

Identifying Correlations between Aviation Mishaps and Attrition of Aviation Maintenance Personnel in the Armed Forces (Phase II)



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Identifying Correlations between Aviation Mishaps and Attrition of Aviation Maintenance Personnel in the Armed Forces (Phase II)

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ABSTRACT

Congress formed the National Commission on Military Aviation Safety (NCMAS) to investigate a purported increase in aviation mishaps. To aid in that investigation, NCMAS collaborated with The Research Analysis Center – Monterey and the Naval Postgraduate School to examine the numbers of military aviation mishaps, and to determine whether there is a correlation between the number of aviation maintenance personnel and accident rates, between fiscal years 2010 and 2019.

For two of the four services, the Army and Air Force, there was no evidence of an increase in overall mishap numbers either in total, or by accident class during the period under investigation, although both saw decreases in the number of maintenance personnel. The research team also noted that the provided data from either service did not specify flight hours, platforms, carrier operations, or other possible factors that would allow the team to conduct a more in-depth analysis of the determinants of mishaps.

There was an increase in mishaps that occurred in the Navy over the period. Although personnel numbers temporarily decreased, they did begin to return to levels seen at the beginning of the period. There was also an increase in mishaps in the Marine Corps during the period. This correlated with a loss in maintenance personnel of approximately the same magnitude as the Air Force's maintenance personnel loss. The mishaps were roughly evenly distributed between fixed- and rotary-wing aircraft across all platforms. The research team was not able to find a reason for the increase in accidents.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAG-RFL: Army Analytics Group-Research Facilitation Laboratory
AFQT: Armed Forces Qualification Test
AFMS: Active Federal Military Service
APU: Auxiliary Power Unit
ASVAB: Armed Services Vocational Aptitude Battery
AV: Aviation
BASH: Bird and Animal Strike Hazard
CAC: Common Access Card
CRISP-DM: Cross-Industry Standard Process for Data Mining
CTRLG: Controlling
CUST: Customer
DMDC: Defense Manpower Data Center
DoD: Department of Defense
DoDI: Department of Defense Instruction
DoD ODB: Department of Defense Occupational Database
DST: Decision Support Tool
FOD: Foreign Object Damage
HFACS: Human Factors Analysis and Classification System
INVLVD: Involved
IRB: Institutional Review Board
MN: Month
MOS: Military Occupational Specialty
NCMAS: National Commission on Military Aviation Safety
NCOs: Non-Commissioned Officers
NDA: Non-Disclosure Agreements
NPS: Naval Postgraduate School
NSC: Navy Safety Center
PDE: Person-event Data Environment
PGRD: Paygrade
PII: Personally Identifiable Information
PPLN: Payplan
QY: Quantity
RPRTBL: Reportable
UIC: Unit Identification Code
TRAC: The Research and Analysis Center

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SECTION 1. INTRODUCTION

1.1. PURPOSE

The Research and Analysis Center – Monterey (TRAC-MTRY) conducted this analysis as a part of the National Commission on Military Aviation Safety (NCMAS) investigation; the focus of the study was to ascertain whether there was a correlation between aviation mishaps and attrition of aviation maintenance personnel, covering the period from FY 2010 to FY 2019. The study was conducted in two phases: Phase I addressed attrition trends of aviation mechanics in the Armed Forces based on rank and job and evaluated the number of experienced personnel leaving the aviation field. Phase II furthered the study by incorporating data on military and civilian education levels and Armed Forces Qualification Test (AFQT) scores. Phase II also examined the Human Factors Analysis and Classification System (HFACS) codes associated with mishaps.

1.2. BACKGROUND

Congress formed NCMAS to investigate a perceived increase in aviation mishaps that was purported to have occurred between FY 2013 – FY 2018. Congress directed NCMAS to address four areas of concern: 1) rates of military aviation mishaps, 2) underlying causes contributing to physiological episodes, 3) causes for delays in aviation maintenance, and 4) causes of aviation mishaps. Congress also asked the NCMAS to make recommendations based on their findings in each area of concern. According to Department of Defense (DoD) safety manuals, aviation mishaps occur because of environmental factors, human factors (pilot, maintainer or other), or non-human factors (faulty material or equipment, enemy action, and so on) (Safety, 2015). Material and pilot error have been heavily researched (Baumann, 2017), (Brobst, Thompson, & Brown, 2008), and (Thompson, Brobst, Brown, & Brown, 2009), but maintainer error has not received the same amount of attention (Clifford, Callender II, & O'Meara, 2003). Therefore, NCMAS collaborated with TRAC-MTRY, The Army Analytics Group-Research Facilitation Laboratory (AAG-RFL), and the Naval Postgraduate School (NPS) to analyze the manning and attrition trends of aviation maintenance personnel across the Services.

1.3. CONSTRAINTS, LIMITATIONS, & ASSUMPTIONS

Constraints. (A restriction imposed by the study sponsor that limits the study team's options during the event as part of conducting the study.)

- Phase I of the project had to be completed by July 2020, and Phase II by September 2020.
- The analysis had to be conducted in the Person-event Data Environment (PDE).
- The analysis concerns Active Duty service members only and is conducted at the Service (rather than, say, squadron) level.

Limitations. (An inability of the study team to fully meet the event study objectives or fully investigate the event study issues.)

- Delays in gaining access to data within the PDE limited the timeline of the analysis.
- The timeframe for available data was from 2000 to the present.
- The PDE contained safety data for the Navy only. NCMAS provided safety data for all the Services, but that data was not available within the PDE where it could have been linked to personnel. Air Force safety data ended at 2018.
- Mishaps were aggregated to the Service level and could not be investigated down by individual platform.
- The study team did not have access to qualitative information to ascertain a Servicemember's experience or knowledge within their MOS or rate.

Assumptions. (A statement related to the event that is taken as true in the absence of facts, often to accommodate a limitation.)

- Data in PDE is authoritative.
- NCMAS data will be included in PDE to be utilized in the analysis of the safety data.

- Personnel with 24 months of experience have graduated initial training and established one year of on-the-job experience.
- Servicemembers promoted past the rank of E7 are no longer involved in daily maintenance activities.
- Time-in-service and rank serve as adequate proxies of a Servicemember's experience and skill level.

1.4. STUDY TEAM

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SECTION 2. METHODOLOGY

2.1. CRISP_DM

The team utilized the six-phase Cross-Industry Standard Process for Data Mining (CRISP-DM) to analyze the personnel and safety data. This process outlines a procedure for undertaking data mining projects, starting with eliciting the “business understanding.”

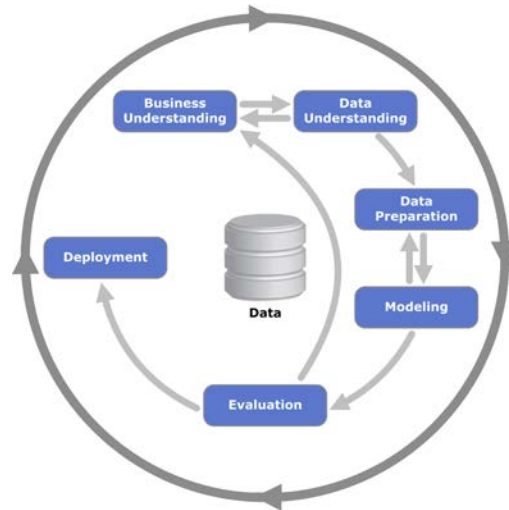


Figure 1: Schematic of the CRISP-DM process (Vorhies, 2016)

2.2. BUSINESS UNDERSTANDING

The business understanding phase is the initial phase and lays the foundation for the project; it outlined the sponsors’ purpose and the end state of the project. This information aided the team in constructing the problem statement, developing the issues for analysis, identifying the data necessary for the study, and determining the project deliverables.

2.3. DATA UNDERSTANDING

The team used the PDE to gain access to the personnel and safety files necessary for the analysis. This phase of the methodology consists of four essential tasks: 1) gathering the data, 2) describing the data, 3) exploring the data, and 4) verifying the data quality.

2.3.1 GATHER THE DATA

The data required to analyze attrition trends of aviation maintenance personnel in the Services, and to identify if personnel numbers are correlated with aviation mishaps, resides in the PDE. The PDE, operated by the AAG-RFL, maintains data on all aspects of a Servicemember's career. The PDE is a CAC-enabled environment that provides researchers with the capability to conduct analysis and collaborate in a secured environment (Vie, 2013). To gain access to the data, the team completed an Institutional Review Board (IRB) application with NPS, created the project in the PDE, signed the necessary Non-Disclosure Agreements (NDAs) and requested access to the DoD personnel files and the Department of the Navy (DoN) and Army safety files. The Air Force Safety Center provided the team the required data outside the PDE. The last data set the team requested was the Occupational Database (DoD ODB). The DoD ODB is available via the internet and requires an account and CAC card to access. The DoD ODB is "an occupation coding structure, designed to group similar occupations from one or more populations into a logical and consistent structure suitable for a variety of analytical purposes" (Personnel Readiness, 2001). All Services are mandated by the Instruction (DoDI) 1312.1 (Personnel Readiness, 2013) to update this database via the Defense Manpower Data Center (DMDC).

2.3.2 DESCRIBE THE DATA

The Army and Non-Army master files contained about 108 million observations with 156 variables, and the Army and Non-Army transaction file contained about 13 million observations with 38 variables. The DoN Safety data set contained aviation mishaps for the Navy and the Marines. The DoN Safety data set was created by combining four separate data tables: NSC_AV_FACTORS (Factor), NSC_AV_HFAC (HFAC, that is, the Human Factors Analysis Classification system), NSC_AV_INVLVD_ACFT (Aircraft), and NSC_AV_RPRTBL_EVENT (Event). The Factor table contained 35,805 observations with three variables, the HFAC table contained 12,033 observations with four variables, the Aircraft table contained 111,984 observations with 26 variables, and the Event table contained 106,490 observations with 32 variables. The Army safety table contained 709,033 observations with 84 variables. The Air Force Safety data set contained seven tables, of which the team used six for this analysis. These are the Mishap (8,735 observations with 163 variables), BASH (1,162 with eight variables), Person

(11,768 observations with 120 variables), Objects (34,489 observations with 86 variable), Physio (2,020 observations with eight variables), and HFAC tables (14,478 observations with 16 variables).

2.3.3 EXPLORATORY DATA ANALYSIS

The three Navy Safety data tables contained mishaps for the Navy and Marines. The study team separated mishaps into Navy Safety and Marines Safety data sets by using the CTRLG_CUST column. The preferred method would have been via the RPTG_UIC column, but under the rules of the PDE, unit identification codes (UICs) are considered personally identifiable information (PII), and thus the study team did not have access to this information. Before the project started, the team completed an IRB with NPS in which it stated it would not require PII to be included in any of our data sets. The Navy does not consider UICs to be PII, but since the PDE does, an alternative column was necessary.

