10 Dynamic	43%	19%	1%	57%	58%	5%	136
GUARD LIFT	35XXX11 Dynamic	44%	12%	2%	54%	56%	2%	983
HURRICANE EVACUATION	35XXX12 Dynamic	23%	0%	0%	23%	23%	0%	64
JCSEXAR	35XXX14 Dynamic	100%	0%	0%	100%	100%	0%	1
OPORD	35XXX15 Dynamic	40%	20%	0%	60%	60%	0%	5
REDEPLOYMENT	35XXX16 Dynamic	100%	0%	0%	100%	100%	0%	5
REFUEL	35XXX17 Dynamic	43%	3%	0%	45%	45%	1%	6856
SAAM	35XXX18 Dynamic	50%	16%	0%	64%	64%	2%	259
SAM	35XXX19 Dynamic	0%	0%	0%	0%	0%	0%	3
SPECIAL	35XXX20 Dynamic	53%	0%	0%	53%	53%	0%	17
SUPPORT	35XXX21 Dynamic	43%	7%	2%	50%	52%	0%	108
TANKER LIFT	35XXX22 Dynamic	44%	6%	2%	49%	51%	0%	222
TRANSFER	35XXX23 Dynamic	37%	15%	0%	47%	47%	5%	118
Mean KC-135 Percentages	35XXX24 Dynamic	44%	11%	1%	53%	55%	2%	14686

Appendix F – Quad Chart



CIRCADIAN RHYTHM DISRUPTION: A COMPARATIVE ANALYSIS OF ENUMERATION FOR THE MOBILITY AIR FORCE

Maj Alexander Criss
Advisor: Lt Col Jason Anderson
Advanced Study of Air Mobility (ENS)

Abstract

Mobility Air Forces (MAF) operate in a 365/24/7 environment of shifting requirements, time zones, and levels of exertion, which can all have negative impacts on the safe execution of mission requirements. The short-notice, variability, and critical nature of airlift and tanker missions translate into circadian rhythm disruption (CRD) being a constant risk factor for MAF operations. The most serious consequences of a CRD when related to aviation, stem from impaired reaction times, lowered attention spans, diminished memory, and personal mannerisms of seclusion, all of which have been shown to increase pilot errors, incidents, and elevated aviation risk (Brown and Antuñano, 2009). This research analyzed the circadian rhythm disruptions for Active and Air Reserve Component (Reserve and Guard) aircrews across four major weapon systems (MWS) via a comparative analysis of enumeration based on over 43,000 operational sorties, across varied mission classifications. The resulting research is the first-ever empirically-based analysis of the MAF for the fleet-wide CRD, for a given year.

Senior Leaders and decision makers could be unknowingly increasing the risk to aircrews by operating them in an environment that may not adequately account for the reduced performance and alertness impacts of a CRD. Through this research, decision makers could be able to make judgments of current operating procedures and recognize the amount of MAF crews impacted by a CRD, through the assumed risk levels to the MAF.

Significance

Senior leaders and decision makers could be unknowingly increasing risk to aircrews by operating them in an environment that may not adequately account for the reduced performance and alertness impacts of CRD.

Mobility aircrews operate in an environment that characteristically nurtures CRD. The reduced performance and alertness effects of CRD could increase the risk to Mobility Air Forces. After reviewing the hazards associated with CRD mismanagement and the quantity of MAF crews impacted, senior leadership can better understand the assumed risk levels for the fleet.