The Navy HFAC table did not contain HFACS information (see appendix II for a listing of codes) for every factor serial listed in the Factors table. In all cases, mishaps without human-related causes were not given HFACS codes. The Army and Navy Safety data provided in the PDE did not match the corresponding data provided by the Army and Navy Safety Centers. For this analysis, the study team used the Safety Center data.

2.3.4 VERIFY THE DATA

The Safety data received from the Safety Centers and the personnel data obtained through the PDE is sufficient for the analysis the study team are conducting for this project. As a team, the study team acknowledge there could be hidden variables the study team did not consider that could cause aviation mishaps to vary. A more robust analysis could be performed if the study team had access to manning guidance (such as numbers of authorized billets) for the Armed Forces, and additional aircraft-related information (such as number of missions, flight hours, take-offs and landings, Navy carrier operations, and changes in Naval platform configurations).

2.4. DATA PREPARATION

The data preparation phase was the most critical of the methodology and, as in many projects, accounted for more than 50% of the team's efforts. The data sets built in this phase

informed the types of models necessary to address our issues for analysis. There were five essential tasks for this phase: 1) selecting the data, 2) cleaning the data, 3) constructing the data, 4) integrating the data, and 5) formatting the data.

2.4.1 SELECTING THE DATA

2.4.1.1. MANPOWER

The optimal way to ascertain whether there was a correlation between the attrition of aviation maintainers and aviation mishaps would be to employ information about the qualifications and knowledge of the Servicemembers doing the maintenance. Some of the variables that might be useful in that endeavor are time in service, time in paygrade, rank, job, AFQT scores (or AFQT tier level), and military and civilian education level. In Phase I, the research team considered time in service and rank among all Servicemembers with an aviation maintenance code as a proxy for experience and knowledge. Phase II additionally considered AFQT tiers levels.

2.4.1.2. SAFETY

From the Safety Center data for all the Services, the study team extracted those mishaps that took place between FY2010 and FY2019 and which were classified into one of the three most severe classes of accidents, A (most severe), B (medium severity), and C (least severe), see figure 2. There were about 9,000 such mishaps recorded in those Fiscal Years (note, our data excludes FY 2019 for the Air Force). This equated to roughly 900 per year, of which on average 50 might be class A, 80 class B, and the remainder class C.

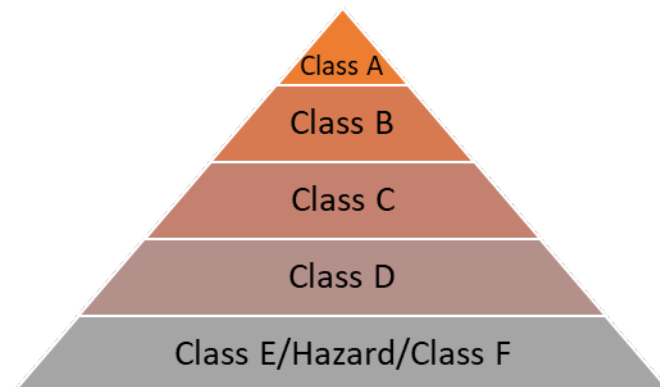


Figure 2 Accident Classification Pyramid (source: author)

2.4.2 CLEANING THE DATA

2.4.2.1 MANPOWER

Manpower data was provided in two types of file: a snapshot file, giving one row describing each member of the service at the end of a calendar quarter, and a transaction file, giving one row for each transaction undergone by a service member. Importantly, these transactions included hiring and separation dates, although not for every member. This was a noticeable gap in the data; many servicemembers had multiple transactions, as expected, but a number of servicemembers had no recorded transactions at all. One pair of files (master and transaction) was provided for each service. Across all services, both the master and transaction files have quality issues. Some personnel were missing transactions entirely; for those personnel, the team declared their start date to be the entry date associated with the first snapshot in which they appeared, and their end dates to be the last snapshot in which they appeared. This approach would bias any investigations of lifetimes, but it did not affect our end-of-quarter analyses efforts in this study. Additionally, a small number of personnel who were present in the first snapshot but missing transactions, have times-in-service that are underestimated. The study team judge this effect to be small for this study due to the limited number of cases where this occurred.

In this study, the interest was on the subset of personnel who were actively maintaining aircraft. Therefore, the research team selected personnel who met three criteria: at least 24 months of service (to ensure that the subset had graduated basic and initial training), one of the aviation maintenance job codes listed in Appendix I, and had a rank of E7 or lower. The study team assumed that E8 or higher personnel would fill primarily administrative roles.

To determine a member's time-in-service, the study team counted from the date of the first transaction, or three months for each snapshot in service if no transaction was present. The built-in AFMS_MN_QY variable, which purports to give time-in-service, was determined to be unreliable since it is sometimes missing and occasionally resets to zero. The rank and code fields come directly from the snapshot data in the PAYGRADE_PDE and PRI_DOD_OCC_CD fields, respectively, and these were rarely missing.

However, the latter of these, Occupation Code, deserves some note. On at least one occasion, a substantial number of Servicemembers go from having an aviation code to not having

one, and back to having one in a short period of time. In particular, about 7,900 Air Force personnel undergo this transition over three quarters, with the non-aviation code (code 100000, “general”) appearing in the final quarter of FY 2017. The study team presume this is merely an administrative adjustment that does not affect the number of airmen working in aviation, so in some cases, the study team have adjusted the records of these roughly 7,900 Airmen, so they are continually listed as being in the aviation field. The study team will refer to this as the “adjusted” Air Force data. Something similar happened with a small number of Marines. A more complicated pattern appears in the Navy data, where a large number of Sailors seem to move into code 110000 (“radio/radar”). The team was not able to determine the reason for this change or if any of the Sailors returned or remained in aviation maintenance positions. Therefore, the study team did not adjusted the Navy data.

2.4.2.2 SAFETY

There was minimal work required to prepare the safety data for analysis. The HFACS codes contained in the data set was a non-descript alphanumeric code. The study team created an HFACS look-up table so the study team could replace the codes with their actual titles. The look-up table was generated using the DoD HFACS version 7.0. The HFACS is a system used to code mishaps related to human-error (DoD HFACS, Version 7.0). Many incidents have no recorded HFACS codes at all; conversely, a single mishap can have multiple HFACS codes associated with it. The set of HFACS codes assigned was quite different from service to service, which makes combining HFACS codes across services problematic. Moreover, the collection of HFACS code categories has changed over time. We analyze HFACS data below.

2.4.3 CONSTRUCTING THE DATA

To conduct our analysis, the study team assigned Servicemembers to paygrade categories. In this phase of the analysis, the study team used paygrade as one aspect of a Servicemember’s experience. However, because of differing promotion timelines, an E4 in the Marines does not have the same experience as an E4 in the Air Force or Army. For this reason, the study team decided to create paygrade categories based on how each Service identifies its junior enlisted, Non-Commissioned Officers (NCOs), and Senior NCOs. These paygrade categories are shown blow in table 1.

Service	Paygrade Category	Paygrades
Army and Air Force	Junior Enlisted	E1 – E4
Navy and Marines	Junior Enlisted	E1 – E3
Army and Air Force	NCOs / Petty Officers	E5 – E6
Navy	NCOs / Petty Officers	E4 – E6
Marines	NCOs / Petty Officers	E4 – E5
Army, Air Force, and Navy	Senior NCOs/CPOs	E7
Marines	Senior NCOs / Staff NCOs	E6 – E7

Table 1 Armed Forces Paygrade Categories

2.4.4 INTEGRATING THE DATA

2.4.4.1 MANPOWER

In its original snapshot form, the manpower data was unwieldy and redundant. For example, there are about 13 million records for the Air Force that represent about 3.5 million airmen, and only about 600,000 of these were of interest as aviation mechanics. Therefore, the study team developed matrices that reported, for each unique mechanic, his or her rank, code, and time in service at each snapshot date.

2.4.4.2 SAFETY

The team built each of the Army, Air Force, and the DoN Safety data sets utilizing the same process. To illustrate this process consider that data associated with the DoN. The DoN Safety was built from three NSC aviation tables: Aircraft, Event, and HFAC. There is a one-to-many relationship between the aircraft and event table and the HFAC and event table. Moreover, not every aircraft involved in an incident has an associated HFACS code. In Phase II, the study team examined the frequencies of the presence and different types of HFACS codes.

The study team noted here that the data provided in the PDE, and the corresponding data from the Navy and Marine Corps Safety center was somewhat different. For this report, the study team have used the latter.

The DoN Safety data set contained both Navy and Marines aviation mishaps, and these were separated into two sets using the CTRLG_CUST_C column since the controlling custodian was the agency responsible for executing a mishap investigation.

2.5 MODELING AND EVALUATION

TRAC employed the R programming language to create and visualize the results of the analysis. The team extracted the manpower data from Oracle by Service into separate data sets. For each service, the study team built matrices giving the rank, time-in-service, and occupation code for every Servicemember.

2.6 DEPLOYMENT

In addition to the analysis, the team developed a decision support tool (DST) for NCMAS, senior leaders, and decision-makers to use to visualize personnel (manning and attrition) trends and aviation mishaps. The visuals produced by the DST can be used to examine whether the attrition of Servicemembers seems to be associated with different classes of aviation incidents. The DST data can be viewed three ways: 1) personnel data by quarter or fiscal year, 2) incident data by quarter or fiscal year, and 3) combined, personnel and incident data over the same time horizon. The personnel data variable options are Service, rank, or rank category (as described above). The incident data variable options are Service, accident class, and HFACS code. The combined data plots the personnel and safety plots for a side-by-side comparison and includes a feature that allows users to shift the personnel data by a quarter or more to see the lag association, if any, of personnel changes with the safety data. The tool has been built as an Rshiny application (Chang, Cheng, Allaire, Xie, & McPherson, 2018) and packaged as a zip file with all associated data sets for easy sharing and deployment with the sponsor; it also continues to be being actively developed.

2.7 COHORT BUILD

2.7.1 MANPOWER

To construct the DoD master personnel file, see figure 3, the study team combined the Army and Non-Army master and transaction files. As mentioned above, the study team filtered the data set based on the following criteria: AV DoD ODB codes (see appendix I), the timeframe of FY 2010 – FY 2019, and time-in-service at least two years. The study team chose two years because a Servicemember with two years of experience would have graduated from training school and

been in the aviation field for at least a year. Next, the study team defined attrition as an aviation mechanic, leaving the field by meeting one of these criteria:

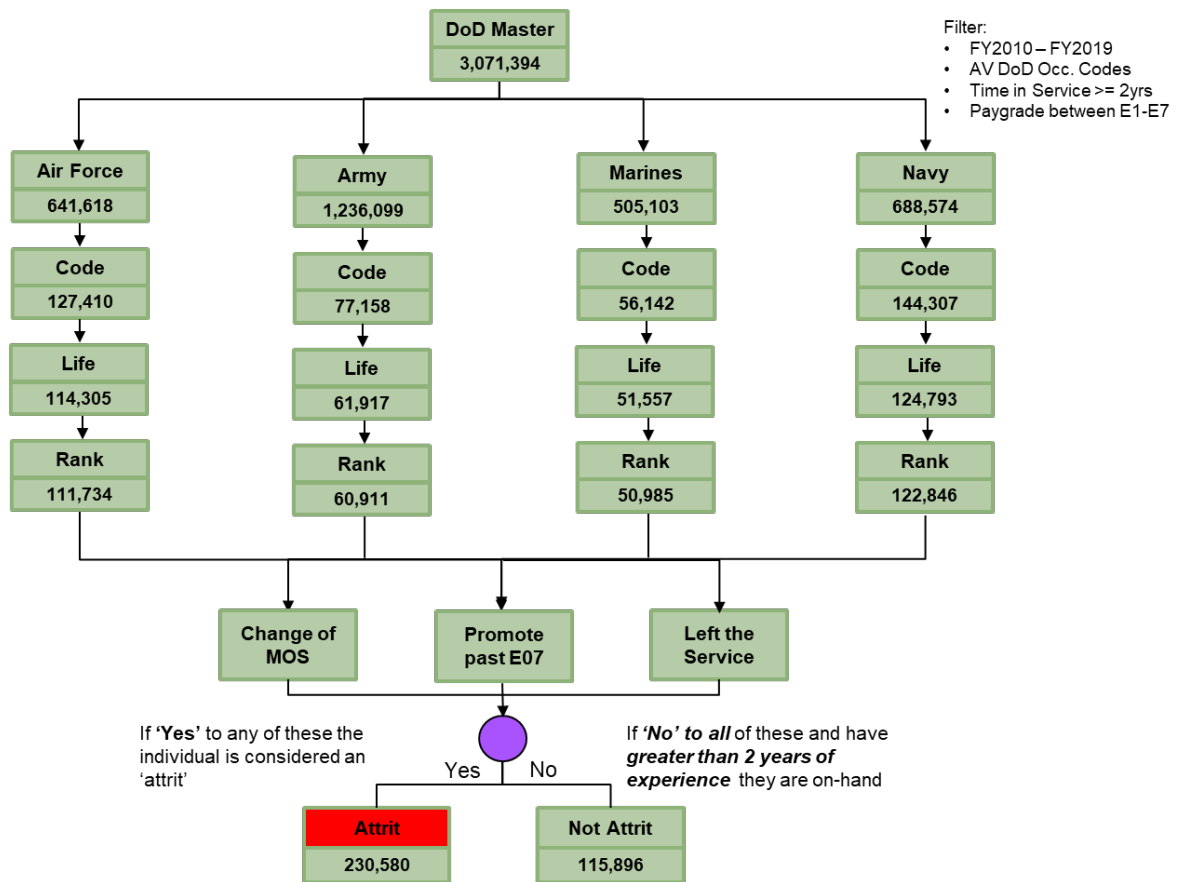


Figure 3: DoD Cohort Build

1. Servicemember left the aviation career field for another MOS.
2. Servicemember was promoted past the E7 rank because, at this point, the Senior NCO is no longer turning wrenches or on the maintenance floor overseeing personnel working.
3. Servicemember left the service by retirement or Expiration of Service (ETS).

A Servicemember with these attributes are considered to have undergone attrition (for short, they “attrited” or “are an attrite”).

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SECTION 3. ANALYSIS AND FINDINGS

3.1. INTRODUCTION

The National Commission on Military Aviation Safety was investigating whether there was an increase in aviation mishaps occurring from FY 2013 to FY 2018. One aspect of this investigation is to identify the factors that contribute to aviation mishaps. An accident can happen for multiple reasons, but they can be grouped into two main categories: human-related and non-human related. This study explored some human-related factors. Two groups of personnel together account for more than 50% of the aviation mishaps, pilots and maintainers. Aside from pilots, maintenance personnel are intimately connected to the operations and repair of the aircraft. As such, it is foreseeable that some mishaps can be the result of the actions or inactions of maintenance personnel. Therefore, this study examined which mishaps can be attributed to maintenance personnel by using the HFACS code, accident classification, and subcategories.

Aviation mishaps are classified by severity, as seen in figure 2, with Class A the most severe. The study team will focus on Class A, B, and C mishaps, categorized into three groups (flight, flight-related, and ground operations). For a detailed description of how the DoD classifies mishaps, see appendix III.

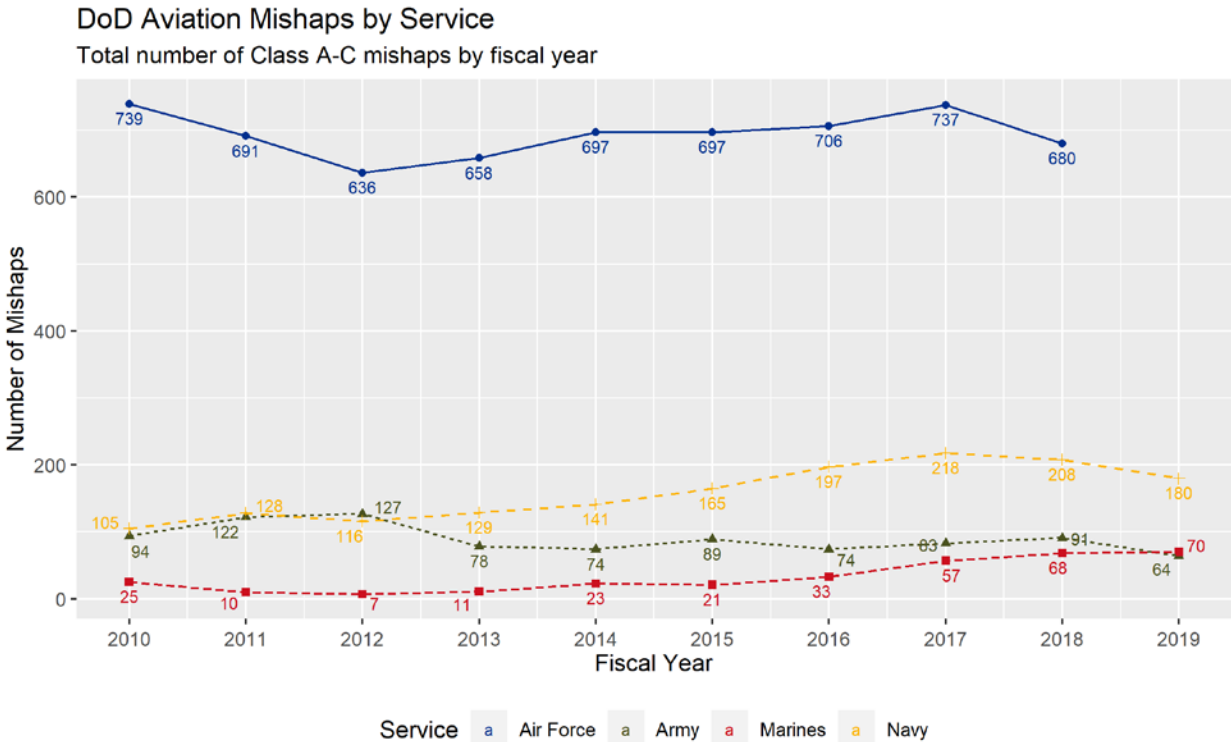
In the next sections, the study team looked first overall, and then service by service, at trends in manpower and trends in mishap numbers. To frame these results, some significant concerns are repeated here:

1. In this phase, the study team looked only at the number and rank of aviation maintainers. The study team take time-in-service as a proxy for skill or experience level, which was much harder to measure. The study team was able to acquire the servicemembers' AFQT scores; these, as we point out in more detail below, serve to determine eligibility to enter the service, but do not indicate specific skills like mechanical aptitude. By request, the study team looked at the service level – that is, the study team combined all maintainers, across all aircraft in a service. In an ideal world, the study team would consider each platform separately for a couple of reasons. First, the study team expected platforms to have inherently different mishap rates.

Second, the service-wide approach makes it impossible to determine whether platforms are losing or gaining personnel, while keeping the service-level totals unchanging.

2. Similarly, the study team took a service-wide look at aviation mishaps without, generally, breaking them down by platform. Again, this is by request (the study team do look at the Marine Corps distribution of mishaps by platform below, for reasons explained there). The study team did not have information on what might be the most critical determinants of the numbers of mishaps: numbers of aircraft, flights and hours flown, number and type of missions, and, particularly for the Naval Services, numbers of carrier take-offs and landings.
3. Our personnel and mishap data both address Active Duty personnel and equipment only and ignore National Guard and Reserve units.
4. The study team make no effort to determine the “lag” in any effect of personnel changes on mishaps. It could be that a reduction in personnel is associated with an increase in mishaps not immediately, but at a later date.

3.2. OVERALL



Total number of aviation mishaps displayed by Service for Accident Class A-C

Figure 4 Aviation Mishaps (classes A, B, C) by Service, by Year

Figure 4 shows the number of class A-C mishaps by service for the period of interest, except that Air Force data was unavailable for 2019. A few key points should be noted: first, mishap counts in the Air Force and the Army are roughly constant across this period. Air Force mishaps average around 700, with a standard deviation of about 33. Army mishaps average about 90, with a standard deviation of approximately 20. The Navy’s story seems different: in the first four years, there was an average of 119 mishaps, compared to an average of 200 per year in the last four years. Mishap counts did, however, decrease after 2017. The Marines have the most obvious trend: an increase in almost every year from the previous, starting in 2012. In 2018 and 2019, there were nearly ten times as many mishaps as in 2011 and 2012.

The number of maintainers, shown at the end of each fiscal year in Figure 5, did not show wide variability over the study period. Steady decreases in the numbers of Air Force and Army maintainers mirrored the reduction in force observed in those services overall. (Although the Air

Force data is adjusted for the reorganization the study team detected at the end of FY2017, the number in that quarter is somewhat anomalous.)