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MAF Combined Data Table	Departure CRD	Arrival CRD	Transit CRD	Critical Phase of Flight	Any CRD Busts?	Departure & Arrival CRD	Sortie Count
10XXX24 Cumulative	46%	17%	2%	60%	62%	3%	2045
05XXX24 Cumulative	38%	23%	4%	56%	59%	5%	3248
35XXX24 Cumulative	44%	11%	1%	53%	55%	2%	14686
17XXX24 Cumulative	36%	20%	2%	50%	52%	6%	23515
Mean MAF Percentages	39%	17%	2%	52%	54%	4%	43494

	Mission Classifications							
AIREVAC	17XXX01 Dynamic	35%	20%	3%	49%	51%	7%	136
CHANNEL	17XXX04 Dynamic	30%	22%	3%	49%	52%	3%	4850
CONTING	17XXX06 Dynamic	40%	21%	2%	55%	58%	6%	6122
EXERCISE	17XXX10 Dynamic	37%	19%	1%	49%	50%	6%	234
GUARDLFT	17XXX11 Dynamic	27%	8%	1%	32%	33%	3%	1366
HURREVAC	17XXX12 Dynamic	32%	0%	0%	32%	32%	0%	34
JAATT	17XXX13 Dynamic	27%	10%	0%	32%	32%	5%	1238
SAAM	17XXX18 Dynamic	38%	21%	3%	51%	54%	7%	9253
SPECIAL	17XXX20 Dynamic	0%	0%	0%	0%	0%	0%	7
SUPPORT	17XXX21 Dynamic	37%	14%	2%	44%	46%	7%	263
TRANSFER	17XXX23 Dynamic	17%	0%	0%	17%	17%	0%	12
Mean C-17 Percentages	17XXX24 Dynamic	36%	20%	2%	50%	52%	6%	23515

	Mission Classifications							
CHANNEL	05XXX04 Dynamic	30%	29%	4%	54%	58%	6%	833
CONTING	05XXX06 Dynamic	40%	21%	4%	57%	60%	5%	1829
EXERCISE	05XXX10 Dynamic	33%	18%	0%	49%	49%	2%	45
SAAM	05XXX18 Dynamic	40%	23%	4%	57%	61%	6%	453
SUPPORT	05XXX21 Dynamic	36%	11%	0%	42%	42%	4%	45
TRANSFER	05XXX23 Dynamic	53%	0%	0%	53%	53%	0%	43
Mean C-5 Percentages	05XXX24 Dynamic	38%	23%	4%	56%	59%	5%	3248

	Mission Classifications							
BUSEFF	10XXX03 Dynamic	49%	2%	0%	49%	49%	2%	53
CHANNEL	10XXX04 Dynamic	37%	26%	1%	58%	60%	5%	298
CONTAR	10XXX05 Dynamic	100%	0%	0%	100%	100%	0%	2
CONTING	10XXX06 Dynamic	59%	21%	3%	74%	77%	5%	668
CORONET	10XXX07 Dynamic	39%	17%	3%	55%	58%	1%	621
DEPLOY	10XXX09 Dynamic	100%	100%	0%	100%	100%	100%	1
EXERCISE	10XXX10 Dynamic	28%	44%	4%	72%	76%	0%	25
JAATT	10XXX13 Dynamic	37%	0%	0%	37%	37%	0%	19
REFUEL	10XXX17 Dynamic	36%	3%	0%	39%	39%	0%	266
SAAM	10XXX18 Dynamic	57%	0%	0%	57%	57%	0%	7
SUPPORT	10XXX21 Dynamic	77%	23%	8%	92%	100%	8%	13
TRANSFER	10XXX23 Dynamic	65%	0%	0%	65%	65%	0%	72
Mean KC-10 Percentages	10XXX24 Dynamic	46%	17%	2%	60%	62%	3%	2045