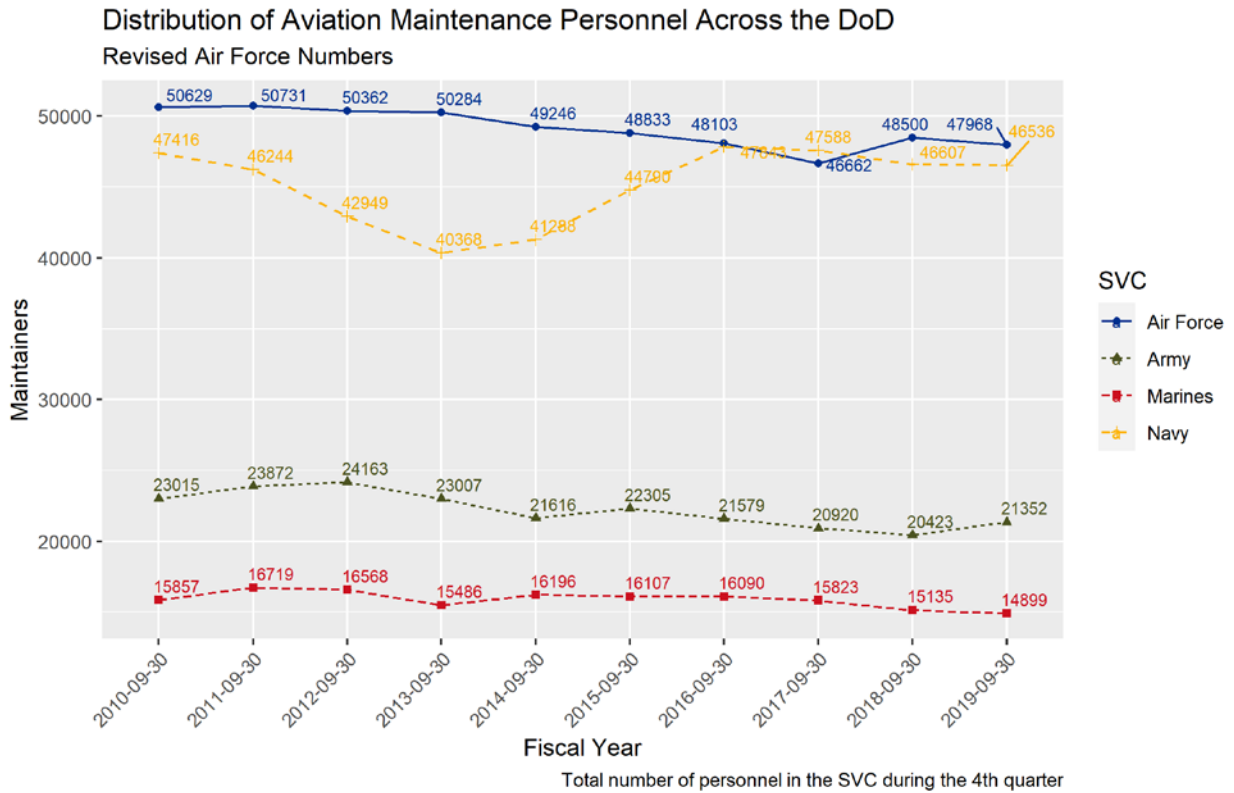


Figure 5 Aviation Maintenance Personnel, by Service, by Year

3.3. ARMY

Unsurprisingly, the Army had a much smaller proportion of aviation maintainers among its personnel, typically around 8% of the total population. The total number of Soldiers in the Army decreased from about 340,000 in FY 10 to about 250,000 in FY 19, an overall decrease of roughly 25%. This decrease is evident in both aviation Soldiers and in the set of Soldiers with non-aviation codes. Figure 6 shows the number of aviation personnel (blue) and other (black), on different scales, across the period of interest. To create similar populations for this figure, the study team restricted the non-aviation Soldiers to have rank less than or equal to E7 and at least 24 months of service. The two lines show mostly similar behavior.

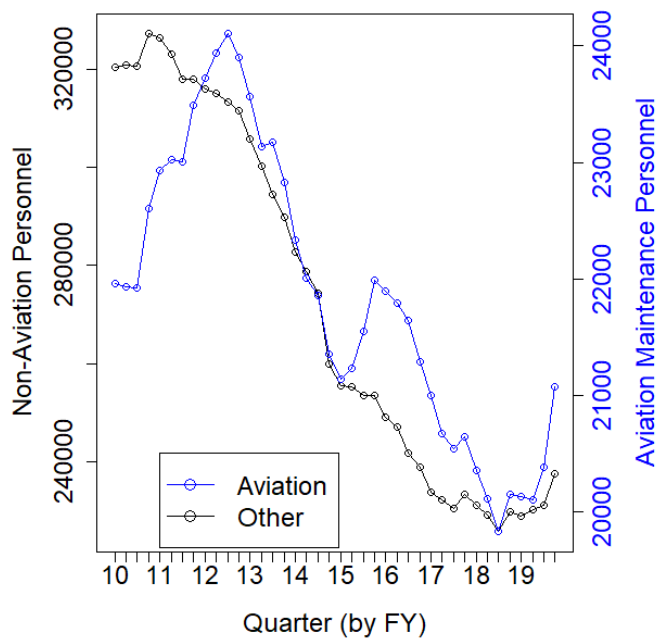


Figure 6: Army Aviation (Blue) and Non-Aviation (Black) Personnel, by Quarter

While the number of maintainers decreased by roughly 4,000 (again, roughly 25% of the complement in 2010), the number of mishaps remained mostly steady across time, as shown in Figure 7.

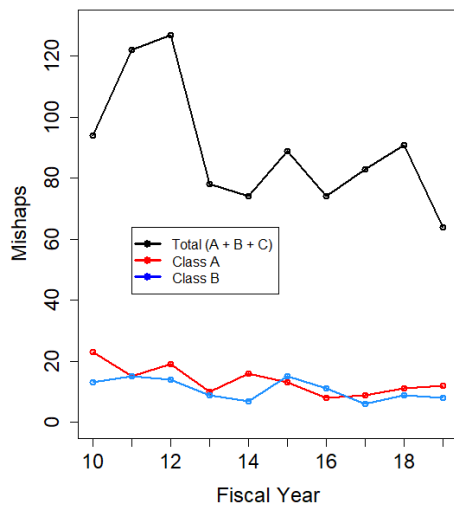


Figure 7: Army Mishaps, by Class and Year

Note that a steady rate could arise in several ways, and our data is insufficient to distinguish between them. It could be that the numbers of flights, flight hours, missions, take-offs and landings, and so on, by platform, flown by the Army were largely constant over this time, and the numbers of mishaps were, too. On the other hand, it could be associated with the 25% reduction in the size of the Army; there was a 25% reduction in the number of flights, flight hours, and so on. In that case, the same number of mishaps would have arisen from fewer flight hours, showing an increase in the rate per flight hour. Of course, rate per flight hour is probably a better measure of mishap-proneness than a simple count. In the absence of flight-hour data, the study team was unable to determine whether the more-or-less constant rate of mishaps reflects a constant underlying rate per flight hour, or whether the more recent mishap counts might have arisen from fewer flight hours, hinted at by the fact of there being fewer maintainers.

3.4. AIR FORCE

The Air Force, for which flight is the primary mission, has the largest number of maintainers among the services, and also produces the largest number of mishaps. As with the Army, the numbers of Air Force maintainers follows the non-maintainers' pattern closely. Each shows a period of stability, followed by an abrupt decline (reason is unknown to the team), and a further period of slower decline, and then an increase in the last two fiscal years. Figure 8 shows the counts of non-aviation and aviation Airmen (on different scales), as before these lines only show personnel at E7 and below with at least 24 months of experience. Note that the range of the two lines represents about a 10% drop in numbers from the peak to the trough.

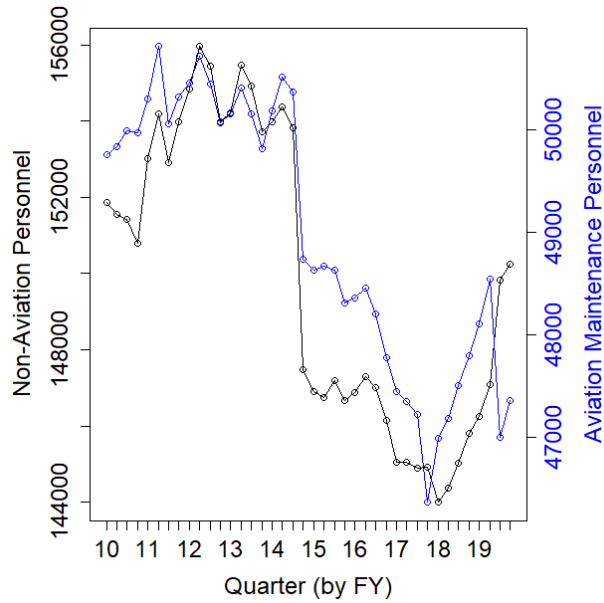


Figure 8: Air Force Aviation (Blue) and Non-Aviation (Black) Personnel, by Quarter

As with the Army, there was no evidence of a change in the overall numbers of mishaps experienced in the Air Force (and there was no way to detect whether this represents real stability or an increased rate associated with fewer flight hours). Since the numbers of types A, B, and C incidents are quite different, Figure 9 uses three vertical scales to show the numbers of mishaps by year (except for 2019, for which data was not currently available). The number of class A mishaps hit its highest value in 2018, but there was no apparent trend for those, nor class B or total mishaps.

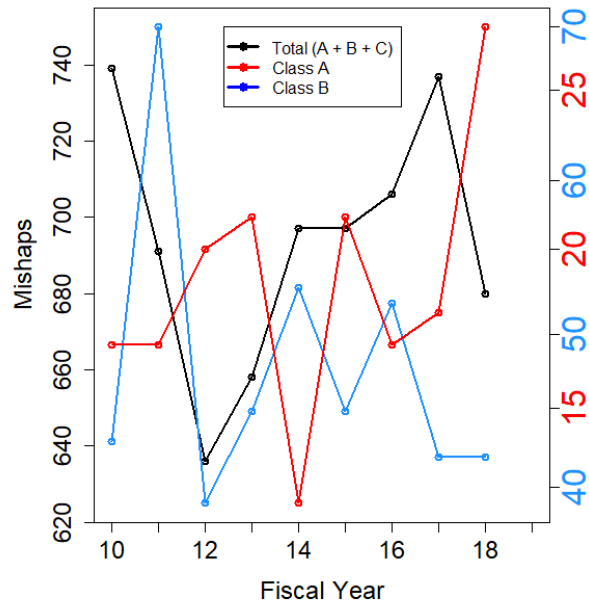


Figure 9: Air Force Mishaps, by Class and Year

3.5. NAVY

The Navy exhibited a decline both in aviation and non-aviation Sailors between FY 2010 and FY 2013 or FY 2014, followed by an increase. Figure 10 shows the quarter-by-quarter counts of Sailors in these groups (counting, as always, just those at rank E7 and below with at least 24 months of service). While the two graphs have similar shapes, it is noteworthy to mention that the loss of aviation Sailors was much greater in percentage terms: roughly 13% from peak to trough, compared to about 5% for the non-aviation group. The study team believed that at least part of this decline arises from a re-organization in which comparatively large numbers of Navy Sailors had their specialties abruptly changed.

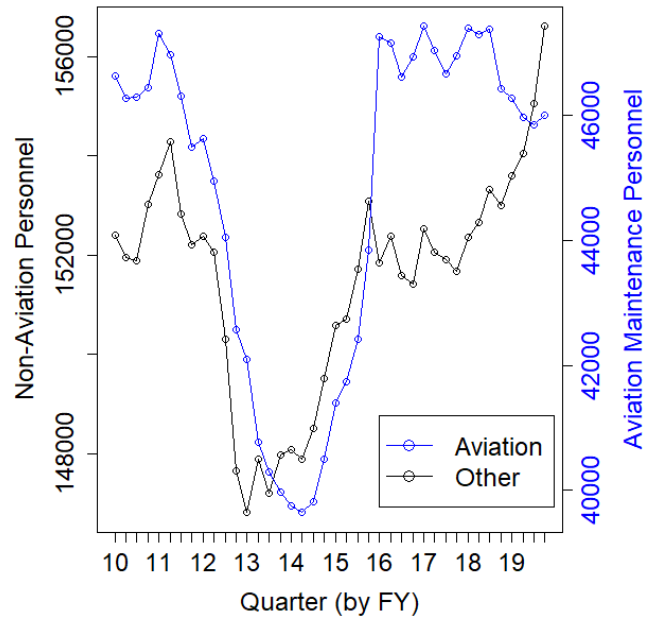


Figure 10: Navy Aviation (Blue) and Non-Aviation (Black) Personnel, by Quarter

The numbers of Navy mishaps appear to have increased, at least until FY17. Figure 11 shows the number of mishaps (with class A and B on a common scale from the scale for class C). It is possible to speculate that the decrease in personnel observed in FY13-15 was associated with the increase in mishaps seen in the subsequent year, but this cannot be verified with the data at hand.

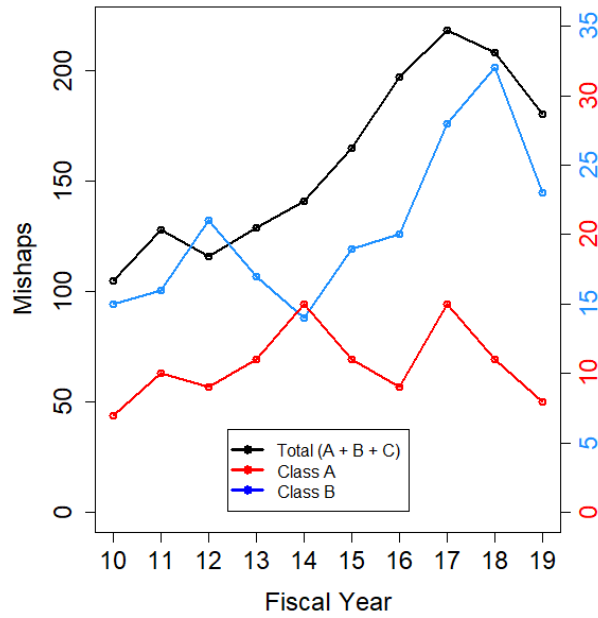


Figure 11: Navy Mishaps, by Class and Year

3.6. MARINE CORPS

The Marine Corps' overall level of personnel decreased substantially between FY 10 and FY 19, with a net loss of close to 20% between the peak in 2010 and the low point at the end of FY 2016. However, the population of aviation maintainers was more stable, losing only about 9% of personnel from FY 2010 to FY 2019. Figure 12 compares the quarter-by-quarter numbers of non-aviation and aviation Marines (on different scales).

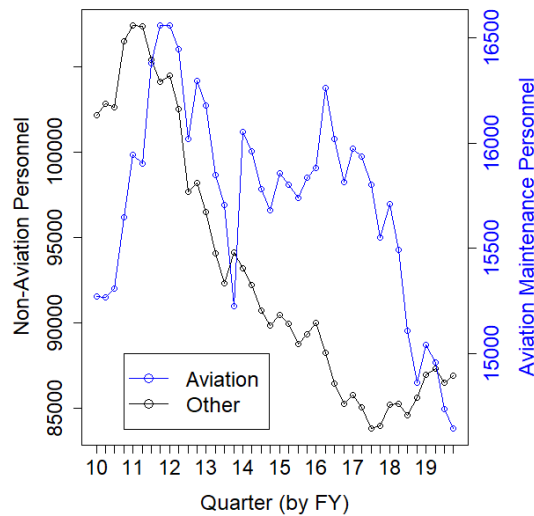


Figure 12: Marine Corps Aviation (Blue) and Non-Aviation (Black) Personnel, by Quarter

The Marines are not significantly different from the other services in their manpower trends; the Air Force and Army both see decreases in manpower over roughly the same period. It was in the Marine Corps, however, that the study team saw the most evidence of an increase in mishaps throughout the period of interest. The number of observed mishaps increased across both fixed- and rotary-wing and across all major platforms. Figure 13 shows the number of classes A, B, and C mishaps, with fixed-wing incidents in black and rotary-wing incidents in red. The tables show the numbers of mishaps by aircraft type and model. The increases was particularly striking among the helicopter models, where the FY18 and FY19 mishap counts were many times those of FY15 and FY16. The increase is less evident in fixed-wing aircraft, where the F-18 seems to account for a large portion of the change. An increase in incidents associated with the F-35 presumably was associated with increasing numbers of this newer aircraft. However, as noted, the study team did not have data on numbers and types of aircraft and flight hours.

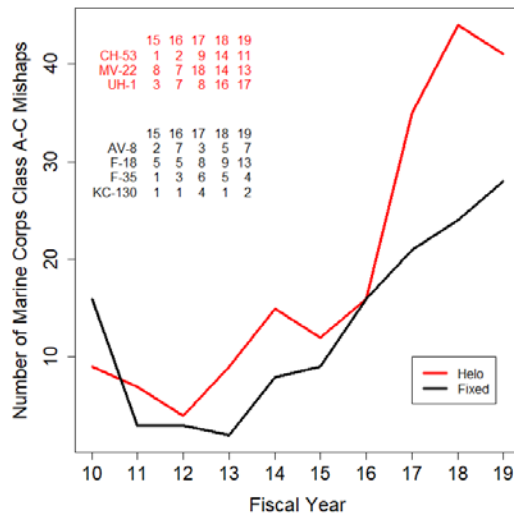


Figure 13: Marine Corps Mishaps, by Fixed- and Rotary-Wing, With Counts for Common Platforms

3.7. EXAMINING HFACS DATA

HFACS codes arise from mishap investigations. Their intent is to identify factors that contribute to the mishaps, be they organizational, supervisory, the result of errors or violations, or of other origins. Correlating HFACS codes to mishaps is complicated by a number of issues. First, not every mishap is recorded in the data as having produced HFACS codes. Second, any mishap might create multiple codes, since an incident might have multiple causes. Third, it became clear during the analysis that the services produce HFACS codes in different ways. One glaring example of this is the service-level differences between the rates of mishap-level and person-level codes. Mishap-level codes refer to organizational or supervisory shortcomings, like “failure to provide adequate funding” or “failure to provide adequate training” (Air Force Safety Center, 2020). Person-level codes refer to unsafe preconditions in the environment (“heat/cold stress impairs performance”) or in an individual or team (“complacency,” “fatigue”) as well as to unsafe acts (“checklist not followed”). We observe that the Navy’s investigations never produce mishap-level codes; every incident is considered to be entirely at the person level. Figure 14 shows the distribution of the numbers of person-level (orange) and mishap-level (blue-green) HFACS codes reported in each year of interest. Note that the Air Force data is missing for 2019: this shows both

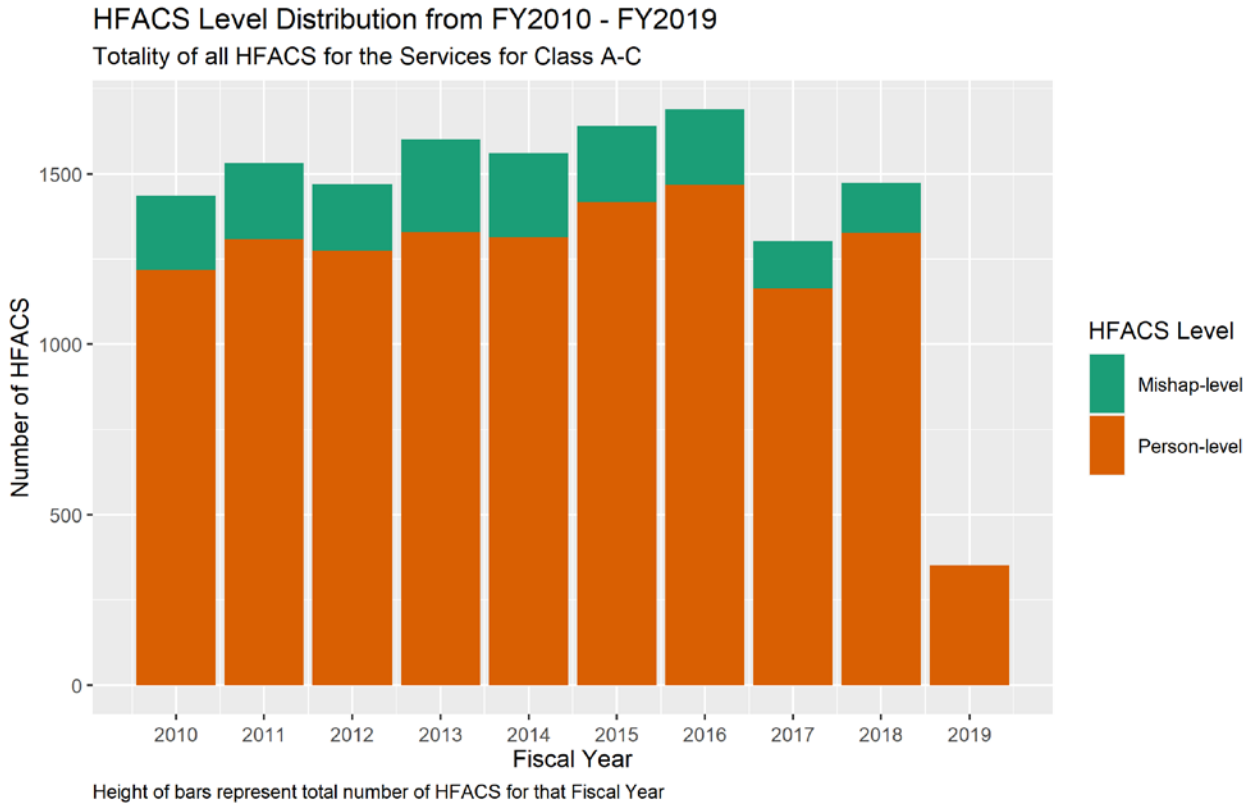


Figure 14: HFACS Level Distribution by Year (Air Force missing for 2019)

the contribution of the Air Force to the number of codes reported, and also specifically to the number of mishap-level codes, since the other services produced essentially zero in 2019. It is worth noting that person-level mishaps might refer to non-maintenance personnel, like aircrew or air traffic controllers.

Figure 15 shows the top ten most-common HFACS code in each year, across all services, for mishaps in classes A through C inclusive. Although HFACS codes do not have a one-for-one relationship with mishaps, we can see that in general, the number of codes tracks the observed pattern of mishaps. Moreover there is no evidence of a change in the types of conditions reported as being associated with mishaps.