	Mission Classifications							
AIREVAC	35XXX01 Dynamic	32%	19%	3%	49%	51%	3%	37
AIR REFUELING EXERCISE	35XXX02 Dynamic	63%	0%	0%	63%	63%	0%	24
BUSINESS EFFORT	35XXX03 Dynamic	33%	4%	2%	36%	38%	1%	382
CHANNEL	35XXX04 Dynamic	28%	7%	0%	35%	35%	1%	507
CONTINGENCY	35XXX06 Dynamic	48%	24%	3%	70%	73%	2%	3790
CORONET	35XXX07 Dynamic	44%	20%	1%	62%	63%	2%	1081
CROSS	35XXX08 Dynamic	50%	3%	0%	53%	53%	0%	38
DEPLOY	35XXX09 Dynamic	44%	42%	4%	86%	90%	0%	50
EXERCISE	35XXX10 Dynamic	43%	19%	1%	57%	58%	5%	136
GUARD LIFT	35XXX11 Dynamic	44%	12%	2%	54%	56%	2%	983
HURRICANE EVACUATION	35XXX12 Dynamic	23%	0%	0%	23%	23%	0%	64
JCSEXAR	35XXX14 Dynamic	100%	0%	0%	100%	100%	0%	1
OPORD	35XXX15 Dynamic	40%	20%	0%	60%	60%	0%	5
REDEPLOYMENT	35XXX16 Dynamic	100%	0%	0%	100%	100%	0%	5
REFUEL	35XXX17 Dynamic	43%	3%	0%	45%	45%	1%	6856
SAAM	35XXX18 Dynamic	50%	16%	0%	64%	64%	2%	259
SAM	35XXX19 Dynamic	0%	0%	0%	0%	0%	0%	3
SPECIAL	35XXX20 Dynamic	53%	0%	0%	53%	53%	0%	17
SUPPORT	35XXX21 Dynamic	43%	7%	2%	50%	52%	0%	108
TANKER LIFT	35XXX22 Dynamic	44%	6%	2%	49%	51%	0%	222
TRANSFER	35XXX23 Dynamic	37%	15%	0%	47%	47%	5%	118
Mean KC-135 Percentages	35XXX24 Dynamic	44%	11%	1%	53%	55%	2%	14686

Methodology

This research attempted to delve into the ordinal levels of measurement, comparing not simply if a CRD occurred, but where it occurred and how often. A comparative analysis of enumeration was used as the backdrop of the research, which focused on numbering, classifying, and comparing vast amounts of data against an established standard, in this case windows where circadian rhythm disruption might occur.

Observation and analysis of the 2016 GDSS2 data set provided by AMC/A9 was used as the observable facts. For this research project, aircrews were operating with CRD if they alerted (woke) prior to 0600 body clock time and landed during their CRD window (0000-0600 local, converted to Zulu Time).

Assumptions

1. *Circadian rhythm habits are normally distributed across the MAF*
2. *Circadian rhythm disruption has a negative impact on aircrews*
3. *No circadian shifts occur during missions*
4. *CRD window of 0000 – 0600 local (converted to Zulu Time)*
5. *Delays, Taxi, and In-Flight Operations were not analyzed*
6. *No training, FCF, or Air Show analysis*
7. *Did not analyze day or night flying*

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14. ABSTRACT
Mobility Air Forces (MAF) operate in a 365/24/7 environment of shifting requirements, time zones, and levels of exertion, which can all have negative impacts on the safe execution of mission requirements. The short-notice, variability, and critical nature of airlift and tanker missions translate into circadian rhythm disruption (CRD) being a constant risk factor for MAF operations. The most serious consequences of a CRD when related to aviation, stem from impaired reaction times, lowered attention spans, diminished memory, and personal mannerisms of seclusion, all of which have been shown to increase pilot errors, incidents, and elevated aviation risk (Brown and Antuñano, 2009). This research analyzed the circadian rhythm disruptions for Active and Air Reserve Component (Reserve and Guard) aircrews across four major weapon systems (MWS) via a comparative analysis of enumeration based on over 43,000 operational sorties, across varied mission classifications. The resulting research is the first-ever empirically-based analysis of the MAF for the fleet-wide CRD, for a given year. Senior Leaders and decision makers could be unknowingly increasing the risk to aircrews by operating them in an environment that may not adequately account for the reduced performance and alertness impacts of a CRD. Through this research, decision makers could be able to make judgments of current operating procedures and recognize the amount of MAF crews impacted by a CRD, through the assumed risk levels to the MAF.

15. SUBJECT TERMS
Circadian Rhythm Disruption, CRD, Fatigue, MAF, Risk, Comparative Analysis, GDSS, Safety, Operations, Procedures, FAST, Airlift, Tanker, Reaction Time, Cognitive Ability, Enumeration

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