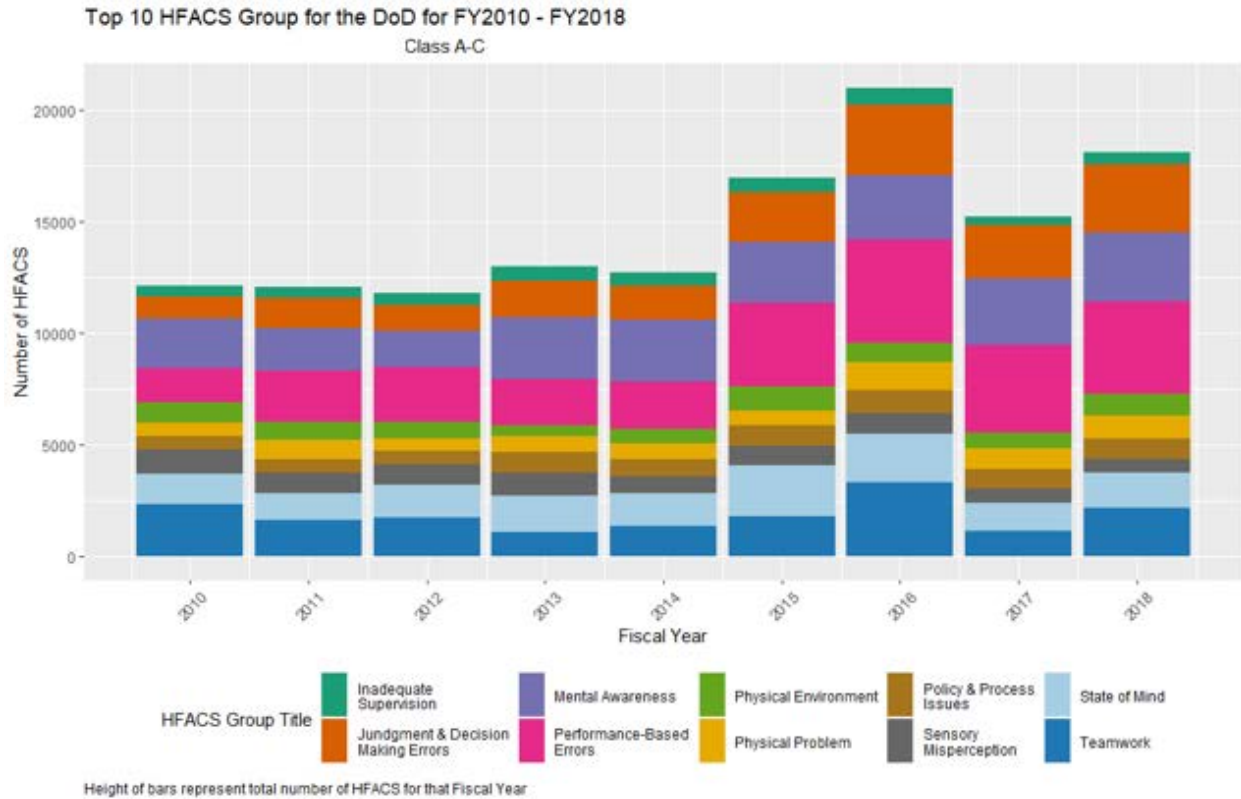


Figure 15: Top Ten HFACS Codes Per Year

3.8. EXAMINING THE “BATHTUB” EFFECT

The “bathtub effect” describes a hypothesis under which the set of aviation maintainers becomes progressively more concentrated in the lower and higher ranks, with fewer of the non-commissioned officers (NCOs). This is potentially hazardous for the maintenance community because the NCOs provide direct leadership, stability, and experience. Under this hypothesis, a force might stay reasonably constant in the total number of maintainers but, because of the loss of this middle group of maintainers, nonetheless, be “hollowed out” and less effective. To examine this claim, the study team divided personnel into Junior Enlisted (E1-E3 for Navy and Marines, E1-E4 for Army and Air Force), NCOs (E4-E6 for Navy, E4-E5 for Marines, E5-E6 for Army and Air Force) and Senior NCOs (E6-E7 for Marines, E7 for the other services). Figure 14 shows the distribution across quarters for these three groups among aviation mechanics in the Army (upper left) and Air Force (upper right), arranged so that the NCO group (blue) is the

lowest and easiest to read. In the Army, the proportion of NCOs does not appear to exhibit a long-term trend; however, the Air Force's proportion of NCOs did decrease over the period of interest.

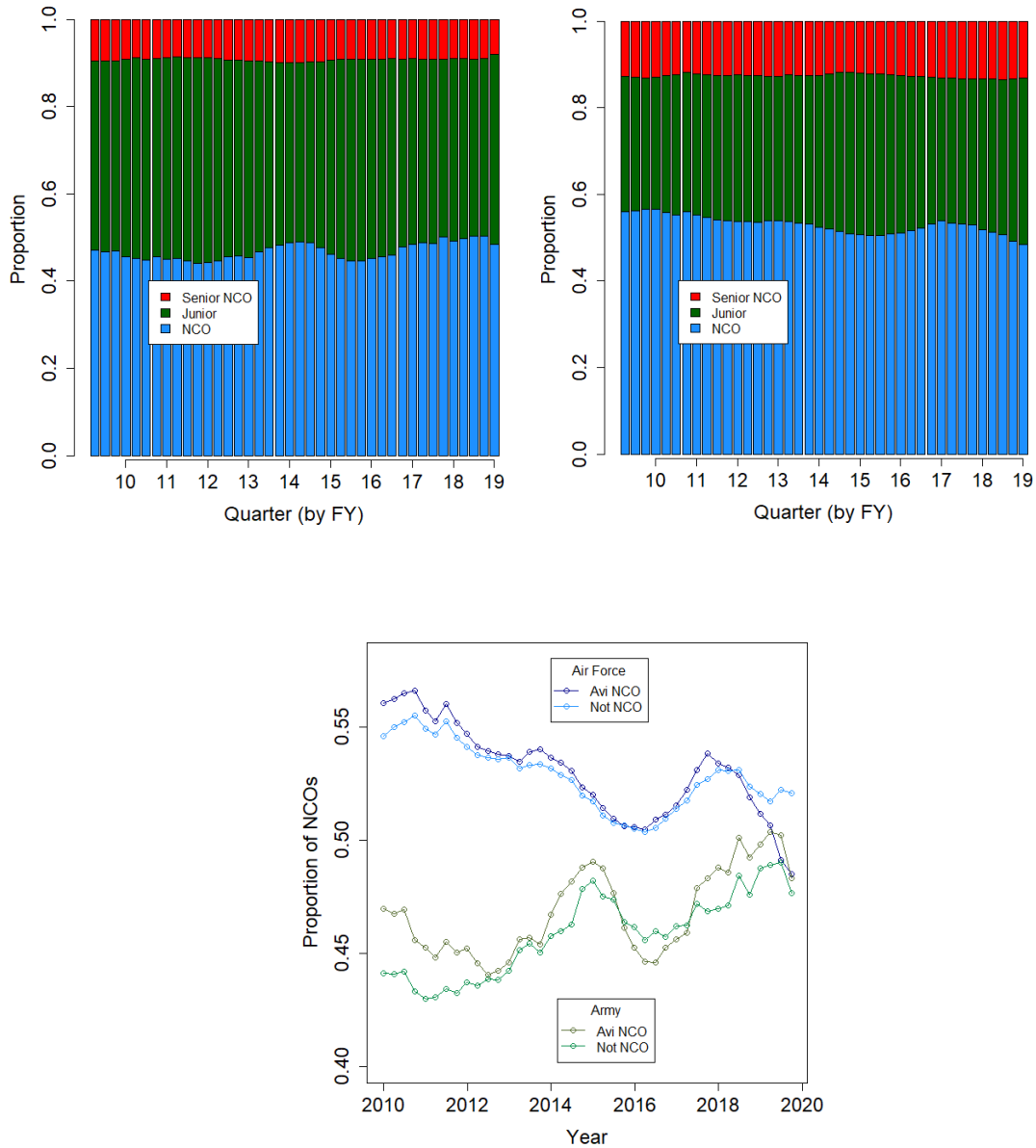


Figure 16: Army (Upper Left) and Air Force (Upper Right) Proportions by Rank Group, and (Below) Compared

The bottom panel compares the proportions of NCOs in the Air Force between aviation mechanics and non-aviation Airmen (blue lines), with the same comparison in the Army (green

lines). The study team saw the proportion of NCOs increasing over time in the Army, and decreasing in the Air Force.

For this facet of the analysis, it is difficult to compare the Navy and the Marines directly to the Army and Air Force, or one another, because of the different definitions of what constitutes a non-commissioned officer. Figure 15 shows the distribution of aviation mechanics across the three groups for the Navy (left panel) and Marines (right panel). While the Navy’s picture shows an unexpected pattern, the study team speculated that this may be related to the reclassification issues mentioned above. In any case, there is no evidence of a loss of the NCO personnel in significant numbers.

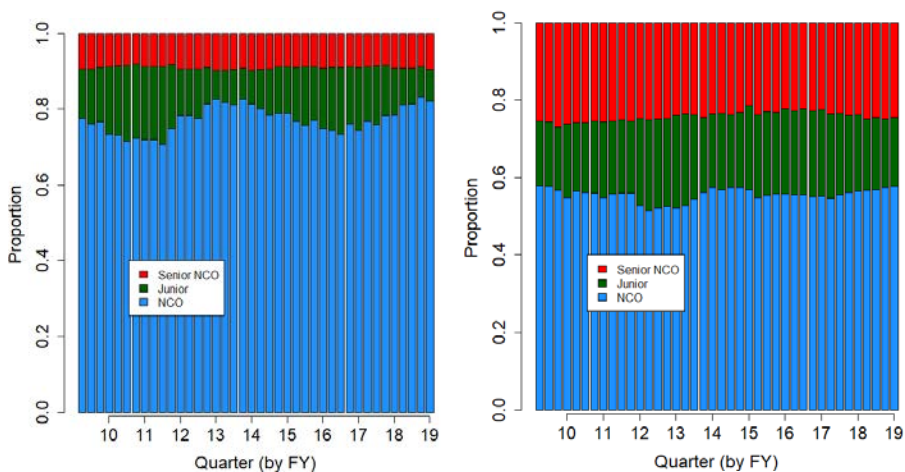


Figure 17: Distribution of Maintenance Personnel by Rank Group for Navy (Left) and Marines (Right)

3.9. THE EFFECT OF AFQT SCORES

As part of Phase II of this analysis, we acquired AFQT scores for each maintainer in the inventory. The AFQT score is typically categorized into six tier levels, denoted by I, II, IIIA, IIIB, IV, and V, see figure 18. Here I represents the highest (that is, best) scores on the test, and V the worst – in fact, recruits whose score puts them in the V level are typically ineligible to join any of the services. We note that in some cases the services will use “Above Average” to characterize tiers I and II, “Average” to characterize tier IIIA, and “Below Average” for tiers IIIB, IV and V, which we combine in this analysis.

	AFQT Category	Score Range
Above Average	I	93-99
	II	65-92
Average	IIIA	50-64
	IIIB	31-49
Below Average	IVA	21-30
	IVB	16-20
	IVC	10-15
	V	1-9

Figure 18 AFQT Tier Level and Scores, source(officialasvab.com)

The purpose of this portion of the analysis was to examine whether the distribution of AFQT tier levels might have changed across time. If that were true, then it might be possible for the services to have an approximately constant number of personnel and still have a group of maintainers whose overall average “quality” (at least, as measured by AFQT) had decreased.

In fact, though, two results emerged from this analysis. First, the proportion of maintainers in each of the AFQT tiers was essentially constant across the period of the study. Figure 16 shows the proportion of Tier I personnel across time. Each of the services shows only a small amount of variability, and this is true for the other tiers as well (not shown). It is interesting to note that the distribution of tier levels is quite different across services: in the Air Force, almost 50% of maintainers come from AFQT tier II, whereas in the Army, the corresponding number is about 32%. Conversely, only about 15% of Air Force’s maintainers come from the “Below Average” Tier IV, compared to about 35% of the Army’s.

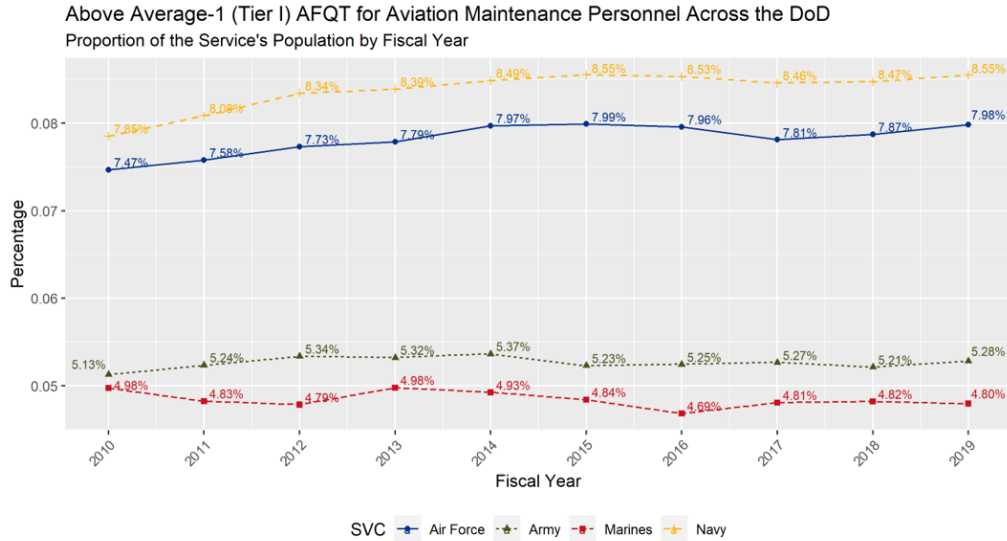


Figure 19: Proportion of Tier I AFQT Personnel, by Service and Year

This disparity seems to be explained by the different strategies that the services use to assign recruits to the aviation mechanic field. The AFQT score is distilled from the larger ASVAB test that every recruit takes. While the AFQT score is used to determine eligibility to join the service, each component has its own criteria for selecting mechanics. Army personnel can become mechanics by performing well on (depending on the specific job) the Electronics, Mechanical, and/or Auto and Shop portions of the ASVAB, without regard to performance on, say, Word Knowledge or Paragraph comprehension. However the rules for the other services are quite different, both from the Army ones and one another's. This study was not given access to individual ASVAB scores. Moreover we expect that after a couple of years' of service, a maintainer's skill will be determined more by his or her training and experience and less by a score on a test taken years before.

SECTION 4. CONCLUSION

4.1. CONCLUSIONS

The NCMAS was charged with examining a purported increase in the number of aviation mishaps in the services. In the phase I analysis, the study team examined staffing levels among active-duty aviation maintainers (at rank E7 or below, with at least 24 months of service) between Fiscal Years 2010 and 2019. The study team also examined classes A, B, and C aviation mishaps over the same period. The study team looked only at the sheer numbers of mishaps since the study team was not afforded data on flight hours, mixtures of platform, takeoffs and landings, and other data that might provide insight into aviation risk.

The numbers of aviation mishaps of classes A, B, and C seems to have been stable in the Air Force and the Army across the period of interest. The Navy appeared to exhibit an increase in the number of mishaps, with a peak in 2017 where the numbers of classes B and C mishaps were roughly double the numbers from the previous five years. The Marine Corps also showed an increase in mishaps, with a peak in the data from the most recent year's data. There does not appear to have been a change in the sorts of mishaps, based on HFACS codes recorded during investigation. However, we note that not every mishap has associated HFACS codes, that many mishaps have multiple codes, and that the Navy and Air Force record codes at quite different rates – specifically, with the Navy reporting every mishap as “person-level.”

In the face of mishap numbers that were stable for some services and changing in others, no relationship between the number of on-hand aviation maintainers and the number of mishaps was evident. Both the Air Force and Army saw a significant decrease in the numbers of aviation maintainers, and personnel overall, over the period of interest without an associated increase in mishaps. However, the study team could not determine if the accident rate per flight hour was constant. A constant level of mishaps might demonstrate an increase in the *rate* of mishaps per 1,000 flight hours if fewer hours were being flown. Conversely, the Navy's personnel levels in recent years were approximately, where they were in the early years of the data, even though mishap levels in the last few years were somewhat higher. The Marines experienced both an increase in mishaps and a decrease in the numbers of aviation maintainers. The study team cannot

determine whether the change in personnel numbers was related to the accident rates from the data, but the study team did observe that the Air Force and Army also saw a decrease in personnel without an increase in mishaps. There was no evidence of a change in the “quality” of the maintainer force as measured by AFQT, although, as we observe, AFQT might not be very a useful measure in this context. There is also no evidence of a “bathtub” effect in which the force is “hollowed out” by a disproportionate loss in non-commissioned officers.

4.2. RECOMMENDATIONS

The ability to answer the Commission’s questions was hindered by the availability of complete and accurate data. The analysts’ spent most of their time and effort on acquiring, cleaning and merging the data. We recommend that DMDC give some thought to the arrangement and maintenance of personnel data. As examples, data checks might ensure that every servicemember has the relevant transactions on file (they do not, now) and that the field giving “number of months in service” is correct and complete (this field sometimes resets to zero, at least for a time). In fact, a complete set of transactions for each servicemember, including not just promotions but job changes, qualifications, changes in marital status and dependents, and so on – might be more useful to analysts than dozens of snapshots. When the services re-classify a number of personnel – as with our 7,000-some Airmen – proper documentation should be generated and retained.

The Committee elected to consider mishap counts at the Service level. While there may be advantages to this, this can also be misleading. Any consideration of mishaps should account for flight hours, missions, and distribution of aircraft types. Moreover it might be valuable to examine mishaps by squadron, to see if they differ, and to link personnel to specific mishaps where applicable. Finally, the services clearly encode mishaps via HFACS in different ways. This system would be more useful if the services acted consistently.

APPENDIX I

The DoD ODB is a database which groups similar military and civilian jobs into one category. This affords researchers and analyst the capability of doing a cross-service comparison of ascension numbers, manning levels, and attrition by job of personnel in the military. The DoD ODB is maintained by the DMDC, and available via the web. Below is a snippet of the database showing aviation occupational codes the study team used in this project.

DoD Occupational Code	Title
105000	Aircrew, General
105100	Pilots/Navigators*
110200	Nav, Comm, & Countermeasure, N.E.C.
110300	Air Traffic Control Radar
122200	Air Traffic Control
155500	Aviation Maintenance Records and Reports
155600	Flight Operations
160000	Aircraft, General
160100	Aircraft Engines
160200	Aircraft Accessories
160300	Aircraft Structures
160400	Aircraft Launch Equipment
164600	Aviation Ordnance

* Marines only

APPENDIX II

The HFACS is utilized by the civilian and military aviation industry to codify human-related errors. The current version being used is 7.0. Below is a listing of the HFACS codes.

Title	HFAC	Category	Group	Category	SubCategory	Level
Failure of Crew/Team Leadership	PP101	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Cross-Monitoring Performance	PP102	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Inadequate Task Delegation	PP103	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Rank/Position Intimidation	PP104	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Lack of Assertiveness	PP105	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Critical Information Not Communicated	PP106	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Standard/Proper Terminology Not Used	PP107	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Failed to Effectively Communicate	PP108	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Task/Mission Planning/Briefing Inadequate	PP109	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Mission Briefing	PP110	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Task / Mission-In-Progress Re-Planning	PP111	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Miscommunication	PP112	Teamwork	PP100	Preconditions	Latent Failures of Conditions	Person-level
Physical Fitness	PP201	Teamwork	PP200	Preconditions	Latent Failures of Conditions	Person-level
Alcohol	PP202	Teamwork	PP200	Preconditions	Latent Failures of Conditions	Person-level
Drugs / Supplements / Self Medication	PP203	Teamwork	PP200	Preconditions	Latent Failures of Conditions	Person-level
Nutrition	PP204	Teamwork	PP200	Preconditions	Latent Failures of Conditions	Person-level
Inadequate Rest	PP205	Teamwork	PP200	Preconditions	Latent Failures of Conditions	Person-level
Unreported Disqualifying Medical Condition	PP206	Teamwork	PP200	Preconditions	Latent Failures of Conditions	Person-level
Geographic Disorientation (Lost)	PC017	Mental Awareness	PC100	Preconditions	Latent Failures of Conditions	Person-level
Not Paying Attention	PC101	Mental Awareness	PC100	Preconditions	Latent Failures of Conditions	Person-level
Fixation	PC102	Mental Awareness	PC100	Preconditions	Latent Failures of Conditions	Person-level
Task OverSaturation/UnderSaturation	PC103	Mental Awareness	PC100	Preconditions	Latent Failures of Conditions	Person-level
Confusion	PC104	Mental Awareness	PC100	Preconditions	Latent Failures of Conditions	Person-level
Negative Habit Transfer	PC105	Mental Awareness	PC100	Preconditions	Latent Failures of Conditions	Person-level
Distraction	PC106	Mental Awareness	PC100	Preconditions	Latent Failures of Conditions	Person-level
Geographically Lost	PC107	Mental Awareness	PC100	Preconditions	Latent Failures of Conditions	Person-level
Interference/Interruption	PC108	Mental Awareness	PC100	Preconditions	Latent Failures of Conditions	Person-level
Technical or Procedural Knowledge Not Retained	PC109	Mental Awareness	PC100	Preconditions	Latent Failures of Conditions	Person-level
Inaccurate Expectation	PC110	Mental Awareness	PC100	Preconditions	Latent Failures of Conditions	Person-level
Learning Ability / Rate	PC401	Physical/Mental Limitations	PC400	Preconditions	Latent Failures of Conditions	Person-level
Memory Ability / Lapses	PC402	Physical/Mental Limitations	PC400	Preconditions	Latent Failures of Conditions	Person-level
Anthropometric / Biomechanical Limitations	PC403	Physical/Mental Limitations	PC400	Preconditions	Latent Failures of Conditions	Person-level
Motor Skill / Coordination or Timing Deficiencies	PC404	Physical/Mental Limitations	PC400	Preconditions	Latent Failures of Conditions	Person-level

Title	HFAC	Category	Group	Category	SubCategory	Level
Technical / Procedural Knowledge	PC405	Physical/Mental Limitations	PC400	Preconditions	Latent Failures of Conditions	Person-level
Motion Illusion – Kinesthetic	PC501	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Turning/Balance Illusion – Vestibular	PC502	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Visual Illusion	PC503	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Misperception of Changing Environment	PC504	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Misinterpreted/Misread Instrument	PC505	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Expectancy	PC506	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Misinterpretation of Auditory/Sound Cues	PC507	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Spatial Disorientation	PC508	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Spatial Disorientation (Type 2) Recognized	PC509	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Spatial Disorientation (Type 3) Incapacitating	PC510	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Temporal/Time Distortion	PC511	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Pre-Existing Personality Disorder	PC201	State of Mind	PC200	Preconditions	Latent Failures of Conditions	Person-level
Psychological Problem	PC202	State of Mind	PC200	Preconditions	Latent Failures of Conditions	Person-level
Life Stressors	PC203	State of Mind	PC200	Preconditions	Latent Failures of Conditions	Person-level
Emotional State	PC204	State of Mind	PC200	Preconditions	Latent Failures of Conditions	Person-level
Personality Style	PC205	State of Mind	PC200	Preconditions	Latent Failures of Conditions	Person-level
Overconfidence	PC206	State of Mind	PC200	Preconditions	Latent Failures of Conditions	Person-level
Pressing	PC207	State of Mind	PC200	Preconditions	Latent Failures of Conditions	Person-level
Complacency	PC208	State of Mind	PC200	Preconditions	Latent Failures of Conditions	Person-level
Motivation	PC209	State of Mind	PC200	Preconditions	Latent Failures of Conditions	Person-level
Misplaced Motivation	PC210	State of Mind	PC201	Preconditions	Latent Failures of Conditions	Person-level
Overaggressive	PC211	State of Mind	PC202	Preconditions	Latent Failures of Conditions	Person-level
Excessive Motivation to Succeed	PC212	State of Mind	PC203	Preconditions	Latent Failures of Conditions	Person-level
Get-Home-Itis / Get-There-It is	PC213	State of Mind	PC204	Preconditions	Latent Failures of Conditions	Person-level
Response Set	PC214	State of Mind	PC205	Preconditions	Latent Failures of Conditions	Person-level
Mentally Exhausted (Burnout)	PC215	State of Mind	PC200	Preconditions	Latent Failures of Conditions	Person-level
Effects of G Forces (G-LOC, etc.)	PC301	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Substance Effects (alcohol, supplements, medication)	PC302	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Operational Injury/Illness	PC303	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Loss of Consciousness (sudden or prolonged)	PC304	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Physical Illness/Injury	PC305	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Physical Fatigue (Overexertion)	PC306	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Fatigue	PC307	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Circadian Rhythm Desynchrony	PC308	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Motion Sickness	PC309	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Trapped Gas Disorders	PC310	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Evolved Gas Disorders	PC311	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Hypoxia/Hyperventilation	PC312	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level

Title	HFAC	Category	Group	Category	SubCategory	Level
Inadequate Adaptation to Darkness	PC314	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Dehydration	PC315	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Physical Task Oversaturation	PC316	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Body Size/Movement Limitations	PC317	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Physical Strength & Coordination (inappropriate)	PC318	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Nutrition/Diet	PP319	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Seat and Restraint System Problems	PE201	Technological Environment	PE200	Preconditions	Latent Failures of Conditions	Person-level
Instrumentation and Warning System Issues	PE202	Technological Environment	PE200	Preconditions	Latent Failures of Conditions	Person-level
Visibility Restrictions (not weather related)	PE203	Technological Environment	PE200	Preconditions	Latent Failures of Conditions	Person-level
Controls and Switches are Inadequate	PE204	Technological Environment	PE200	Preconditions	Latent Failures of Conditions	Person-level
Automated System Creates an Unsafe Situation	PE205	Technological Environment	PE200	Preconditions	Latent Failures of Conditions	Person-level
Workspace Incompatible with Operation	PE206	Technological Environment	PE200	Preconditions	Latent Failures of Conditions	Person-level
Personal Equipment Interference	PE207	Technological Environment	PE200	Preconditions	Latent Failures of Conditions	Person-level
Communication Equipment Inadequate	PE208	Technological Environment	PE200	Preconditions	Latent Failures of Conditions	Person-level
Environmental Conditions Affecting Vision	PE101	Physical Environment	PE100	Preconditions	Latent Failures of Conditions	Person-level
Vision Restricted by Meteorological Conditions	PE102	Physical Environment	PE100	Preconditions	Latent Failures of Conditions	Person-level
Vibration Affects Vision or Balance	PE103	Physical Environment	PE100	Preconditions	Latent Failures of Conditions	Person-level
Vision Restricted in Workspace by Dust/Smoke	PE104	Physical Environment	PE100	Preconditions	Latent Failures of Conditions	Person-level
Windblast	PE105	Physical Environment	PE100	Preconditions	Latent Failures of Conditions	Person-level
Heat/Cold Stress Impairs Performance	PE106	Physical Environment	PE100	Preconditions	Latent Failures of Conditions	Person-level
Thermal Stress – Heat	PE107	Physical Environment	PE100	Preconditions	Latent Failures of Conditions	Person-level
External Force or Object Impeded an Individual	PE108	Physical Environment	PE100	Preconditions	Latent Failures of Conditions	Person-level
Lights of Other Vehicle/Vessel/Aircraft Affect	PE109	Physical Environment	PE100	Preconditions	Latent Failures of Conditions	Person-level
Noise Interference	PE110	Physical Environment	PE100	Preconditions	Latent Failures of Conditions	Person-level
Brownout/Whiteout	PE111	Physical Environment	PE100	Preconditions	Latent Failures of Conditions	Person-level
Performs Work-Around Violation	AV001	Violations	AV000	Acts	Active Failures or Actions	Person-level
Commits Widespread/Routine Violation	AV002	Violations	AV000	Acts	Active Failures or Actions	Person-level
Extreme Violation - Lack of Discipline	AV003	Violations	AV000	Acts	Active Failures or Actions	Person-level
Inadequate Real-Time Risk Assessment	AE201	Judgment & Decision Making	AE200	Acts	Active Failures or Actions	Person-level
Failure to Prioritize Tasks Adequately	AE202	Judgment & Decision Making	AE200	Acts	Active Failures or Actions	Person-level
Error due to Misperception	AE301	Perception Error	AE300	Acts	Active Failures or Actions	Person-level
Necessary Action – Rushed	AE203	Judgment & Decision Making	AE200	Acts	Active Failures or Actions	Person-level
Necessary Action – Delayed	AE204	Judgment & Decision Making	AE200	Acts	Active Failures or Actions	Person-level
Ignored a Caution/Warning	AE205	Judgment & Decision Making	AE200	Acts	Active Failures or Actions	Person-level
Wrong Choice of Action During an Operation	AE206	Judgment & Decision Making	AE200	Acts	Active Failures or Actions	Person-level
Unintended Operation of Equipment	AE101	Performance-Based Errors	AE100	Acts	Active Failures or Actions	Person-level
Checklist Not Followed Correctly	AE102	Performance-Based Errors	AE100	Acts	Active Failures or Actions	Person-level
Procedure Not Followed Correctly	AE103	Performance-Based Errors	AE100	Acts	Active Failures or Actions	Person-level
Over-Controlled/Under-Controlled Aircraft	AE104	Performance-Based Errors	AE100	Acts	Active Failures or Actions	Person-level

Title	HFAC	Category	Group	Category	SubCategory	Level
Learning Ability / Rate	PC401	Physical/Mental Lim	PC400	Preconditions	Latent Failures of Conditions	Person-level
Memory Ability / Lapses	PC402	Physical/Mental Lim	PC400	Preconditions	Latent Failures of Conditions	Person-level
Anthropometric / Biomechanical Limitations	PC403	Physical/Mental Lim	PC400	Preconditions	Latent Failures of Conditions	Person-level
Motor Skill / Coordination or Timing Deficiencies	PC404	Physical/Mental Lim	PC400	Preconditions	Latent Failures of Conditions	Person-level
Technical / Procedural Knowledge	PC405	Physical/Mental Lim	PC400	Preconditions	Latent Failures of Conditions	Person-level
Motion Illusion – Kinesthetic	PC501	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
Turning/Balance Illusion – Vestibular	PC502	Sensory Misperception	PC500	Preconditions	Latent Failures of Conditions	Person-level
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Motivation	PC209	State of Mind	PC200	Preconditions	Latent Failures of Conditions	Person-level
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Physical Fatigue (Overexertion)	PC306	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Fatigue	PC307	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level
Circadian Rhythm Desynchrony	PC308	Physical Problem	PC300	Preconditions	Latent Failures of Conditions	Person-level

APPENDIX III

Accident Classification System

Aviation mishaps are classified by severity: class A, B, C, D, E (Army), E (Air Force), F (Army), H (Navy not a mishap). A class A mishap occurs when the damage to the aircraft totals more than \$2 million, destruction of the aircraft or if a member of the crew/Servicemember is permanently injured or killed as a result. A class B mishap occurs when the damage to the aircraft is between \$500,000 – \$2 million, a member of the crew/Servicemember is partially disabled, or three or more personnel are hospitalized (not for observation). A class C mishap occurs when the damage to the aircraft is between \$50,000 – \$500,000, or a member of the crew/Servicemember is injured, which requires time off from work (not the day of). A class D mishap occurs when the damage to the aircraft is between \$20,000 – \$50,000, or a member of the crew/Servicemember is injured which do not meet the threshold for accident class A, B or C. Class E (Army) mishap occurs when the damage to the aircraft is between \$5,000 – \$20,000 or a member of the crew/Servicemember requires first aid only and no injury. Class E (USAF) is used for physiological events or propulsion related events. Class F (Army) is used for internal/external FOD damage confined to the aircraft engines only (not APU) (USD, Acquisition, Technology, and Logistics, 2011). Class H (“Hazard”) is a classification used by the Department of the Navy to describe low-cost, non-mishaps events like bird strikes.

Aviation mishaps are categorized into three subcategories (USD, Acquisition, Technology, and Logistics, 2011).

Aviation Mishap Category and Subcategories

AVIATION MISHAPS INVOLVE AIRCRAFT OR FLYING OPERATIONS.	
Subcategory	Subcategory Characteristics
Flight	A mishap where there is intent for flight and damage to DoD aircraft. Explosives, chemical agent, or missile events that cause damage to an aircraft with intent for flight are categorized as flight mishaps to avoid dual reporting. (Mishaps involving factory-new production aircraft until successful completion of the post-production flight are reported as contractor mishaps.)
Flight Related	A mishap where there is intent for flight and no reportable damage to the aircraft itself, but the mishap involves fatality, reportable injury, or reportable property damage. A missile that is launched from an aircraft, departs without damaging the aircraft, and is subsequently involved in a mishap is reportable as a guided missile mishap.

Ground Operations	A mishap where there is no intent for flight that results in damage to an aircraft or death or injury involving an aircraft. This applies to aircraft both on land and on board ship. Damage to an aircraft when it is being handled as a commodity or cargo is not reportable as an aircraft mishap.
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